Developing the Supply Chain Capabilities of Chinese Small and Medium Size Textile & Apparel Manufacturers with E-business Initiatives

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Abstract

Chinese small and medium textile & apparel manufacturers are facing dynamic environments, industry upgrading, and escalating global competitions. Compared with large manufacturers, they have relatively limited resources to access advanced technologies and formulate strategies. To thrive and identify opportunities in such surroundings, SMEs must design and implement a more competitive strategy based on new initiatives. They should consider utilising e-business to manage their business and understand how e-business affects their supply chain capabilities.

E-business can facilitate information flow speed and manage business transactions in the supply chain, so the study proposes that a more advanced e-business utilisation level should reduce order fulfilment time and accelerate supply chain efficiency. This research uses a mixed method to collect and analyse data. The study designs conceptual models to represent different levels of e-business utilisation in the textile & apparel supply chain based on literature review, adopts agent based modelling (ABM) to simulate an apparel order fulfilment under different scenarios to collect data, and conducts statistical methods to analyse the data. All the model designs and ABM simulations are based on the interview results with SMEs. The research findings indicate that an advanced e-business engagement level brings less order fulfilment time and higher supply chain efficiency. SMEs need to realise the value of e-business, utilise appropriate e-business and consider the potential benefits and the investment costs before making the e-business strategy. Research objectives are reached with the aid of the literature review and the analysis results of all the work undertaken.

This study targets on small and medium textile & apparel manufacturers in China and provides practical implications to utilise e-business. The thesis implements the simulations incrementally to study an apparel order fulfilment process in the textile & apparel supply chain, provides a theoretical template for further research of e-business utilisation in supply chain management. The method can be used to identify the effects of e-business engagement on different aspects of the manufacturing supply chain.

Declaration

I declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright Statement

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I want to give special thanks to my dear husband and son for understanding, patience, and encouragement, keeping me optimistic during difficult times. Without their help, none of the current work would have been feasible.

Chapter 1 Introduction

This study focuses on Chinese small and medium size textile & apparel manufacturers to explore how to use e-business initiatives to improve their supply chain capabilities. This chapter introduces areas of concern within the study. Section 1.1 introduces the brief industrial background of textile & apparel manufacturing, section 1.2 identifies the chosen area of the research, and section 1.3 presents the research aim and objectives. The thesis structure and the critical information in each chapter are summarised in section 1.4.

1.1 Research Background

As one of the oldest industries, the textile & apparel industry is considered a sunset industry in most developed countries. However, it has made a significant contribution to the economy and helped host countries promote their industrialisation and enhanced economic development. The textile & apparel industry is characterised by labour-intensive, low capital investment, low mechanical innovation levels, fluctuating demand, low predictability and short product life cycle (Felfel *et al.,* 2015, 2018; Meng, 2015; Rinaldi and Bandinelli, 2019). Nevertheless, the textile & apparel industry used to hire the largest number of employees in the worldwide manufacturing sector (WIEGO, 2020). The textile & apparel industry provides 20 million full-time jobs and more than 60 million part-time jobs, and most of these jobs are in developing countries (UNIDO Report, 2020; WIEGO, 2020). In high-wage countries, it has been common for textile & apparel companies to outsource production to obtain lucrative returns (Kumar *et al.,* 2017). For example, apparel assembly is a low-technology industry with minimal entry barriers; neither high capital investment nor specialist skills are needed, so less advanced countries use it to secure economic growth.

The global textile & apparel industry has other key features, which have formed a threshold of industrialisation for developing countries. Most of these countries are located in Asia, Eastern Europe, Latin America and Africa, and they use the opportunity to improve economic growth through textile & apparel export (Vanathi and Swamynathan, 2016). Meanwhile, investors tend to save costs, so companies have to migrate to low-cost labour markets to gain competitive advantages since a declining industry in one country may provide an opportunity in another country to create jobs. The production activities in the textile & apparel industry have been through ongoing relocation based on different countries' economic development situations (Vanathi and Swamynathan, 2016).

Due to globalisation, the international trade of textile & apparel products has grown in the last few decades. Except for the incentive of low production costs, textile & apparel industry shifts were besieged by a quota system managed by Multi-Fibres Agreement (MFA). The quotas were established by the US, Canada, EU, and Norway to protect their domestic textile & apparel industries, which were weak compared with some developing countries (Curran, 2007). The quotas set an overall limit of the increases of particular textile & apparel product imports from developing countries. These countries were only allowed to export to developed countries on a fixed market share. Under such circumstances, trade restrictions became one of the most important driving forces to hinder the global distribution of textile & apparel production and some countries' textile & apparel industry development. A new production system occurred; low-wage countries assembled apparel and exported the finished products using outsourcing countries' textiles, those outsourcing countries have contracts with retail buyers. The quota system was abandoned in 2005. Since then, developing countries can export textile & apparel products without restriction, and developed countries seek to reconfigure their resources and production networks. Worldwide retailers in developed countries need suppliers to provide full-package production and services (Min, 2012). Some countries like Turkey and China can provide such services, so they own significant global market shares and earn benefits, but some small countries have encountered industrial decline because they can not offer such services (Min, 2012; Morris and Barnes, 2008).

Textile & apparel manufacturers need to minimise costs and develop capabilities such as management practices, production skills, long-term relationships management with raw material suppliers and customers, and distribution capabilities to fulfil the order (Jatuphatwarodom *et al.*, 2018; Vanathi and Swamynathan, 2016). They have to improve such abilities, so new products can be delivered to retail outlets more quickly to satisfy the global market dynamic demand. To obtain and maintain rapid reaction, textile & apparel manufacturers must focus on production flexibility because consumers' tastes change quickly. They are obliged to undertake extra responsibilities such as quality management, packaging, transportation, and, most importantly, participating in the product development process (Rinaldi and Bandinelli, 2019). They have to produce small quantity orders more frequently and give faster feedbacks to variable market demands. Textile & apparel supply chain involves different partners, such as raw material suppliers, spinners, weavers, knitters, manufacturers, brand owners/retailers, retail shops, customers, etc. They need to exchange information with each other. Internet networks and e-business technologies connect all these partners (Kumar *et al.,* 2017; Xing *et al.*, 2016). Above all, information sharing and cooperation in the textile & apparel supply chain network are essential to achieve order fulfilment efficiency and supply chain capabilities.

1.2 Research Context

Manufacturers face ever-changing customer preferences and new competitors in the current global market. Meanwhile, new technologies emerge constantly to make the status quo more complicated. The textile & apparel manufacturing industry is facing tough competition recently. Major manufacturing bases have shifted to developing countries, such as China, Turkey, Pakistan and India, because these local governments provide low-cost labour workers and grant subsidies (Vanathi and Swamynathan, 2016). Low-cost countries can export more textile & apparel products, and lower production costs can help developing countries export products at lower prices than developed countries.

1.2.1 Textile & Apparel Industry in China

Chinese textile & apparel industry has undergone profound changes from a self-sufficient and central planning system to a business-driven and export-oriented system. These changes affected consumer demand, product mixture, strategy implementation and skill development. China is the lead producer and exporter of textile & apparel products. Chinese textile industry[1] has been relatively mature. The National Bureau of Statistics (NBS) of China (http://www.stats.gov.cn/english/Statisticaldata) shows that in 2019, Chinese textile & apparel exports were USD 271.836 billion. Chinese textile & apparel products are mainly exported to the EU, USA and Japan. But many textile & apparel companies in China find their weak trading positions compared with some foreign competitions because these competitors can cost much lower on textile & apparel production outside China. Chinese textile & apparel manufacturers have to face other Southeast Asian countries, such as Vietnam and Cambodia. These governments encourage the development of the textile & apparel industry, and their labor costs and tariffs are lower than in China (Vanathi and Swamynathan, 2016). Chinese textile & apparel manufacturers have suffered torment in such a dynamic environment. Demand for economic growth and labour shortages have made it challenging to recruit new workers in China. Labour costs continue to rise, and environmental protection policy has been strengthened.

Figure 1.1 shows the Chinese textile & apparel industry manufacturing outputs long-term perspective against gross output. These data come from annual data issued by China NBS. From 2000 to 2017, gross output grew by 776%. During the same period, the textile & apparel industries manufacturing output grew by 343.2%. The textile & apparel industry manufacturing output contribution added to Chinese gross output was 6.6% in 2000 but dropped to 3.4% in 2017. Compared with the high-speed increase of the gross output, although the textile & apparel industries manufacturing output increased, its contribution to the gross output declined.

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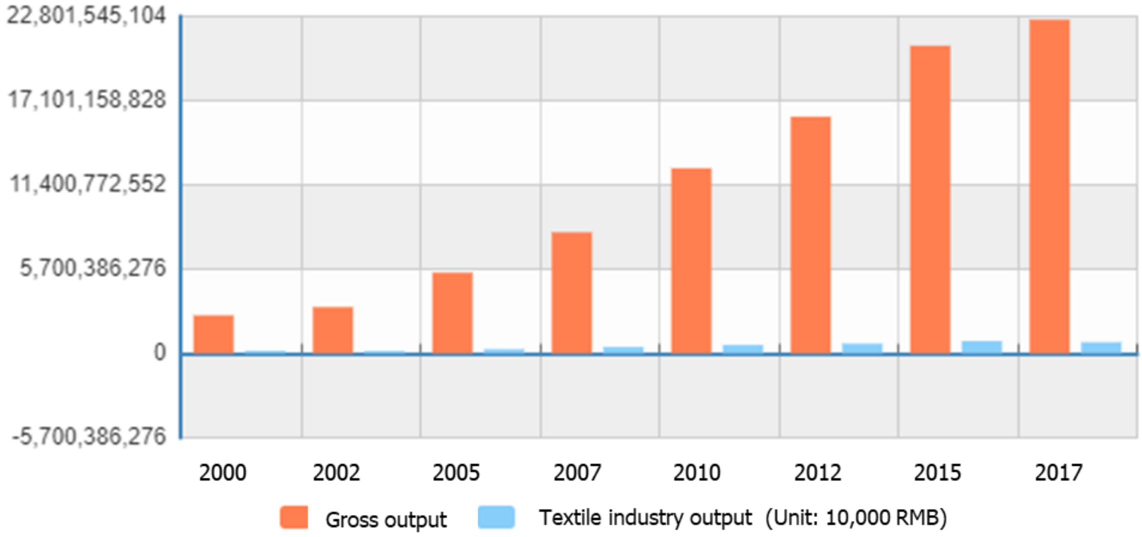
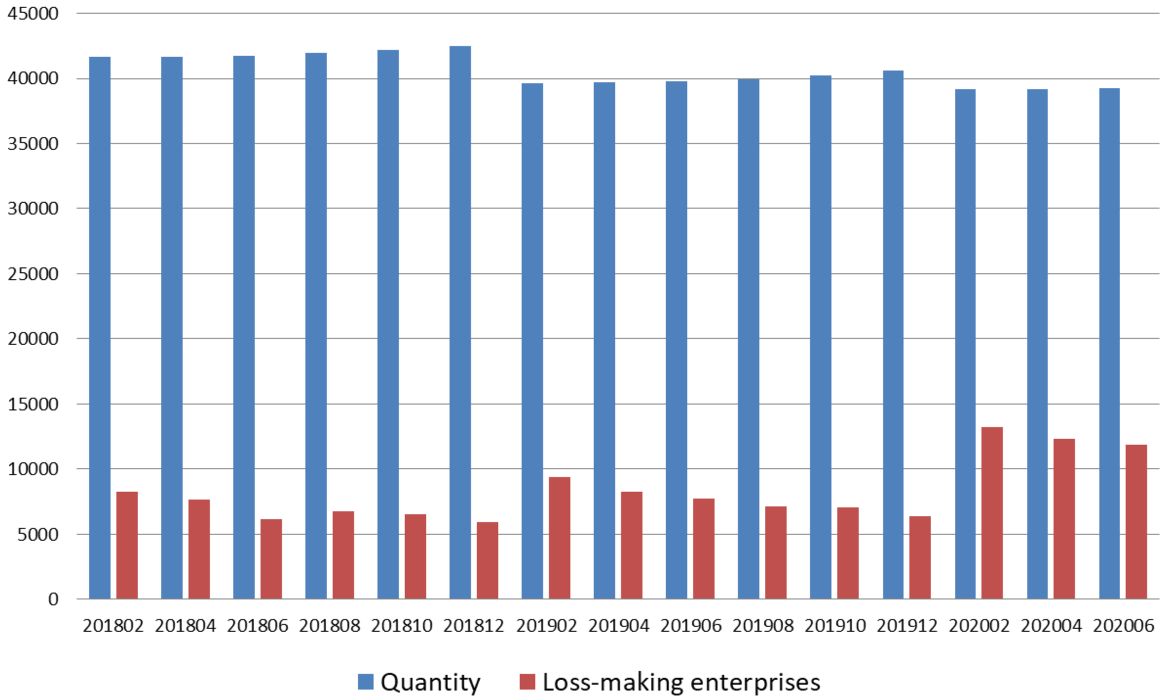
[1] According to classification of the National Bureau of Statistics (NBS) of China, the textile industry involves three categories: textile material, textile & apparel, and shoe, hat manufacturing, leather, fur, feather (velvet) and their products.

Figure 1.1 Manufacturing output of Chinese textile & apparel industry (2000-2017)



By the end of June 2020, there were 39,218 textile & apparel manufacturers in China, but 11,836 of them made a loss simultaneously, which was 30.18% of all manufacturers (see Figure 1.2), almost a third of Chinese textile & apparel manufacturers made a loss. These data come from monthly data issued by China NBS.

Figure 1.2 Quantity of Chinese textile & apparel manufacturers and loss-making enterprises



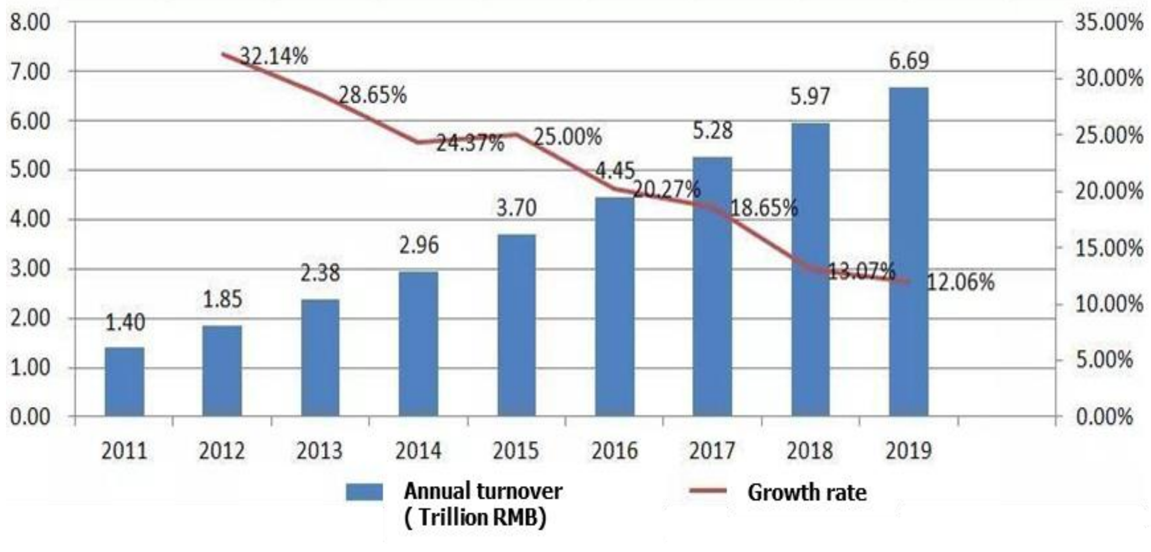
As shown in Figure 1.2, from February 2018 to June 2020, the number of textile & apparel manufacturers remained relatively stable, from 41,671 to 39,218, with a slight decrease of 6.25%. During the same period, the number of manufacturers not making profits increased from 8,240 to 11,836, and the percentage increased from 19.77% to 30.18%. Although Chinese textile & apparel industry development still keeps stable, manufacturers have to face deficit problems and try to find and use advanced methods to accelerate their capabilities.

1.2.2 E-business Transaction of Chinese Textile & Apparel Industry

E-business is a high-level interactive internet communication method compared with traditional methods, facilitating co-creation values for all partners more effectively and efficiently in the supply chain (UNIDO Report, 2016). For instance, a manufacturer can co-create more values for its customers and itself in the value chain in various ways, such as participating in new product innovation, offering electronic invoices, and providing necessary and prompt feedbacks. A manufacturer can offer a customised solution for clients and create value for both parties. Sharma (2013) indicates that even small companies employ e-business to manage various business activities, from seeking novel material resources and business techniques to searching for new customers and business partners to market their products and services.

E-business transaction (applications of Information & Communication Technology) of the Chinese textile & apparel industry is 6.69 trillion RMB in 2019, an increase of 12.06% over the same period of 2018 (see Figure 1.3). These data come from annual data issued by China National Textile & Apparel Council (CNTAC) (http://www.ctei.cn/). As Figure 1.3 shows, e-business turnover continues to grow, and the market scale is further expanded. The contribution of e-business to the textile & apparel industry is constantly being reinforced, and the online trading mode is optimised and innovative. However, the e-business transaction turnover growth rate decreased from 2012 to 2014 and from 2015 to 2019. Chinese textile & apparel manufacturers need to find the reason and consider using more advanced initiatives such as e-business in the supply chain to increase turnover.

Figure 1.3 Annual e-business turnover of Chinese textile & apparel industry: 2011-2019



1.2.3 Small and Medium Size Textile & Apparel Manufacturers in China

Chinese textile & apparel manufacturers are facing a volatile market environment. Under such a background, the state-owned enterprises (SOEs) in the monopoly position have declined quickly. In the same period, private enterprises rose and changed the industry profile fundamentally and overtook most industry output and GDP contributions. The National Bureau of Statistics of China (NBS) defines SMEs of the textile & apparel industry. Small size enterprise employs 10-100 persons, and medium size enterprise employs 100-300 persons (http://www.stats.gov.cn/tjsj/tjbz/201801/t20180103_1569357.html). Based on monthly data issued by China NBS, there were 39,218 textile & apparel manufacturers in China in June 2020, and 90% were SMEs. SMEs occupy important positions in the Chinese textile & apparel industry and whole GDP development, and they also contribute to employment growth and have positive effects on economic development.

At present, SMEs' capabilities and competitiveness determine the Chinese textile & apparel industry development. The continuous improvement of SMEs' knowledge and management skills plays a vital role in attaining the China national industry upgrading goal. SMEs are shifting from original equipment manufacturers (OEM) to original brand manufacturers (OBM), which means they are concentrating on differentiation and added value but not on the low costs (Chi, 2015). The Chinese government issued a series of laws to accelerate and promote SMEs development since 2014 when it recognised the crucial position of SMEs in the national economy, for example, the "Law of the People's Republic of China on the Promotion of SMEs" and the "Detailed Procedures to Financing SMEs on International Market Expansion". But Chinese small and medium size textile & apparel manufacturers are still increasingly confronted by the challenges of foreign competitors and dynamic international markets.

Chinese small and medium size textile & apparel manufacturers face severe environmental turbulence, industry upgrading and escalating global competition. Their small size and limited resources hinder them from competing with large enterprises. They have to face severe market challenges, more barriers to upgrading, difficulties accessing buyers and a financial burden (Li *et al.,* 2019). To survive and flourish in such fluctuating environments, SMEs must adopt advanced technology and utilise their potential (Chatzoglou and Chatzoudes, 2016; Chi, 2015; Mazzarol, 2015) and do this with ever-increasing speed. But most SMEs make little use of e-business because they are unaware of the potential benefits, and their hesitance derives from the high perceived costs and the uncertain returns of investments (Meng, 2015). Small and medium size manufacturers must focus on partner collaboration, communication channel establishment, and information flow in the supply chain. E-business can support small and medium size textile & apparel manufacturers to achieve lean supply chain management (Manfredsson, 2016) due to its advantages in facilitating information flow speed and managing business transactions across the long distance between supply chain partners (Sharma, 2013). Manufacturing industries have found e-business initiatives and strategic alliances to respond to business cost pressures and the need for quicker response (Kumar *et al.,* 2017). E-business tools such as e-commerce have facilitated Chinese small and medium size manufacturers' development in the apparel value chain (Li *et al.,* 2019).

The popularisation of e-business utilisation in China provides a good research background. This study focuses on SMEs in the Chinese textile & apparel supply chain for the following reasons. Firstly, China is the lead producer and exporter of textile & apparel products. The volume of e-business transactions in the textile & apparel industry has kept rising in the last ten years. Secondly, e-business pushed the traditional Chinese sectors such as the textile & apparel industry to transform to the digital era in recent years (Zhu *et al.,* 2015). For example, ERP (Enterprise Resource Planning) has proliferated into Chinese textile & apparel manufacturing extensively and pushed the whole industry to the ICT (Information and Communication Technology) frontier (Zhang *et al.*, 2016). With increasing numbers of textile & apparel manufacturers, customers, raw material suppliers, and supply chain partners applied e-business technologies and tools in operations (CNNIC Report, 2020). All size enterprises, including SMEs, must adopt e-business to gain profits (Mazzarol, 2015). Manufacturers, especially SMEs, are under external pressures from e-business transactions, so executives need to consider using e-business initiatives in the supply chain under such pressures. Meanwhile, SMEs always have limited resources to adopt e-business than larger enterprises. They may be in a weak position to utilise e-business initiatives, so executives experience difficulties in the usage of e-business initiatives (Zhu and Lin, 2019).

The study will focus on Chinese small and medium size textile & apparel manufacturers to study how to utilise e-business initiatives to improve supply chain efficiency and capabilities.

1.3 Research Aim and Objectives

It is essential to study how to develop the supply chain capabilities of small and medium size textile & apparel manufacturers with e-business initiatives. Only a few researchers have studied the specific effect of e-business on the textile & apparel supply chain, and none have considered a particular apparel order fulfilment for SMEs in the supply chain. For example, Raymond *et al.* (2015) study the effects of e-business on SMEs' performance (including textile & apparel supply chain). Hamad *et al.* (2018) investigate e-business adoption in Egyptian SMEs (including textile & apparel supply chain). Xing *et al.* (2016) study cloud computing utilisation for the textile & apparel supply chain. This study intends to explore how e-business initiatives can be used to improve full supply chain capabilities and SME competitiveness. From a SMEs perspective, in the textile & apparel supply chain, they need to fulfil the order to satisfy customer requirements. The order fulfilment time is crucial for supply chain management efficiency and competitiveness, so it is essential to focus on order fulfilment efficiency.

The research investigates the use and potential use of e-business initiatives to facilitate and strengthen supply chain capabilities for textile & apparel manufacturers. In particular, this study endeavours to explore current barriers to adopting e-business initiatives by small and medium size textile & apparel manufacturers and evaluate the benefits for these SMEs to implement e-business initiatives. This study further conducts and develops modelling simulation to study how e-business implementation affects the apparel order fulfilment efficiency and supply chain for Chinese small and medium size textile & apparel manufacturers.

Research aim: Analyse how e-business utilisation affects Chinese small and medium size textile & apparel manufacturers' supply chain capabilities.

The research objectives (ROs) of this study:

RO1 To identify e-business technologies and tools used in the textile & apparel supply chain.

RO2 To explore the barriers for textile & apparel manufacturers to implement e-business in the supply chain and the benefits of implementing e-business based on literature review and the interview with small and medium size textile & apparel manufacturers.

RO3 Conduct modelling simulation to:

- Design conceptual model to represent different levels of e-business utilisation (from no e-business to more advanced e-business level) in textile & apparel supply chain;

- Run the simulation based on the conceptual model to understand the effects of varying e-business utilisation levels in an apparel order fulfilment for a Chinese small and medium size apparel manufacturer in textile & apparel supply chain;

- Identify how e-business implementation influences textile & apparel order fulfilment efficiency and supply chain capabilities.

RO4 To compare and contrast the research results with the literature to develop the theory of e-business utilisation in textile & apparel supply chain, provide practical suggestions for Chinese small and medium size textile & apparel manufacturers to implement e-business initiatives.

1.4 Thesis Structure

Chapter 1 introduces the research background, chosen area, and the research aim and objectives.

Chapter 2 reviews the literature concerning e-business utilisation in the textile & apparel supply chain. It identifies the textile & apparel supply chain and e-business. The literature review explores e-business technologies and tools used in the textile & apparel supply chain like ERP, cloud computing, social media, platform, etc. The advantages and disadvantages of e-business utilisation in supply chain management are discussed. This chapter explores e-business applications for SMEs in the textile & apparel supply chain.

Chapter 3 is a bridging chapter that summarises the literature, it discusses research gaps based on chapter 2, gives the research design concepts based on the literature reviewed, and lists research propositions.

Chapter 4 provides the research methodology. It introduces research processes, such as research epistemology, theoretical perspective, methodologies and methods. This chapter examines different research approaches, such as qualitative, quantitative and mixed methods, and inductive, deductive and abductive methods. This chapter assesses different research methods' advantages and disadvantages separately, intending to select the most appropriate research method to achieve the research aim and objectives. It is followed by the research design explaining the adopted research methods and the justification.

Chapter 5 contains the conceptual model design and implementation, which form this thesis heart. It presents the four e-business utilisation levels. These sections include the environment design, agents design, modelling structure, architecture, interactions among the agents, and parameters. This chapter describes the detailed experiment design and model implementation in four scenarios.

Chapter 6 gives the simulation results obtained from the different sets of experiments and analyses the data, compares the influence of four e-business utilisation levels on the average time of different steps to fulfil an apparel order in the textile & apparel supply chain. The data collected from the agent based modelling (ABM) simulation are analysed by ANOVA, Boxplots, and Spearman’s rank correlation coefficient using the software of SPSS statistics. This chapter conducts difference analysis and correlation analysis to explore e-business utilisation level effects on apparel order fulfilment efficiency, discuss results, and test propositions.

Chapter 7 forms the conclusion of the thesis. The research objectives are reviewed in light of the research implications, and it is hoped that adequate answers to the initial research questions have emerged. The findings of this study are compared with the existing literature, theoretical contribution and practical implications are also provided. Research limitations are addressed, together with recommendations for further research.

The study results are expected to contribute to current knowledge for both academic and Chinese small and medium size textile & apparel manufacturers. Figure 1.4 shows the thesis structure.

Figure 1.4 Overview of the thesis

Project Stage	Key Elements	Comments
Analysis of gaps and justification of research propositions based on literature review	**Literature Review** • **Textile & apparel SCM** Textile & apparel SC Information sharing in SCM Relationship marketing in SCM Supply chain integration • **E-business utilisation in textile & apparel SCM** E-business application in textile & apparel SC E-business application for SMEs in textile & apparel SC E-business technologies and tools Benefits and barriers of e-business utilisation in in textile & apparel SC E-business process management E-business strategy management • **Conceptual framework** • **Research gaps** • **Research propositions**	**Chapter 2** Identifies e-business, supply chain management and introduce textile & apparel supply chain, e-business adoption in textile & apparel SC, e-business application for SMEs, benefits and barriers of e-business utilisation, and e-business process management and strategy management. **Chapter 3** Provides theoretical framework, describes the research gaps and research propositions.
Agent based modeling simulation Data analysis	**Research Methodology** • **Research process** Epistemology, paradigms, methodologies, and methods • **Quantitative, qualitative, and mixed method** • **Inductive, deductive, and abductive method** • **Research design** • **Adopted data collection method: ABM** **The Model Design Representing E-business Utilisation Level** • **Conceptual model design** Environment design Agents design and behaviors Modelling structure • **General consideration of model design architecture** Produce process map: an order fulfilment Agents architecture design Interactions among agents • **Experiment design** Experimental scenarios and flowcharts Experimental process • **Model implementation** **Results and discussion** • **Simulation outcomes** • **Data Analysis** The difference analysis The correlation analysis	**Chapter 4** Describes research process, illustrates different research methods, provides research design, and justifies the data collection method: ABM. **Chapter 5** Provides the conceptual model design, experiment design, and model implementation. **Chapter 6** Analyses the simulation results.
Contribution	**Discussion and conclusion** • **Research objectives** • **Theoretical contribution and practical implications** • **Research limitations and further work**	**Chapter 7** Compares research results with literature, gives contribution and implications, provides research limitations and the suggestions for future research.

Chapter 2 Literature Review

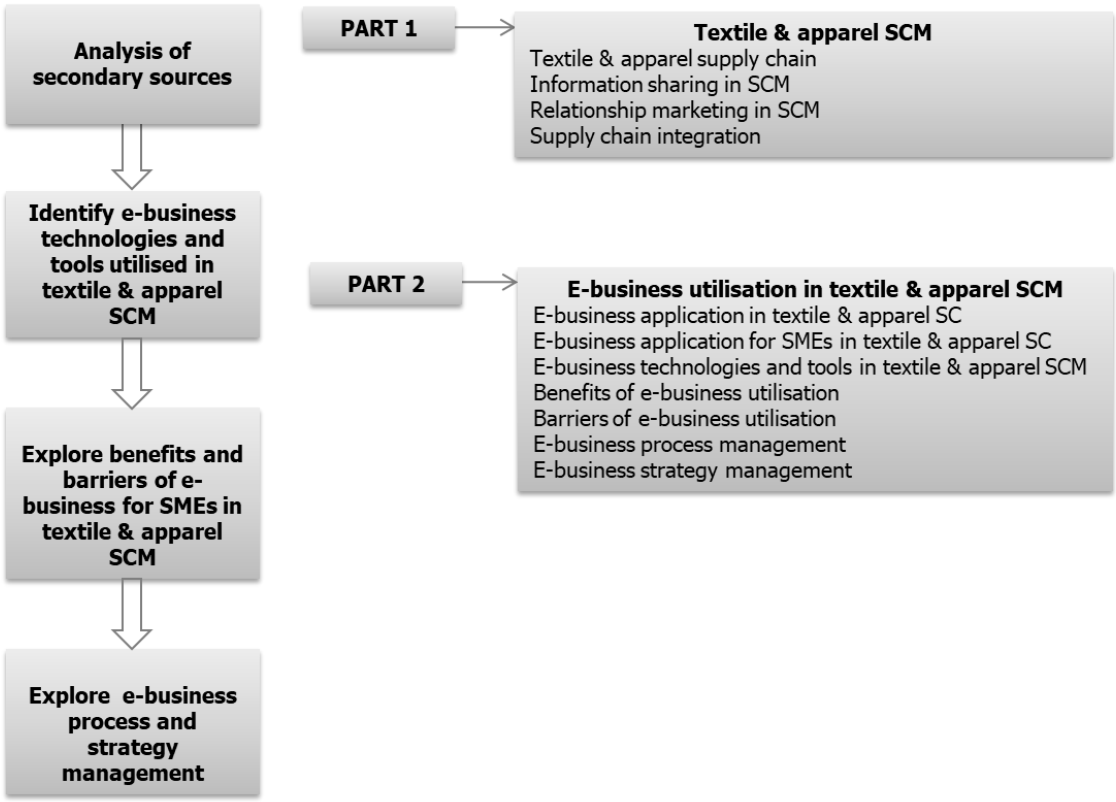
Topics in supply chain management have been widely studied. The issues of e-business are getting more attention in the age when e-business technology reaches such a height but has never been fully researched. The advancement of e-business makes it possible to quickly and precisely transfer and communicate information or data. Note that e-business does not guarantee effective applications, so research is indispensable to examine the impact of e-business utilisation in supply chain management in more detail.

Manufacturers of different industries face e-business development challenges, which pushes them to adopt internet-based technologies and tools to accelerate their business management efficiency. Ignoring initial enthusiasm and expectation, it is unclear how e-business is related to textile & apparel manufacturers and the actual profits. There is little evidence of effectiveness and the practical implementation of e-business practices in the textile & apparel supply chain for SMEs. Although some current research results are still preliminary, it seems that the choice of e-business has a relationship with the overall successful strategic factors of the manufacturers. Following this principle, it is meaningful to explore e-business utilisation and integration in the textile & apparel supply chain and understand its advantages and disadvantages in textile & apparel supply chain management.

2.1 Literature Map

This section illustrates recent literature on textile & apparel supply chain and e-business utilisation in supply chain management. The key point is to gain a necessary explanation of e-business utilisation in the textile & apparel supply chain, such as current e-business technologies and tools, advantages and disadvantages of e-business adoption, e-business process management, and e-business strategy design and implementation. Additionally, as shown in Figure 2.1, this chapter describes how to combine e-business initiatives within the supply chain to develop e-business strategies to improve supply chain capabilities, especially for small and medium size textile & apparel manufacturers.

Figure 2.1 Literature map



2.2 Textile & Apparel Supply Chain Management

Supply chain and supply chain management have made a remarkable appearance in management literature since the 1980s and have received considerable attention from academics and practitioners. Textile & apparel supply chain has some specific characteristics comparing with other industries.

2.2.1 Definition of Supply Chain Management

Oliveira *et al.* (2016, p.166) define the supply chain as "an aggregate set of value chains linked by inter-organisational relationships, both upstream and downstream of the leader company to deal with all the flows involved (such as cash, material, goods and information), from the first suppliers' supplier to the last customer of the end customer, as well as the reverse flow of products and returnable and/or disposable products, generating value for the end consumer and for SC stakeholders." Bhuniya *et al.* (2021) describe a supply chain as a medium to deliver goods produced in one place to another place globally and insist that it plays an undeniable role in various aspects of the world. A supply chain comprises all business activities, such as order planning, production scheduling, demand forecasting, raw material replenishment, production, distribution, logistic management, etc. These activities guarantee orders flow smoothly from the supplier to the factory and products flow from the factory to the customer. They are indispensable for effective order fulfilment and supply chain management to satisfy customer and stakeholder requirements.

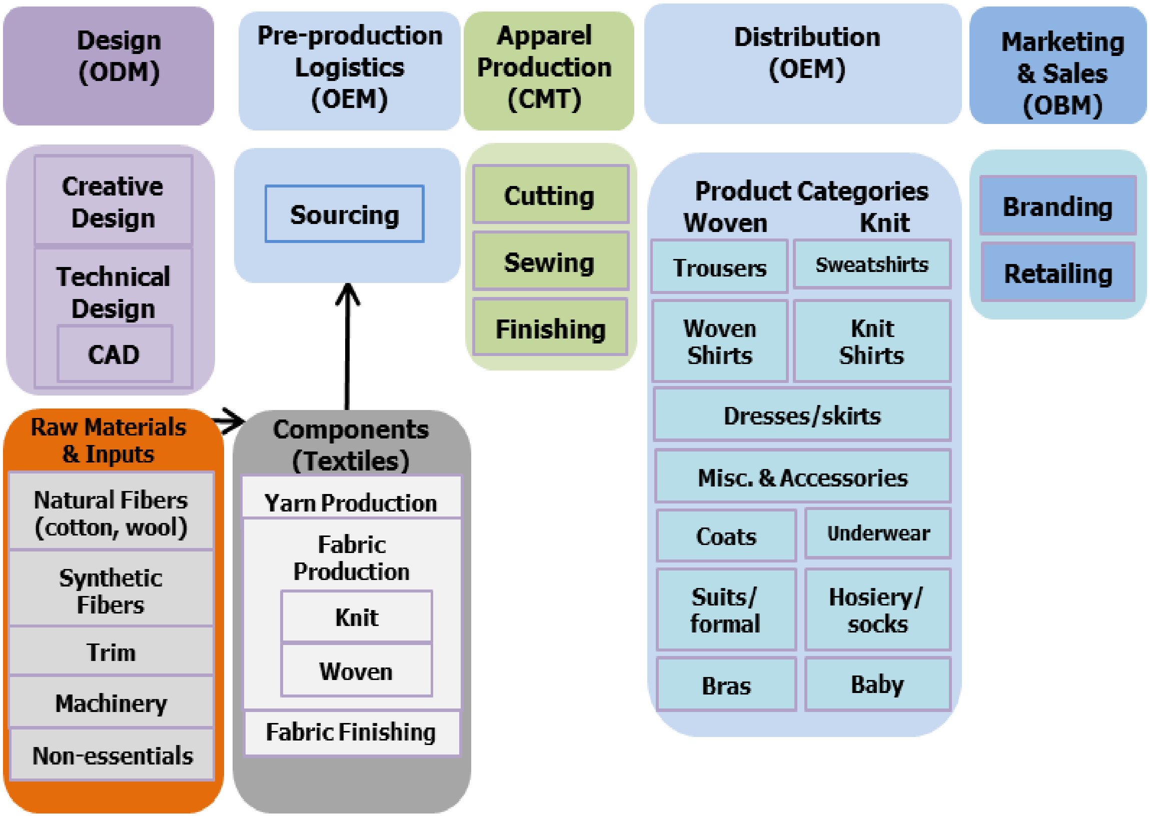
The Council of Supply Chain Management Professionals (CSCMP) defines supply chain management (SCM) as integrating supply and demand management inside and outside the company (2013). Thus, supply chain management connects units along the supply chain by coordinating information and product flow, integrating and managing relationships with suppliers and customers, and providing high-level value to different partners by reducing costs. Hsu *et al.* (2008) indicate that effective supply chain management can be considered a valid driver to reduce raw material costs and lead time, improve product and service quality and responsiveness, and create profits for all supply chain partners. Therefore, effective supply chain management helps companies reduce costs without deducting customer satisfaction and keeping competitive as a strategic weapon. Supply chain management roots can be studied intensively as system dynamics and analysis in response to customer demands, supply chain fluctuations, and the integration of logistics management (Chopra and Meindl, 2010).

2.2.2 Textile & Apparel Supply Chain

In the global market, textile & apparel manufacturers are under pressure to reduce costs and lead time (Warasthe *et al.,* 2020), respond quickly to constantly changing market demands, and face the challenges from geographic complexities (Iannone *et al.,* 2015). More and more firms purchase goods and materials from overseas, such as South East Asia and the Far East; some firms are moving manufacturing to neighbouring countries with lower labour costs, which may adversely affect the delivery cycle. Such conditions could affect enterprises to provide timely feedback for partners, and weak cooperation between suppliers and customers could lead to other arguments. Mensah *et al.* (2015B) insist that supply chain partners can benefit from the value chain when they understand the core value: improve supply chain network, reduce delays, enhance cooperation and partnerships, and cut costs. Therefore, effective management of the textile & apparel supply chain is essential to maintain effective collaboration and responsiveness between parties.

Frederick and Daly (2019) introduce the textile & apparel value chain in the global market (see Figure 2.2); there are five significant networks: design, pre-production (including textile production), apparel production, distribution, marketing and sales, and the apparel order fulfilment process also follows these steps. They also conclude some trends of textile & apparel industry development. For example, buyers prefer to purchase products from larger and more capable first-tier suppliers. Full package capability and lead time are more important than price. New markets in Asia bring more business opportunities. Country and industry characteristics still affect supply chain relationships, for example, tariff policies in some regions, particularly in South Asia.

Figure 2.2 Textile & apparel value chain

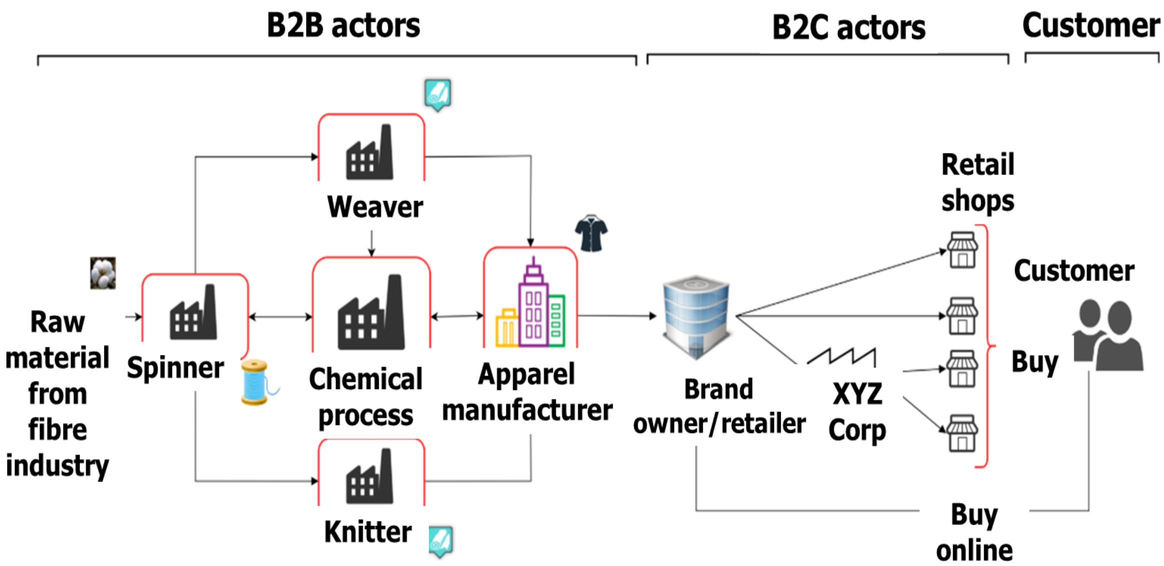


Source: Frederick and Daly (2019), p.11.

The entry barriers are relatively low for textile & apparel production. Such barriers will increase if the apparel value chain moves downstream to retail, as retail activities involve advertising and other expensive promotional activities, such as technological investments. The primary nature of the textile & apparel value chains is the power asymmetry between the manufacturer and retailer/buyer (Meng, 2015). Retailer/buyer can establish particular standards and require manufacturers to follow, or introduce some specific production processes, or even monitor production procedures, etc. The lead company usually decides how other partners conduct transactions in the supply chain. Thus, the textile & apparel supply chain is characterised by retailer/buyer-driven; only competent manufacturers can survive in the supply chain to provide global buyers products. For backward integration of raw material production, some competitive manufacturers may offer a full packaging service to integrate the entire textile & apparel supply chain (Frederick and Daly, 2019). However, not all textile & apparel manufacturers are qualified to do it; in developing or undeveloped countries, it is arduous to invest in advanced technology and production machinery, especially for small and medium size manufacturers.

The textile & apparel supply chain is managed by internet networks (Xing *et al.*, 2016). Figure 2.3 illustrates a textile & apparel supply chain network. It includes all business processes, from raw material purchasing, fibre production, apparel production to logistics management, all of which are under the e-business environment (Kumar *et al.,* 2017). The textile & apparel supply chain may vary in the real world; the diagram below shows only one example. Some partners may settle in different countries or fields in a global market environment, but e-business technologies and ICT tools connect all partners.

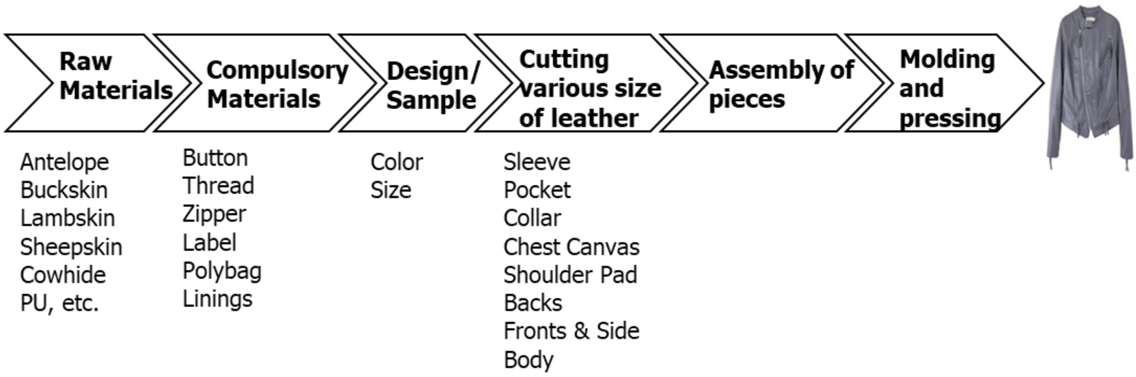
Figure 2.3 Textile & apparel supply chain network



Source: Kumar *et al.* (2017).

Following Frederick and Daly (2019), leather jacket production may include such steps: purchase raw materials or trims, design (or produce-to-sample), cutting various sizes of leather, assembly of the pieces, moulding and pressing (see Figure 2.4). The other textile & apparel order fulfilment process also can be described as such figures.

Figure 2.4 The leather jacket production process



Source: based on Frederick and Daly (2019).

The supply chain can be designed as a process, and in that process, all partner activities need to be pre-configured. The simplest design is to identify all the necessary partner interactions needed to fulfil supply chain management objectives. Process maps can be used to describe the interactions between each partner in supply chain processes, and process mapping symbols can be used to categorise different kinds of activities. Slack *et al.* (2016) introduce some commonly used symbols derived from scientific management or system analysis, and these symbols can be arranged in series, in parallel, to describe any process. Many techniques can be adopted for process maps (flowcharts) design. Each technique identifies different activities during the process and shows the information flow, people flow, materials flow, or money flow.

Process maps or flowcharts can illustrate textile & apparel order fulfilment processes. The textile & apparel supply chain connects raw materials suppliers, textile manufacturers, retailers/buyers and logistics companies (Frederick and Daly, 2019; Kumar *et al.,* 2017); these companies coordinate to achieve their different goals. The manufacturer is responsible for order production. Based on different customer requests, it may be resource-to-order, produce-to-stock, produce-to-order, part produce-to-order, or produce-to-sample, etc. (Slack *et al.,* 2016; Wikner and Rudberg, 2005). Frederick and Daly (2019) introduce the textile & apparel value chain, which involves an order fulfilment process; when textile & apparel manufacturers produce ordered products based on customer requests, the order fulfilment process may involve such steps: raw materials and trims purchasing, production, distribution, and the apparel order fulfilment process also follow these steps.

Figure 2.5 illustrates the fabric order fulfilment process (resource-to-order). The raw materials may be cotton, flax, silk, wool, rayon, nylon, polyester, etc. The customer request is at *Purchase*. The textile manufacturer purchases raw materials to produce ordered fabrics based on customer requests.

Figure 2.5 Fabric order fulfilment process map (resource-to-order)

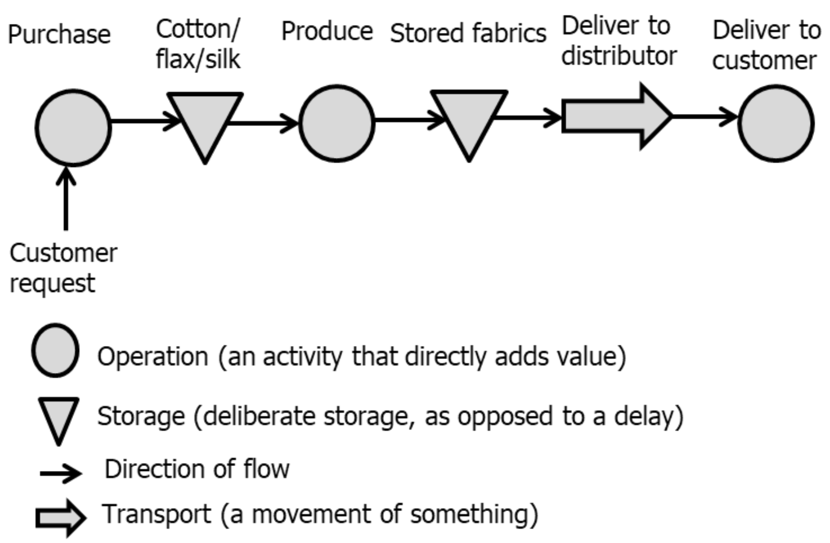


Figure 2.6 is the fabric order fulfilment process map (produce-to-order). The raw materials may be cotton, flax, silk, wool, rayon, nylon, polyester, etc. The textile manufacturer has enough raw materials to produce fabrics, so customer request is at *Cotton/flax/silk*.

Figure 2.6 Fabric order fulfilment process map (produce-to-order)

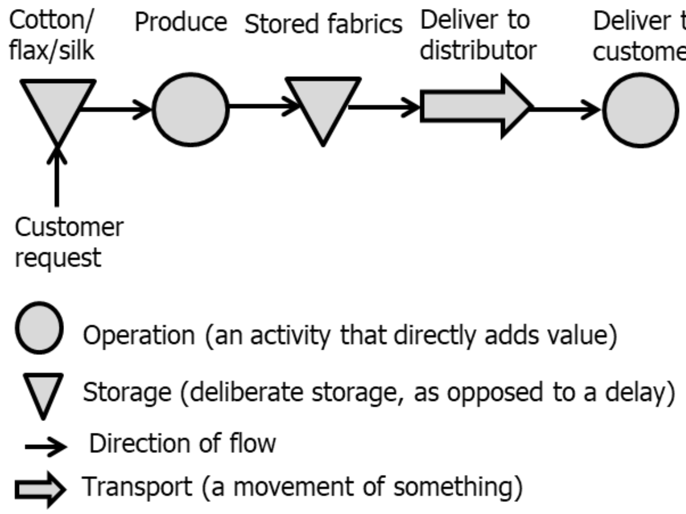


Figure 2.7 depicts the fabric order fulfilment process (produce-to-stock). The raw materials may be cotton, flax, silk, wool, rayon, nylon, polyester, etc. The textile manufacturer has enough finished fabrics, so the customer request is at *Stored fabric* before delivering to the customer.

Figure 2.7 Fabric order fulfilment process map (produce-to-stock)

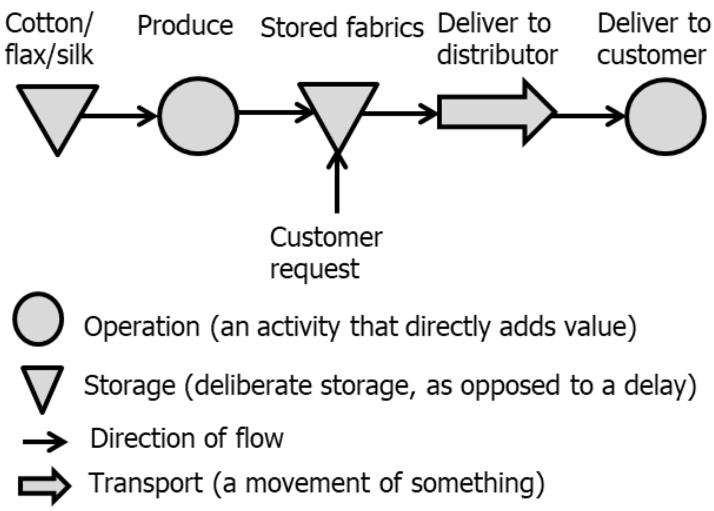


Figure 2.8 illustrates the apparel (jacket) order fulfilment process (resource-to-order), the raw materials may be cotton or leather (it depends on the customer order), and the stored jacket

replaces stored fabric. Meanwhile, the apparel manufacturer needs to purchase raw materials and trims according to customer request, so the customer request is at *Purchase*.

Figure 2.8 Apparel (jacket) order fulfilment process map (resource-to-order)

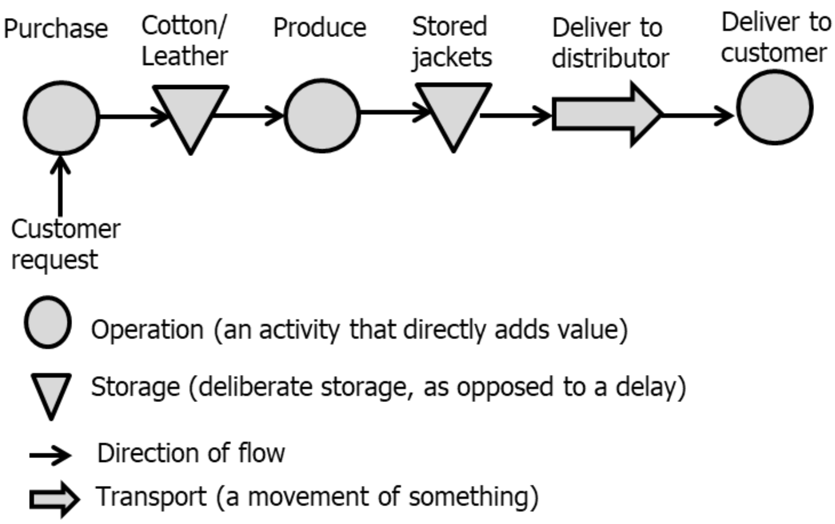


Figure 2.9 illustrates the apparel (jacket) order fulfilment process (produce-to-order); the raw materials may be cotton or leather (it depends on the customers request). The apparel manufacturer has enough trims and raw materials to produce the order, so the customer request is at *Cotton/leather*.

Figure 2.9 Apparel (jacket) order fulfilment process map (produce-to-order)

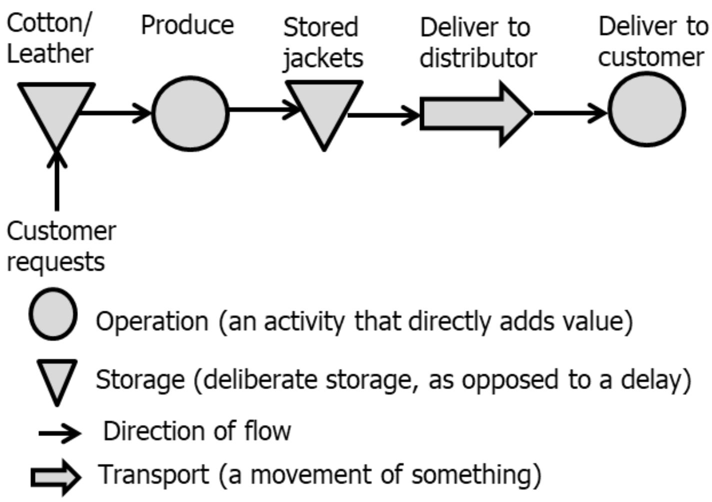


Figure 2.10 illustrates the apparel (jacket) order fulfilment process map (assemble to order). The apparel manufacturer has enough processed parts or trims such as sleeves, chests, shoulders, etc., to assemble the order jackets, so the customer request is at *Stored materials*.

Figure 2.10 Apparel (jacket) order fulfilment process map (assemble-to-order)

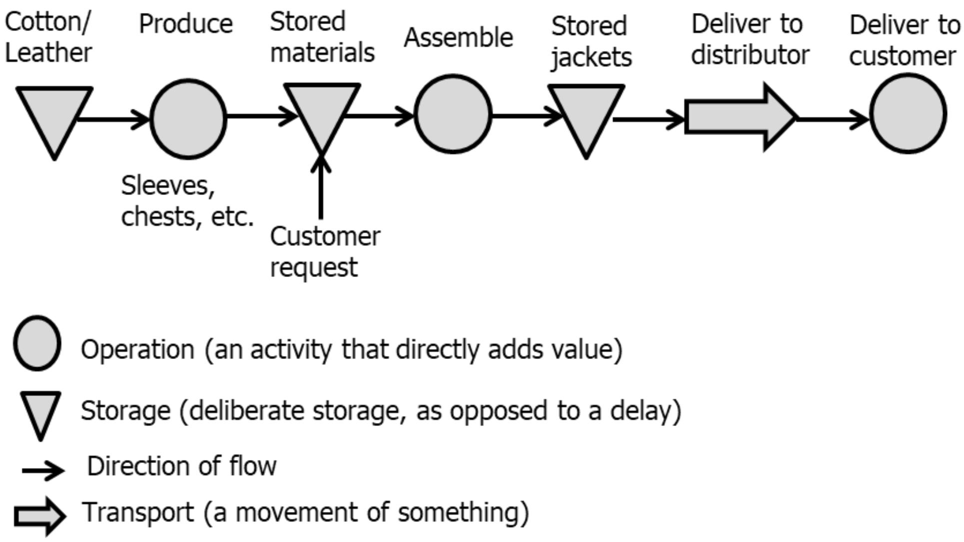
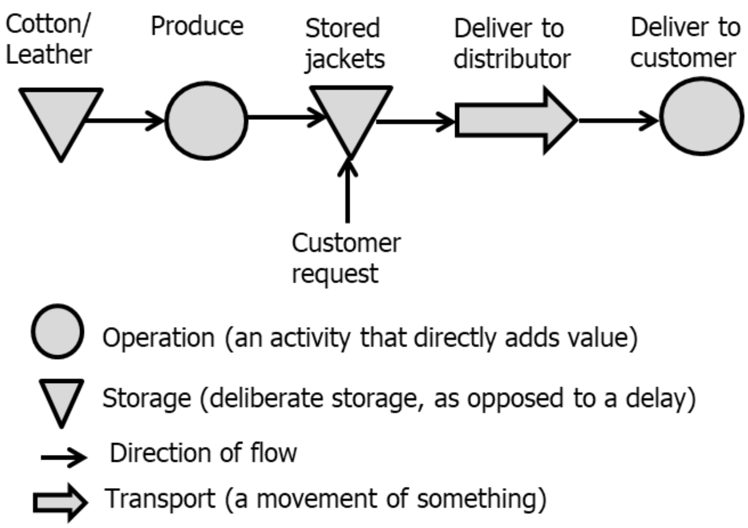


Figure 2.11 illustrates the apparel (jacket) order fulfilment process (produce-to-stock); when the apparel manufacturer receives the order, it will prepare raw materials based on customer request, make the jackets and deliver the jackets. Sometimes some steps can be cut; for example, if the apparel manufacturer has enough finished jackets, these jackets can be delivered directly from the warehouse to the customer when it receives the order. Hence, the customer request is at *Stored jackets.*

Figure 2.11 Apparel (jacket) order fulfilment process map (produce-to-stock)



To summarise, under different situations (resource-to-order, produce-to-stock, produce-to-order, part produce-to-order, or produce-to-sample), a jacket order fulfilment process may involve different steps: apparel manufacturer needs to receive the order, check the inventory, inquire raw materials, provide the offer and wait for the confirmation from customer or buyer, purchase raw materials, produce the ordered jackets, and deliver the finished jackets to customer or buyer.

Each activity can be reorganised within the mapping processes to improve the entire business process, which is the key benefit of the mapping process. Intel Corporation uses a process chart to examine the whole process operation. After careful consideration and calculation, the company adopts some new methods. It cuts some activities, then the actions are reduced from 26 down to 15, and several delays such as the time needed to finish the job are reduced by 28% (Slack *et al.*, 2016). Slack *et al.* (2016) also introduce some ratios to assess the order fulfilment efficiency and supply chain management efficiency, such as Little's law and throughput efficiency.

Little's law: throughput time = work-in-process × cycle time

Throughput time is the time between the release of an order and the shipment to the customer. The cycle time means the average time to complete one order production, and work-in-process implies the number of orders in the production process. It is simple and helpful to evaluate if the order fulfilment process is efficient. Textile & apparel manufacturers can reduce throughput time by improving production capacity or reducing the order quantity.

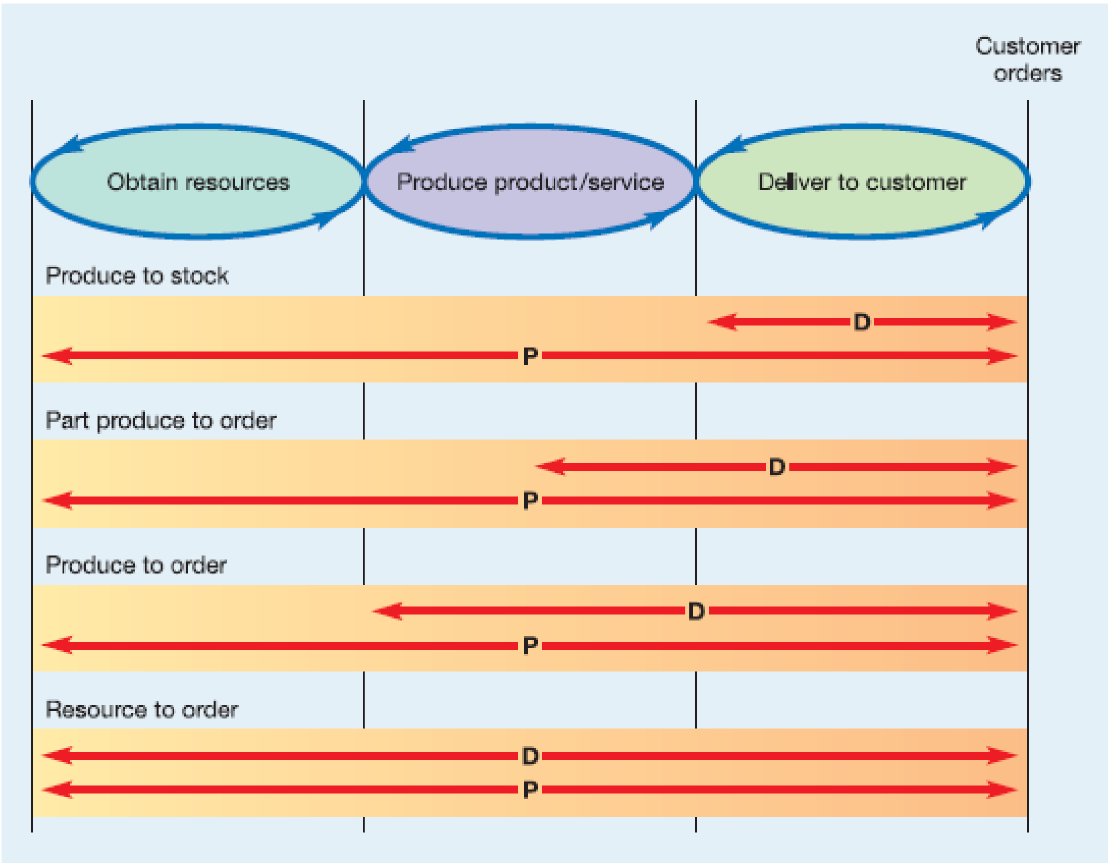
Percentage throughput efficiency = Work content/ throughput time×100.

Work content refers to the total amount of work needed to meet customer requirements. There are some unnecessary work contents in the order fulfilment process; these work contents may include some activities that cannot add value to the task. Such actions can be removed by utilising some new technologies and methods. Value-added throughput efficiency means that the work content should only include tasks that may add value to the order fulfilment process. Companies can calculate the throughput efficiency, evaluate all tasks, and remove some activities, such as delays, inspections, or unnecessary transportations (Slack *et al.*, 2016).

The P:D ratio is the ratio of demand time, production lead time (P) means the time needed for the manufacturer to produce and deliver the products, and demand lead time (D) represents the time required for the customer to place the order and receive the products. P:D ratio is designed by Shingo (1981) and extended by Mather (1998). It is used to contrast the total length of time the customer has to wait between placing the order and receiving the products. Slack *et al.* (2016) use the P:D ratio to characterise the grade between four different production operations.

Production lead time (P) and demand lead time (D) depend on the operations, such as produce-to-stock, part produce-to-order, produce-to-order, and resource-to-order (purchase resources and produce products for specific customer demands) (Slack *et al.,* 2016). In produce-to-stock operation, the manufacturer has finished products. Production lead time (P) is the sum of the time to transmit the order to the warehouse or distributor and then deliver the products to the customer. The customer only can see *Deliver to customer* cycle, so the demand lead time (D) is very short compared with the total throughput cycle. In resource-to-order operation, demand lead time (D) is the same as production lead time (P); both include the whole cycle of obtaining resources, making product/service, and delivering to customer. The produce-to-order operation lies in between the part produce-to-order and resource-to-order operation (see Figure 2.12).

Figure 2.12 P (production lead time) and D (demand lead time) for the different types of planning and control

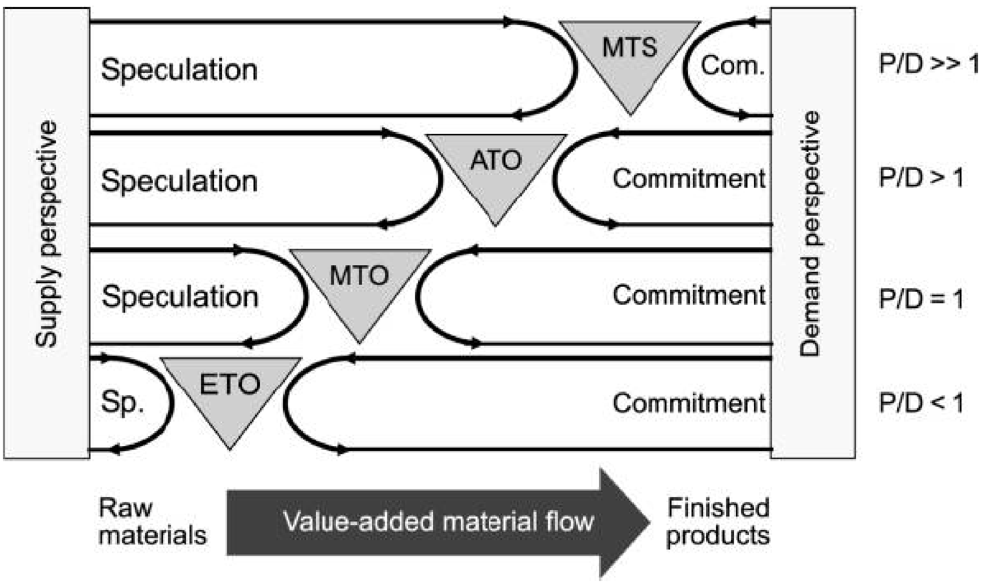


Source: Slack *et al.* (2016), p.277.

Reducing total production lead time (P) will influence the time customer has to wait to receive the ordered products. As shown in Figure 2.12, in resource-to-order operation, the production lead time (P) and the demand lead time (D) are the same. The customer waits from *Obtain resources* to *Deliver to the customer*. Expedite any portion of the production lead time (P), such as stock replenishment, production or delivery, customer waiting time, i.e., the demand lead time (D) will be shortened. Generally speaking, the production lead time (P) is always longer than the demand lead time (D) for most companies. A big P:D ratio is unsuitable for a manufacturer because it takes much more time to fulfil an order than the customers desire.

Customer order decoupling point (CODP) usually is defined as the point in the value chain, which decouples operation risks in two separated parts: forecast-driven production and customer order-driven production (Wortmann *et al.*, 1997). Operating activities are conducted in the upstream value chain to forecast (or speculate) and in the downstream value chain to fulfil customer orders. The CODP position impacts a manufacturer in many business aspects, so the company can adopt it as a business-level concept to develop strategies, tactics and manage operations. In this respect, CODP is designed based on the P:D ratio. The manufacturer may use the P:D ratio to determine the production plan and quantity based on the speculation or customer order (Wikner and Rudberg, 2005). Figure 2.13 represents four different P:D ratios and four typical CODP positions based on speculation and customer order: make to stock (MTS), assemble to order (ATO), make to order (MTO), and engineer to order (ETO).

Figure 2.13 Typical CODPs with P:D ratio



Source: Wikner and Rudberg (2005), p.626.

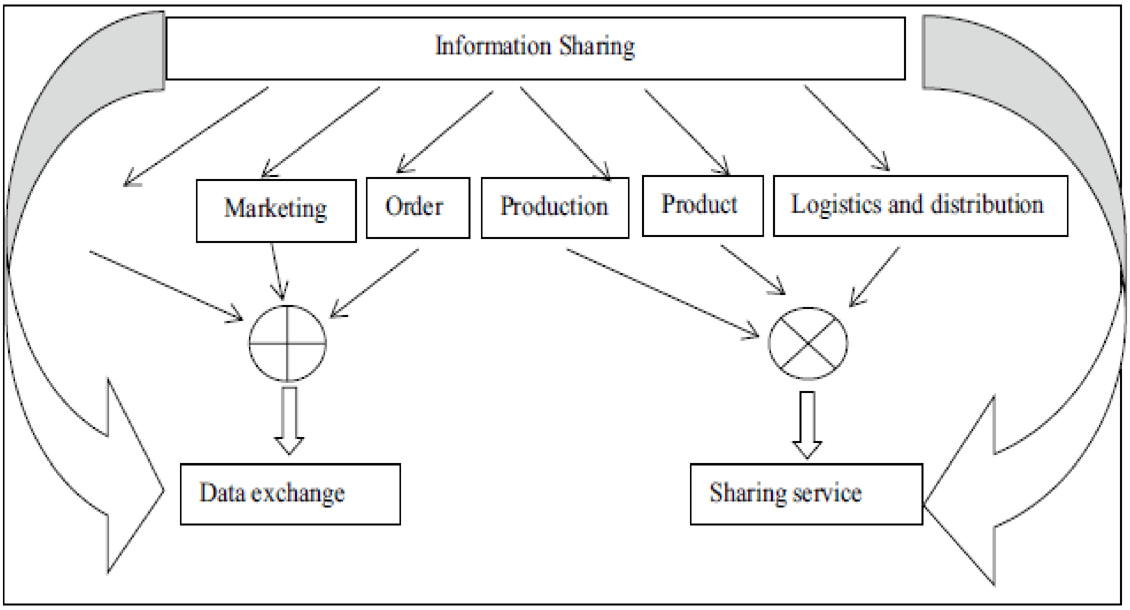
The production lead time (P) and demand lead time (D) frequently change, therefore reducing the production lead time (P) and demand lead time (D) means lowering costs and increasing profits. How much larger the production lead time (P) than the demand lead time (D) is essential because this ratio indicates the percentage of speculative activities in operation management. Suppose the production lead time (P) is much larger than the demand lead time (D). In that case, the operation carries significant risk. The proportion of speculative activities is too high, so reducing the P:D ratio is a valuable method to reduce some business risks for manufacturers. Textile & apparel manufacturers can use advanced e-business technologies and tools to reduce the P:D ratio to improve order fulfilment and supply chain efficiency.

Academics have studied supply chain management for different purposes, such as managing the process (Frederick and Daly, 2019; Xing *et al.*, 2016), using ratios to evaluate the business process efficiency (Slack *et al.*, 2016; Wikner and Rudberg, 2005), etc. The common goal is to improve supply chain capabilities and create competitiveness. Researchers use different methods to assess the supply chain efficiency, such as Little's law, P:D ratio, and the customer order decoupling point (CODP). These studies focus on the time and the steps of the production process and order fulfilment, trying to find the method to reduce the time needed to fulfil the order and minimise process time in the supply chain. Suppose a manufacturer can shorten raw materials purchase time, production time and delivery time, etc. The whole lead time will be shortened, and the manufacturer can complete more orders or produce more products in the same period.

2.2.3 Information Sharing in Supply Chain Management

Zhao and Zhao (2018) indicate that information sharing can affect supply chain efficiency and effectiveness. They summarise the main characteristics of the supply chain: complexity, dynamics, crossing, user-oriented demands, and provide the content of information sharing in the supply chain (see Figure 2.14). Information sharing in the supply chain involves exchanging data and services (supply chain partners can access the information service via an information-sharing platform). The information-sharing platform links a company to its customers, suppliers and distributors, and can create competitive advantages by accelerating information flow across organisational boundaries. In the meantime, some obstacles are hindering information sharing in a supply chain, for example, demand fluctuation, flexible production capacity, additional investment costs, conflicts of interest caused by information sharing between companies or apartments inside the company, inappropriate organisational structure, managers' and employees' ability, etc. (Zhao and Zhao, 2018).

Figure 2.14 Information sharing content and mechanism in supply chain



Source: Zhao and Zhao (2018).

Relationship management, information quality and information sharing can improve supply chain operational performance. A higher level of relationship and information sharing can optimise cost, improve responsiveness, and information technology capability significantly affects supply chain performance (Naqbi *et al.,* 2018). Manufacturers can use e-business as a pivotal component to integrate services, link partners into the supply chain. Good relationships between partners can speed up business process management to attain common goals and generate specific strengths to create mutual value for all partners. While these relationships may not always exist, they may only exist when companies seek market opportunities (Christopher, 2011). Information sharing links all partners and helps them survive and develop in this turbulent market; it is also an important indicator for measuring supply chain performance (Neria *et al.,* 2021; Susanty *et al.,* 2019). Information sharing allows for practical cross-functional and horizontal management in the supply chain and pushes the product and financial flow from one partner to another. E-business is the perfect tool for connecting all supply chain entities and establishing the virtual supply chain, and partners can share information to manage orders, replenishment, production, shipment, etc.

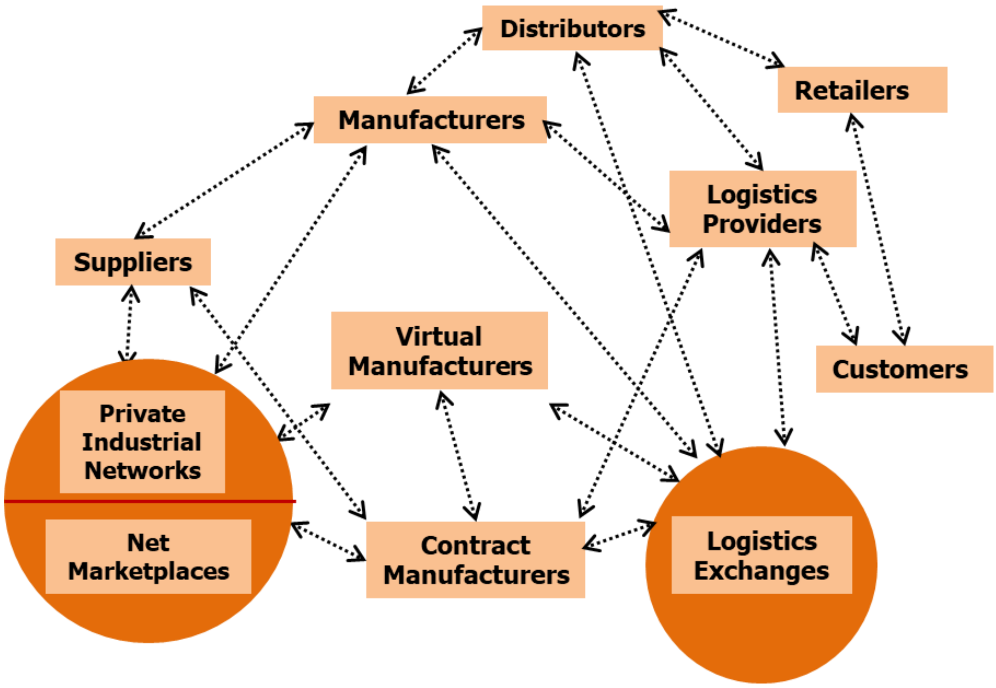
There are four phases along the textile & apparel value chain: design, raw material procurement, production and delivery (Frederick and Daly, 2019). Each stage has different information system modules, and these modules are integrated by information sharing. The manufacturer can use these modules to make strategic plans, provide training and education for staff even executives, establish communication and information systems, and implement the strategy. E-business technologies and tools can accelerate data gathering, information collection and sharing. Information systems can be designed to promote the integration of four phases of the supply chain and accelerate a virtual supply chain. Participants work together in the virtual supply chain as if they are doing a large business. Once the project is completed and the task is solved, the virtual supply chain will be dissolved, and new participants will form the new virtual supply chain.

Shamsuzzoha and Helo (2017) investigate the events and risks in a business network and indicate that cooperation in a virtual supply chain can reduce risks and manage events more effectively and efficiently. Manufacturers can use a virtual supply chain to create a competitive business. The virtual supply chain uses suitable e-business to link companies producing and distributing products or services without considering the organisational boundaries and physical locations. Partners in the virtual supply chain can take advantage of each other without being physically tied. Companies can use the virtual supply chain model to exploit new opportunities. For example, Hong Kong-based Li & Fung is enlisted by some fashion companies, such as Ann

Taylor, GUESS and Reebok, to manage apparel production and delivery. Li & Fung sends instructions to more than 15,000 suppliers in over 40 countries, from product R&D, inventory replenishment, production control and shipping. Working in a virtual supply chain enables Li & Fung to quickly satisfy clients' requirements to keep pace with flexible fashion trends (https://funggroup.com).

Given the impact of globalisation, the supply chain spans multiple countries and faces additional challenges and complexities. Information exchange becomes more critical in the global supply chain, and e-business can help companies manage procurement, production, transportation and payment in the supply chain. For example, the textile & apparel industry relies heavily on manufacturers in China, Turkey, and other low-cost regions. Textile & apparel manufacturers have to use internet technology to manage production and the global supply chain (Laudon and Laudon, 2014). Internet technology accelerates material flow and information flow sequentially between supply chain partners, so raw material suppliers, manufacturers, distributors, and customers can adjust orders or schedules immediately. Laudon and Laudon (2014) claim that an internet-driven supply chain helps companies streamline both inside and outside supply chain and provide managers detailed data about the production, store and delivery (see Figure 2.15). By integrating and managing the internet-driven supply chain, manufacturers can build a multi-directional communication system to predict customer demand, launch new products, enhance logistic service, and reduce inventory costs.

Figure 2.15 The emerging internet-driven supply chain



Source: Laudon and Laudon (2014), p.380.

In a volatile marketing environment, textile & apparel manufacturers have to compete in limited markets and offer a wider variety of products and services. Retailers tend to place small orders to deal with lean retail practices, so predicting demand, planning production, and synchronising orders are major tasks for manufacturers. Under such an environment, supply chain management risks have increased, such as increased transaction costs and lower profits. Hence, designing a robust and resilient supply chain is indispensable without undermining its effectiveness. Ait-alla *et al.* (2014) indicate the importance of robust production planning in the fashion apparel industry. In the new situation, e-business can play a crucial role in improving performance. E-business can be used to support information management and accelerate information flow, so the supply chain can be more robust and resilient without reducing its efficiency. The supply chain management objective is to improve the supply chain efficiency, and a robust and resilient supply chain can reduce risks and improve efficiency (Cox *et al.*, 2020). To enhance supply chain resilience and robustness, managers should consider some factors:

interactions, supply chain flexibility, decision-maker, and attitude: proactive or reactive (Mackay *et al.,* 2020).

Information sharing plays a vital role in managing the business process (Laudon and Laudon, 2014), connecting partners (Zhao and Zhao, 2018), and driving the essential information flow between partners (Naqbi *et al.,* 2018). Information sharing involves all supply chain functions, such as order confirmation, raw materials procurement, production, delivery, etc., and positively affects supply chain efficiency (Laudon and Laudon, 2014). Manufacturers can use e-business solutions to accelerate information sharing in the supply chain, manage business processes, support partners to cooperate, and establish a robust and resilient supply chain.

2.2.4 Relationship Marketing in Supply Chain Management

As an academic domain separate from marketing, relationship marketing emerged in the 1980s and became more comprehensive. Morgan and Hunt (1994, p.22) provide a broad definition of relationship marketing: "Relationship marketing refers to all marketing activities directed towards establishing, developing, and maintaining successful relationship exchanges", most of these activities are in the supply chain. Other researchers consider relationship marketing as a process. Palmatier (2008, p.3) argues relationship marketing is "the process of identifying, developing, maintaining, and terminating relational exchanges to enhance performance". So relationship marketing is a process that allows partners to identify and exchange values to gain what they want (Kotler and Armstrong, 2010).

The success of an enterprise depends not only on integrating its business process but also on its relationships with supply chain partners (Yuen and Thai, 2017). Long-term relationships are essential for a firm to achieve collaboration in the supply chain to produce higher quality goods, reduce costs and risks, generate innovative products, and enhance market value (Gunasekaran *et al.,* 2015). Relationship marketing aims to establish, maintain, and terminate relationships with customers and stakeholders, suppliers, partners, and even competitors when necessary, so relationships (mutual trust, commitment and satisfaction) among partners can positively influence supply chain performance (Osobajo *et al.,* 2021). The critical concept of relationship marketing is establishing and nurturing long-term relationships based on mutual benefits. All supply chain partners can trust each other and improve the whole supply chain performance. By establishing and maintaining relationships with supply chain partners, manufacturers can gain profits and obtain long-term relationships, high-level loyalty and closer cooperation (Baron *et al*., 2010). The intended benefit of establishing cooperative and collaborative partnerships is to reduce business uncertainties through commitment and collaboration. Therefore, partners will understand and accept the purpose of deep participation. This concept is already realised by the reality that firms know they have to trust each other and cooperate in the competitive environment to survive. As a result, collaboration and interdependence between supply chain partners become increasingly crucial in creating sustainable competitive advantages and improving all participants' values.

Establishing and maintaining long-term relationships with partners is crucial for enterprises (Leahy, 2011). Relationship marketing becomes a business necessity as it can be deployed across the supply chain to enhance efficiency. Relationship marketing can improve operational effectiveness in the short term and affect strategy direction. Facilitating long-term partner relationships can accelerate competitive advantages, and e-business integration positively affects relationship management and operational performance in the supply chain context (Shi and Liao, 2015). Choi and Jin (2015) use structural equation modelling to study dynamic trust in social e-commerce in the Chinese market. They classify trust as initial trust and ongoing trust. The research results show that ongoing trust affects purchase intention more positively and significantly than initial trust based on the questionnaire survey and data analysis. Companies must be agile enough to adopt the advanced e-business technologies and tools to build and maintain ongoing trust to attract new clients and keep current customers. They also suggest that the Chinese government should emphasise ongoing trust when making an e-business policy. Oelze (2017) claims that intra-industry collaboration is critical to develop sustainable supply chain management for the textile & apparel industry. A healthy and stable relationship helps companies save resources and earn knowledge and communication benefits. Accenture (2020) insists that future success in the fashion supply chain will depend on mutual respect and trust between supply chain partners. Advanced e-business technologies can enable collaboration by automating business processes, sharing data and ideas, facilitating communication, etc.

Literature about relationship marketing focuses on establishing, developing, and maintaining relationships between supply chain partners, so companies should try to trust each other, achieve coordination and accelerate business activities to improve supply chain efficiency (Osobajo *et al.,* 2021). E-business has positive effects on relationship marketing. As the development trend of the supply chain management is integration, better integration needs excellent communication and cooperation between partners, so relationship marketing becomes very important. Managers may consider using e-business solutions to accelerate relationship marketing management.

2.2.5 Supply Chain Integration

Under normal circumstances, the supply chain management objective is to effectively create and manage the order fulfilment that competitors cannot easily match (Cox *et al.*, 2020). Integration has significant impacts on supply chain performance; the higher integration means better business performance and a higher level of collaboration (Naqbi *et al.,* 2018; Prajogo and Olhager, 2012), so manufacturers should value and invest in the supply chain integration. Furthermore, the overall and strategic perspective of the supply chain should support the integration among partners.

Supply chain integration means integrating financial, physical, and information flow in the business process (Manuel Maqueira *et al.,* 2019), which involves interaction, cooperation, and collaboration among all supply chain partners (Bui *et al.,* 2021). Companies try to use IT tools to seek such integration in the supply chain (Gorkhali and Xu, 2016). Advanced e-business facilitates information integration in the supply chain (Gorkhali and Xu, 2016; Yang *et al.,* 2016, 2018). For example, cloud computing can improve supply chain integration and efficiency (Bruque *et al.,* 2015; 2016). Llach and Alonso-Almeida (2015) also insist that ICT utilisation has essential effects on supply chain performance. ICT is the key driver for small companies to survive and maintain competitiveness in such a volatile global market. Zhang *et al.* (2016) study the impact of ICT on supply chain performance from two sides: the inter-organisational and intra-organisational sides. The research result shows that the utilisation of inter-organisational ICT has more positive and direct effects on supply chain integration and performance improvement, and intra-organisational ICT improves information quality. They insist that it is necessary to integrate the supply chain effectively. Kauremaa and Tanskanen (2016) establish a conceptual framework to design inter-organisational ICT for supply chain integration. The research results stress the effects of ICT on the supply chain, which provides a systematic tool to develop and evaluate inter-organisational ICT implementation on supply chain integration. Garcia-Alcaraz *et al.* (2019) investigate the effect of ICT integration on a Mexican maquiladora supply chain and indicate that high-level ICT means a high level of flexibility and agility in the supply chain and brings more financial incomes.

Some researchers focus on textile & apparel supply chain integration. Bruce and Daly (2011) use a case study to explore how to combine the lean and agile supply chain of the UK apparel industry. Meng (2015) designs a model to manage the supply-demand relationship using information technology based on modularity theory in the textile supply chain. Vanathi and Swamynathan (2016) investigate the positive impacts of supply chain strategies on the south Indian textile & apparel industry competitiveness. Kumar *et al.* (2017) highlight the importance of traceability in the textile & apparel industry, which is established on the information flow. Partners in the textile & apparel supply chain may locate in different worldwide regions. They have to face various problems, such as geographical distance, time difference, local law and other issues. The textile & apparel supply chain will become increasingly complex, so traceability can affect its effectiveness and efficiency.

Industry cluster theory in supply chain decision-making is recommended for the textile & apparel industry. In recent decades, the Chinese textile & apparel industry has fostered economic development at a high level, with some typical characteristics. Many raw material suppliers have moved to major raw material production regions, such as Xinjiang Province. A lot of deep processing and finished product manufacturers have moved to developed areas, such as the southeast coast. In these regions, the local government provides preferential policies and systems to support textile & apparel manufacturers to accelerate their development, so textile & apparel industry clustering becomes increasingly important. Liu *et al.* (2017) focus on Chinese textile & apparel industrial clustering to construct the geo-relationship network and competing relationship network, and the study investigates 2,436 enterprises from 11 different industrial clusters. They insist that coordinating different relationships among supply chain partners can develop the whole textile & apparel supply chain capabilities and foster economic development.

Integration is not the new theme of supply chain management, and researchers study integration from different angles. For example, from adding value and improving performance (Naqbi *et al.,* 2018; Prajogo and Olhager, 2012), managing production process seamlessly (Manuel Maqueira *et al.,* 2019), affecting supply chain performance (Llach and Alonso-Almeida, 2015; Zhang *et al.*, 2016), utilising ICT in the supply chain, and establishing industrial clustering (Liu *et al.,* 2017), etc. These studies indicate that integration positively impacts supply chain efficiency and performance, and ICT places a vital role in the supply chain integration process. Successful information flow is crucial in integrating the whole supply chain and improving performance (Wong *et al.*, 2015). There are some obstacles for enterprises to integrate the supply chain. A few companies object to integration or lack confidence or enthusiasm to integrate supply chain partners (Yuen and Thai 2017).

2.3 E-business Utilisation in Textile & Apparel Supply Chain Management

E-business initiatives have become the central theme of the business strategy. Firms should understand e-business development trends and have a vision of the applications. Supply chain partners can use e-business to exchange information, communicate with each other, improve order fulfilment efficiency, accelerate business process management, and improve supply chain performance and capabilities (Chandak and Kumar, 2020). It is reasonable that an e-business solution could support supply chain management, formulate and implement corporate strategy.

2.3.1 Definition of E-business

Ciarniene and Stankeviciute (2015) define e-business as a critical competitive strategy that uses innovative ICT inside and outside the enterprise to automatically manage business processes, improve competitiveness, and add customer value by the internet-connected network. Therefore, e-business means applying digital technology to support online business process management and a strategic capacity. A company can use it to identify and take advantage of potential opportunities through cooperation with suppliers, customers and other partners (Arias-perez *et al.,* 2020). Bi *et al.* (2014) define e-business capability as a concept; enterprises may use it to track orders, communicate within the organisation, purchase raw materials, and cooperate with customers. E-business connects all partners, pushes information flow throughout the supply chain, manages all business processes, such as production, financial transactions, office automation, cooperation with partners, supply chain management, and distribution network management. Companies can market products, provide customer service online, or purchase raw materials online (Zhu *et al.*, 2015), so e-business accelerates digital supply chain management.

Following the emergence of internet technologies, nearly all companies use e-business to manage business processes. Compared to traditional methods, as a high-level interactive internet platform, e-business promotes value co-creation for all business partners more efficiently (Sharma, 2013). Companies can use e-business to simplify their business processes and improve their presence in the competitive marketplace (Simic *et al.,* 2019). Therefore, companies can co-create value with their suppliers and customers through order fulfilment by utilising various e-business technologies and tools, such as participating in new product design and launch and offering the necessary feedback quickly. Similarly, companies can create value for themselves and their partners by providing customised solutions in marketing. Even small companies are trying to utilise e-business to conduct various business activities. They use e-business to seek more resources and relevant investments, explore new business partners, discover new customers, and find new business tools to market their products and services.

Ciarniene and Stankeviciute (2015) list the categories of e-business adoption based on the type of activities: e-commerce, business intelligence, supply chain management, customer relationship management (CRM), enterprise resource planning (ERP), e-marketing and e-services. E-business is sometimes considered to have the same meaning as e-commerce, but they are different. E-commerce means to sell goods and services online, so it is a subset of e-business. E-commerce is part of e-business because e-business includes all business activities using ICT. E-commerce only consists of online sales, and it is a platform to connect manufacturers and buyers. Meanwhile, e-business involves ICT and tools, such as CRM, ERP and EDI; firms can purchase and use such software to communicate with clients and supply chain partners and manage business processes.

2.3.2 E-business Applications in Textile & Apparel Supply Chain

The supply chain encompasses different business process activities, such as transferring raw materials and products, information and services flow from suppliers to end customers. These activities can be divided into two fundamental stages: supply chain planning and implementation. Supply chain planning includes advanced planning, demand calculating, production planning and transportation planning, which are necessary components of effective replenishment and production cooperation according to customer needs. Supply chain implementation includes order planning, production, material replenishment, distribution and logistics. These factors can guarantee a smooth flow of orders through the system, from material procurement to production operations and customer transportation. The supply chain objective is to improve efficiency through all business processes (Cox *et al.*, 2020), which can be achieved by using the appropriate e-business tools to accelerate information sharing between supply chain partners.

Many researchers are interested in optimisng the supply chain network and looking at the supply chain from demand management, inventory management, logistic management and information management (Zarandi and Kazemi, 2012). Moreover, it is arduous to copy or imitate successful e-business application capability because each manufacturer faces different situations to design and implement e-business, such as investment and management. As a result, manufacturers have entirely different e-business performances by utilising the same e-business technology. E-business can create and sustain competitiveness, although it cannot directly affect performance. The manufacturer can only transform the potential benefits into practical benefits when it employs the appropriate e-business to accelerate production and business process management. Its ultimate competitive advantage may depend on e-business capabilities and complementary resources within the company.

E-business and supply chain management have been studied for about 30 years. E-business plays a more critical role in supply chain management. It connects all partners and affects all business process activities, from planning to execution, from raw material procurement to delivering products to the end customer. Advanced e-business solutions bring more flexible communication between partners and reduce the overall time. E-business initiatives can help manufacturers carry out strategic activities to develop their supply chain capabilities. For a textile & apparel manufacturer, external factors are the motivation to improve technological capabilities, such as customer demands. Not all manufacturers are willing to invest in it, especially SMEs (Kayabasi and Gumus, 2012). By utilising e-business, enterprises can increase sales, improve customer service level and distribution channels, increase communication flexibility with partners, push managers to touch new technology, and support strategic decision making and implementation (Kayabasi and Gumus, 2012). Enterprises also have to face some obstacles in the supply chain when they utilise e-business, for example, lack of time, high investment costs (Zhao and Zhao, 2018), the complexity of e-business application (Krishna and Singh, 2018). It is also challenging to choose an appropriate e-business solution to construct an e-business infrastructure (Chatzoglou and Chatzoudes, 2016; Raymond *et al.,* 2015).

A textile & apparel supply chain involves different partners, so it is a network. It is increasingly fragmented as a result of globalisation. Buyers can find new sources of supply on global scope then reduce costs, and suppliers can also reap huge fruits because they can attract new clients worldwide. The textile & apparel supply chain has undergone significant manufacturing automation changes, information technology development and system modernisation. New manufacturing philosophies and new types of organisations have emerged under competitive pressure, such as computer integrated manufacturing systems (CIMS), virtual organisation, internet-based manufacturing and remote manufacturing. In recent decades, advanced e-business has accelerated textile & apparel manufacturing technologies and pushed manufacturers to increase their productivity, improve product quality, and cut production costs. For example, in China, more and more textile & apparel manufacturers use different kinds of e-business, such as e-commerce platforms, like Taobao, Tmall, JD, etc. and social media, like WeChat, QQ and WeCom, etc. WeChat and QQ connect people and organisations, so staff and departments can establish different chat groups to exchange information online. Enterprises can apply for an official account to manage the business process online. WeCom is only open for official organisations; registered companies can use WeCom to establish official groups for staff and departments inside the company and connect raw material suppliers, distributors, and buyers in the supply chain to manage the business process. Many textile & apparel manufacturers can be searched by these social media Apps and e-commerce platforms. CNNIC Report (2015, 2020) investigates e-business applications in the Chinese manufacturing industry (including the textile & apparel industry) and lists e-business technologies and tools. For example, website, webpage, software, such as CRM (customer relationship management), ERP, e-commerce platforms, such as Taobao, Tmall, Tnc and JD, search engines, such as Baidu, 360, App, 5G technology, big data, etc.

An example is Tnc. Tnc.com.cn is an e-commerce platform in China that links textile & apparel manufacturers and retailers and has 2.06 million registered members in 2020. By the end of 2020, there were 620,000 registered companies, 110,000 customers from 80 different countries worldwide, and over 80,000 online stores. There are 1.2 million page views per day. Tnc introduces 17 kinds of textile & apparel products, like raw materials, fabrics, textiles, apparel, etc.; users can search for helpful information on the website. Tnc helps registered members introduce their products and services. It also provides supply and procurement information, introduces fabric or apparel manufacturers, and provides news and policies about the Chinese textile & apparel industry. It also provides an English webpage and App service so that foreign companies also can use the platform and mobile devices to do business anytime, anywhere. In 2020, the online turnover was 60.705 billion RMB, an increase of 15.28% compared to 2019. Since 90% of Chinese textile & apparel manufacturers are SMEs, it is an excellent opportunity to use such a platform to attract more customers and improve profitability. They can register as members, display their products and services online, attract orders, and manage order fulfilment by e-business tools. Customers can search for them or their products and services to connect with new clients worldwide. But SMEs may need skilled staff to manage the online business process, advertise their products and services online. They also should consider their production capability and the order quantity they can afford. Meanwhile, if they receive overseas orders, they need professional staff to deal with some problems, such as foreign language, time difference, foreign law, international transport, etc.

2.3.3 E-business Applications for SMEs in Textile & Apparel Supply Chain

SMEs have some unique characteristics; for example, they vary in sectors and have different business objectives. Some SMEs are motivated by lifestyle or family, and others may focus on economic goals. Because of the limited scale, SMEs have small and centralised management, and the owner or senior managers can influence the administration (Abdullah *et al.*, 2018; Zhao and Zhao, 2018). SMEs also have limited resources, so they tend to avoid risk and are more adaptive or agile than large enterprises (Fatimah *et al.*, 2016).

Compared with large size manufacturers in the textile & apparel supply chain, SMEs have small scales, insufficient resources such as money, skilled staff, etc. (Abdullah *et al.,* 2018; Zhao and Zhao, 2018). They also have to face social, economic, geographic, or cultural problems, so it is difficult to forecast the market need (Vesela, 2017). SMEs have small scales, so it is more flexible for them to adjust their strategies, change production plans and predict fashion compared with large companies. They are still weak in planning strategy, accessing advanced technology, and obtaining necessary resources (Bi *et al.,* 2017), so they struggle to develop even survive.

SMEs play an essential role in the textile & apparel supply chain; for example, the Textile/Clothing and Footwear (TFC) industry in Europe is the global leader and second exporter in the top and luxury fashion goods. Rinaldi and Bandinelli (2019) suggest that one reason for its success is the excellent relationship between international brands and related SMEs in the supply chain. The strong cooperation promotes the launch of new designs, accelerates high levels of feedback and flexibility, and provides customers with high-quality products and services. In addition, textile & apparel products have very short life cycles. The market is seasonable; manufacturers tend to serve smaller or niche markets and then keep limited growth, so it is no coincidence that most textile & apparel manufacturers are SMEs (Euractiv, 2019).

Meanwhile, small and medium size textile & apparel manufacturers are in a recessionary environment and face large, influential retailers and meet variable market demands. For example, there are large apparel retailers/buyers like Zara and Mango. SMEs have to satisfy changeable or particular requests from different retailers and buyers and, at the same time, predict fashion demand correctly and provide quick replenishment. Therefore, information exchange becomes more critical in the textile & apparel supply chain. SMEs can use e-business tools to control and facilitate all supply chain processes, achieve a quick response, improve supply chain efficiency and develop capabilities, especially in a dynamic environment.

Considerable studies have been initiated to investigate e-business utilisation for SMEs. The research results indicate that successful adoption of e-business is vital for SMEs to survive and obtain profitability (Fatimah *et al.,* 2016; Mazzarol, 2015). SMEs must understand the impact of e-business first and then develop necessary e-business capabilities better than competitors. Current online business development puts severe pressure on SMEs to survive in the dynamic market. E-business can help SME reduce costs, combine capital and information, improve operational efficiency, gain business value, and improve supply chain performance by strategic IT alignment, market orientation, and business partnership management (Raguseo, 2018; Razali *et al.,* 2018; Suresh and Mohideen, 2016).

Some researchers study the relationship between e-business and SMEs in the textile & apparel supply chain. Raymond *et al.* (2015) adopt a survey method to study the effects of e-business on international manufacturing SMEs performance (including small and medium size textile & apparel manufacturers). The research results show that e-business capabilities significantly impact SMEs' internationalisation performance when facing increased environmental uncertainty. The appropriate e-business projects can support these SMEs to do business more efficiently and effectively. Hamad *et al.* (2018) investigate the business-to-business e-commerce adoption of Egyptian manufacturing SMEs (including textile & apparel manufacturers). The research results indicate that manufacturing SMEs still do not understand the positive relationship between e-commerce and competitive advantages. The reason could be the lower recognition of its value and the high investment costs. Popa and Soto-Acosta (2015) conduct a pilot study and a questionnaire in Spanish manufacturing SMEs to study factors affecting e-business adoption: information systems integration, commitment-based human resource practices and horizontal competition. They use partial least squares structural equation modelling to analyse the data. The empirical results reveal that information system integration is the most vital factor affecting e-business adoption. Commitment-based human resource practices have positive effects on e-business adoption. Besides, the results show that e-business adoption positively impacts organisational innovation and enterprise performance. Chatzoglou and Chatzoudes (2016) use a structured questionnaire research method to investigate the factors influencing e-business utilisation in Greek SMEs and list some critical factors, such as firm size and scope, internet technology infrastructure and skills; they give some suggestions for SME managers to utilise e-business initiatives: establish appropriate infrastructure, obtain integrated e-business solutions, adopt proper security tools to protect critical data, obey industry-standard to share information and train staff to use e-business tools.

It is difficult for SMEs to use e-business in the textile & apparel supply chain successfully. SMEs face some obstacles, such as investing and maintaining costs, the complexity of applications, selecting an appropriate tool, resistance from staff even executives, inapposite organisation culture, technical issues, the lack of government financial support, etc. (Krishna and Singh, 2018). For SMEs, even for large manufacturers, there are still significant opportunities to utilise e-business to improve their turnover and competitiveness, especially in dynamic situations. For example, the recent COVID-19 affects the whole world and all industries, businesses, economy and human life. More and more companies have to use e-business tools to work and manage business processes. Small and medium size textile & apparel manufacturers face a severe challenge in surviving and developing compared with big companies. So advanced e-business can be utilised in the textile & apparel supply chain to facilitate process management, integrate business management, support business strategy, design and implement supply chain strategy, and improve enterprise capabilities and competitiveness. E-business can bring textile & apparel manufacturers turnover benefits and operational efficiency. Although more and more SMEs use e-business, most utilisations are still elementary (CNNIC Report, 2015, 2020). SMEs use broadband connection or email, but only a few SMEs do business via a high level of e-business, such as ERP, so they still have chances to improve competitiveness via a different kind of e-business engagement.

2.3.4 E-business Technologies and Tools in Textile & Apparel Supply Chain Management

Nowadays, companies are taking advantage of e-business to prompt business process management, and according to Ciarniene and Stankeviciute (2015), e-business uses innovative ICT technologies to manage business processes. Manuel Mauqeira *et al.* (2019) define e-business technologies as inter-organisational IT, so firms can use many e-business technologies and tools to meet supply chain management challenges. Scholars, governments, and organisaitons investigate e-business applications in supply chain management and list some e-business technologies and tools. For example, Hadi Putra and Santoso (2020) introduce ERP, CRM, SCM, website, cloud computing, social media, EDI and online advertising. China National Textile & Apparel Council (CNTAC) lists some common e-business technologies used by textile & apparel manufacturers: broadband, 5G, big data, cloud computing, the internet of things, AI, ERP, CRM, RFID, webcast, social platforms, etc. (http://www.ctei.cn/). More advanced ICT, such as intelligent technology, is evolving rapidly, which is used in more and more textile & apparel supply chains. Vermesan and Friess (2015) introduce big data, cloud services, business analytics software, sensing technology/sensor networks, embedded technologies, RFID, the global positioning system (GPS), machine-to-machine (M2M), ID recognition technology, mobility security, standardisation and wireless networks, etc.

E-business allows manufacturers to deal with procurement, production, inventory control, track order fulfilment, and provide a real-time view for raw material suppliers, customers, distributors, and other partners about the whole business process. Using e-business, companies can reduce costs and the time needed to deliver the finished products to customers and improve their channel relationships to gain competitive advantages. Manufacturers can purchase web-based software, such as enterprise resource planning (ERP), material requirement planning (MRP), manufacturing resource planning (MRP II), electronic data interchange (EDI), and Oracle's Siebel brand software of partner relationship management (PRM). Resellers and distributors can obtain e-business software from their manufacturers' websites or directly purchase the software.

E-business software allows them to bargain with manufacturers, order products and services, upload applications for advertising funds, track orders and shipments, manage sales, etc.

This study focuses on e-business applications used by textile & apparel manufactures, and four main e-business software and one e-business service are listed below.

(1) Enterprise Resource Planning (ERP)

ERP is the most significant and latest MRP (Material Requirement Planning) theory. Big firms grow up almost exclusively based on ERP systems such as SAP and Oracle. ERP system includes software support modules: material procurement, production and inventory management, industrial facilities control, process design and improvement, manufacturing, quality control, marketing and sales, service, human resources management, finance and information service.

Reorder point systems appeared in the 1960s and then evolved into MRP systems in the 1970s; since then, more firms have started to use them. The reason is the computer can be used to accelerate essential planning and control calculation. In the 1980s, MRP was advanced into the MRP II (Manufacture Resource Planning) system, an innovative system that could be upgraded. The advantage of MRP and MRP II is that the system can discover the consequences of even tiny changes and then suggest the following action: if demand changes, the MRP system will calculate all the effects and issue instructions. ERP has the same function, even a much wider area. MRP II system was developed to manufacture execution system in the 1990s. Finally, in the late 1990s, ERP was created.

Manufacturers can use EDI or WFT (Web Forms Technology) to communicate with clients or partners through the ERP system. A company can provide information among departments inside the company or between supply chain partners by intranet, extranet, or internet to establish business relationships between customers and suppliers. Then these relationships will create a virtual value chain, which can provide information-based channels for manufacturers and partners to manage supply chain activities. ERP system tries to use one computer system to integrate all department functions, satisfying all departments' particular requirements. ERP system can integrate all company departments databases and decisions reflected in the planning and control system to see any department decisions consequences. ERP equals the central nervous system; it explores helpful information from different parts of the business process and transfers it to other parts. ERP system updates the data in real-time, so it is invariably available to the user who is connected to the system.

ERP systems are generally considered to have the potential to improve performance significantly in different sectors. Web-based communication technology accelerates the further promotion of ERP systems. Many suppliers, customers, and business partners are collaborated by ERP-type systems. The apparent tendency is these systems can communicate with each other. Hence, organisational and strategic consequences of such techniques can be more consequential. The next step of internal ERP systems with direct suppliers and customers is integrating all ERP systems and related systems through the supply chain, which may never be achieved directly because the systems are particularly complicated. Different kinds of ERP systems have to exchange information and integrate with other different types of systems. For instance, marketing and sales functions often utilise CRM systems to manage customer requirements and transactions. ERP can use a CRM system to learn customer behaviours, expectations, and preferences to provide appropriate goods and services to satisfy customer demands.

Meanwhile, ERP can also integrate data services systems, project management systems and other systems, such as engineering systems, purchasing systems, access control systems, etc., to improve the whole system performance to provide customers better services. For example, Oracle designs an ERP system as a part of the entire Oracle e-business suite. Bouchemal and Bouchemal (2018) propose the concept of cloud ERP. Traditional ERP supports companies to aggregate and organise data and information between different departments inside one company. Cloud ERP is based on cloud computing technologies to support information exchange among partners. It integrates some essential or complete functions to manage the business process, for example, order management, inventory management, accounting management, human resource management, CRM, etc., into an entire ERP system. However, a full-scale ERP system is still too expensive for SMEs, so SMEs can consider cloud ERP techniques, for example, just select some simple modules they need to manage their operations but not the whole complex ERP system (Wijaya and Dhewanto, 2019). Manufacturers can choose entire ERP systems or niche solutions based on the industry, products, services and budgets. Small and medium size textile & apparel manufacturers should consider which kind of products or services they can provide, produce or assemble and their budgets. Significantly, communication costs in the supply chain could be reduced dramatically, and ERP could also avoid errors that appeared from information flow and product movement between supply chain partners. Eventually, it is necessary to mention that although ERP integration can bring benefits by increasing transparency in the supply chain, sometimes it may also bring system failure. Suppose one segment of the ERP system fails for some reason within a supply chain; it may obstruct the entire integrated information systems' effective operation throughout the whole supply chain.

(2) Electronic Data Interchange (EDI)

EDI is the direct data exchange system among computers to integrate internal and external data from all departments and supply chain partners. It follows the recognised standard by transmitting formal electronic documents to complete the entire business process. Those electronic documents include lists of materials, quotations requests, orders, invoices and bills and shipping notices. Vrbova *et al.* (2018) give four steps to implement and integrate EDI systems: firstly, select EDI solutions provider; secondly, ensure communication; thirdly, provide identification; and finally, ensure integration (see Table 2.1). Firms can benefit by utilising the EDI system rather than paperwork, such as lower postage costs, less labour-intensive work, and faster and more accurate data transmission.

Table 2.1 Steps of EDI adoption

Step	Action
1	Select EDI solutions provider
2	Ensure communication
3	Provide identification
4	Ensure integration

Source: based on Vrbova *et al.* (2018).

To improve communication efficiency among partners, manufacturers need to use a value-added network (VAN), web browser, or the internet to support the data generation and flow. VAN is the third-party provider to help enterprises interchange data with each other. It is expensive, and the high price has become an obstacle for SMEs to conduct EDI systems. Therefore larger companies implement EDI systems to support data flow through all supply chain partners in open networks. The high investment cost is why companies intend to manage the EDI process by employing web browsers and internet technologies (Tan and Ludwig, 2016; Vrbova *et al.*, 2018). Because of the high price and high implementation costs, many SMEs do not utilise EDI. However, EDI systems can support them in transferring information and managing data more effectively, reducing transaction costs and error rates and shortening lead times. EDI is not considered the technic to cut the edge and has gradually been replaced by more flexible, user-friendly, and lower-cost systems, but it still has its customers. Buiten *et al.* (2018) insist that EDI solutions can blur the variances between primary and secondary data collection. The future will be collecting and exchanging data in the business process and establishing an integrated business information chain.

Except for the expensive investment costs, some other factors influence manufacturers to adopt EDI: potential interests, readiness, pressures from customers or competitors, enthusiasm from executives, products, a willingness from partners, etc. (Vesela, 2017; Vrbova *et al.,* 2018). Tan and Ludwig (2016) use a survey method to investigate internet-based EDI adoption in China. The research results show that primary influencers are economic and cultural conditions. Smaller companies are less likely to adopt EDI; their limited resources may make the costs too high. SMEs can consider web EDI. Web EDI uses internet technology to provide less functionality, easy usage, and less cost than classic EDI.

(3) Radio Frequency Identification (RFID)

Manufacturers can improve supply chain management by getting real-time data effectively and improve dynamic control and management by sharing information among partners. A radio frequency identification (RFID) system is introduced to strengthen the cooperation and integration of supply chain activities and functions in the textile & apparel industry (Kumar *et al.,* 2017). RFID means identifying track data by utilising radio waves. The US Department of Defense required suppliers to adopt RFID from 2004, and the US Food and Drug Administration also authorised the use of RFID tags in 2004 (Rajaraman, 2017).

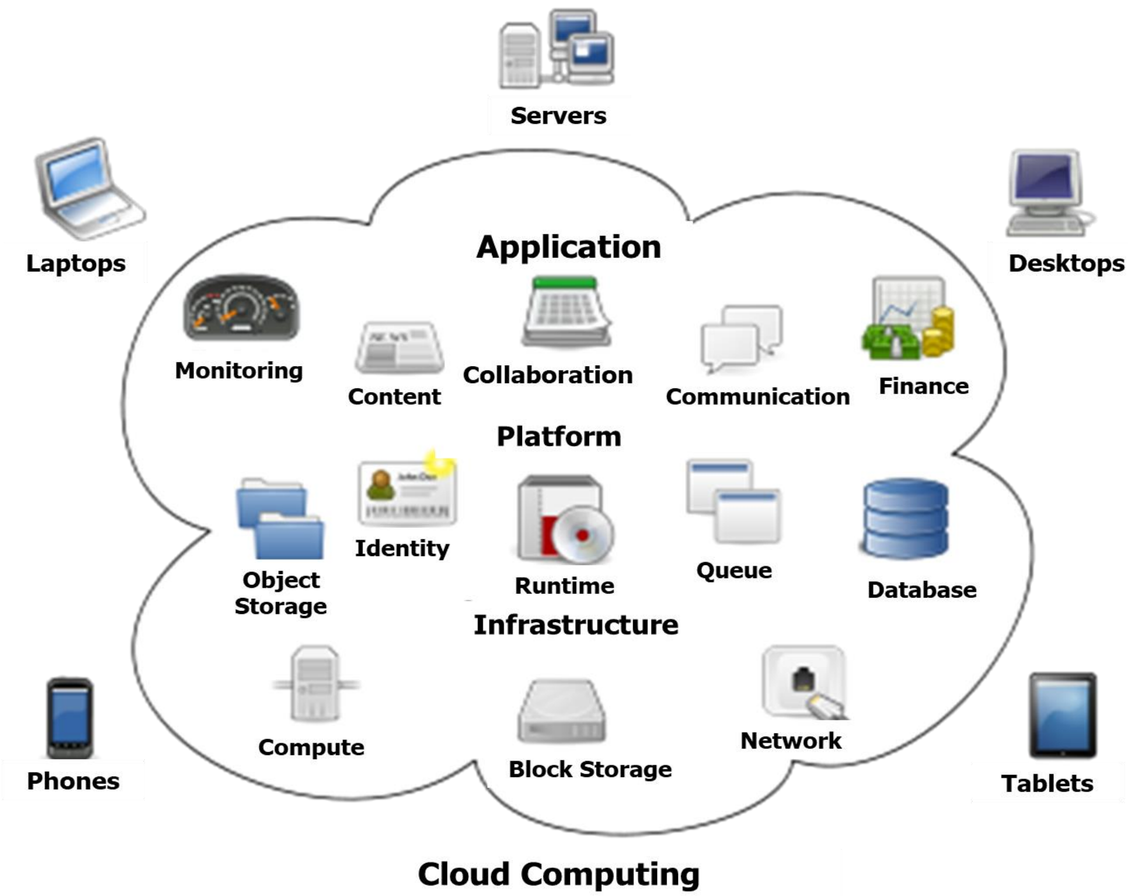
In recent years, RFID has become more prevalent in material flow, logistic management, and supply chain management as a representative technic of data collection and automatic identification. RFID is an automated identification solution that can streamline data capture and identification. Manufacturers can track pallets, individual products, and cases automatically, even track recycle assets, such as containers and bins throughout the supply chain by RFID. Integrating technology such as RFID can help manufacturers accelerate information flow effectively in the supply chain. They can track products, improve warehouse management, supervise discrete manufacturing processes, and influence production plans to improve the whole supply chain performance (Yuan *et al.,* 2017). Supply chain partners can access information and practice quality management based on information sharing; for example, RFID is used in food supply chain management because its traceability is vital for managing food safety and quality (Dabbene *et al.,* 2014).

As the most cutting-edge technology, RFID technology owns the ability and integrity to trace information in the supply chain to facilitate real-time traceability. RFID can be assisted by mobile devices such as tablet computers or mobile phones to support staff seamlessly integrating work processes outside the office. RFID can be used in the manufacturing process to collect real-time production information to produce better production performance (Yuan *et al.,* 2017). As the cost of RFID has decreased rapidly and the technique has been advanced, RFID is used in many innovative ways. In the supply chain, RFID is used to track production lines, manage databases, warehouse, inventory, and can be used as a part of ERP (Rajaraman, 2017). Meanwhile, it has been proven to be a valuable tool to increase textile & apparel supply chain benefits (Rinaldi and Bandinelli, 2017).

(4) Cloud Computing

Companies can access the third parties e-business technologies through the internet instead of establishing their own IT infrastructures. These resources are commonly defined as "cloud computing" by European Commission (2014), an essential strategic digital technology enabling companies to gain higher productivity and provide better service. Enterprises must connect to the internet to apply cloud computing because they are only delivered online. Matured internet is a valuable infrastructure in business process management. Today, growing applications, information, data, and services are transferred from individual computers to the "cloud". These resources, such as databases, applications, documents, storage capacities, emails and processing capacities, etc., are open to users. Users can access these computational resources by the cloud platform (see Figure 2.16). They need to gain the application to access the cloud and open the web browser on the computer, laptop, mobile phone, tablet, or other mobile devices connected to the internet anywhere and anytime. Clients do not have to know the computing infrastructures' configurations and location when using the cloud.

Figure 2.16 Cloud computing logical diagram



Source: The Earthnet Datacenter (2016).

Cloud computing enables clients to access resources faster with less maintenance and easier management. It can adjust resources quickly to meet unpredictable and fluctuant requirements from different clients and boost information sharing between supply chain partners (Bi and Cochran, 2014). Partners can trace the purchase and sales of materials and goods, monitor the financial flow, establish a precautionary measure to prevent accident issues, and take the correct measurement (Yang *et al.,* 2018). Meanwhile, cloud computing increases data analysis speed, accelerates agile supply chain establishment and maintenance (Lal and Bharadwaj, 2016; Mishra *et al.,* 2016), and cloud computing assimilation has a positive and significant influence on supply chain integration and efficiency (Manuel Maqueira *et al.,* 2019).

The term "could" is used to indicate the demarcation point between the providers' responsibility and the clients' responsibility (The Earthnet Datacenter, 2016). Cloud computing extends the company boundary and covers network infrastructure and servers. Eucalyptus Systems Incorporation built the first open-source platform (Elastic utility computing architecture for linking your programs to proper systems) to deploy private clouds in early 2008. Meanwhile, OpenNebula initiated the RESERVOIR European Commission-funded project and became the first open-source software to deploy private and hybrid clouds. EBuilder (www.ebuilder.com) provides cloud computing solutions to accelerate inventory and delivery management, and DHL and Volvo are the users of this service. Baidu provided the cloud service in September 2012 in China, and at the end of 2020, more than 700 million clients used Baidu Cloud services.

Xing *et al.* (2016) propose a cloud-based life cycle assessment platform to collect and exchange dynamic life cycle data of cotton T-shirt production in the green supply chain. This platform involves four processes of the supply chain: cotton production, textile production, apparel production and distribution. Cloud collaboration platforms can be used to gather and manage information and data, share information and data among partners to improve supply chain management efficiency. According to the Ministry of Industry and Information Technology of the People's Republic of China, the Chinese cloud service market reached 161.24 billion RMB in 2019, increasing 57.1% compared with 2018. The primary cloud service is cloud database. SMEs can consider using cloud-based e-business to improve IT adoption, select the services they need to accelerate the business process, and only pay for the services they use (Iswari *et al.*, 2018). Some factors influence SMEs to adopt cloud computing services: relative advantages, observability, security, cost, existing system, and the pressure from competitors, etc. (Hsu and Lin, 2016). SMEs should consider these main factors before adopting cloud computing solutions. Iresearch Report (2020) lists some factors that effecting Chinese large and medium, and small size enterprises to utilise cloud services: security issues, cost management, governance, shortage of resources, professional capabilities, etc., and indicates that COVID-19 will push more enterprises to utilise cloud services to do business.

Managers can use e-business to monitor current supply chain processes, analyse, improve and innovate these processes. In the past years, supply chain management was just about selling products. Under the changeful and competitive market, it is all about integrating processes - inside one company and across the whole value network of companies - to gain complete visibility to satisfy the dynamic customer demands. For manufacturers, some risks damage productivity, profitability, and competitive advantages in supply chain management, such as natural disasters, data breaches, transport network disruption, outsourcing service failure, etc. E-business tools, for example, the internet, cloud computing, and big data can be used in collaboration to develop a resilient global supply chain to prevent such risks (Mensah *et al.,* 2015A) and enhance logistics management in the supply chain (Yu *et al.*, 2017). Benitez *et al.* (2018) indicate that e-business can help companies obtain and maintain operational capability by exchanging information, facilitating functional routines management, and getting greater agility when providing products and services to markets and customers.

Enterprises have to consider their conditions before making an e-business strategy. For example, competitive pressures, executives support, compatibility, financial resources, enterprise size, investment costs and risks, the government supports, etc. (Bankole and Olatokun, 2017; Hadi Putra and Santoso, 2020; Kwilinski *et al.,* 2019; Mazzarol, 2015). For SMEs, Hadi Putra and Santoso (2020) divide these factors into three contexts: technological contest, such as complexity, trialability, compatibility and observability, etc., organisational context, such as innovativeness, executive supports, process management and e-business expertise, etc., and environmental context, such as vendor support, government support, competitive pressures, and financial support, etc. Each firm is unique; for some firms, these factors may be advantageous, but some elements may be disadvantages for other firms. Due to this, enterprises have to face and minimise these weaknesses.

Some scholars focus on e-business adoption in China. For example, Stanworth *et al.* (2015) list some crucial factors affecting e-commerce adoption from the customer perspective, such as order fulfilment (delivery time, product description), IT technologies (access, system design), etc. Gou and Gao (2017) conduct a survey method to investigate e-commerce adoption in Chinese rural areas and list some barriers: lack of platform and cooperation atmosphere; expensive and inconvenient logistics; low margin due to high production and operation cost; lack of market information; it is hard to find buyers; the difficulty of recruitment and high logistics costs due to remote and decentralised production or living area. These studies do not mention small and medium size textile & apparel manufacturers. Still, most manufacturers are SMEs, so these barriers also fit small and medium size textile & apparel manufacturers.

To summarise the literature mentioned before, some common e-business technologies and tools are used in the manufacturing supply chain (including the textile & apparel supply chain) (see Table 2.2).

Table 2.2 Common e-business technologies and tools in textile & apparel SCM

Type	Technologies and Tools
Internet access	E-mail Website Webpage
Software	ERP: enterprise resource planning MRP: material requirement planning MRP II: manufacturing resource planning EDI: electronic data interchange PRM: partner relationship management RFID: radio frequency identification CRM: customer relationship management Mobile App Mobility security software Social media (WeChat, QQ, WeCom, Facebook, Twitter, etc.)
Platform (e-commerce marketplace)	DBE: Digital business ecosystem GS1.org Tnc.com.cn Taobao Tmall Jd.com Amazon.com, etc.
Search engine	Baidu 360 Google, etc.
	Big data
	Cloud services
	GPS: the global positioning system
	5G
Source: collected from Abdullah *et al.*, (2015); CNNIC Report, (2015, 2020); China National Textile & Apparel Council (CNTAC) Website; Hadi Putra and Santoso, (2020); Liu and Wang, (2016); The Earthnet Datacenter, (2016); Vermesan and Friess, (2015).	

2.3.5 Benefits of E-business utilisation in Textile & Apparel Supply Chain Management

E-business has positive effects on textile & apparel manufacturers and supply chain management. Many researchers list the benefits for manufacturers to adopt e-business: reduce production, inventory and transaction costs (Bankole and Olatokun, 2017), increase sales

(Kayabasi and Gumus, 2012), increase communication flexibility between supply chain partners (Kayabasi and Gumus, 2012; Mazzarol, 2015), discover new material suppliers (Sharma, 2013), attract more clients (Sharma, 2013), improve business management flexibility (Rinaldi and Bandinelli, 2019), reduce lead time and cycle time (Benitez *et al.*, 2018), reduce some human errors (Hoffman, 2016), improve order fulfilment and supply chain management efficiency so that e-business utilisation can enhance manufacturer capabilities (Kumar *et al.,* 2017; Shen *et al.*, 2019; The International Trade Center Outlook, 2015; UNIDO Report, 2016) (see Table 2.3).

Table 2.3 Benefits of e-business utilisation in textile & apparel SCM

Benefits of e-business	
• Reduce production, transaction and inventory costs	(Bankole and Olatokun, 2017)
• Increase sales	(Kayabasi and Gumus, 2012)
• Increase the flexibility of communication with partners	(Kayabasi and Gumus, 2012; Mazzarol, 2015)
• Find new sources of supply	(Sharma, 2013)
• Attract new clients	(Sharma, 2013)
• Improve flexibility	(Rinaldi and Bandinelli, 2019)
• Reduce cycle time and lead time	(Benitez *et al.*, 2018)
• Reduce some human errors	(Hoffman, 2016)
• Improve firms operational capability and competitiveness	(Kumar *et al.*, 2017; Raguseo, 2018; Shen *et al.*, 2019; The International Trade Center Outlook, 2015; UNIDO Report, 2016)

Many scholars study e-business. These studies explore how to utilise e-business to gain benefits, promote values for all supply chain partners, and make the supply chain more resilient and robust (Ciarniene and Stankeviciute, 2015; Mackay *et al.,* 2020; Rinaldi and Bandinelli, 2017). E-business technologies bring all supply chain partners benefits. The internet connects a manufacturer with partners worldwide; the website helps the manufacturer introduce products and services. E-business solutions help the textile & apparel manufacturers manage production, procurement, relationship with customers and raw material suppliers. Customers can use App to get product introduction and place an order by mobile phone. Big data help manufacturers collect and analyse valuable data and information to explore and generate business opportunities. Cloud computing connects all business functions, manages the whole process automatically. E-commerce marketplace provides different platforms to put related companies in one system, helps them communicate with each other, and accelerates supply chain efficiency. The current trend is the integration of different kinds of e-business technologies. An e-business system may involve some modules, provide various services, so the company can select appropriate modules to manage procurement, production, delivery, finance to accelerate its competitive capabilities.

2.3.6 Barriers of E-business utilisation in Textile & Apparel Supply Chain Management

When manufacturers realise the benefits of e-business utilisation in supply chain management, they also need to understand the barriers of e-business. Researchers list barriers for manufacturers to adopt e-business in the supply chain. There are some internal barriers: firms have to push employees, even executives to accept e-business (Chatzoglou and Chatzoudes, 2016; Mazzarol, 2015; Vesela, 2017); to change the organisational culture to encourage innovative ideas (Kayabasi and Gumus, 2012); to reorganise business process to adopt e-business (Ciarniene and Stankeviciute, 2015); high investment costs on hardware, software, and training on the employee (Bankole and Olatokun, 2017; Mazzarol, 2015; Zhao and Zhao, 2018); technical issues (Krishna and Singh, 2018); SMEs have insufficient resources (Kayabasi and Gumus, 2012); security concerns (Abdullah *et al.,* 2015); e-business advantages decrease over time even vanishes (Benitez *et al.*, 2018). Meanwhile, manufacturers also have to face external barriers: less demand from the customer and product type may not fit for e-business (Eurostat Report, 2018), etc. (see Table 2.4).

Table 2.4 Barriers of e-business utilisation in textile & apparel SCM

	Internal Barriers	
Individual	• Need to push employees and executives to understand and accept e-business	(Chatzoglou and Chatzoudes, 2016; Mazzarol, 2015; Vesela, 2017)
Organisational	• Need to change the organisational culture to encourage innovative ideas	(Kayabasi and Gumus, 2012)
	• Reorganisation of the business process	(Ciarniene and Stankeviciute, 2015)
	• High investment costs on hardware, software and training	(Bankole and Olatokun, 2017; Mazzarol, 2015; Zhao and Zhao, 2018)
	• Technical issues	(Krishna and Singh, 2018)
	• Insufficient resources for small firms	(Bankole and Olatokun, 2017; Kayabasi and Gumus, 2012; Mazzarol, 2015)
	• Security concerns	(Abdullah *et al.,* 2015)
	• Advantages decrease over time even vanishes	(Benitez *et al.,* 2018)
	External Barriers	
Less demand from customers		(Eurostat Report, 2018)
Product type may not fit for e-business		(Eurostat Report, 2018)

The textile & apparel industry characteristics are demand volatility, short product lifecycle, and hard to forecast. Effective e-business utilisation helps textile & apparel manufacturers accelerate process management to obtain benefits. Textile & apparel manufacturers have to find solutions to deal with barriers to adopting e-business, such as pushing employees even executives to accept e-business, improving organisational culture, reorganising business processes, attracting more funds to invest in e-business utilisation, upgrading security systems, etc. Meanwhile, they still have to face and conquer other obstacles, such as the dynamic environment, volatile market, high production costs, expensive salary costs, etc. E-business implementation can prompt textile & apparel manufacturing companies to find new raw material suppliers and attract new customers worldwide. Textile & apparel manufacturers can deduct management and inventory costs by automating procurement procedures and integrating production processes and the supply chain to improve flexibility. E-business provides customers with self-access to their orders, transactions, and accounts while reducing cycle time and lead time. As a result, textile & apparel manufacturers can build more substantial and long-term relationships with partners, transfer information and data quickly, improve customer service levels in the supply chain.

2.3.7 E-business Process Management

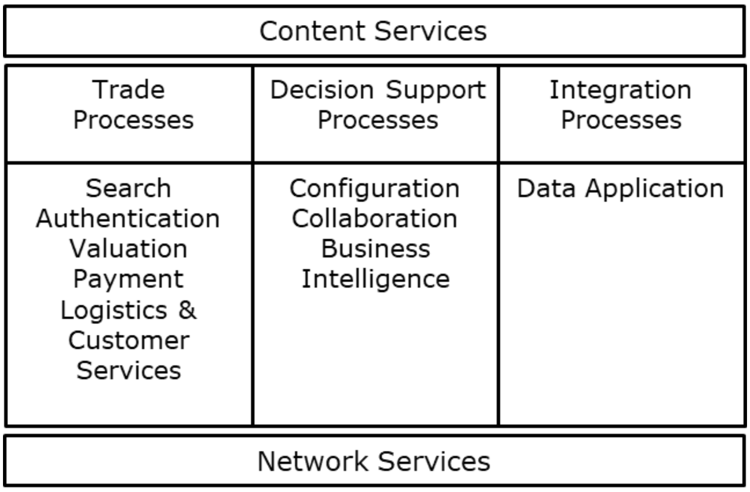
Modern companies have to explore new initiatives to compete effectively and satisfy direct customer preferences under tremendous pressure from stakeholders and outside markets in such current fickle surroundings. Therefore, companies manage the e-business process to improve communication efficiency, integrate different partners' resources and capabilities in the supply chain, enhance collaboration efficiency, and create benefits. For example, Amazon, Dell, and Lenovo's successful practical evidence show that e-business process management effectively facilitates supply chain management (Zhu *et al.,* 2020). Zhu *et al.* (2020, p.273) define e-business process as "a form of the business process that represents internet-enabled information flows across organisational boundaries and links supply chain partners to support digital operations activities". They indicate that the e-business process involves three components: technical component (platform, architecture and flexibility), relational component (partner engagement) and business component (e-business operations capabilities). Companies need to establish a digital platform to guarantee information exchange among supply chain partners, encourage partners to participate in the e-business process, and gain the digital ability to share information and conduct business activities in the supply chain, such as transactions, collaborations and services, etc.

Many scholars introduce different kinds of e-business process frameworks and models. These studies focus on e-business process management and explore how to manage the e-business process to accelerate supply chain efficiency and improve competitive performance.

(1) E-business process framework

Basu and Muylle (2011) introduce the e-business process framework (see Figure 2.17). In this framework, there are three levels in the process. The first level is the infrastructural network services level. The second level is the e-business processes level, which involves three types of processes. The third level is the content services level, which involves specialised processes for a particular sector or industry.

Figure 2.17 E-business process framework



Source: Basu and Muylle (2011), p.439.

Level 1: Network services

Network services involve services and capabilities, which are the basis of e-business (Basu and Muylle, 2011). These services and capabilities include infrastructure components and essential communication services to guarantee reliability and security. The company mainly depends on improving reliability and efficiency at this level rather than exploring sustainable competitive differentiation. However, an efficient and effective e-business network is necessary to achieve business value. These services and capabilities are also required for business processes management, and in these processes, e-business innovation should be considered.

Level 2: Business processes

At the application level, firms can find opportunities to utilise e-business in three types of processes: trade processes, decision support processes and integration processes, as described below.

• Trade processes. These processes enable buying and selling online, saving costs, and promoting business transactions. Specific processes include: search for products, buyers and sellers; authenticate products, buyers and sellers; valuate products; payment and payment clearance; logistics services such as delivery and customer service (Basu and Muylle, 2011).

• Decision support processes. These processes support a company to improve its capability to make effective business decisions by collecting and analysing data. These processes also enable the company to cooperate with other supply chain partners to support these participants to make better business decisions. Decision support processes include configuration, collaboration and business intelligence (Basu and Muylle, 2011). Configuration means utilising configurator tools, electronic requirement determination tools, and sharable Computer-Aided Design (CAD) tools under the current situation. Collaboration means using different tools such as conferencing, white-boarding, electronic brainstorming, and shared data repositories to collect essential data inside and outside the company. Business intelligence means conducting analytical tools to generate valuable results to support decision-making.

• Integration processes. Integration processes can help companies integrate all information systems to automate tasks across different information systems. There are two types of integration: horizontal integration between a company and its horizontal supply chain partners (e.g., making integrated products or consolidated purchasing system) and vertical integration between a company and its suppliers or customers. Specific processes include data integration, enabling a company to access its partners' databases, even across autonomous database structures, hardware and software platforms (Basu and Muylle, 2011).

Level 3: Content processes

These processes are particular for the industry or sector to which the company belongs (Basu and Muylle, 2011). Therefore, it is not easy to specify these processes by the company or some industrial organisations such as regulatory agencies or trade associations.

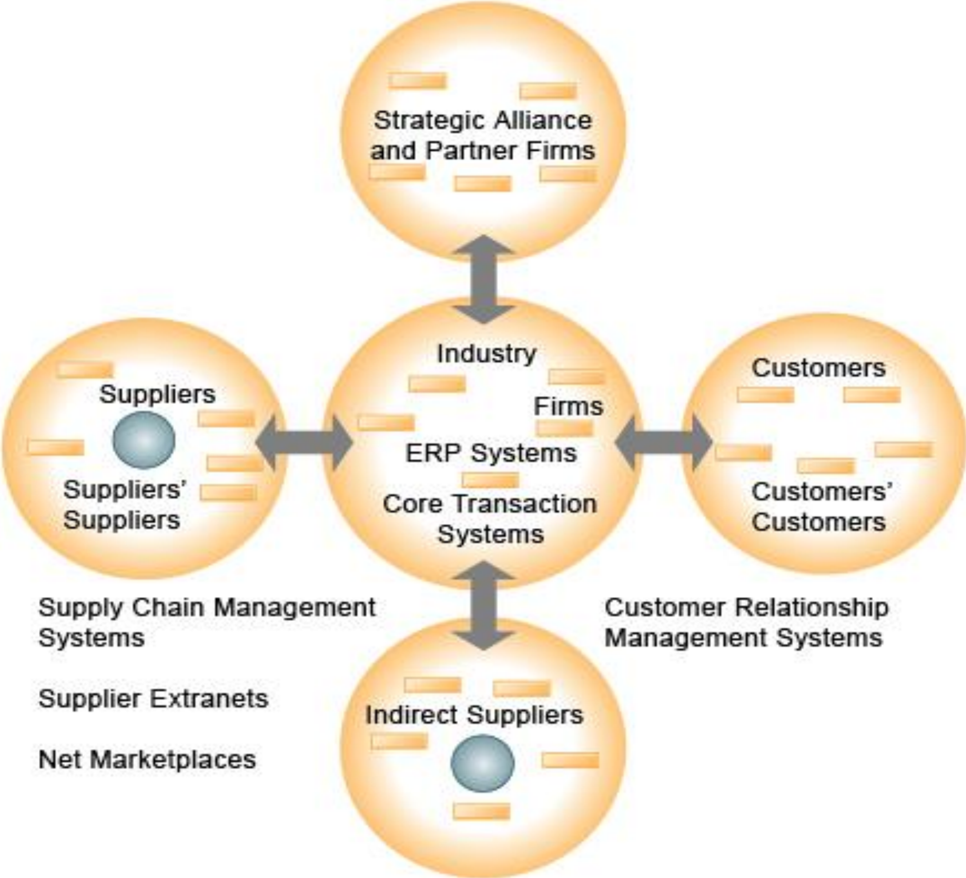
Basu and Muylle (2011) suppose that the above kinds of e-business processes apply to all industry types. For any specific company, the critical point of different processes depends on its strategic context. When a company manages its business processes automatically, its online activities and operations will become more vital to its competitive strategy. This e-business process framework does not mention a specific industry. This study will consider e-business utilisation for SMEs in the textile & apparel supply chain as a critical aspect of its strategic context.

(2) The value web model

The specific value-based discipline can affect e-business process management. The company performance depends not only on the business process management of one firm but also on its coordination with other partners in the supply chain, such as suppliers, distributors, customers, etc. These partners also have different partners (Malik and Sarkar, 2020). Accordingly, companies should consider using advanced e-business technologies and tools to extend the value chain, coordinate with partners more efficiently and connect their value chain to their partners' value chain to obtain competitive advantages.

Laudon and Laudon (2014) indicate that value web (highly synchronised industry value chain) can be created by implementing e-business. As a networked system, the value web consists of different companies within one industry who coordinate to provide products or services in aggressive marketplaces (see Figure 2.18).

Figure 2.18 The value web model



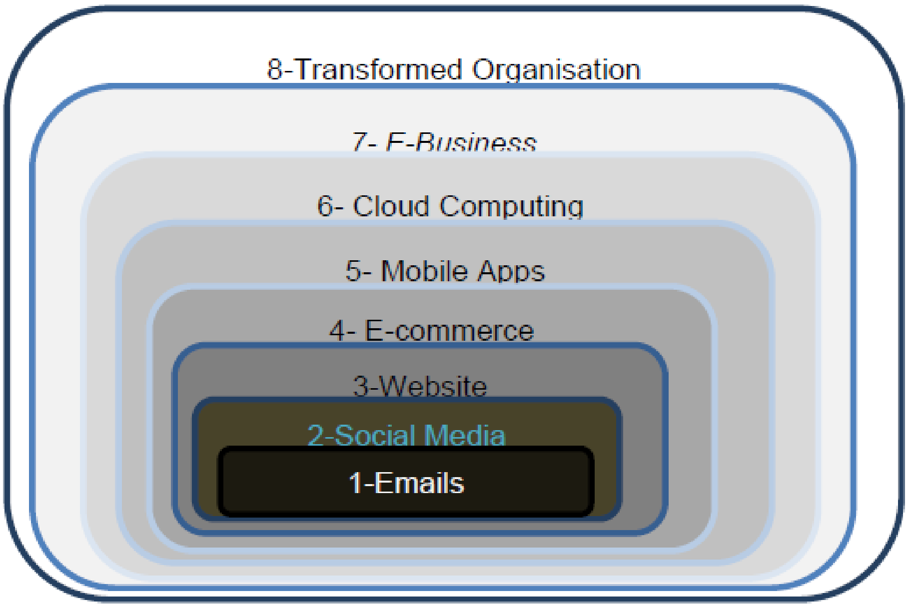
Source: Laudon and Laudon (2014), p.136.

As Figure 2.18 shows, in the value web, the manufacturer can use e-business such as ERP systems or core transaction systems to synchronise different partners business processes, such as suppliers, suppliers' suppliers, indirect suppliers, customers, customers' customers, strategic alliance, partner firms and other partners (Laudon and Laudon, 2014). Meanwhile, it also can respond to changes in demand or supply rapidly, and customer relationships can be bundled or unbundled to apply different market conditions. By optimising value web relationships, companies can reduce response time to customer requests and market fluctuations, access necessary information quickly, and select appropriate partners to do business.

(3) E-business measurement evolution model

Abdullah *et al.* (2015) investigate SMEs' e-business adoption in Yemeni, list some e-business technologies such as emails, social media, websites, e-commerce, mobile apps, cloud computing, etc. The study establishes a nine stages specific e-business measurement evolution model (see Figure 2.19), stage 0: no internet connection, stage 1: use email to connect supply chain partners, stage 2: use social media such as Facebook for advertising their products and services, stage 3: use the simple website to provide company introduction, stage 4: use e-commerce to sale products and services online, stage 5: use mobile apps to do business with customers, stage 6: use cloud computing to store files and applications services, and provide business access from anywhere, stage 7: use e-business to integrate all business process, e.g., marketing, order process, order fulfilment and accounts, etc., and stage 8: use internet technologies to manage all business processes more efficiently.

Figure 2.19 E-business measurement evolution model for SMEs



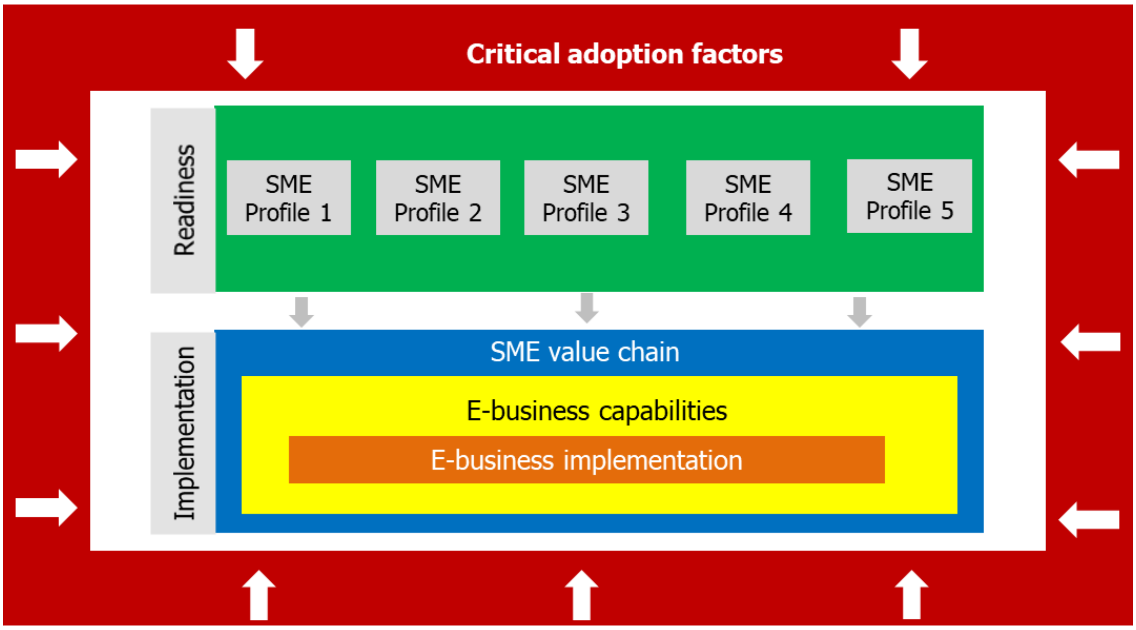
Source: Abdullah *et al.* (2015).

This model focuses on SMEs, measures the advancement of e-business utilisation level, and higher-level means the company uses more advanced e-business technology to manage e-business processes. The investigation results state that internet connection, email and website are the leading technologies used by SMEs, so SMEs are still at the early stages of e-business engagement. SMEs must move toward the higher stages to utilise e-business. The executive and owner can seek supports from ICT experts, design and implement a suitable e-business strategy. They can connect high-speed broadband, design mature websites, upgrade order processing and payment security systems, and train employees to accept and use e-business (Abdullah *et al.,* 2015).

(4) Initial descriptive model of integrated e-business

SMEs are mainly diverse; for example, they belong to different industries, countries, societies, etc., so various SMEs may adopt different e-business solutions. Hadi Putra and Hasibuan (2015) propose a descriptive model of integrated e-business for SMEs to manage e-business processes; the model encompasses three main elements: (1) critical adoption factors, (2) adopter profiles, and (3) implementation models (see Figure 2.20).

Figure 2.20 Initial descriptive model of integrated e-business for SMEs



Source: Hadi Putra and Hasibuan (2015), pp.520.

Critical adoption factors involve potential benefits and barriers. Potential benefits motivate SMEs to use e-business, and barriers hinder SMEs from using e-business because many different constraints hamper the e-business adoption. It is necessary to understand the benefits and obstacles of e-business for SMEs before adopting, so SMEs can fully realise their potentials. Adopter profiles mean SMEs' capabilities and readiness to adopt the e-business. Dyerson and Spinelli (2011) define readiness as preconditions that SMEs can fully utilise e-business potentials, such as enough financial resources, managers' support, and skilled employees to use e-business. Each SME has its unique characteristics, so it is necessary to list adopter profiles before deciding. Implementation models involve specific e-business applications or technologies that SMEs can adopt. The successful implementation model design and selection heavily depend on the unique nature of the SME. SMEs should adapt to the advancement of e-business, design, implement a reasonable e-business model and strategy, and explore the potentials that e-business can offer (Hadi Putra and Hasibuan, 2015).

Some scholars study the e-business maturity of developing economics. For example, Cataldo *et al.* (2020) use the clustering analysis to discover e-business applications in Chile. They divide Chilean enterprises into three groups based on e-business advancement level - cluster 1: basic desktop software. Most companies only have essential software to deal with documents in this group. Cluster 2: web-based technology. Companies use their website for marketing their products and services. Cluster 3: Complex systems. Companies use advanced ICT technologies to manage their business and use social networks to promote marketing strategies. The research results show that large size companies prefer cutting-edge e-business to manage business processes compared with SMEs.

Above, researchers establish e-business models to study e-business processes management. Basu and Muylle (2011) set an e-business process model. Laudon and Laudon (2014) define the value web model. Abdullah *et al.* (2015) design a nine-stage specific e-business measurement evolution model to study SMEs' e-business adoption levels. Hadi Putra and Hasibuan (2015) provide an initial descriptive model of integrated e-business to explore the integration of e-business process management for SMEs. All these researches introduce ICT engagement processes, provide significant guidance for studying e-business process management and illustrate how companies can adopt e-business.

The range of e-business tools utilisation is diverse: at the most basic level, these tools may comprise nothing more than a desktop computer with access to email and the world wide web; at more sophisticated levels, these tools may include software, for example, ERP, which is developed by professional companies such as SAP or Oracle, these software companies provide full supports to all aspects of the business process, such as establish databases of products, suppliers and customers, provide email and internet access, deal with accounting information and print invoices, notify suppliers to provide raw materials, and even create automatic reminders and prompt various employees to take activities to complete tasks (so-called "workflows"). When a company manages the e-business process, it should establish infrastructural networks, adopt appropriate e-business tools and technologies to guarantee information and data flow frequently in the supply chain, and connect all partners. SMEs should understand their current e-business utilisation maturity level, consider the advantages and disadvantages of e-business, prepare to adopt e-business, and then implement the e-business process management. Manufacturers can achieve some objectives if it accelerates e-business engagement and considers e-business as part of the strategy, such as earning more benefits and developing capabilities.

2.3.8 E-business Strategy Management

Nowadays, e-business provides innovative business management methods, which calls for companies to reconsider the traditional strategy development and new methods. The popularity of e-business technology can inspire manufacturers' strategy design and improve its ability to connect partners and customers in the supply chain. Companies can use e-business technology to build network communities to attract more customers who want to communicate and share business experiences in the supply chain. These communities can cultivate customer loyalty and establish unique relationships with customers. For example, eBay, the giant online auction website, uses internet technologies to build a community to provide millions of users a platform to bargain. Tmall, the largest online retailer in the Asia-Pacific region, uses an e-commerce platform to connect buyers and sellers, memberships can do business online, and the platform uses Alipay to guarantee the safety of payment. It sold 4,982 hundred million RMB on 11 November 2020. If these network communities can attract more clients to use their platforms, the trading volume will improve. The growing numbers of memberships guarantee the continued sales of products and services.

E-business strategy has been introduced to highlight how the e-business can reshape the competitive advantages in supply chain management. E-business strategy can accelerate information sharing and relationship marketing in the supply chain. All supply chain partners can earn tremendous benefits from e-business engagement because e-business can reduce inventory costs and production costs, shorten lead time, reduce delivery time, and reduce demand variations (Laudon and Laudon, 2014). Executives and entrepreneurs may be under pressure from partners, political actions, consumer economics, or regulatory standards to seek opportunities to design e-business plans and strategies (Hu *et al.,* 2016). When companies try to manage e-business strategies, they should consider designing, investing and implementing them. First, they need to establish a knowledge architecture and capability evaluation method and then create an e-business strategy to fulfil business goals. The company should consider the critical objectives of e-business, provide an e-business blueprint, and develop and deploy e-business applications. When the company gets feedback from e-business applications, it can improve its e-business strategy design.

(1) E-business strategy design

Designing an e-business strategy requires integrating business process management, marketing management, supply chain management, and information technology implementation. The idea of e-business emphasises how to rebuild the company to produce competitive advantages using internet-based technologies (Shehata and Montash, 2020). Incessant fluctuation pushes firms to design new strategies, provide unique products, and adopt advanced internet strategies to reduce the supply chain risks (Duhadway *et al.,* 2017). Textile & apparel manufacturers also need to implement an appropriate ICT strategy to create a quicker response than competitors (Ding *et al.,* 2011).

New technology will affect organisational operation. Each management part will get in touch with enormous data; the most powerful data transformation will push companies to improve their relationship marketing and leadership in the new world. Winston (2016) argues that supply chain partners will open up all their information for public scrutiny. Companies will be glad to build a thriving world to earn benefits because the public will supervise and demand more. The managers have to change management methods, from focusing only on shareholders to more stakeholders, from pursuing narrow goals to collaborative system thinking, from short-term operation to long-term strategy design.

Managers need the latest information to manage the business process, and such information must be updated quickly to satisfy fluctuating marketing needs and customer demands. E-business facilitates these business processes and transactions rapidly. No matter the company plans or does not intend to sell products or services on the internet, their suppliers or customers may request trade online one day. COVID-19 pushed such online transactions to flourish in 2020. The COVID-19 has disrupted global economic development and all industries and supply chains. WTO (2020) indicates that due to the COVID-19, world merchandise trade declined by 9.2% in 2020, and the textile & apparel industry is no exception. Textile & apparel manufacturers have to bring e-business into business process management, adjust the systems constantly with their fast-changing business priorities, and deploy systems strategically. Moreover, textile & apparel manufacturers can use e-business to collect and analyse data about their end-users, such as industry trends, demographics and buying behaviours. They also can design and implement appropriate e-business strategies to accelerate the information sharing and collaborative management skills in supply chain management.

E-business enables companies to respond to marketing pressures more innovatively by collecting information about industry trends, marketing and customisation. Moreover, e-business reduces the cost of information collection, provides direct advertising, and removes obstacles to access international markets directly. However, e-business design and implementation meet various challenges, for example, necessary IT infrastructure, regulation, law enactment, security issues, and the readjustment of business processes. Manufacturers must face continuous pressures from rivals, markets, and even stockholders and investors, so executives must seek opportunities and take immediate action to put themselves in a superior position. Hence, if a manufacturer aims to gain a sustainable competitive advantage by adopting e-business, it should consider the long-term strategy. There are some critical success factors of an e-business strategy design and implementation: IT governance (involves information systems strategy and technology strategy), customers, suppliers-partners, personnel, executives, data, information, knowledge management, risks management, and strategic performance assessment (Sanaei and Sobhan, 2018; Tsironis *et al.,* 2017; Yan *et al.,* 2019). Companies should analyse the above factors one by one, identify critical aspects of the e-business strategy, and then design and implement the e-business strategy.

(2) E-business investment cost

When a manufacturer decides to implement e-business strategies, it should consider the investment costs, for example, the price to buy and install hardware and software, ongoing costs such as training, maintenance, upgrades, technical support, etc. The manufacturer can calculate direct and indirect costs to determine the actual price of specific e-business utilisation and consider its financial situation. When a manufacturer wants to utilise e-business, it should consider such investments in infrastructure and maintenance costs (see Table 2.5).

Table 2.5 E-business investment costs

Hardware costs	Purchase computer equipment include monitors, terminals, storage, printers, etc. Purchase mobile devices, such as laptops or mobile phones, etc.
Software costs	Price for connecting internet, e.g., broadband, Wifi, etc. Register some business platforms. Purchase e-business software, such as ERP, MRP, or EDI, etc.
Installation costs	Install hardware and software.
Support costs	Purchase continuous technical supports.
Maintenance costs	Update the hardware and upgrade the software.
Downtime costs	If hardware or software is damaged or needs to be updated or upgraded, the e-business will stop working.

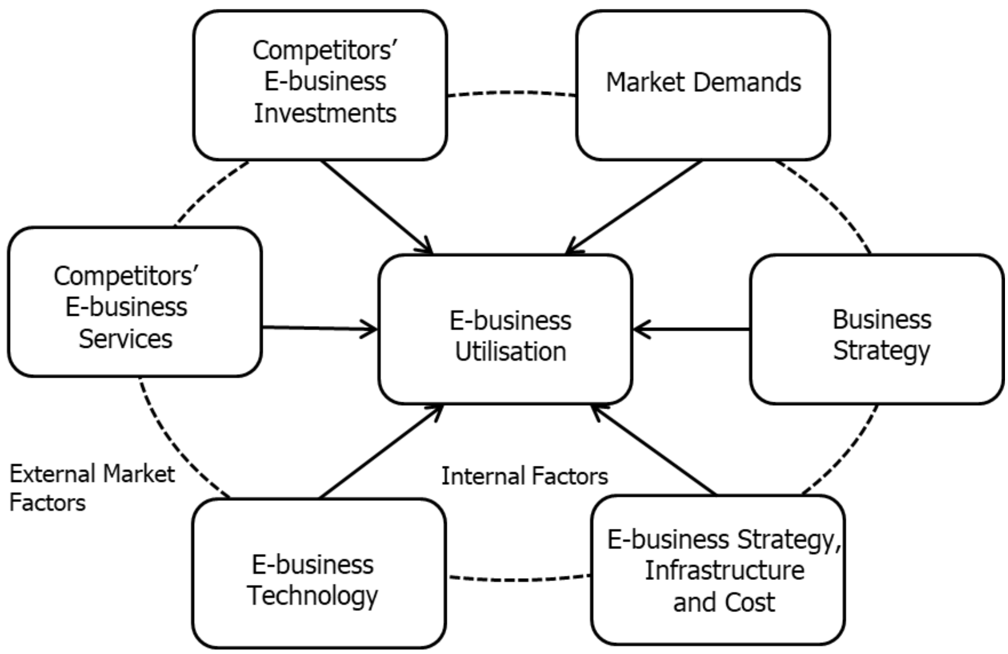
Hardware and software purchasing costs account for only about 20% of the total costs (Laudon and Laudon, 2014), so managers should calculate the administration costs and reduce maintenance costs by appropriate management, especially for SMEs. The latter have limited budgets for e-business investments, and prices are even higher if the company provides employees with mobile computing devices or purchases high-quality equipment. If the manufacturer switches to cloud services, it may reduce total costs by connecting the cloud services, administrating its information systems, and troubleshooting from a central location. Hence, the manufacturer can minimise hardware and software costs and employ less staff to maintain the e-business system.

Wang *et al.* (2017) propose a discounted cash flow model to study how to invest in e-business systems for the Chinese fresh agricultural food industry. This model considers the cash flow, demand structure and cost characteristics. The findings show that the investment time point depends on when consumers buy products online and the urbanization rate. If larger numbers these two factors are, then an early investment in e-business systems will bring more benefits. This model also considers the government financial support, and if the support fluctuates frequently, the investment time point should be in the very beginning or in the end. They also indicate that this e-business investment decision model fits the fresh agricultural food industry and other sectors such as the fashion industry.

(3) E-business strategy implementation

After understanding the cost of e-business utilisation, a manufacturer can use the competitive forces model to implement an e-business strategy. There are six steps the manufacturer should consider (Laudon and Laudon, 2014) (see Figure 2.21).

Figure 2.21 Competitive forces model for e-business utilisation



Source: based on Laudon and Laudon (2014).

Step 1: Market demand for the services. The manufacturer should examine the services provided for material suppliers, customers, employees and other groups. And then investigate if each group is satisfied with these services and find out the shortages.

Step 2: Business strategy. The manufacturer should intimately know its strategic option to keep internal competencies and available resources and understand its position in the supply chain, such as a lead company or just a participant supplier. Long-term relationships built on trust enable the manufacturer to share information and resources with partners to facilitate operational efficiency while generating competitive advantages.

Step 3: E-business strategy. The manufacturer should review long-term e-business strategy and assess if it is aligned with the business strategy. If e-business is new for the manufacturer, the manufacturer should devise a new plan based on a long-term business strategy. Hence, The manufacturer can calculate the total e-business investment costs.

Step 4: E-business technology. The manufacturer should update technological abilities constantly, not only innovative products but also learning ability. E-business technologies are highly recommended to aid and accelerate information sharing internally and externally to prompt closer relationships with other supply chain partners.

Step 5: Competitors' services. The manufacturer should investigate competitors' e-business services provided for raw material suppliers, customers, employees and other groups. Then compare these services with its services, determine if it has a competitive advantage or disadvantage, and seek the methods the manufacturer can exceed at service levels.

Step 6: Competitors' e-business investments. The manufacturer should investigate competitors' e-business expenditures information and benchmark its e-business investments against competitors. The manufacturer should try to discover less expensive ways to provide services to get a cost advantage.

At the same time, the manufacturer has to consider some internal factors, such as staff (their attitudes or capabilities to use e-business), organisational culture, current ICT technology, products, services, etc. Some external market factors, such as market volatility, competitors' behaviours, industry fluctuations, government policy adjustment and technology development, etc., can affect e-business strategy design and implementation at any time (Laudon and Laudon, 2014).

(4) Political factors

E-business adoption is not only the companies' mission; it also attracts public opinion, government agencies, consumer pressure groups, and industry background organisations to concern. Government agencies can control the adoption of e-business by enacting political actions, for example: introducing the benefits of e-business to companies; enacting laws and regulations to deduct taxation or protect firms' privacy related to e-business utilisation; providing necessary guidelines or assistance; establishing international groups or institutes to coordinate the e-business deployment, especially for SMEs (Mazzarol, 2015). Huo *et al.* (2018) investigate the effects of institutional supports for cross-border e-business at Chinese pilot cities. The research results indicate that institutional supports for cross-border e-business has positive effects on export trade. A cross-border e-business policy can improve the export probability because China is the lead exporter of textile & apparel products, so policymakers and relevant institutions should consider the effects of cross-border e-business policy on export.

There are some essential nonprofit textile & apparel organisations in China, such as the China National Textile & Apparel Council (CNTAC), the China Chamber of Commerce for Import and Export of Textiles (CCCT), the China Textile Commerce Association (CTCA), etc. These nonprofit organisations or groups can shape the political environments and provide manufacturers support. For example, CNTAC was established to replace the Chinese Textile industry Ministry in 2001. Its responsibility is to design textile & apparel industry regulations and policies, standardise industrial behaviour, investigate and study the development trend of the textile & apparel industry - for example, technological progress, international market tendency. CNTAC provides consulting services for government and textile & apparel enterprises. In addition, it participates in the formulation and revision of textile & apparel industry standards and manages the implementation of the standards. CNTAC also designs the development strategy and provides suggestions for the Chinese government to administrate the textile & apparel industry.

This chapter discusses literature about textile & apparel supply chain, e-business utilisation in the textile & apparel supply chain, and textile & apparel SMEs. The next chapter will provide a theoretical framework, discuss research gaps, and illustrate research propositions based on the literature review.

Chapter 3 Conceptualisation of Research Framework

The study aims to analyse how Chinese small and medium size textile & apparel manufacturers utilise e-business and propose recommendations to develop supply chain capabilities with e-business initiatives. The study explores common e-business technologies and tools used by textile & apparel manufacturers in the supply chain, categorises the barriers and benefits of adopting e-business initiatives in the supply chain for textile & apparel manufacturers. The study will conduct the modelling simulation to design and develop conceptual models representing e-business utilisation in the textile & apparel supply chain. Then the study will try to understand different levels of e-business utilisation in an apparel order fulfilment for a Chinese SME in the textile & apparel supply chain and identify how to use e-business to improve order fulfilment efficiency and supply chain efficiency.

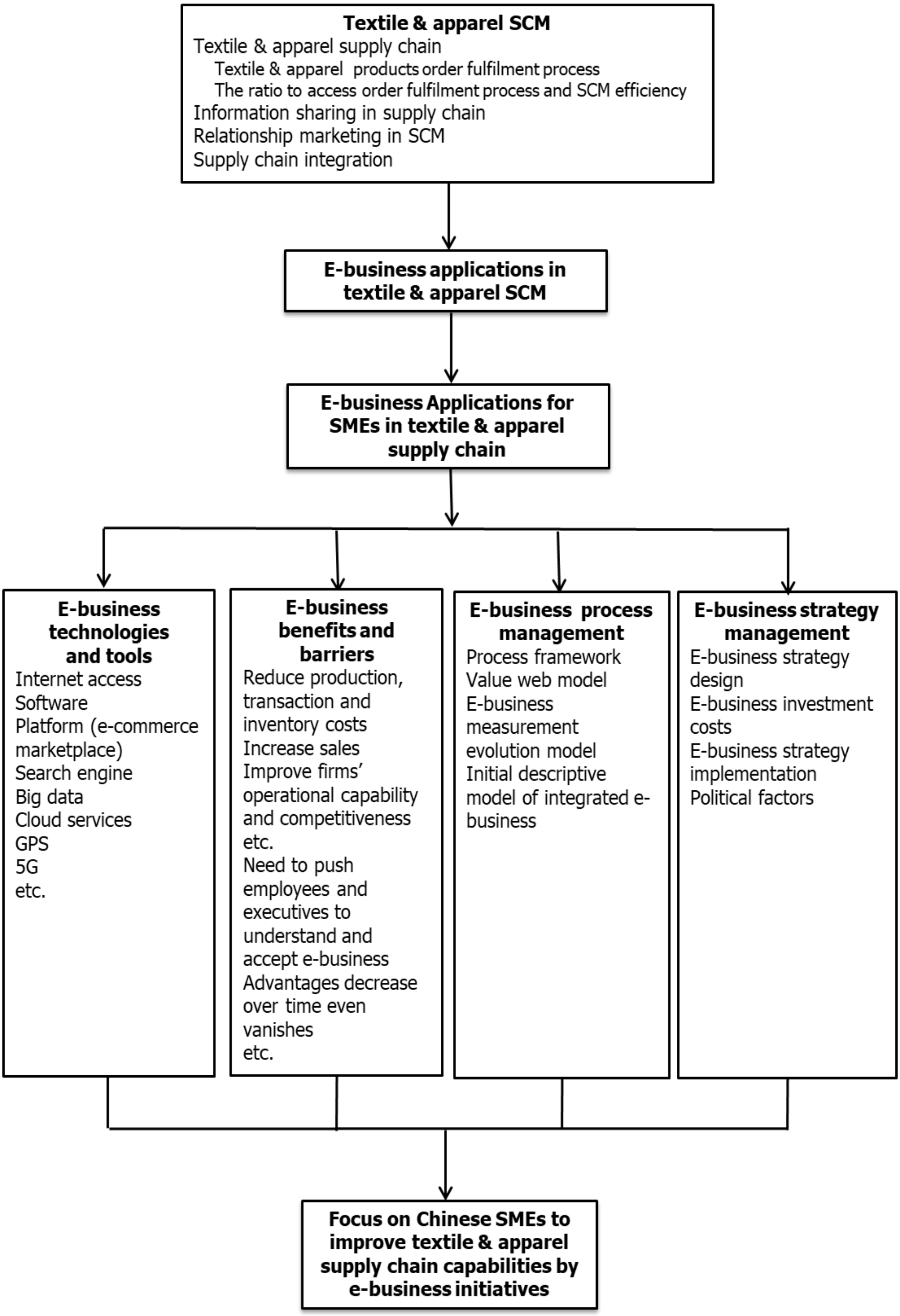
3.1 Conceptual Framework

Supply chain capability is crucial for small and medium-sized textile & apparel manufacturers because they have to confront keen competition and challenges to survive and develop. There are massive strategy theories helping manufacturers accelerate their supply chain capability, and e-business initiative is one of these strategies to obtain competitive advantages. The positive impacts of e-business on the supply chain have been identified. Small and medium size textile & apparel manufacturers have to face some particular issues in the supply chain when fulfiling the order, such as long production lead time, prediction mistakes for fashion items, and short lifecycle of products. Information sharing among the supply chain is significant for them. Using e-business to integrate and coordinate with other supply chain partners to fulfil the order is crucial for small and medium size textile & apparel manufacturers.

To answer research questions and explore the study in more depth, this research first investigates the current literature on textile & apparel supply chain and e-business utilisation in textile & apparel supply chain management. Emphases in previous literature related to e-business initiatives in the supply chain are diverse. Some literature focus on the development of e-business tools (Bouchemal and Bouchemal, 2018; Buiten *et al.,* 2018; Kumar *et al.,* 2017; Lal and Bharadwaj, 2016; Manuel Maqueira *et al.,* 2019; Mishra *et al.,* 2016; Rajaraman, 2017; Rinaldi and Bandinelli, 2017; Vrbova *et al.,* 2018; Wijaya and Dhewanto, 2019; Yuan *et al.,* 2017), some researchers study the e-business models (Abdullah *et al.,* 2015; Basu and Muylle, 2011; Hadi Putra and Hasibuan, 2015; Laudon and Laudon, 2014), and some literature study e-business applications in the supply chain (Abdullah *et al.,* 2015; CNNIC Report, 2015, 2020; CNTAC website; Hadi Putra and Santoso, 2020; Liu and Wang, 2016; The Earthnet Datacenter, 2016; Vermesan and Friess, 2015). Many researchers list the benefits of e-business engagement (Bankole and Olatokun, 2017; Benitez *et al.,* 2018; Hoffman, 2016; Kayabasi and Gumus, 2012; Kumar *et al.,* 2017; Mazzarol, 2015; Raguseo, 2018; Rinaldi and Bandinelli, 2019; Sharma, 2013; Shen *et al.*, 2019; The International Trade Center Outlook, 2015; UNIDO Report, 2016) and obstacles of e-business adoption (Abdullah *et al.,* 2015; Bankole and Olatokun, 2017; Benitez *et al.,* 2018; Chatzoglou and Chatzoudes, 2016; Ciarniene and Stankeviciute, 2015; Eurostat Report, 2018; Kayabasi and Gumus, 2012; Krishna and Singh, 2018; Mazzarol, 2015; Vesela, 2017; Zhao and Zhao, 2018). Some current literature mention e-business utilisation in the textile & apparel supply chain (CNTAC website; CNNIC Report, 2015, 2020; Kayabasi and Gumus, 2012; Kumar *et al.,* 2017; Rinaldi and Bandinelli, 2017; Xing *et al.*, 2016). Some researchers study e-business utilisation for SMEs (Abdullah *et al.,* 2018; Chatzoglou and Chatzoudes, 2016; Fatimah *et al.,* 2016; Hadi Putra and Santoso, 2020; Hamad *et al.*, 2018; Hsu and Lin, 2016; Mazzarol, 2015; Popa and Soto-Acosta, 2015; Raguseo, 2018; Raymond *et al.*, 2015; Razali *et al.,* 2018; Suresh and Mohideen, 2016; Vesela, 2017; Zhao and Zhao, 2018). But no researcher illustrates e-business utilisation in specific order fulfilment for SMEs in the textile & apparel supply chain.

The concepts acquired from the literature review are developed into a conceptual framework in Figure 3.1. The framework provides a conceptual basis to study how textile & apparel manufacturers use e-business initiatives to fulfil the order and develop supply chain capabilities. The current research did not mention Chinese small and medium size textile & apparel manufacturers in the supply chain. It is necessary to explore and understand how Chinese small and medium size textile & apparel manufacturers can develop their supply chain capabilities by utilising e-business initiatives.

Figure 3.1 Conceptual framework



3.2 Research Gaps

Chinese small and medium size textile & apparel manufacturers have contributed to the industry and economic development. SMEs play very significant roles. More than 90% of textile & apparel enterprises are SMEs in China, making tremendous contributions to GDP, exports and job creation. They are pressured by a challenging situation and must become more efficient in the supply chain to stay competitive. More and more partners in the textile & apparel supply chain apply e-business; SMEs are under external pressures from e-business transactions. E-business can enhance company strategy implementation and supply chain capabilities (Chandak and Kumar, 2020; Raguseo, 2018), so e-business initiatives are considered strategically important for manufacturers to develop competitive capabilities. Despite its significant contribution to supply chain management, researchers and practitioners face research gaps in this domain. This study approaches three of them.

The first gap concerns summarising e-business initiatives in the best way so small and medium size textile & apparel manufacturers can integrate e-business solutions to improve order fulfilment and supply chain efficiency.

Most current research focuses on e-business theories, such as definitions, categories, and e-business adoptions in the general supply chain and industry. Few studies concern e-business utilisation in the textile & apparel supply chain, especially for SMEs. Only a few articles have attempted to group appropriate e-business models and strategies for textile & apparel manufacturers (Ding *et al.*, 2011; Meng, 2015). Although the relationships between e-business and supply chain capabilities are widely acknowledged, there is still little advice for small and medium size manufacturers' executives to connect their company strategic context and priorities with e-business initiatives in supply chain management. It is an essential topic for theoretical and practical purposes. Researchers need to study e-business adoption in the textile & apparel supply chain and provide SME executives suggestions to improve order fulfilment efficiency and develop the whole textile & apparel supply chain capabilities.

Scholars use time and cost to measure supply chain efficiencies, such as order cycle time, lead time, total costs and inventory costs (Hsu *et al.*, 2008; Slack *et al.*, 2016; Wikner and Rudberg, 2005). Suppose SMEs can reduce the lead time and minimise the total costs in supply chain management; they will fulfil more orders in the same period and cost less to complete the same order. Only a few scholars consider the specific manufacturing industry, for example, the textile & apparel supply chain (Euractiv, 2019; Kayabasi and Gumus, 2012). None of them thinks about the influence of e-business on one typical textile & apparel order fulfilment efficiency for SMEs in the supply chain, and there is a research gap.

The second gap concerns the rigorous analysis of e-business utilisation for Chinese SMEs in the textile & apparel supply chain.

Many scholars have started to explore e-business utilisation in China, and most studies are cross-industry analyses (Choi and Jin, 2015; Gou and Gao, 2017; Huo *et al.,* 2018; Stanworth *et al.,* 2015; Wang *et al.,* 2017). There are very few empirical studies to understand e-business utilisation in the textile & apparel industry (CNNIC Report, 2015, 2020). There is no study to research e-business utilisation for Chinese small and medium size textile & apparel manufacturers, so it is necessary to study how e-business initiatives improve Chinese small and medium size textile & apparel manufacturers' capabilities and competitiveness.

It is indispensable to explore the current status of e-business utilisations in the textile & apparel supply chain, such as current e-business technologies and tools, benefits and obstacles of e-business adoption. The goal is to find out how to use e-business initiatives to improve order fulfilment efficiency and provide practical suggestions for Chinese small and medium size textile & apparel manufacturers to improve order fulfilment efficiency and develop supply chain capabilities.

The third gap concerns how ABM can be used in textile & apparel order fulfilment and supply chain for small and medium manufacturers to study e-business utilisation. ABM is a new method to study the supply chain since it is impossible to collect all data from the actual supply chain. Only a few scholars use ABM to analyse textile & apparel supply chains (Felfel *et al.,* 2015, 2018). Current researches only consider one-to-one information sharing model, none of them design a one-to-many information sharing model to represent a specific textile & apparel order fulfilment in the supply chain for SMEs.

Scholars admit that textile & apparel manufacturers have to use new initiatives such as e-business to improve their capabilities (CNNIC Report, 2015, 2020; Manfredsson, 2016; Zhang *et al.,* 2016; Zhu *et al.,* 2015). However, some textile & apparel manufacturers still do not recognise the potential benefits of e-business adoption. Small and medium size textile & apparel manufacturers have to face obstacles when utilising e-business technologies and tools (Meng, 2015; Sharma, 2013). They have to face the costs of instability, so it is hard to invest in e-business because they may have to borrow money to meet such costs (Dezi and Giudice, 2014). From an internationalisation perspective, small and medium size textile & apparel manufacturers should realise that information exchange can drive export performance (Zucchella and Siano, 2014). Suppose they want to improve their export performance. In that case, they should consider the internationalisation path in emerging markets (Gonzalez-Perez *et al.*, 2016), and advanced e-business tools can support them in improving export performance (Simic *et al.*, 2019). Therefore, studying e-business initiatives for small and medium size textile & apparel manufacturers can provide insights into the existing literature in the domain of textile & apparel supply chain capabilities.

3.3 Research Propositions

The research propositions push the study to search for variables and relationships among these variables. Unlike the research question, the proposition means a subject is acknowledged or denied and provides research directions for the study.

As the foundation of an internet-based network, e-business supports companies' decision-making and coordinates inter-organisational relationships by searching and retrieving information. E-business provides company information about the product demand, inventory, manufacturing process, delivery, and customer requests to manage supply chain activities. When manufacturers and their business partners well recognise these benefits, it is easier for them to understand how these methods influence the relationship between manufacturers and partners and the whole supply chain performance.

It is widely accepted that all participants in the textile & apparel supply chain will benefit from the utilisation of e-business. A more advanced e-business utilisation level means less time to fulfil an order and brings more benefits for manufacturers. Small and medium size textile & apparel manufacturers and raw material suppliers can forecast the demand more accurately to reduce the stock and total costs and improve supply chain efficiency. Time can be used to evaluate order fulfilment efficiency and supply chain performance. Suppose small and medium size textile & apparel manufacturers can use e-business technology to fulfil an order quickly. As a result, they can perform more orders simultaneously and improve supply chain competitive advantages. This study proposes that the advancement of e-business utilisation level (from no e-business to more advanced e-business) affects order fulfilment efficiency and supply chain performance for small and medium size textile & apparel manufacturers. The textile & apparel order fulfilment process involves various steps: the inventory check time, the raw materials inquiry time, the order confirmation time, the raw materials purchase time, the order production time, the order delivery time (Frederick and Daly, 2019), so there are seven propositions listed below.

P1. The advancement of e-business utilisation level influences the inventory check time; when the e-business level improves, the time taken to check inventory decreases.

When a small and medium size textile & apparel manufacturer uses more advanced e-business technology or tools in the supply chain, for example, from no e-business to email, ERP, and cloud computing services, it uses less time to check inventory.

E-business adoption can reduce cycle time (Bankole and Olatokun, 2017; Benitez *et al.,* 2018) and improve operational capability (Kumar *et al.,* 2017; Raguseo, 2018; Shen *et al.*, 2019). A small and medium size textile & apparel manufacturer can reduce cycle time when it starts to adopt e-business and upgrade e-business utilisation level in the operation process management. The inventory check time is part of the cycle time, so P1 is developed to explore how e-business adoption levels affect inventory check time in the textile & apparel supply chain.

P2. The advancement of e-business utilisation level influences the raw materials inquiry time; when the e-business level improves, the time taken to inquire about raw materials decreases.

Small and medium size textile & apparel manufacturers can reduce time communicating with suppliers to inquire about raw materials when they upgrade their e-business technologies and tools.

Manufacturers need to communicate with suppliers before they place the order to purchase raw materials. According to Kayabasi and Gumus (2012), Mazzarol (2015), and Rinaldi and Bandinelli (2019), e-business adoption can increase communication flexibility between supply chain partners. Small and medium size textile & apparel manufacturers can save time to exchange information with suppliers. P2 is developed to test how e-business adoption levels affect raw materials inquiry time in the textile & apparel supply chain.

P3. The advancement of e-business utilisation level influences the order confirmation time; when the e-business level improves, the time taken to confirm the order decreases.

When small and medium size textile & apparel manufacturers accelerate their e-business advancement level, they will save time to confirm the order in supply chain management.

Manufacturers need time to calculate the order costs, production time, and delivery date before giving the retailer offer, so they need to exchange information and negotiate with supply chain partners. Kayabasi and Gumus (2012) and Mazzarol (2015) insist that partners can improve communication flexibility by using e-business. Small and medium size textile & apparel manufacturers can save time by adopting more advanced e-business to confirm the order. P3 is developed to test how e-business adoption levels affect order confirmation time in the textile & apparel supply chain.

P4. The advancement of e-business utilisation level influences the raw materials purchase time; when the e-business level improves, the time taken to purchase raw materials decreases.

When SMEs adopt a more advanced e-business level in the textile & apparel supply chain, for example, from no e-business to email or Wechat, ERP, MRP or MRP II, and cloud computing, they use less time to purchase raw materials.

Manufacturers need to purchase raw materials to produce ordered products when they have insufficient raw materials, so they need time to exchange information with suppliers. E-business adoption can increase communication flexibility in the supply chain (Kayabasi and Gumus, 2012; Mazzarol, 2015). Small and medium textile & apparel manufacturers can save time communicating with raw material suppliers when adopting and upgrading e-business utilisation levels. P4 is developed to test how e-business adoption levels affect raw materials inquiry time in the textile & apparel supply chain.

P5. The advancement of e-business utilisation level influences the order production time; when the e-business level improves, the time taken to produce the order decreases.

When a small and medium size manufacturer uses more advanced e-business levels in the textile & apparel supply chain, such as using ERP and cloud computing to replace email, it takes less time to produce the order.

For manufacturers, production is a critical step of operational process management. E-business adoption supports manufacturers to improve operational capability (Kumar *et al.,* 2017; Raguseo, 2018; Shen *et al.*, 2019). Small and medium size textile & apparel manufacturers can save time to manage production when it adopts more advanced e-business technologies and tools in the supply chain. P5 is developed to test how e-business adoption levels affect order production time in the textile & apparel supply chain.

P6. The advancement of e-business utilisation level influences the order delivery time; when the e-business level improves, the time taken to deliver the order decreases.

When a small and medium size textile & apparel manufacturer uses more advanced e-business to arrange the delivery, for example, using ERP but not just email or using cloud computing services, it uses less time to deliver the ordered products to the retailer.

Manufacturers need to exchange information with distributors to arrange the delivery. E-business utilisation can accelerate communication flexibility in the supply chain (Kayabasi and Gumus, 2012; Mazzarol, 2015). A textile & apparel manufacturer can save time to exchange information with distributors when it adopts and upgrades e-business utilisation level to arrange the delivery. P6 is developed to test how e-business adoption levels affect order delivery time in the textile & apparel supply chain.

P7. The advancement of e-business utilisation level influences the whole order fulfilment time; when the e-business level improves, the time taken to fulfil the order decreases.

When a small and medium size textile & apparel manufacturer uses more advanced e-business technology or tools in the supply chain, for example, from no e-business to email, ERP, and cloud computing, it uses less time to fulfil the order.

The order fulfilment process involves different steps in the supply chain management, for example, inventory check, raw materials inquiry, order confirmation, raw materials purchase, order production, and order delivery. Textile & apparel manufacturers need to complete each step to fulfil the order. Manufacturers can use e-business to reduce cycle time and lead time (Benitez *et al.,* 2018) and improve operational capability and competitiveness (Kumar *et al.,* 2017; Raguseo, 2018; Shen *et al.*, 2019). Small and medium size manufacturers can use less time to fulfil the order by adopting more advanced e-business technologies and tools to manage the supply chain. P7 is developed to test how e-business adoption levels affect the order fulfilment time in the textile & apparel supply chain.

Based on the literature review of chapter two, this chapter constructs a theoretical framework, further discusses the research gaps, and lists research propositions. The next chapter will provide a research design to illustrate how to test propositions and achieve the research aim and objectives.

Chapter 4 Research Methodology

In general terms, research means searching for knowledge in common parlance. Research also can be defined as a systematic and scientific search for relevant information on a particular topic. The primary purpose of research design is to avoid such situations that the result does not relate to the original research aims. Hence, the research design should deal with specific logical issues but not irrelevant and illogical issues. The appropriate research design should be decided at the beginning of the research to avoid potential biased outcomes. Effective research design includes specific procedures, such as selecting data, collecting data, analysing data, linking research results to research aims, etc. (Creswell, 2009; Tull and Hawkins, 1993). Yin (2009) lists five components of a research design: study questions, study propositions, units of analysis, the logic linking the data to the propositions, and the criteria for interpreting the findings.

Study questions. The first mission of the study is to identify and clarify the nature of the research questions. The research aim and objectives are listed in section 1.3.

Study propositions. After reviewing literature and analysing theories, this thesis proposes that the advancement of e-business adoption level affects the order fulfilment efficiency and the whole supply chain performance for Chinese small and medium size textile & apparel manufacturers. Propositions have been addressed in section 3.3 and will be tested in chapter 6.

Units of analysis. The units of analysis of this study is the time needed for different steps to fulfil an apparel order, so information about them must be collected. Propositions can identify and narrow the relevant information required since it is impossible to collect all information. The study will adopt ABM based on interview results with Chinese small and medium size textile & apparel manufacturers as the main data collection method.

The logic linking the data to the propositions and the criteria for interpreting the findings. It is the data analysis and discussion step. The analysis results will be used to test propositions, and research results will be used to compare with current literature and achieve research aim and objectives.

This research includes different phases: defining problems, formulating propositions based on literature, using a mixed method to collect and analyse data, making deductions, coming to conclusions, and testing conclusions to confirm if they fit hypotheses or propositions, and then trying to achieve research aim and objectives.

This chapter will review and examine various research methods and explain the adopted methods to accomplish the research aim and objectives. Benefits, problems, and purposes are examined in detail, along with a justification for the selected research method.

4.1 Research Process

According to Crotty (1998), there are four elements in any research process (see Table 4.1): epistemology, theoretical perspective, methodology and methods. Epistemology is the theory of knowledge embedded in the theoretical perspective and, thereby, in the methodology. The theoretical perspective is the philosophical stance that informs the methodology, and it builds an environment for the process and establishes the criteria and logic. The methodology is a strategy, an action plan, a design, or a process behind the particular research methods and links the methods to the desired results. Methods can be considered techniques and procedures employed to accomplish the systematic process of knowledge inquiry and finding.

Table 4.1 The elements in the research process

Epistemology	Theoretical Perspective	Methodology	Methods
Objectivism Subjectivism Constructionism	Positivism (and post-Positivism) Interpretivism -Symbolic interactionism -Phenomenology -Hermeneutics Critical inquiry Feminism Postmodernism, etc.	Experimental research Survey research Ethnography Phenomenological research Grounded theory Heuristic inquiry Action research Discourse analysis Feminist standpoint research, etc.	Sampling Measurement and scaling Questionnaire Observation -Participant -Non-participant Interview Focus group Case study Life history Narrative Visual ethnographic methods Statistical analysis Data reduction Theme identification Comparative analysis Cognitive mapping Interpretative methods Document analysis Content analysis Conversation analysis, etc.

Source: Crotty (1998), p.5.

Epistemology provides a philosophical basis for determining possible knowledge, including scope, foundation and validity. As a systematic process, research is expected to explore new knowledge; it is necessary to consider the methodological paradigms to achieve the research aim. The assumption of the researchers' worldview guides the investigation and the method of the research. It guides the research design, conduction, and analysis, so the researchers' philosophical perspective is crucial when selecting the research paradigm (Creswell, 2009; Easterby-Smith *et al.,* 2008; Saunders *et al.*, 2016). The research methodology is the plan of action or research strategy. Research methods involve specific techniques or procedures such as interviews, comparative analysis, etc., to collect and analyse data.

4.1.1 Research Epistemology

Epistemology refers to the origin and structure of knowledge, which is invariably defined as the theory of knowledge (Rawnsley, 1998). According to Kitchin and Tate (2000), epistemology guides researchers to obtain knowledge about a subject, such as sources, nature and the scope. For any research field, it is crucial to explore reasonable knowledge and obtain it (Saunders *et al.*, 2016). Epistemology consists of a series of assumptions regarding the most appropriate approach to explore the nature of the world, concentrating on the relationship between the knower and what will be known (Easterby-Smith *et al.*, 2008).

Crotty (1998) indicates that epistemology includes objectivism, subjectivism and constructionism. Saunders *et al.* (2016) suggest that researchers consider the theoretical assumptions when making business and management methodological choices. Objectivism believes in realism. Following Crotty (1998), objectivism assumes that the meaning is independent of the observer and is "out there", waiting to be discovered by researchers. This study explores the effects of e-business advancement on textile & apparel supply chain capabilities for SMEs. Subjectivism incorporates the humanity and art assumptions, and social reality is composed of social entities' perceptions and actions (Saunders *et al.*, 2016). The subjectivist seeks different opinions to explain the different social realities of various entities. Subjectivists insist that it is impossible to separate themselves from their values as they use these data actively. Hence, they rethink their study actively, doubt their values, and incorporate these ideas in their researches (Saunders *et al.*, 2016). According to Crotty (1998), constructionism signifies that meaning is constructed through the interaction of subjects (social entities) and objects (existing things, concepts, etc.), and the meaning develops as these interactions occur.

To summarise, objectivism means the meaning that exists in the real world, constructionism means the meaning comes from human interactions with the real world, and subjectivism means how to impose meaning in the world.

4.1.2 Research Paradigms

The research paradigm behinds the chosen methodology provides the context for the process and the basis of logic and criteria (Saunders *et al.,* 2019). For example, positivism and post-positivism are usually regarded as quantitative research methods (Creswell, 2009). They are fit for analysing statistical data and a small number of variables (Hussey and Hussey, 1997).

Positivism holds that the research phenomena should be scientific in the way of natural science (Malhotra, 1999; Saunders *et al.,* 2016). Easterby-Smith *et al.* (2008) insist that positivism emphasis the necessity of finding factual explanations and fundamental laws. Saunders *et al.* (2019) list the characteristics of positivist research: it is deductive and tries to find causal explanations between different variables; it uses quantitative data to test hypotheses; it employs a highly structured approach to facilitate replication of the research. This study uses deductive methods to achieve research objectives.

Symbolic interactionism brings many assumptions; it directly deals with fundamental social interactions, such as language, communication and community (Crotty, 1998). Nevertheless, critical inquiry is usually regarded as a qualitative research method related to interpretivism and subjectivism and can be used to explain a theory (Hussey and Hussey, 1997).

4.1.3 Research Methodologies

The methodology is the technique that the researcher uses to discover the reality. The methodology focuses on collecting reliable and valid information (Malhotra, 1999). Somekh and Lewin (2005, p.346) indicate methodology is the "principles, theories and values that underpin a particular research approach." Saunders *et al.* (2012) claim that a methodology is a comprehensive approach linked with the research paradigm and theoretical assumptions. A well-defined research methodology with a philosophical viewpoint can help researchers understand the process of scientific investigation and can be acted as the rule for reasoning (Denscombe, 1998). Reliability and validity are the critical points of data evaluation and research credibility, ensuring the adaptability or accuracy of the data (Creswell, 2009; Hussey and Hussey, 1997).

4.1.4 Research Methods

Crotty (1998) introduces specific research methods, such as sampling, questionnaire, observation, interview, case study, statistical analysis, comparative analysis, etc. These methods can be divided into quantitative and qualitative research methods or deductive and inductive research methods. The quantitative and qualitative research methods will be illustrated in section 4.2, and the deductive and inductive methods will be illustrated in section 4.3.

4.2 Quantitive, Qualitative, and Mixed Method

Before the 1980s, the quantitative method was dominant. After that, the qualitative method became an alternative. The mixed research method became the legitimate third paradigm when Tashakkori and Teddlie (2003) published the *Handbook of Mixed Methods in Social and Behavioural Research*.

The quantitative research method includes collecting precise data and making statistical analyses to achieve the objective. On the contrary, the qualitative research method involves exploring and reflecting perceptions to understand human and social activities (Hussey and Hussey, 1997). Furthermore, quantitative research seeks to justify generalisation by linking the development of theories and hypotheses (Creswell, 2009; Hussey and Hussey, 1997). Qualitative research tends to discover new phenomena, establish holistic and complex perspectives to describe and analyse a detailed view (Amaratunga *et al.*, 2002; Creswell, 1994; Ghauri and Gronhaug, 2001). Mixed research involves a mixture of qualitative and quantitative methods or paradigm characteristics, it can be used in various forms, and the mix possibilities are almost limitless (Johnson and Chirstensen, 2008).

Over the past few decades, the debates focusing on these methods' weaknesses and strengths have never stopped, and researchers have identified and exemplified many differences. Scholars compare the main difference among quantitative, qualitative, and mixed research methods (Johnson and Chirstensen, 2008; Stainback and Stainback, 1988), see Table 4.2.

Table 4.2 Differences among qualitative, quantitative, and mixed method

Dimensions	Quantitative Research	Qualitative Research	Mixed Research
Scientific method	Deductive or "top-down"	Inductive or "bottom-up"	Deductive and inductive
Purpose	Prediction and description	Understanding	Multiple purposes
Reality	Objective	Subjective	Common sense realism and pragmatic view
Focus	Particularistic – defined by variables studied	Holistic	Multilens focus
Conditions	Under controlled	Naturalistic	More than one condition
Data collection	Structured and validated data collection instruments	Primary data collection instruments	Multiple forms
Nature of data	Variables	Words, images, categories	Mixture of variables, words and images
Data analysis	Identify statistical relationships	Search for patterns, themes and holistic features	Quantitative and qualitative
Results	Generalisable findings	Particularistic findings	Corroborated findings may generalise

Source: based on Johnson and Chirstensen (2008) and Stainback and Stainback (1988).

There are a lot of distinct differences among these three research methods. The qualitative research method is oriented from a belief that the social sciences deal with an open but not closed system; therefore, it is not easy to conceptualise it in the same way as the natural sciences (Glaser and Strauss, 1967; Miles and Huberman, 1994). The qualitative research method invariably focuses on complexity, case-oriented with a small size sample or intensive survey methods. The qualitative method concentrates on individuals' experiences and the meaning of the phenomenon (Miles and Huberman, 1994); on the contrary, the quantitative research method focuses on the case (Stainback and Stainback, 1988). Compared to these two research methods, mixed research has multiple purposes and focuses.

Quantitative methods try to confirm the hypothesis of the phenomenon with objective and singular reality, and qualitative methods seek to discover the phenomenon with subjective and multiple realities (Bryman, 1988; Creswell, 1998). In terms of categorising questions, qualitative approaches use a flexible and iterative style to elicit and categorise these questions' responses; on the contrary, quantitative methods use a more rigid type to deal with such questions (Johnson and Onwuegbuzie, 2004). The research in quantitative studies is independent of what is being studied but explores new research topics; by contrast, in qualitative research, the research involves what is being studied and how to interact with participants (Lincoln and Guba, 2000). Qualitative methods are inductive, context-bound, and process-oriented; their analytical objectives can link with a description of variation, interpretation of relationship, illustration of personal experience, or expression of group specifications (Creswell, 1998). On the contrary, quantitative approaches are outcome-oriented, deductive, and context-free; meanwhile, their analytical objectives link with variation quantifying, casual relationships prediction, or description of one population characteristics (Sobh and Perry, 2006). Mixed methods seek to discover the phenomenon with common sense based on realism and a pragmatic view.

Table 4.3 lists the strengths and limitations of quantitative and qualitative approaches. Given its phenomenological and exploratory nature, the study adopts the mixed research approach, which will be further discussed in section 4.4.

Table 4.3 Advantages and disadvantages of quantitative and qualitative research approach

	Quantitative Approach	Qualitative Approach
Advantages	Provide large samples.	It is the best strategy to explore new areas and develop hypotheses.
	Collect a wide range of data based on a large, statistical portion of the population.	Encompass a real-life scenario.
	Provide statistical reliability validity, which may be more objective than qualitative research method.	Provide rich, detailed and holistic data.
	Use standardised questionnaires or survey to collect data shown as percentages in the figure or table.	Discover complexities beyond the scope of more controlled methods.
	Compare outcomes by evaluating quantitative measures.	It is flexible to collect data.
Disadvantages	Difficulty in ascertaining deeper meanings.	It is time consuming to analyse volume and complex data.
	Issues are only measured if they are known before the survey.	Research results may just be suitable for the particular groups.
	A designed formulation with specific hypotheses is required.	The data collection may be affected by research bias.
	Ignore the unique characteristics of individual samples.	
	The limited in-depth description.	

Source: based on Amaratunga *et al.* (2002) and Creswell (2009).

In brief, the arguments between the quantitative and qualitative research approaches are described as "wars between the followers of two divergent paradigms" (Creswell and Plano-Clark, 2007, p.42). Those "wars" mainly focus on the advantages and disadvantages of these two paradigms.

Reliability and validity are the critical points of data evaluation and research credibility, which ensures data adaptability or accuracy (Creswell, 2009; Hussey and Hussey, 1997); they concern the same or similar results which can be produced when repeating a research process (Creswell, 2009; Yin, 2009). Joseph *et al.* (2007) indicate that reliability is related to the credibility or consistency of the research results. Quantitative and qualitative researches can utilise different techniques to enhance reliability. Quantitative research requires many tests or measurements to reproduce the results to improve reliability (Churchill and Brown, 2004), while qualitative research depends on spreading the analysis across multiple researchers or conducting similar observations and explanations in different studies to achieve a similar purpose (Creswell, 2009; Yin, 2003).

Validity refers to obtaining accurate results from reality which connects to the effectiveness of the research process (Hussey and Hussey, 1997). It is indispensable to check for the accuracy of research results by conducting specific procedures (Creswell, 2009). Quantitative and qualitative researches utilise different ways to achieve validity. Quantitative research concerns how to make the accuracy of variables be measurable in a project, while qualitative research concerns procedures to gather the data (Ruyter and Sholl, 1998). Qualitative research can use several methods to assess its validity by employing different techniques to produce data. For example, adopting triangulation of additional data, recruiting many scholars to research to ensure the accuracy of the data; providing various and rich perspectives of the theme; clarifying research bias; prolonging the time in the research area, and recruiting external auditors to review and debrief (Creswell, 2009).

Mixed research combines quantitative, qualitative, techniques, or other paradigm characteristics in one comprehensive study as a general research method. Johnson and Chirstensen (2008) introduce two significant types of mixed research: the mixed method and the mixed model research. Mixed method research means the qualitative research paradigm is used in one phase of a study. The quantitative research paradigm is used in another phase, which looks like conducting two tasks in one research. Mixed model research means qualitative and quantitative research approaches are mixed within a research study stage or across two stages. For example, the researcher can collect qualitative data and then quantify them. Researchers can use mixed research to corroborate the research results provided by qualitative or quantitative research approaches, to expand one set of results, to complement one set of research results with another, or to discover some missed knowledge obtained from only one approach (quantitative or qualitative) (Johnson and Chirstensen, 2008). Some researchers use the mixed research method to study supply chain management because it allows to solve a wide variety of supply chain management questions and provides robust and valid research results (Golicic and Davis, 2012). The mixed method is also used to study e-business applications on organisational transformation (Bak, 2012) and the determinants of internet technologies adoption in logistic and supply chain management (Tu, 2017).

4.3 Inductive, Deductive, and Abductive Method

Johnson and Chirstensen (2008) and Stainback and Stainback (1988) indicate that quantitative research is deductive and qualitative research is inductive. Saunders *et al.* (2012) introduce three main research methods: induction, deduction and abduction. Generally speaking, the inductive method collects and analyses data and then develops a theory due to the data analysis. Meanwhile, the deductive method develops a theory or hypothesis and designs a research strategy to test it. The abduction method uses data to explore a phenomenon, identify topics, explain patterns, generate a new theory or modify an existing theory, and test it, usually through additional data collection (Saunders *et al.*, 2019).

According to Gill and Johnson (2002), the inductive method starts from observing the natural world and then constructing the explanations and theories of things that have been observed. The inductive method is widely used in the social sciences to analyse macroeconomic data and opinion surveys. They also indicate that the deductive method is the reverse of the inductive method, which develops a theoretical and conceptual structure and then tests it by empirical observations. The deductive research method emphasises standardised procedures to avoid possible biases and permits others to replicate the study, for example, concept, rules, operationalisation and instruction. Bryman *et al.* (2005) insist that the deductive method is the most common method to prove the connexion between hypothesis and empiricism. According to Ketokivi and Mantere (2010), the abductive method begins with a conclusion. A set of feasible premises is then identified and considered sufficient or almost sufficient to support the conclusion. It is conjectured that if these promises are true, then the conclusion is undoubtedly true. Since the set of promises is adequate or almost sufficient to reach a conclusion, then there is the reason to believe that they are also true.

Table 4.4 lists the difference among inductive, deductive, and abductive methods. Saunders *et al.* (2012) suggest that the research can use an inductive method if it begins with data collection to explore a phenomenon and develop a theory (usually in the conceptual framework). On the contrary, the research can use a deductive method if it begins with a theory, hypothesis, or proposition, usually generated from academic literature. A research strategy is designed to prove the theory. The researcher can use an abductive method to collect data to explore a phenomenon, identify topics, and explain patterns, intending to build a new theory or modify an existent theory.

Table 4.4 Induction, deduction, and abduction: from reason to research

	Induction	Deduction	Abduction
Logic	In a inductive inference, known premises are used to generate untested conclusions.	In a deductive inference, when the premises are true, the conclusion must also be true.	In an abductive inference, known premises are used to generate testable conclusions.
Generalisability	Generalising from the specific to the general.	Generalising from the general to the specific.	Generalising from the interactions between the specific and the general.
Use of data	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework.	Data collection is used to evaluate propositions or hypotheses related to an existing theory.	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth.
Theory	Theory generation and building.	Theory falsification or verification.	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory.

Source: Saunders *et al.* (2019), p.145.

As Table 4.4 shows, considering the logic, the generalisability, the data, and the theory, induction, deduction, and abduction are different. The researcher should consider the research's aim and character and then choose an appropriate research method.

4.4 Research Design

Malhotra (1999, p.12) indicates that research design is "a framework or blueprint for conducting a marketing research project." According to Yin (2009, p.26), the research design is "the logical sequence which connects the empirical data based on initial research questions to the conclusions.” Research design connects compatible components to generate knowledge, which is the innate character of research methods. Research design produces implicit or explicit hypotheses regarding philosophical and epistemological paradigms to conduct the research (Bryman, 2001). The study aims to explore, describe, explain and understand the phenomenon or discover differences (Blaikie, 2000). Research design means using particular methods and linking them to obtain the desired outcomes.

The study aims to analyse how e-business utilisation affects Chinese small and medium size textile & apparel manufacturers to develop supply chain capabilities. The main objectives of this research are listed below.

(1) To identify e-business technologies and tools used in the textile & apparel supply chain.

(2) To explore the barriers for textile & apparel manufacturers to implement e-business in the supply chain and the benefits of implementing e-business based on literature review and the interview with small and medium size textile & apparel manufacturers.

(3) Conduct modelling simulation to:

- Design conceptual model to represent different levels of e-business utilisation (from no e-business to more advanced e-business level) in textile & apparel supply chain;

- Run the simulation based on the conceptual model to understand the effects of varying e-business utilisation levels in an apparel order fulfilment for a Chinese small and medium size apparel manufacturer in textile & apparel supply chain;

- Identify how e-business implementation influences textile & apparel order fulfilment efficiency and supply chain capabilities.

(4) To compare and contrast the research results with the literature to develop the theory of e-business utilisation in textile & apparel supply chain, provide practical suggestions for Chinese small and medium size textile & apparel manufacturers to implement e-business initiatives.

According to Creswell (2009), there are three main research designs: qualitative, quantitative, and mixed approaches. These three approaches can be practical, depending on available resources, circumstances, and researchers' abilities. Saunders *et al.* (2019) list three research methods, induction, deduction and abduction, and suggest that researchers can use a deductive method when the study begins with a theory or hypothesis and then test it. Bryman *et al.* (2005) also insist that the deductive method is the most common method to prove the connection between a theory or hypothesis and empiricism. As propositions are generated from academic literature and will be tested by research results, the study considers the deductive method. The data will be generated by ABM based on interview results, so this research will use a mixed research method to achieve research objectives.

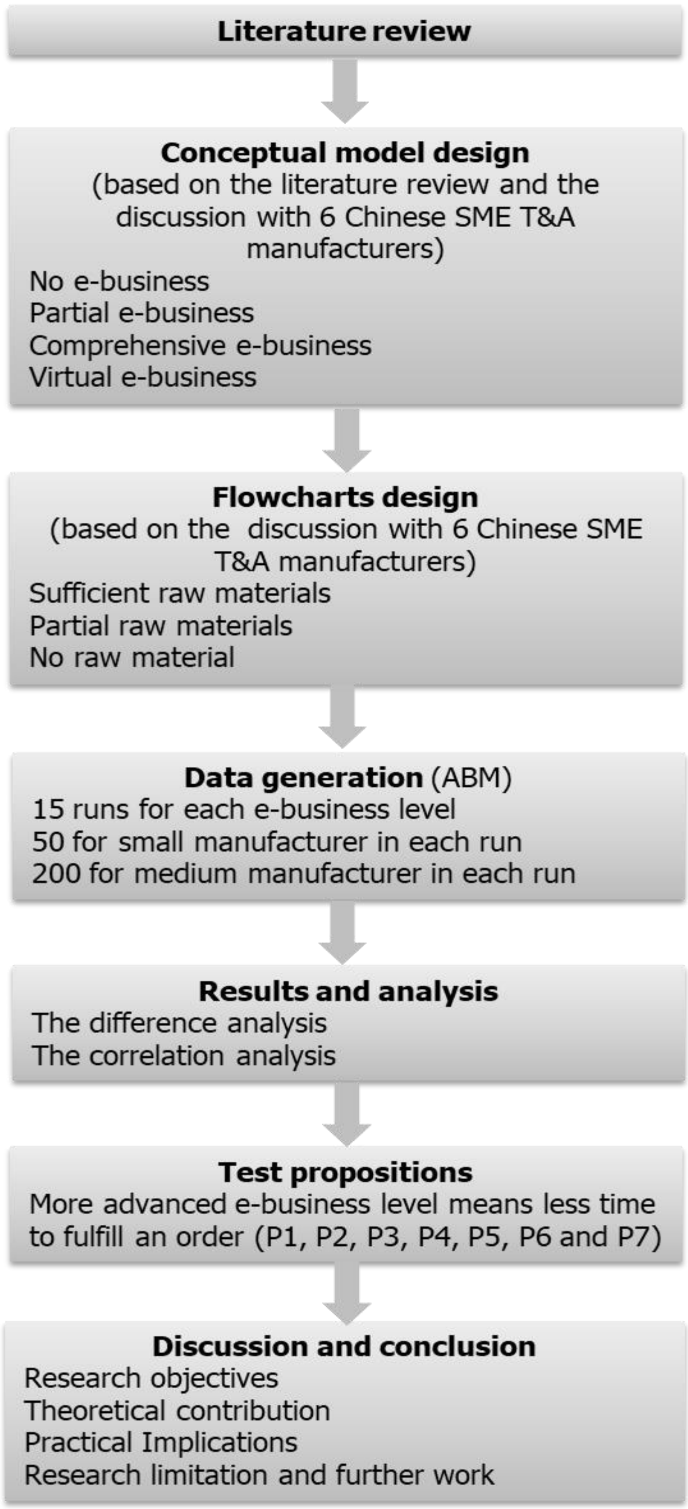
This research explores the obstacles and benefits textile & apparel manufacturers face when implementing e-business. It proposes that the advancement of e-business utilisation level affects the order fulfilment efficiency and supply chain capabilities for small and medium size textile & apparel manufacturers. The study focuses on Chinese small and medium size textile & apparel manufacturers. It is impossible to collect all data from the real world, so this research uses ABM as the main data collection method. Agent based modelling allows agents to interact continuously and simulates these interactions repeatedly (Macal and North, 2009). ABM captures emergent phenomena, provides a natural description of a system, expresses the supply chain precisely (Jain and Deshmukh, 2009). It is flexible, researchers can adjust it and gain more information (Benabeau, 2002), so ABM is one of the best approaches to study supply chain (Jain and Deshmukh, 2009; Um *et al.,* 2010). Section 4.5 will introduce ABM and justify using ABM as the main data collection method.

Based on current research, the conceptual model representing different e-business adoption levels will be proposed (Abdullah *et al.*, 2015; Basu and Muylle, Cataldo *et al.*, 2020; Shamsuzzoha and Helo 2017, 2018) and will be described in section 5.1.3. The flowcharts illustrate a jacket order fulfilment under different situations, and the original parameters will be designed in section 5.3.1. The flowcharts and initial parameters will be developed based on the discussion with Chinese small and medium size textile & apparel manufacturers to ensure those designs represent the actual order fulfilment process and supply chain. The researcher will conduct interviews until all managers confirm the procedure and no new information emerges. The research seeks to discover things from participants' perspectives. That is why the research tends to conduct semi-structured interviews and use nondirective forms of questions. The study will analyse simulation results to compare different e-business levels' influence on SMEs' jacket order fulfilment.

ANOVA (Analysis of Variance) tests, Boxplots, and Spearman's rank correlation coefficient in SPSS will be conducted to analyse the data obtained from simulations to test seven propositions: if e-business advancement level has a significant impact on inventory check time, raw materials inquiry time, order confirmation time, raw materials purchase time, order production time, order delivery time, and order fulfilment time under three different situations: sufficient raw materials, partial raw materials, and no raw materials to produce an order. ANOVA will be used to test if there is a statistically significant difference between e-business levels and the time taken to fulfil the order. Then the Boxplots will be used to illustrate the differences graphically. Finally, Spearman's rank correlation coefficient will be used to explore the relationship between the e-business level and the average times of different steps to fulfil an order.

The research will test seven propositions and achieve the research aim and objectives based on research results. The study will compare and contrast research results with the literature reviewed, provide practical suggestions for Chinese small and medium size textile & apparel manufacturers, and identify further work (see Figure 4.1).

Figure 4.1 Research methodology framework



4.5 Adopted Data Collection Method: Agent Based Modelling

Crotty (1998) introduces many different data collection and analysis methods, such as sampling, measurement, scaling, questionnaire, observation (participant or non-participant), interview, focus group, case study, statistical analysis, data reduction, comparative analysis, cognitive mapping, document analysis, content analysis and conversation analysis, etc. Simulation is an appropriate choice because it is not practical to collect all data from the real textile & apparel supply chain. Swaminathan *et al.* (1998) insist simulation is the only viable platform for complicated analysis when organisations seek reengineering solutions. Axelrod (2006) also insists that the simulation research method, especially ABM, is another effective way to study science. Besides utilising numerical tests to analyse the model mathematically, simulation is also crucial in supply chain management. Simulation techniques are employed because it is arduous to obtain practical information and validate data. It has been proved that analytical models involving mathematical optimisation techniques are helpful in many cases. Still, sometimes they are too simplistic to solve practical and complex supply chain management problems (Hung *et al.,* 2006).

Meanwhile, simulation models can help the modeller discovers the supply chain characteristics and construe them into the simulation environment. Artificial intelligence (AI) and simulation have been extended to configure the supply chain structure to avoid the shortage of analytical methods. Akanle and Zang (2008) claim that AI techniques are helpful to address the qualitative aspect of decision-making, but AI techniques are not adequate when utilising analytical models. Examples of AI and simulation applications include multi-agent systems, case-based reasoning (CBR), and neural networks (Chan *et al.*, 2006; Lau *et al.*, 2006). These implementations broaden the supply chain configuration manner and prompt the representation of complicated interactions between supply chain partners and the associated flow of materials and information among those partners.

4.5.1 Definition of ABM

Axelrod (1997) defines ABM in his earlier published papers. Some researchers claim that ABM is "a third way of doing science"; it expands traditional deductive reasoning and inductive reasoning (Axelrod, 2006). Agent based modelling has many different names, such as agent based modelling (ABM), agent based systems/simulation (ABS), individual based modelling (IBM) and multi-agent based simulation (MABS), etc. Generally speaking, an agent based model is a model in which agents interact repeatedly, and agent based simulation means a model in which these interactions are simulated repeatedly (Macal and North, 2009).

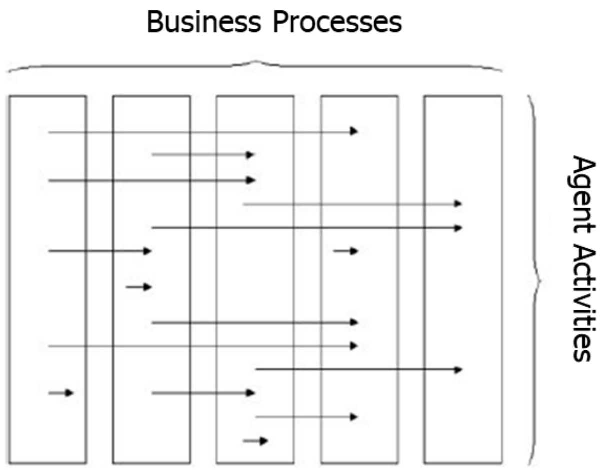
ABM involves a set of autonomous entities called agents. Each agent estimates its situation and makes decisions based on predefined rules. An agent can perform various behaviours in the system, such as producing, selling, purchasing, etc. The repetitive interaction between agents is one of the features of ABM, and these interactions rely on the sophisticated computer system to explore the dynamics which pure mathematical methods cannot achieve (Axelrod, 1997; Epstein and Axtell, 1996). An ABM consists of collecting agents and their interactions at the most superficial level. A simple ABM model can demonstrate complicated agents' behaviour patterns and produce valuable data regarding the dynamic natural world environment. Furthermore, agents may have the ability to upgrade so that unexpected behaviour may occur. Sometimes a complex ABM system involves evolutionary algorithms, neural networks, or other learning techniques to achieve realistic study.

Bonabeau (2002) lists three advantages of the ABM research method over other modelling techniques: it captures emergent phenomena, describes a system naturally, and, finally, is flexible.

ABM captures emergent phenomena. Emergent phenomena derive from individual agents' complicated behaviours and interactions, making it difficult to understand and predict. ABM is the appropriate approach to model the emergent phenomena because it designs and simulates agents' behaviours and interactions in the system, captures emergent phenomena from the beginning of the simulation process.

ABM describes a system naturally. ABM makes the model closer to reality, so it is most natural to describe and simulate a system composed of active agents. Bonabeau (2002) indicates that a business process is abstract, and it is often not easy for people to control and manage the business inside the organisation. ABM focuses on the organisation from activities (what people do inside the organisation) but not the business processes (see Figure 4.2). Moreover, these two descriptions, business processes, and agent activities must be mutually consistent. Business process description gives the researcher a helpful, constant inspection. Nevertheless, when it comes to launching, verifying, and calibrating the model, people inside the organisation can answer questions more easily about their activities: the model describes them and relates them to the model.

Figure 4.2 Illustration of the business process and agent views of a business



Source: Bonabeau (2002), p.7281.

ABM is flexible. More agents can be added to an ABM system easily when it is necessary. Meanwhile, ABM provides a natural environment to adjust agents' complexities: degree of rationality, behaviours, learning and evolvement capabilities and interaction rules. Moreover, ABM can adjust description levels and aggregation levels: one agent can interact with another single agent and subgroups of an agent. It is accessible to aggregate agents with different descriptions in one given model (Bonabeau, 2002).

ABM has been employed in different business management fields, such as supply chain management and organisational science (Rand and Rust, 2011). Some researchers employ ABM to discover how competitive forces and interaction networks affect company positioning (Rand and Rust, 2011). Hill and Watkins (2007) and Watkins and Hill (2009) investigate moral behaviour in marketing relationships based on ABM models. Procter & Gamble has successfully applied ABM in the consumer market to increase incomes (North *et al.*, 2010).

ABM can integrate all agent characteristics, and it is arduous to do the work in a traditional model because the traditional model only models the individual agent characteristic. Meanwhile, researchers have to face some constraints when using ABM. For example, Bonabeau (2002) indicates the only challenge is the availability of models; that is what the study got from the literature. Researchers need to review the literature and design the appropriate models to represent the research objective. Critiques of ABM usually include two points: ABM does not process actual data, so it is only for "toy problems", the other issue is that many parameters of ABM can fit any data, so it is just "computer games". Concerning the first point, Siebel and Kellam (2003) argue that ABM can integrate actual data and complexities into the model. The researcher must prove how the model corresponds to real-world phenomena. As for the second point, once the model starts to work, outputs and process are proved to be valid, which means they correspond to reality, so the ABM cannot fit for any data set, users should consider how to input the valid data (Siebel and Kellam, 2003).

4.5.2 Agent Characteristics

Each agent is responsible for some supply chain activities in ABM. These agents need to plan and implement their responsibilities, such as decision-making or communicating with other agents (Weiss, 2013). Each agent is a goal-oriented and autonomous software process under specific protocols. These protocols control the manufacturing operations, the inference mechanism, the knowledge base and the explicit model (Kamble *et al.*, 2004). The agent operates asynchronously under these protocols, communicates, negotiates, and cooperates with other agents based on accessible data and information (Fox *et al.*, 2000). Uppin and Hebbal (2010) claim that the definition of a multi-agent system includes technical and organisational aspects, e.g., technically, agents have enough knowledge and capabilities to act in a manner that can be called intelligent. Meanwhile, organisationally, agents have sufficient authority to commit for customers to represent their principals and comply with the same policies, procedures and rules. Kamble *et al.* (2004) list some common characteristics of an agent:

Autonomy: An agent can independently do at least part of its functionality and autonomously follow the goals.

Intelligence: An agent possesses some particular knowledge in even more application fields.

Interaction: An agent can collect data or information and react to its environment.

Reactivity: An agent must react to inputs from the environment appropriately.

Pro-activity/goal-orientation: An agent can react to changes and take the initiative to interact with the environment appropriately.

Mobility: An agent can transport from one node to another in a network.

Communication/cooperation: An agent possesses the communication capability to contact the environment.

Limitation: An agent cannot perform everything a person can because it cannot think like a real person. An agent can model human behaviours only when these behaviours can clearly be understood and described in detail.

4.5.3 Agent Structure Design

Agent structure design means organising specifications and decomposing the agent to construct a set of component modules that enable them to interact with each other based on specific behavioural regulations. Nevertheless, reactive architectures may become more critical because of two fundamental properties: "situatedness" and "embodiment" (natural intelligence exists in the real world but not in disembodied system), and intelligence and emergence (intelligence is not an isolated property, intelligent behaviour derives from the interaction between an agent and its environment) (Brooks, 1991).

Drogoul and Ferber (1992) provide an example of reactive agent architecture. They consider every agent as an object and put them in an environment named space. The primary communication mechanism is designed based on the stimulus-reaction scheme. An agent consists of a set of tasks or behaviours. In the simulation, agents select behaviours flexibly and take former experiences of interactions with the environment to choose the following behaviour. Some non-environmental factors, as an example, motivations, are also be integrated by activation of behaviours.

Nwana (1996) investigates the software agents and identifies six agent architectures: collaborative (symbolic, deliberative), interface, internet, mobile, reactive and hybrid. Each of these types has its advantages and disadvantages. The architecture used in this study tries to minimise the weaknesses and maximise these agent architectures’ benefits. The agents' architecture design will be described in section 5.2.2.

4.5.4 Agent Based Modelling Adoption in Supply Chain Management

In recent years, the market environment is becoming more complex and unstable; it is challenging to analyse the supply chain; mainly, it is an open and complex system. A supply chain involves many enterprises that can be a complex network, partners in the supply chain have different and conflicting objectives. As a dynamic system, production capacity and demands fluctuate frequently. Meanwhile, the relationships among all partners are also continuously evolving. Simangunsong *et al.* (2012) list some sources of uncertainty in the supply chain, such as the bullwhip effect and parallel interaction. It is tough to manage the uncertain, stochastic, and dynamic supply chain characteristics.

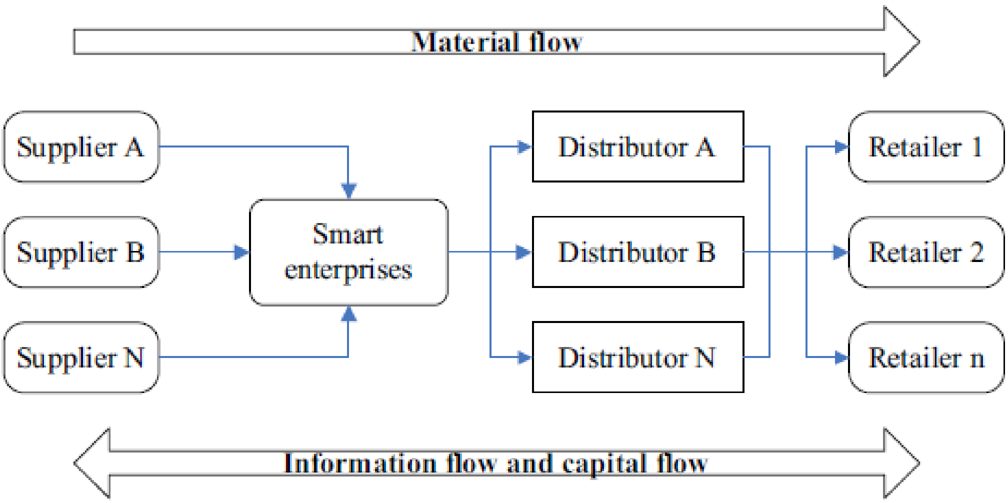
Researchers started to use modelling and simulation methods to study the supply chain 30 years ago. Since then, many studies have designed and used modelling and simulation methods to research the supply chain. Hikkanen *et al.* (1997) insist that on account of the recursive composition of the architecture, the SWARM-based modelling approach accelerates the representation of a complex supply chain. A communication channel can be established before the interaction occurs to characterise the type of information exchange between the agents in the supply chain. Swaminathan *et al.* (1998) use agent communication language (ACL) to illustrate the mechanism of communications between agents in detail, such as control elements and interaction protocols. Fox *et al.* (2000) indicate that the supply chain demonstrator (SCD) can help researchers to model and simulate complicated conversations on a high cooperative level using COOL language. SCD also provides an excellent opportunity to exhibit the communication between supply chain partners. Frayret *et al.* (2001, 2007) describe the NetMan strategic framework and the multi-agent integration approach in an agent-oriented prototype. Petersen *et al.* (2001) design the AGORA, a multi-agent architecture, to model and support cooperation among distributed agents in virtual enterprises. Sadeh *et al.* (2003) use a multi-agent supply chain coordination tool (MASCOT), an agent-oriented simulator, to study supply chain performance based on three lateral coordination policies.

Hung *et al.* (2006) list two different modelling approaches: analytical model and simulation model. They conclude that the analytical model is too simplistic to solve practical problems in a complex supply chain; by contrast, the simulation model can capture the actual supply chain characteristics. Longo and Mirabelli (2008) argue that modelling and simulation-based technology is the practical research method to deal with stochastic actions in the supply chain. Akanle and Zhang (2008) design an agent based model to optimise supply chain configuration. Pirard *et al.* (2011) establish a simulation model to evaluate different supply network designs, reproducing all activity dynamics in the supply chain. Kravari *et al.* (2012) use EMERALD and Rule Responder to study cross-community interoperation between supply chain partners based on MAS. Chiu and Choi (2016) use mean-variance models to learn how to reduce supply chain risks. Esmaeilikia *et al.* (2016) insist that tactical supply chain models improve usual operation efficiency and resiliency supply chain. Rouzafzoon and Helo (2016) adopt ABM to study the service supply chain and insist that ABM has advantages in analysing complicated customer-oriented service industries and designing service networks. ABM is also used in the biojet fuel supply chain under different policy landscapes to explore this new industry (Moncada *et al.,* 2019). In the agri-food supply chain, the use of ABM has been increasing in recent years (Utome *et al.,* 2018).

Many scholars focus on the textile & apparel industry, and some have made valuable achievements. Pan *et al.* (2009) provide ABM application in the apparel and fashion industry. Zulch *et al.* (2011) use a simulation approach to compare different product customisation scenarios in the apparel industry. Felfel *et al.* (2015, 2018) use a two-stage stochastic linear programming approach to study multi-site textile & apparel supply chain planning. Pan and Choi (2016) build a two-phase agent based negotiation system in a make-to-order fashion supply chain to reduce production costs and add both manufacturers and suppliers mutual benefits. The results show the negotiation approach can realise the optimal utility of agents and generate benefits for manufacturers and suppliers simultaneously. Macchion *et al.* (2017, 2019) design simulation models to compare the different supply chain configurations under product customisation in the shoe manufacturing industry. Backs *et al.* (2020) use an agent based modelling simulation approach to investigate fashion supply chain strategies in the apparel industry. They design two groups: manufacturer agents and consumer agents, and consider five factors: communication, advertising, information exchange, purchase and firsthand experience. They test six scenarios in terms of the different market shares of manufacturers. The result demonstrates that the ABM can capture emergent behaviours of the apparel industry.

Some researchers focus on information exchange in supply chain management. Dong *et al.* (2006) introduce an agent based architecture for supply chain management by analysing the material flow, information and finance flow. Lo *et al.* (2008) establish a multi-agent system to integrate different information technologies to improve the information collection efficiency of an e-fashion supply chain. Long (2015) designs a comprehensive three-dimensional flow model (material flow, information flow and time flow) to produce a functional architecture for the supply chain under a complex environment to support multi-agent modelling implementation. Pu *et al.* (2018) also indicate that the supply chain involves material flow, information flow, and capital flow among agents: supplier, smart manufacturer, distributor and retailer (see Figure 4.3). They also indicate that for the dynamics of the supply chain management, the synergy among agents is essential, so the critical problem of utilising ABM in supply chain management is how agents fulfil coordination.

Figure 4.3 Management model of supply chain



Source: based on Pu *et al.* (2018).

All above ABM studies concentrate on supply chain management activities from different aspects, such as communication channel (Backs *et al.,* 2020; Fox *et al.,* 2000; Hikkanen *et al.,* 1997), coordination management (Pu *et al.,* 2018; Sadeh *et al.*, 2003), partner relationship management (Hill and Watkins,2007; Watkins and Hill, 2009), supply chain configuration (Macchion *et al.*, 2017, 2019), information sharing and integration (Backs *et al.*, 2020; Dong *et al.*, 2006; Lo *et al.*, 2008; Long, 2015), information, finance and material flow (Dong *et al.*, 2006; Long, 2015; Pu *et al.*, 2018), product customisation (Macchion *et al.*, 2017, 2019; Zulch *et al.*, 2011), supply chain strategy (Backs *et al.*, 2020; Rouzafzoon and Helo, 2016), etc. These studies aim to reduce the supply chain risks and improve supply chain performance and capabilities. Most of them study general industries; only some of them consider the fashion industry and textile & apparel industry (Backs *et al.,* 2020; Felfel *et al.,* 2015, 2018; Macchion *et al.,* 2017, 2019; Pan *et al.,* 2009; Pan and Choi, 2016; Zulch *et al.,* 2011). None of them concentrates on a specific order fulfilment for SMEs in the textile & apparel supply chain based on e-business utilisation. Simulation methods help the researcher identify a framework of ABM in the textile & apparel supply chain and comprehend the effects of e-business utilisation in order fulfilment. The above research methods have theoretical underpinnings and provide some detailed process guidelines. However, it is still necessary to give a rigorous analysis based on the relevant theories to understand how a small and medium size textile & apparel manufacturer can improve order fulfilment efficiency and supply chain capabilities by utilising e-business. Nevertheless, an ABM simulation analysis considering the specific textile & apparel order fulfilment efficiency is still missing. This research fills the gap and takes inspiration from the previous studies to design and develop a conceptual ABM model. The study will generate and analyse data to test the effects of e-business initiatives on supply chain capabilities for small and medium size textile & apparel manufacturers.

4.5.5 Justification of Using ABM

Manufacturing enterprises are suffering the uncertainties of supply chain networks. These uncertainties may make the supply chain imprecise, such as raw materials purchase or customer service. The major problem is maybe ambiguous and vague data. For example, order fulfilment involves various elements, such as setup time, processing time, mean time to prepare, etc. These elements can be better expressed as fuzzy variables but often be described imprecisely, like "setup time is high" or "processing time is low" (Jain and Deshmukh, 2009). Therefore, production planning, scheduling problems, and inventory management are usually imprecise in the real world. However, supply chain partners try to interact with each other in real-world situations. Order type, quantity, and frequency vary frequently, and production is invariably affected by many factors, such as information shortage, demand forecasting mistakes, information flow uncertainties, high costs, etc. Hence, manufacturers need to dominate variations, i.e., demand, material supply, and inventory management, etc., to overcome uncertainty problems in the supply chain. Supply chain management problems are characterised by uncertainty and complexity. Jain and Deshmukh (2009) insist that applying ABM technology and fuzzy logic is an appropriate alternative to study the dynamic and complicated supply chain.

The supply chain is a domain where structural changes often take place. Agents are autonomous and distributed based on clearly, pre-defined interfaces, i.e., information flow. Compared with the weak performance of other types of systems often has to suffer, ABM provides a robust system that can continually adapt to environmental changes, both locally and globally. Automated software can be designed to handle adding and removing agents in the system. Meanwhile, adjusting one agent does not affect other agents in the system. Many researchers have used ABM in supply chain management as a helpful research method in recent years. ABM's characteristics are the rapid response to accidents and the decentralisation of optimisation, so it is appropriate to study the backfill supply chain (Vincent and Cheng, 2015). Tu *et al.* (2018) propose an architectural framework of information technology system modelling to model the manufacturing supply chain systematically. Pu *et al.* (2018) use ABM to design an allocation planning model to promote information exchange and coordinate profits distribution in a dynamic supply chain. The research results show that ABM implementation improves smart manufacturers' performance.

Um *et al.* (2010) insist that characteristics of multi-agent technology fit autonomous, collaborative, and intelligent systems, enabling ABM to be one of the best approaches to study the supply chain. A supply chain can be visualised as a series of entities and processes. A process is a series of behaviours and entities that may be different companies, such as suppliers, manufacturers, distributors, retailers, etc., or just some internal departments, such as purchasing, planning, producing, sales, or R&D department. Entities are responsible for a set of processes, e.g., the purchasing department might be responsible for functions related to material procurement. The sales department might be responsible for operations related to order confirmation, R&D department might be responsible for new product launches. Entities can be modelled as autonomous agents by adopting ABM. ABM models a system involving different agents as a new and different approach. Individual agents and their interactions are directly represented in the system (Macal and North, 2009). Therefore, ABM is becoming popular as a modelling approach in social science. The modeller can control every single agent absolutely as in physics and chemistry experiments, and meanwhile, it also can manage simulation environments. Compared with system-based approaches adopting differential equations or variable-based methods adopting structural equations, ABM provides the possibility to model individual heterogeneity, situate agents in a specific space, and represent agents' decision rules (Weiss, 2013). ABM enables modellers to define multiple scales of analysis. Individual actions can be generated from macro or societal level structures; none is easy to complete by another approach (Uppin and Hebbal, 2010).

Ignoring the business type of supply chain, every participant aims to earn maximum profits by reducing total costs, increasing working capital, and managing debts. Hence, effective information sharing and communication mechanisms are essential in supply chain management. E-business can satisfy the need for this communication mechanism. Scholars also use ABM to study e-business utilisation; for example, Giannakis and Louis (2015) use multi-agent simulation to learn how to use big data analytics to enhance supply chain agility. Bouchemal and Bouchemal (2018) use multi-agent systems to study intelligent ERP and cloud computing. They propose an intelligent ERP system based on ABM and cloud computing. They design a user manager agent to represent the user, an ERP manager agent to represent the enterprise, and a cloud manager agent to represent the mediator between the user manager agent and the ERP manager agent, and then use the JADE platform to design the concept simulation. The goal is to assist enterprise managers, employees, and customers in gaining data from ERP systems by mobile devices. They insist that ABM is an effective method to implement such a system; agents make ERP systems and cloud computing systems more intelligent. These agents can independently interact with the surrounding environment and take actions autonomously when cooperating with other systems.

ABM is the most suitable tool to address the research questions, which provides an approach to integrate the whole supply chain as a network of different echelons. Hence, it helps model the textile & apparel supply chain. Rand and Rust (2011) give some guidelines for selecting an appropriate time to use the ABM research method: (1) medium size numbers, (2) local and potentially complex interactions, (3) heterogeneity, (4) under a rich environment, (5) temporal aspects and (6) adaptive agents. Medium size numbers refer to the number of agents in simulations; if there are only two agents, such as the manufacturer and the buyer, the game theory will be the better method than ABM. On the contrary, if there are hundreds of agents, then the statistical regression will be better than ABM. There are medium numbers of agents in the textile & apparel supply chain: manufacturer, retailers, raw material suppliers and distributors. As for local and potentially complex interactions, in the model, all agents will make decisions and give other agents feedback to fulfil the order, so they have direct interactions with other agents. About heterogeneity, agents have different responsibilities and take further actions. As for the fourth, the environment is rich in the model because of the rich interactions between agents. The temporal aspect is necessary because the model will focus on the time needed to fulfil an order. As for adaptive agents, in the model, some agents give different feedbacks based on the information they received, so this meets to some degree.

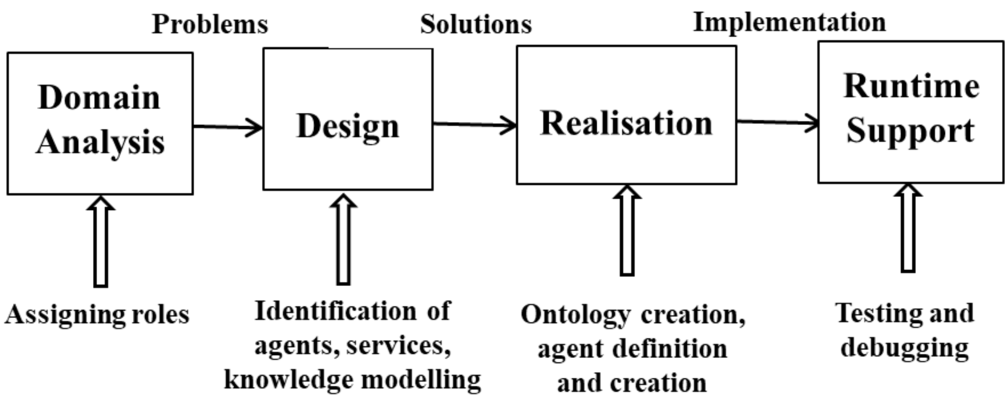
ABM simulation enables agents to interact with other agents and environments, monitor agents' behaviours, and take appropriate actions. Thus, ABM is the only approach that can observe behaviours of each entity in the supply chain based on other entities' interactions. Therefore, after careful consideration, the researcher decides that the ABM research method is the most appropriate approach to collect data in this study because it provides rich and meaningful data and can represent the actual supply chain operations.

Chapter 5 The Model Design Representing E-business Utilisation Level

The primary purpose of this study is to provide preliminary research on developing textile & apparel supply chain capabilities by e-business utilisation and discover how to use e-business initiatives to maintain and develop Chinese small and medium size textile & apparel manufacturers' competitiveness. For this purpose, a methodological framework based on ABM technology for supply chain modelling and e-business utilisation level is proposed in this chapter.

The thesis follows the agent based application development method Kendall (1998) proposed to design and implement the ABM for e-business utilisation in textile & apparel supply chain management (see Figure 5.1) to generate the data.

Figure 5.1 Agent based application development methodology



Source: based on Kendall (1998).

According to Kendall (1998), researchers should first confirm problems, design the model, and implement the simulation. ABM system design and implementation are based on role modelling; hence, agents' behaviours are modelled based on their roles. Relevant role models are identified in the domain analysis phase based on agents interactions. In the design phase, the agent roles are identified. In the realisation phase, agents are created based on their roles identified in the previous stages; meanwhile, a specific solution based on the knowledge modelling from the design phase is also developed. ABM is used to generate the data in the study, so in the runtime support phrase, ABM simulation will only be run to get simulation outcomes.

5.1 Conceptual Model Design

There are many types of flows within a supply chain, such as materials flow, orders flow, money flow, personnel flow, capital equipment flow and information flow. Information sharing may have different impacts on these flows to certain degrees. For simplicity but without losing generality, this research assumes that the effects of information flow will hold constant throughout the simulation. The study will focus on those impacts in operational time, such as the average time of different steps in an apparel order fulfilment and lead time.

It is indispensable to point out that some researches focus on information sharing from the manufacturers' side (Laudon and Laudon, 2014; Naqbi *et al.,* 2018). Some others involve the retailer side when modelling the value of information sharing (Long, 2015), but only some literature considers both sides (Pu *et al.*, 2018). It is inadequate to consider either side alone because the interactions between the manufacturer and raw material suppliers, between the manufacturer and retailers, and between the manufacturer and distributors may affect how to maximise supply chain value. However, it is understandable that it may be very formidable to capture these interactions in the supply chain by a mathematical modelling approach because there is no general pattern. The mathematical models cannot adapt to the dynamics in information exchange. ABM approach may be an appropriate method to overcome these shortcomings.

The research design attempts to provide a simple view of a complex system, i.e., the research considers the supply chain as a complex system. Partners are not isolated and interact with each other. Instead, different agents represent supply chain partners; each performs specific tasks in the supply chain. The agent design and modelling, and the interactions among agents are described below.

5.1.1 Environment Design

According to Kendall (1998), researchers should confirm problems, and the first step is to assign relevant role models. Simply put, the purpose of the model is to examine the impact of e-business utilisation in the textile & apparel supply chain. As most supply chain management studies did, the implementation uses a small representative portion of a textile & apparel supply chain. The implementation supposes a textile & apparel supply chain with one manufacturer, three raw material suppliers, one distributor, one retailer, and one apparel product. More raw material suppliers, retailers, and more products may be added in the future, following the similar principles described below to inspect the impact of multiple interactions among agents on the system.

All agents are located in a particular environment, following predetermined behavioural rules and objectives. It is convenient to organise communications between agents in the environment because it is natural to do it, just like the environment's role in human affairs. The specific environment enables the monitor of agents' behaviours easier in implementation. It guarantees the messages are delivered to the recipients as expected; meanwhile, it brings up the time, which is the necessary and crucial factor in the simulation implementation.

5.1.2 Agents Design and Behaviours

According to Kendall (1998), when roles are assigned, the researcher should identify agents. Kumar *et al.* (2017) list the textile supply chain network, which involves raw material suppliers, manufacturers, retailers, logistic companies and customers; they are autonomous business entities responsible for purchasing, manufacturing, and distribution activities. Based on Kumar *et al.* (2017), four main agents have been identified in this research: raw material supplier, manufacturer, distributor and retailer.

Manufacturer agent. The manufacturer agent produces apparel products by using some particular technologies and instruments. This agent is responsible for receiving the order from the retailer agent, checking the inventory, purchasing raw materials, making the product, and informing the distributor agent to deliver products to the retailer.

Raw material supplier agent. The raw material supplier agent provides raw materials, such as leathers or interfacings, or trims. It receives the order from the manufacturer agent and then produces and delivers raw materials.

Distributor agent. The distributor agent delivers ordered products from the manufacturer agent to the retailer agent to complete the order fulfilment process. It manages the delivery of commodities from the manufacturer agent to the retailer agent based on the manufacturer agents' requests.

Retailer agent. This agent denotes the retailer or the buyer. It is responsible for all the activities about sales. It collects and manages consumer information and tracks the market demand, and the main task is to place the order to the manufacturer and receive the ordered products.

Each agents' objectives vary depending on the type of agent modelled, and its behaviours will be modelled in the form of rules based on the predefined protocols. Each agent knows when to take action and respond when it receives a message from other agents (see Table 5.1).

Table 5.1 Objectives and behaviours of agents

	Objectives	**Behaviours**
Manufacturer agent	Fulfil the order. Reduce order fulfilment time.	Receive the order from the retailer agent. Check the inventory first and decide if or how to place the order to raw material suppliers agents. Give an offer to the retailer agent and wait for confirmation. Need a fixed amount of time to make products. Inform the distributor agent to deliver products to the retailer agent.
Raw material supplier agent	Produce and deliver raw materials to the manufacturer without delay.	Receive the order from the manufacturer agent. Need a fixed amount of time to produce raw materials, then delivery them to the manufacturer agent.
Distributor agent	Deliver the product from the manufacturer to the retailer without delay.	Need a fixed amount of time to transport the products to the retailer agent.
Retailer agent	Receive products from the manufacturer.	Place the order to the manufacturer agent, confirm the order, and receive the ordered products.

5.1.3 Modelling Structure

According to Kendall (1998), researchers should design and realise the specific ABM simulation when agents are identified.

Tesfatsion (2002) analyses real-world economics' essential properties and then indicates that real-world economies are a series of locally constructive sequential games. She recommends an ABM approach: agent based computational economics (ACE), enabling economic systems to act as locally productive sequential games. ACE is defined as the computational modelling of economic processes and open-ended dynamic systems with interacting agents. Tesfatsion (2002) lists seven basic modelling principles of the ACE approach to help agent based modellers study real-world dynamic systems.

Agent definition: The agents are software entities; they act over time based on their state, for example, internal data, methods, and attributes in a computational system.

Agent scope: Agents represent different entities, such as individuals, institutions, social groups, physical entities and biological entities.

Agent local constructivity: Agent behaviour is determined as its own states' function when it happens.

Agent autonomy: Free-floating restrictions cannot impose interactions among agents externally, i.e., restrictions are not embodied in agent states.

System constructivity: The state of the modelled systems is determined by the agent states' ensemble when it happens.

System historicity: In the modelled system, given initial agent states, all subsequent events are determined only by agents interactions.

Modeller as culture-dish experimenter: The modellers' work is limited to setting initial agent states, observing, analysing, and reporting the implementation outcomes.

Following these ACE modelling principles in a modelled dynamic system, researchers can explore how changes in original conditions affect simulation outcomes over time. The exploration process is similar to biological experimentation. First, the researcher sets initial conditions in a modelled dynamic system with purposes. This system runs through time as a virtual world; the dynamics are determined by agents' interactions (Tesfatsion, 2002). This study follows these principles to design agents and modelling structure, then uses the simulation to reveal the real-world dynamic system.

In the textile & apparel supply chain, improving the overall supply chain efficiency is fundamental. The importance of supply chain networks increases because of market globalisation and e-business technology advancement. It is very arduous for supply chain partners to share information efficiently. A supply chain can produce products and services for multiple markets. An individual textile & apparel manufacturer is likely to have limited supply chain visibility, making it difficult to estimate future demand.

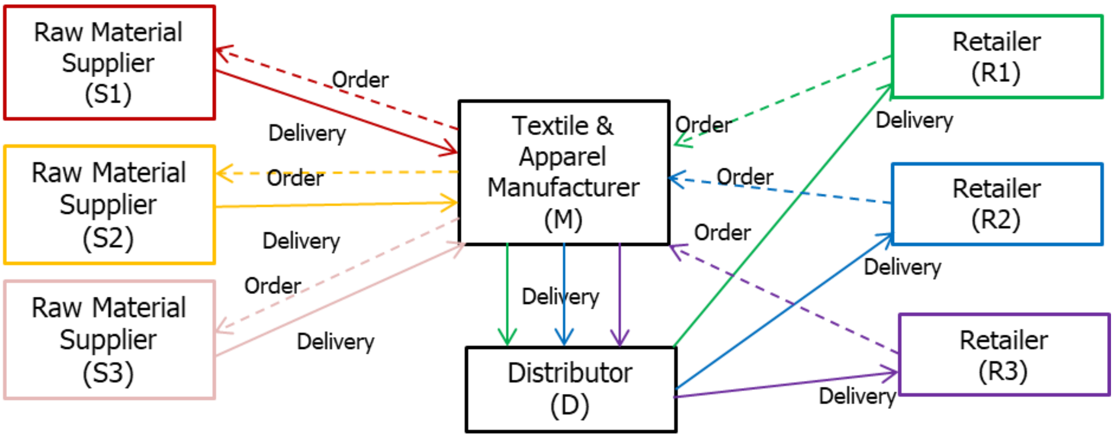
By searching and retrieving valuable information and data, e-business helps manufacturers make decisions and coordinate relationships with their partners and customers. E-business provides the manufacturer with helpful details on the product demand, inventory, manufacturing process, delivery, and customer sites to manage supply chain activities. So the critical point of e-business utilisation in the textile & apparel supply chain is information sharing and cooperation among partners. Information sharing can be modelled differently in various types. The model design focuses on evaluating the benefits of information sharing in the supply chain from the manufacturers' perspective. Information-sharing has direct effects on the performance of the whole supply chain. Many early literature mentions that information flows between the raw material suppliers and the manufacturer, between the manufacturer and retailers/buyers (Sharma, 2013; Wong *et al.*, 2015). The early literature ignores one aspect: supply chain partners are not isolated from other partners but interconnected. These interconnections may have direct or indirect effects on information sharing. Smitha *et al.* (2020) establish three models to represent different information sharing levels between producer and purchaser in the supply chain. They are limited information sharing (just capacity), full information sharing (use ERP and EDI), and hybrid information sharing (inform the purchaser that supplier will invest in the capacity). Smitha *et al.* (2020) compare these models to test the purchasers' responses. The research results show that the purchaser prefers to accept contracts at the hybrid information sharing level because it can get goods at the lowest possible costs at this level, so the advancement of information sharing is an essential strategic factor for the producer.

E-business conceptual model design in this section is based on the e-business process typology developed by Basu and Muylle (2011), the e-business measurement evolution model developed by Abdullah *et al.* (2015), and the model design of Smitha *et al.* (2020). The conceptual model design also considers characteristics of the textile & apparel supply chain. This study anticipates that the range of use of e-business tools is diverse: at the most basic level, these tools may only comprise a desktop computer with access to the world wide web and email; at more sophisticated levels, these tools may include software that provides full support to all aspects of the business including databases of products, suppliers and customers, email and internet access, electronic links to suppliers for purchases, etc.

The thesis extends the views of information sharing from purely one-way to multi-way interactions and summarises four modes described below.

Model 1: This model is called "no e-business utilisation" by following the existing literature model (see figure 5.2). There is no internet connection at the most basic level; enterprises only have essential software to deal with documents (Abdullah *et al.*, 2015). The textile & apparel manufacturer exchanges necessary information with raw material suppliers, retailers, and distributors by telephone or other traditional methods to place and deliver orders. The data exchange between the manufacturer and partners is limited.

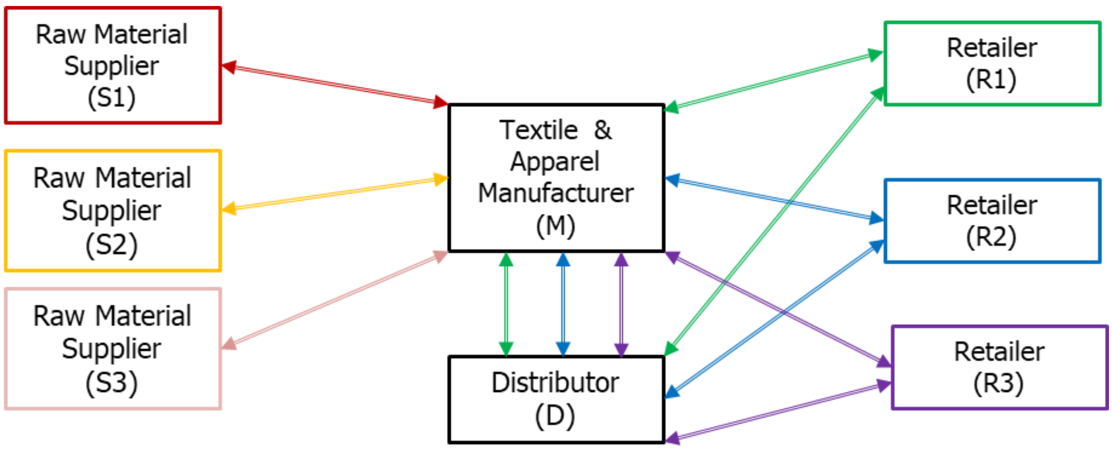
Figure 5.2 No e-business utilisation



The dotted line: the order placement
The solid line: the delivery of fulfilment
The lines and boxes are colour-coded to indicate the exchange of order and delivery information of individual suppliers and retailers.

Model 2: This model is called "partial e-business utilisation" by following the existing literature model (see Figure 5.3). Some literature focus on the advantages of information sharing from the manufacturers' side. As the phrase "partial e-business utilisation" suggests, the manufacturer and retailers, the manufacturer and raw material suppliers, the manufacturer and the distributor have established formal communication channels and stable relationships so information about the order can flow both ways fluently. At this level, manufacturers use e-mail (or WeChat, intranet, MRP, etc.) to exchange information with supply chain partners (Abdullah *et al.*, 2015; Cataldo *et al.,* 2020).

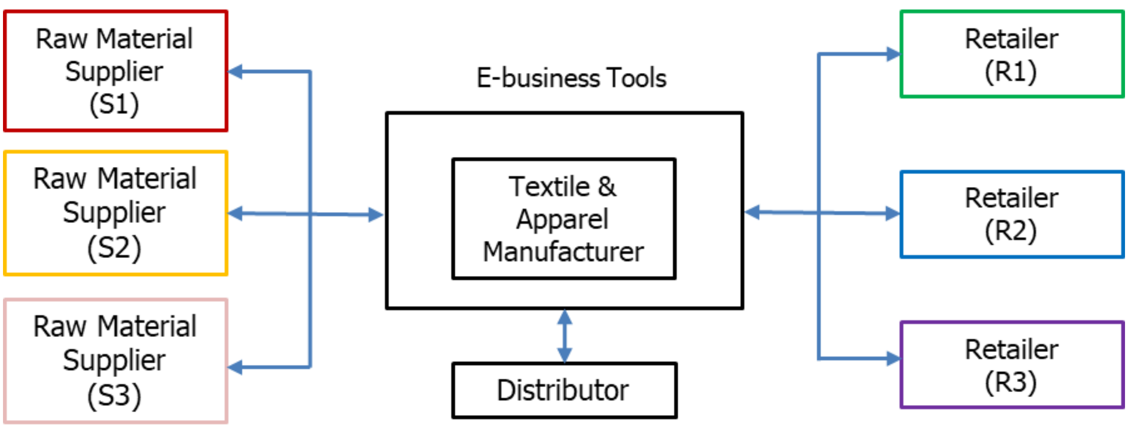
Figure 5.3 Partial e-business utilisation



The line: the information exchange
The lines and boxes are colour-coded to indicate the exchange of order and delivery information of individual suppliers and retailers.

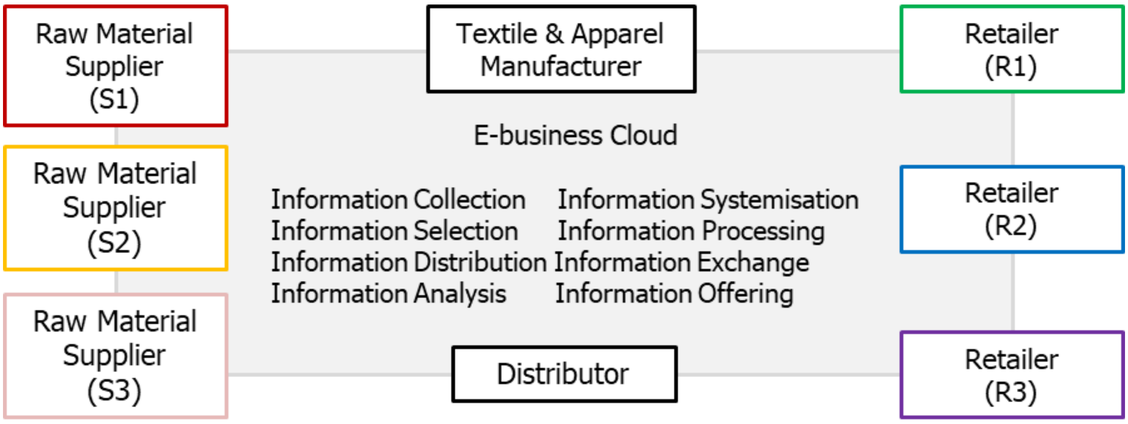
Model 3: This model is called "comprehensive e-business utilisation" (see Figure 5.4). The supply chain is a networked system. The manufacturer uses e-business technologies, such as ERP, SAP, EDI, RFID, etc., to exchange information in the supply chain. Each partner of the supply chain, raw material suppliers, the manufacturer, the distributor, and retailers are all the supply chain components and interact with each other through the networked system provided by the manufacturer. Some decisions can be made by advanced e-business tools, like decision support processes described by Basu and Muylle (2011) and complex systems described by Cataldo *et al.* (2020). Current literature only models part of this situation.

Figure 5.4 Comprehensive e-business utilisation



Model 4: This model is called "virtual e-business utilisation" by following the existing literature model (see Figure 5.5). The virtual supply chain is a flexible network based on fast, real-time internet communication (Shamsuzzoha and Helo, 2017; 2018), so it is necessary to integrate different information systems to automate tasks. The manufacturer, raw material suppliers, retailers, even competitors can be connected by advanced e-business technologies in the supply chain to share skills, information, and access to global markets. This e-business utilisation level has only been partially modelled in the current literature (Shamsuzzoha and Helo, 2017, 2018), but the virtual supply chain can be established to connect all partners by utilising e-business tools based on cloud environments.

Figure 5.5 Virtual e-business utilisation



E-business cloud can help partners collect, systemise, select, process, analyse, distribute, and exchange data and information in the supply chain. All participants can find the information required to process the business (Yang *et al.,* 2018). Trust in each other is exceedingly important so partners can depend on each other and obtain competitive advantages. Participants contribute their best capabilities and communicate under less limited boundaries.

The information flow among supply chain partners can be considered as interactions. There are many forms of interactions, for example, negotiation, cooperation, trust, etc. The relationships among supply chain partners are established and enhanced due to these interactions. Good relationships impact the whole supply chain dynamics: partners seek possible cooperation to minimise costs and maximise benefits (Osobajo *et al.*, 2021; Yuen and Thai, 2017). Information is a kind of resource. Some information can be acquired inside the company, such as the order quantity, requirement, inventory situation, etc., but other information can only be obtained outside the company, such as exchanging or sharing information or resources with other companies. The information about the customer demand, inventory, production process, delivery, and services flows among different supply chain partners. ABM is employed to evaluate the impact of e-business utilisation in the supply chain. Macchion *et al.* (2017, 2019) claim this approach is practical in researching information sharing in the supply chain.

The conceptual model design: Model 1 no e-business, Model 2 partial e-business, Model 3 comprehensive e-business, and Model 4 virtual e-business will be used to test seven propositions listed in section 3.3.

5.2 General Consideration of Model Design Architecture

When the models' overall design has been determined, the implementation process must be configured before running the model, such as parameters design, architecture design, and interactions among agents.

This chapter develops an ABM system to test the proposition: The advancement of e-business utilisation level influences the whole order fulfilment time; when the e-business level improves, the time taken to fulfil the order decreases. The simulation involves one apparel manufacturer, three raw material suppliers, one distributor, and one retailer and will examine the e-business effects in jacket order fulfilment. The implementation only takes a small representative portion of a textile & apparel supply chain. More suppliers and more retailers can be added in further research following the same principles.

5.2.1 Produce Process Map: An Order Fulfilment

A supply chain can be visualised as a process; for example, the textile & apparel supply chain process includes raw material suppliers, one manufacturer, distributors and retailers/buyers (Xing *et al.*, 2016). This process consists of a series of steps; for instance, the retailer places the order, the manufacturer identifies the order, and fulfils the order. When the manufacturer receives the order, it checks the stock first to ensure the current materials are sufficient to produce the order. The manufacturer will decide to make the products directly or purchase necessary materials from raw material suppliers first, then make the goods and contact the distributor to deliver the goods to the retailer. Each of these steps is connected by information sharing between agents. In the model implementation, the information exchange between agents is considered a type of interaction through communications. Such interactions will affect the order fulfilment efficiency, effectiveness, and supply chain capabilities.

The study proposes that when SMEs utilise more advanced e-business tools to manage the order fulfilment process in the textile & apparel supply chain, they can reduce the lead time or even eliminate unnecessary steps to fulfil the order. Different levels of e-business utilisation can bring out different results. For example, in Model 1 no e-business utilisation, all supply chain partners are connected by telephone, all activities are indispensable, and no time can be saved. In Model 2 partial e-business utilisation, agents use advanced technologies to exchange information (email, WeChat, intranet, MRP, etc.), so the manufacturer needs less time to complete the order. In Model 3 comprehensive e-business utilisation mode, agents use more advanced tools such as ERP to manage the order, the time required to complete the order will be reduced. For example, ERP can automatically calculate the cost, price, delivery date, and exchange information between partners. In Model 4 virtual e-business utilisation mode, all partners are connected by the e-business cloud; they can gain information for the first time. Some decisions can be made automatically so that the order fulfilment time can be significantly shortened. In other words, the more advanced e-business utilisation level brings the higher efficiency of the order fulfilment and the whole supply chain, and the more advanced e-business utilisation level is the basement of a robust and resilient supply chain.

The study adopts the order fulfilment process to test the propositions within different e-business utilisation levels. It creates a four-layer supply chain simulation model, involving one manufacturer (M) as the core member, one retailer (R), one distributor (D), three raw material suppliers (S1, S2 and S3).

Figure 5.6 describes the activities of each agent in the supply chain. R places an order to M: 1,000 jackets; M will check the inventory first; if M has enough raw materials to produce the order, M will make jackets. If not, M will purchase raw materials from S1, S2, or S3 based on the order requests and then produce the ordered products when receiving raw materials. M will notify D to transport products to R when the ordered products are ready; then, order fulfilment is completed when R gets the goods.

Figure 5.6 Agents activities in the supply chain

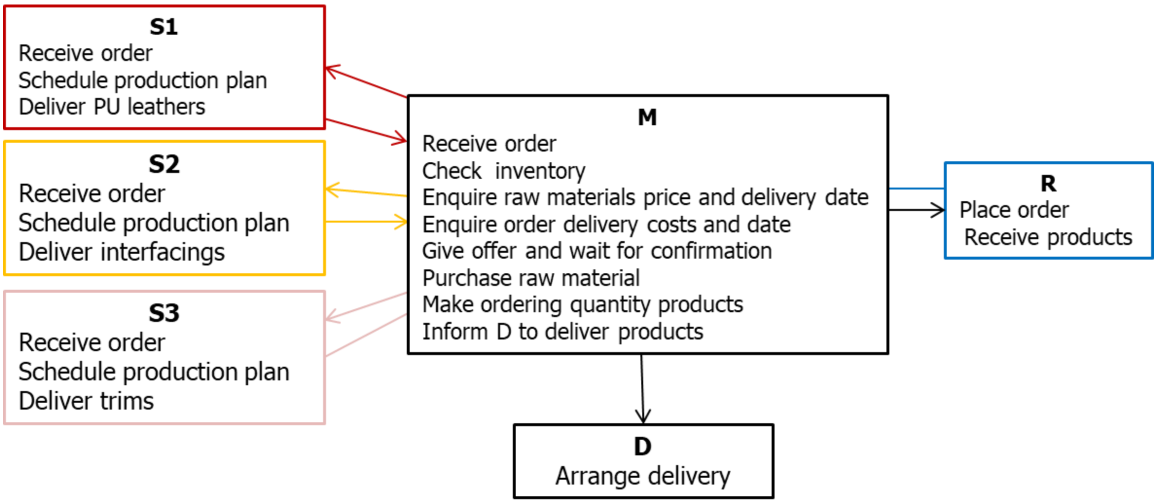
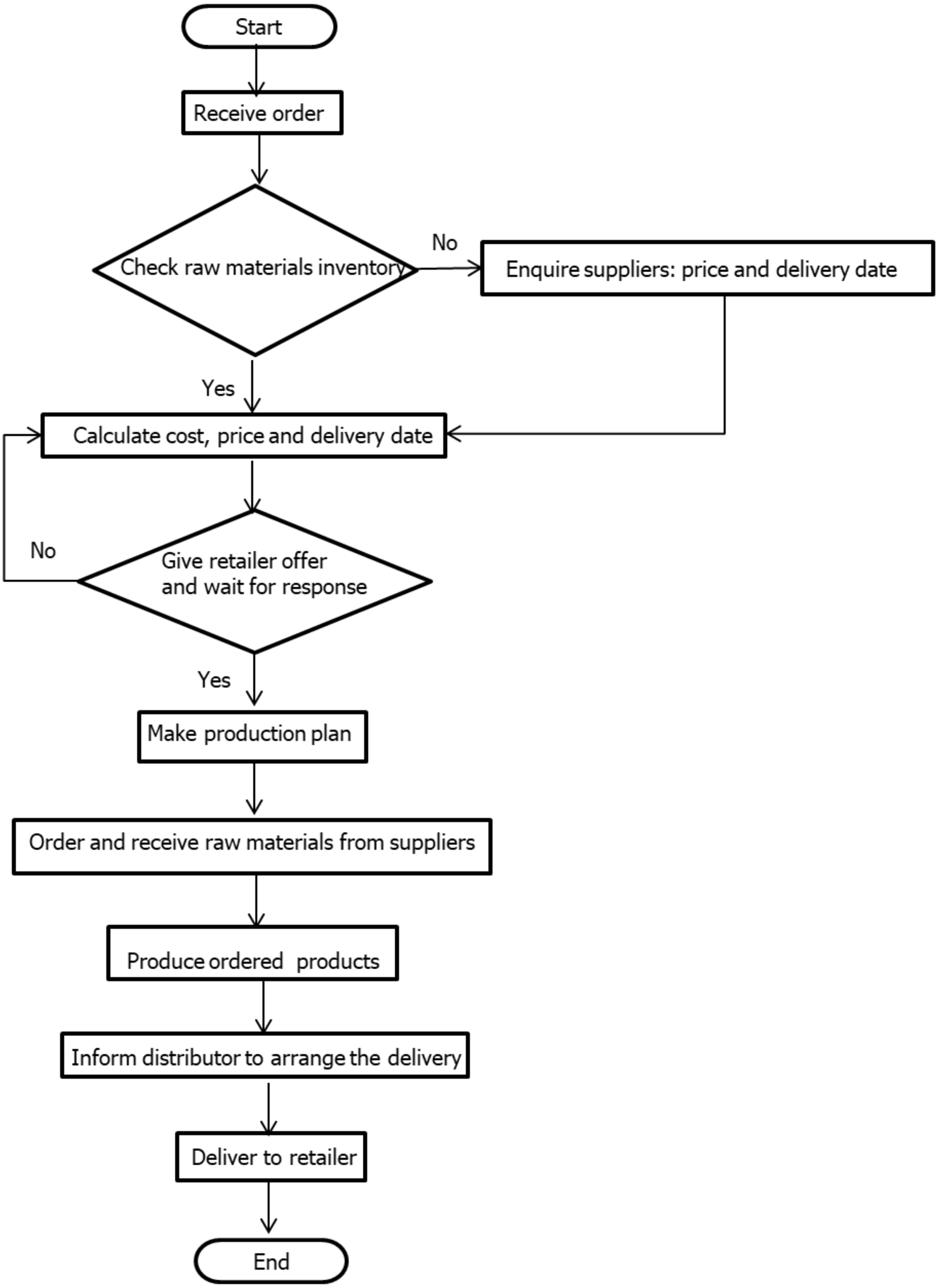


Figure 5.7 shows an order fulfilment process flowchart based on the description of managers from six different Chinese small and medium size textile & apparel manufacturers. All four experimental scenarios follow the below order fulfilment process flowchart.

Figure 5.7 An order fulfilment process flowchart



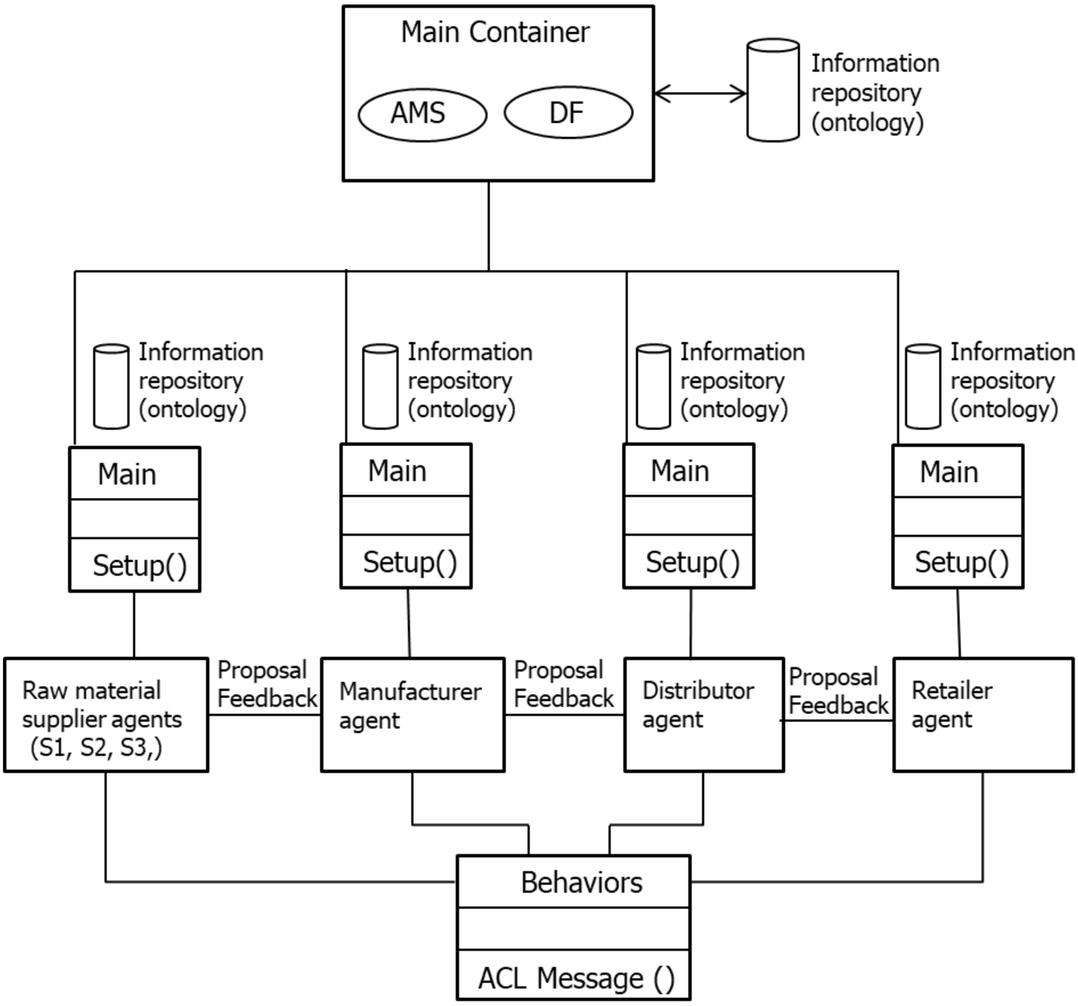
If the manufacturer has enough raw materials and trims to produce an order, the step: order and receive raw materials from suppliers can be deleted. Different possibilities under different four scenarios will be described in experimental scenarios.

5.2.2 Agents Architecture Design

According to Fu *et al.* (2000), layered ABM architecture is based on agent obligation and commitments. Perera and Karunananda (2016) indicate that agents and their interconnections as supply chain components can be illustrated as the terms of responsibilities. Rady (2011) insists that combining architecture is the appropriate solution to eliminate communication problems in the supply chain. To optimise supply chain performance, practical cooperation among partners is indispensable. However, companies still have to deal with different difficulties due to business operation dynamics, such as production failures, delayed shipments, and customers' varying requirements (Chen *et al.,* 2009). The simulation implementation in this research uses the JADE (Java Agent Development framework) environment. It involves supply chain functions in real-time to investigate e-business utilisation in the textile & apparel supply chain.

Figure 5.8 illustrates agent roles, behaviours, and responsibilities. All agents belong to the main container to access its ontology, and they are also authenticated by the main container of the simulation system to access domain ontology. Connected ontologies dominate agent behaviours. The main container has the authority to manage agents, such as agent migration, suspend an agent, or terminate an agent when necessary. Agent Management System (AMS) and Directory Facilitator (DF) are two agents in the main container. AMS is an agent to supervise and manage agent platform operation; it provides life-cycle service and maintains the Directory of Agent Identifiers (AID). DF is an agent to provide the default yellow page service of the agent platform. Each agent must be registered in AMS to obtain a valid AID to access the platform. Agent communications occur by transferring messages, and these communications are illustrated in the diagram as requests and responses from agents. Agents can also interact based on agent communication language (ACL), which can specify the agents' detailed communication mechanisms.

Figure 5.8 Architecture of multi-agent SCM



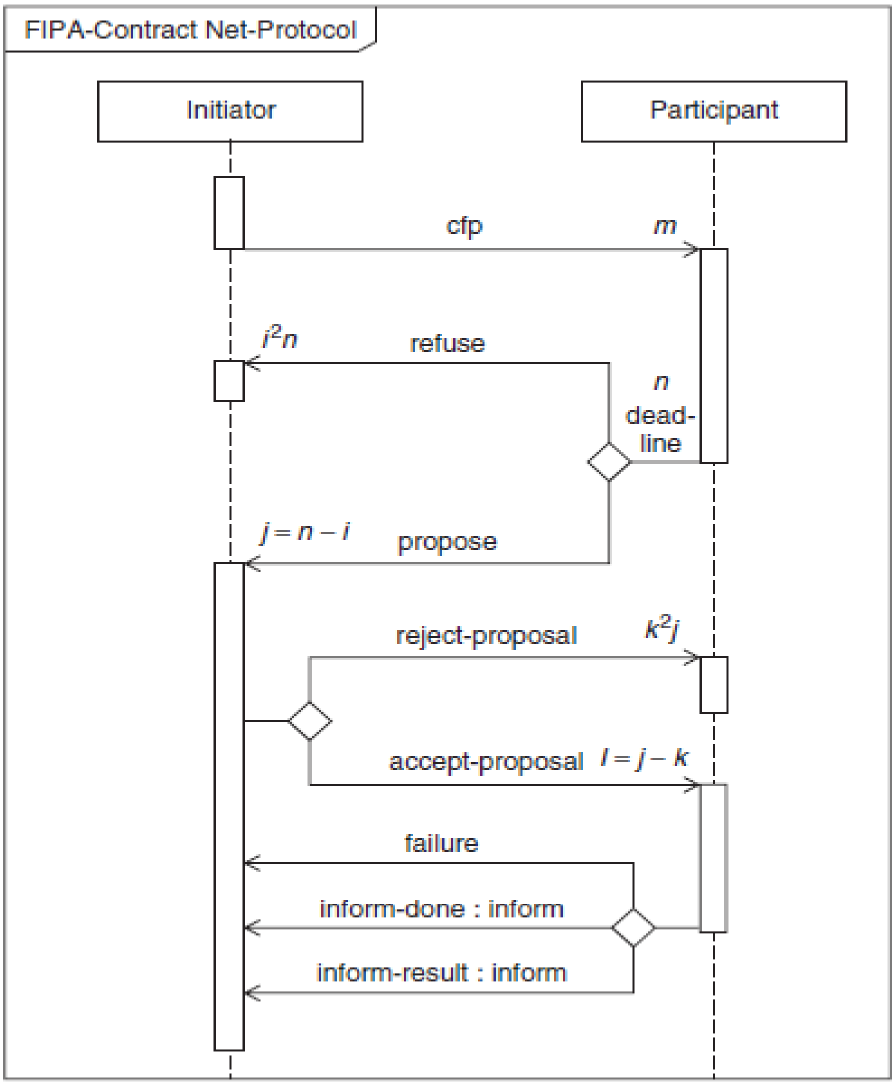
Source: based on Perera and Karunananda (2016).

5.2.3 Interactions among Agents

Interaction is the critical factor in a multi-agent system. Interactions between agents enable them to exchange necessary information, make plans and goals, manage resources, distribute tasks, coordinate behaviours, negotiate with other agents, and recognise and handle conflicts.

The most studied and used ACL is the FIPA ACL, which has some primary characteristics: to manage communications through predefined protocols and adopt different content languages (Bellifemine *et al.,* 2006). As an international organisation, the foundation for intelligent physical agents (FIPA) promotes intelligent agents and supports interoperability by openly developing specifications. FIPA Contract Net Interaction Protocol (IP) is used to handle the information exchange between the manufacturer and the customer. FIPA Contract Net Interaction Protocol (IP) describes interaction protocol for one initiator with one or more participants in the ABM simulation and tries to optimise the function of the mission (Bellifemine *et al.,* 2006). The FIPA Contract Net Interaction Protocol characteristic is often expressed as cost or time to complete the task, reasonable distribution of the task, etc. Figure 5.9 illustrates the system of interaction protocol.

Figure 5.9 The FIPA Contract Net Interaction Protocol

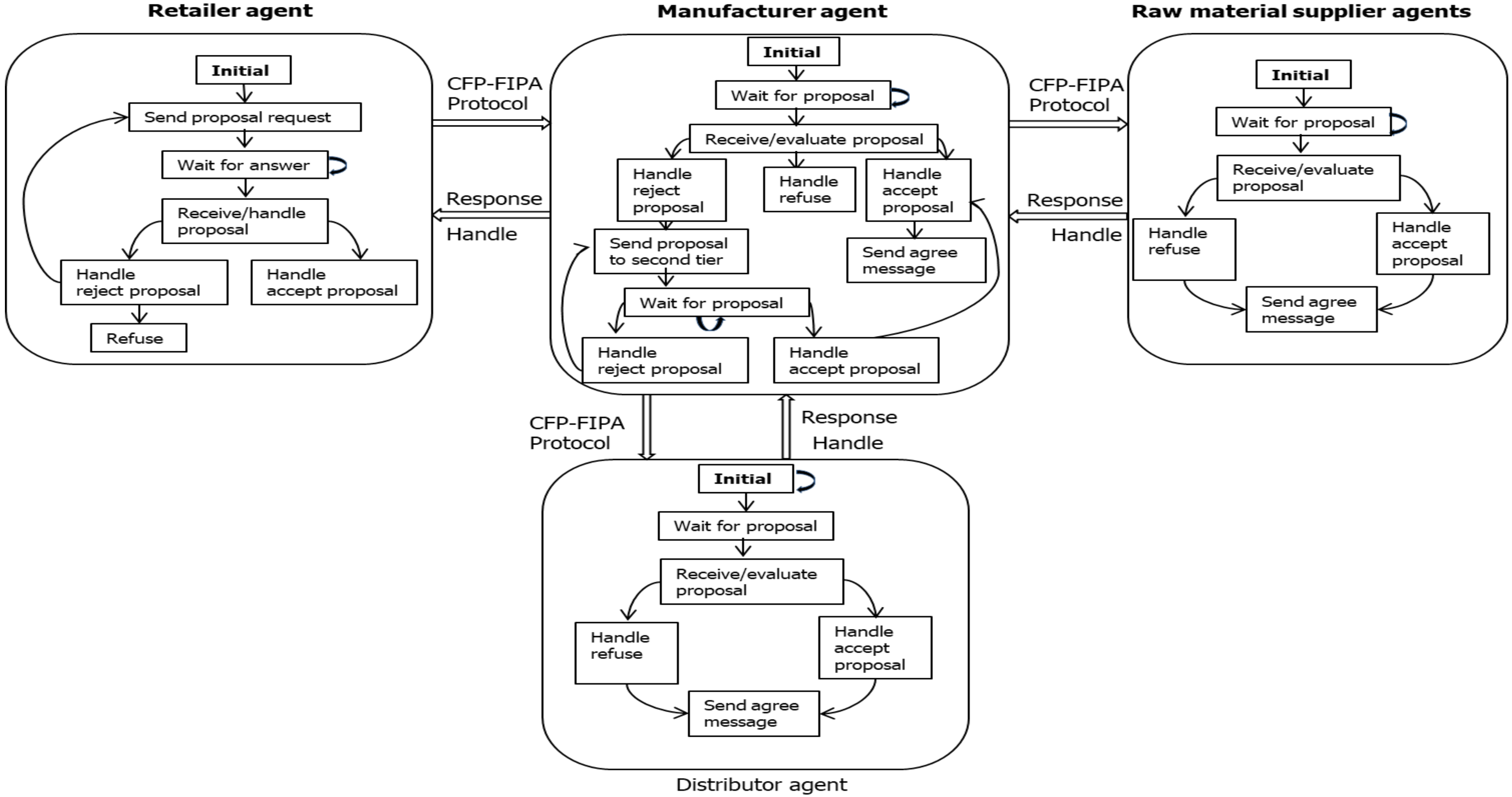


Source: Bellifemine *et al.* (2006), p.23.

The most basic and simplest type of interaction involves two agents in the simulation system. The interaction follows the basic behaviour rules in the communication process: one agent (initiator) sends a proposal, and the other agent (participant) gives feedback. The feedback is sent back to the initiator, and the initiator accepts the feedback and decides the necessity of further interaction. In this continuous process, the interaction between initiator and participant may continue until a satisfactory result is produced and one part chooses to stop the communication.

The sequence diagram illustrates the interaction between the manufacturer and other agents and the ordering of messages exchange. Once an order (1,000 jackets) is received, the manufacturer checks the inventory, calculates the costs, delivery dates, etc., then gives feedback to the retailer. When the retailer confirms the order, the manufacturer accepts the order and contact raw material suppliers to prepare the raw materials, produces the jackets based on the order requests, and contacts the distributor to deliver the jackets; then, the order is completed. Figure 5.10 manifests the interactions between the manufacturer and other agents.

Figure 5.10 Sequence diagram depicting interactions between the manufacturer agent and other agents

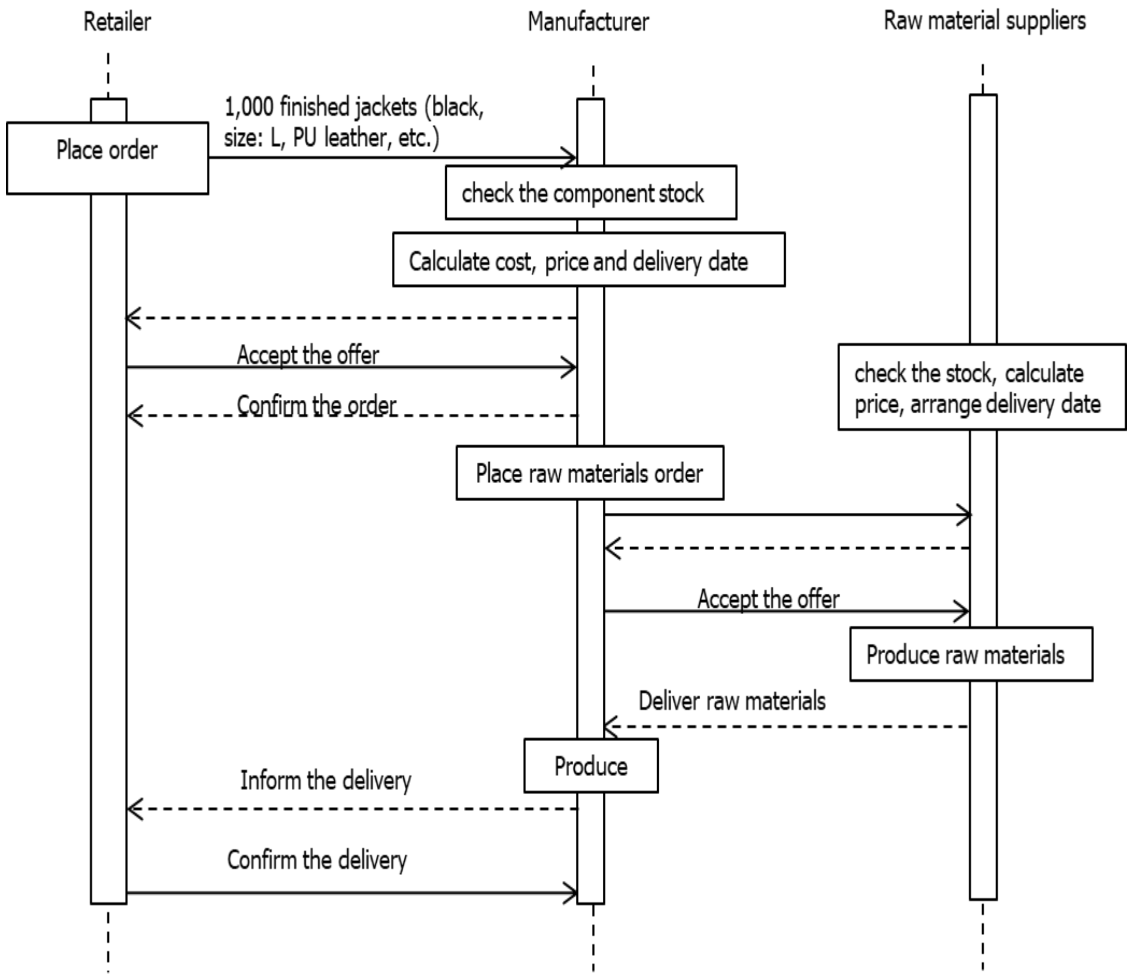


Source: based on Hernandez *et al.* (2009).

The retailer agent issues a call for proposals (cfp) communicative acts (CAs) to the manufacturer agent to send *m* proposals, 1,000 finished jackets, and the cfp specifies the task and conditions of the execution of the task, colour: black, size: L, raw material: PU leather, one zip, etc. If the manufacturer receives the cfp, it will be considered a potential contractor. It can give *n* responses, *j* is the proposal to execute the task, and is designated as proposal CAs. Proposals from the manufacturer agent involve the preconditions to perform the task, such as 300 RMB per jacket, 25 days to transport the products, etc. Alternatively, the manufacturer agent also can refuse the proposal. The retailer agent evaluates the *j* proposal and executes the mission after the deadline. The manufacturer agent will receive an accept-proposal CA. When the retailer agent accepts the proposal, the manufacturer agent needs a commitment to implement the task because the proposal binds to it. When the job has been completed, the manufacturer agent sends an inform-done or a more complicated inform-result message to the retailer agent. Alternatively, the manufacturer agent sends a failure message if the mission is failed. The retailer agent needs to understand when it receives all replies. If the manufacturer agent fails to respond to either a proposal CA or a refuse CA, the retailer agent may have to wait permanently. To avoid such a situation, the cfp CA sets a deadline; the retailer agent should receive feedback. After the deadline, proposals will be rejected automatically because the proposal was expired. ACL message specifies the deadline by the reply-by parameter. Likewise, FIPA Contract Net Interaction Protocol is also applicable for the interaction between the manufacturer agent and the raw material supplier agent and the interaction between the manufacturer agent and the distributor agent.

Figure 5.11 is the example of interactions between the manufacturer and retailer, between the manufacturer and suppliers. The retailer gives an order to the manufacturer, 1,000 finished jackets (colour: black, size: L, raw material: PU leather, etc.). The manufacturer checks the stored inventory and calculates the costs and the delivery date. If the retailer agrees, the manufacturer accepts the order and purchases materials and components from suppliers, assembles the jackets, and then informs the distributor to deliver jackets; when the retailer receives the delivery, the order is completed.

Figure 5.11 Information exchange between the manufacturer and the retailer, between the manufacturer and raw material suppliers



5.3 Experiment Design

The thesis creates a four-layer supply chain simulation model, including the jacket manufacturer, the retailer, raw material suppliers and the distributor. The manufacturer uses a produce-to-order policy for production management, where jackets are made after the manufacturer receives an order from the retailer. There are twelve experiments in four scenarios used in simulation to collect data from experiments and analyse them to test the seven propositions under different situations.

5.3.1 Experimental Scenarios and Flowcharts

As the researcher cannot engage in company management to reflect the actual order fulfilment in the supply chain, this study conducts semi-structured interviews with six managers from different Chinese small and medium size textile & apparel manufacturers. These samples are selected because they have good relationships with the Zhongyuan University of Technology and are interested in this study. The researcher works in ZUT. The semi-structured interview usually consists of a set of predetermined open-ended questions. The interviewer can design a clear list of questions to be answered and decide to ask specific questions during each interview according to the respondent to obtain enough data (Thomas, 2004). All six managers are familiar with textile & apparel production operations and supply chain management. They give suggestions about the details of an order fulfilment design, such as all steps, the time needed for each step, and the method to receive and exchange information with their supply chain partners. The information is used to design and run the simulation. The order fulfilment flowcharts and the average time of each step are designed based on their descriptions and suggestions. The interviews were conducted with six managers by telephone or Wechat until they confirmed the design and no new information emerged. The original interview questions are listed in the appendix, and those questions are adjusted each time based on the interviewees' answers. Below are details of all six textile & apparel manufacturers.

No.1. Medium company (183 employees), produces socks, uses comprehensive e-business (ERP).

No.2. Medium company (240 employees), produces chemical fibre fabrics, lining, woven fabrics, uses comprehensive e-business (ERP).

No.3. Medium company (135 employees), produces yarn and apparel products, uses virtual e-business (ERP and cloud services).

No.4. Small company (46 employees), produces female apparels, uses partial e-business (email and Wechat).

No.5. Small company (31 employees), produces male suits and work jackets, uses partial e-business (email and Wechat).

No.6. Small company (92 employees), produces apparel and accessories, uses partial e-business (email and MRP).

In the study, the example is: one order includes 1,000 finished jackets (colour: black, size: L, raw material: PU leather). Table 5.2 lists the raw materials and trims bill to produce one jacket. All scenarios follow the example. When receiving the order, the manufacturer will check the raw materials inventory based on the bill of materials and decide to produce the jackets or purchase the necessary raw materials and trims.

Table 5.2 Bill of materials - jacket

Bill of Materials - Jacket					
Date:			**Revised Date:**		
Style #			**Season:**		
Size Range:	L		**Classification:**	Women's Active	
Label:	Under Armour		**Group Name:**	Jackets	
Description:	Fitted PU jacket with standing collar, diagonal exposed zipper, elastic banded bottom, and cuff with holes for the thumbs placed in the angled cuff.				
Description	**Colour**	**Material**	**Size**	**Unit**	**Qty**
Fabric:					
Leather	Black	100% PU	58/60	Yard	1.8
Interfacing	Black	100% Polyester	58/60	Yard	0.5
Trims:					
Zipper	Nickel	Metal	20″	Piece	1
Thread	Black	100% Cotton		Spool	0.2
Main Label	Black	Cotton	3″×3″	Piece	1
Care	White	Cotton	1″×1″	Piece	1

Source:
http://s3images.coroflot.com/user_files/individual_files/363316_qCl5NFxlpZFQPKdTyqqzKQLqq.pdf.

Table 5.3 lists the necessary raw materials to produce 1,000 jackets following the order. Supplier 1 provides PU leather, supplier 2 provides interfacing, and supplier 3 provides trims such as zipper, thread, main label and care. The experimental design follows the example.

Table 5.3 Raw materials and trims to produce 1,000 jackets

	Name	Quantity	Supplier
Fabrics	PU Leather	1.8×1,000=1,800 yards	S1
	Interfacing	0.5×1,000=500 yards	S2
Trims	Zipper	1×1,000=1,000 pieces	S3
	Thread	0.2×1,000=200 spools	S3
	Main Label	1×1,000=1,000 pieces	S3
	Care	1×1,000=1,000 pieces	S3

In these scenarios, when the jacket manufacturer receives an order, it checks raw materials inventory first; there are three possibilities: (1) the manufacturer has sufficient raw materials to produce the order; (2) the manufacturer has partial raw materials to make the order; and (3) the manufacturer has no raw materials to make the order, different kind of possibilities means various operations (slack *et al.,* 2016), so the research will run three different simulations following these three possibilities based on the e-business utilisation levels.

All raw material suppliers are equally distanced from the manufacturer in the research, so the transport time is the same. The time needed for each step is designed based on the interviews with six managers. In all twelve flowcharts design, the production times are the same, 120 hours to produce 1,000 jackets, six managers' answers are slightly different, from 4-6 days, so the author uses the average. Suppose the manufacturer needs to purchase raw materials from suppliers. In that case, it uses 120 hours to receive the ordered raw materials from each supplier. Six managers' answers are slightly different, from 5-6 days, so the author uses the average. The delivery times are the same, 240 hours; all six managers say that if their customers are 1,000 kilometres away, their distributors need about 10 days to arrange and deliver products from their warehouses to the customer.

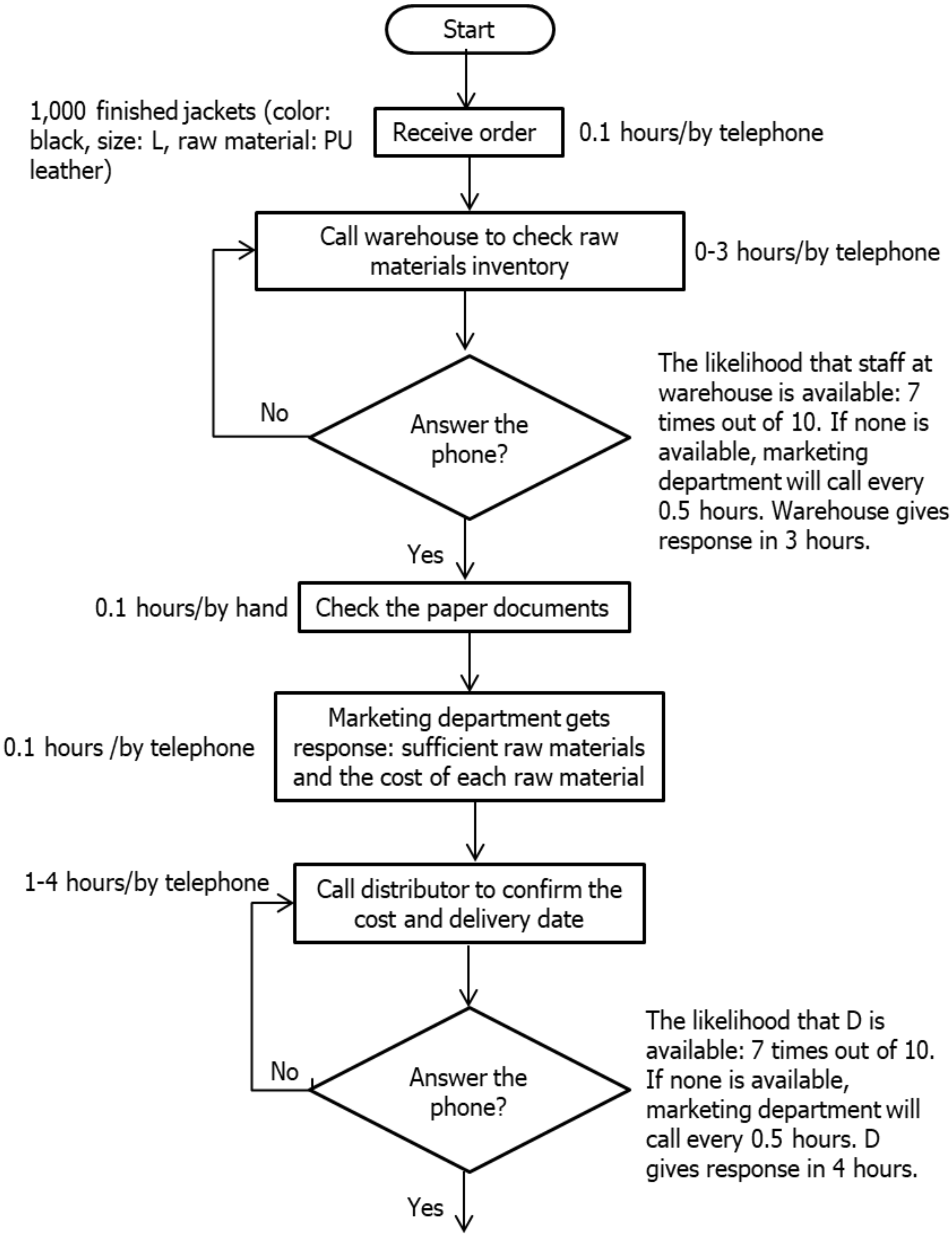
5.3.1.1 Scenario 1: No e-business (as Model 1)

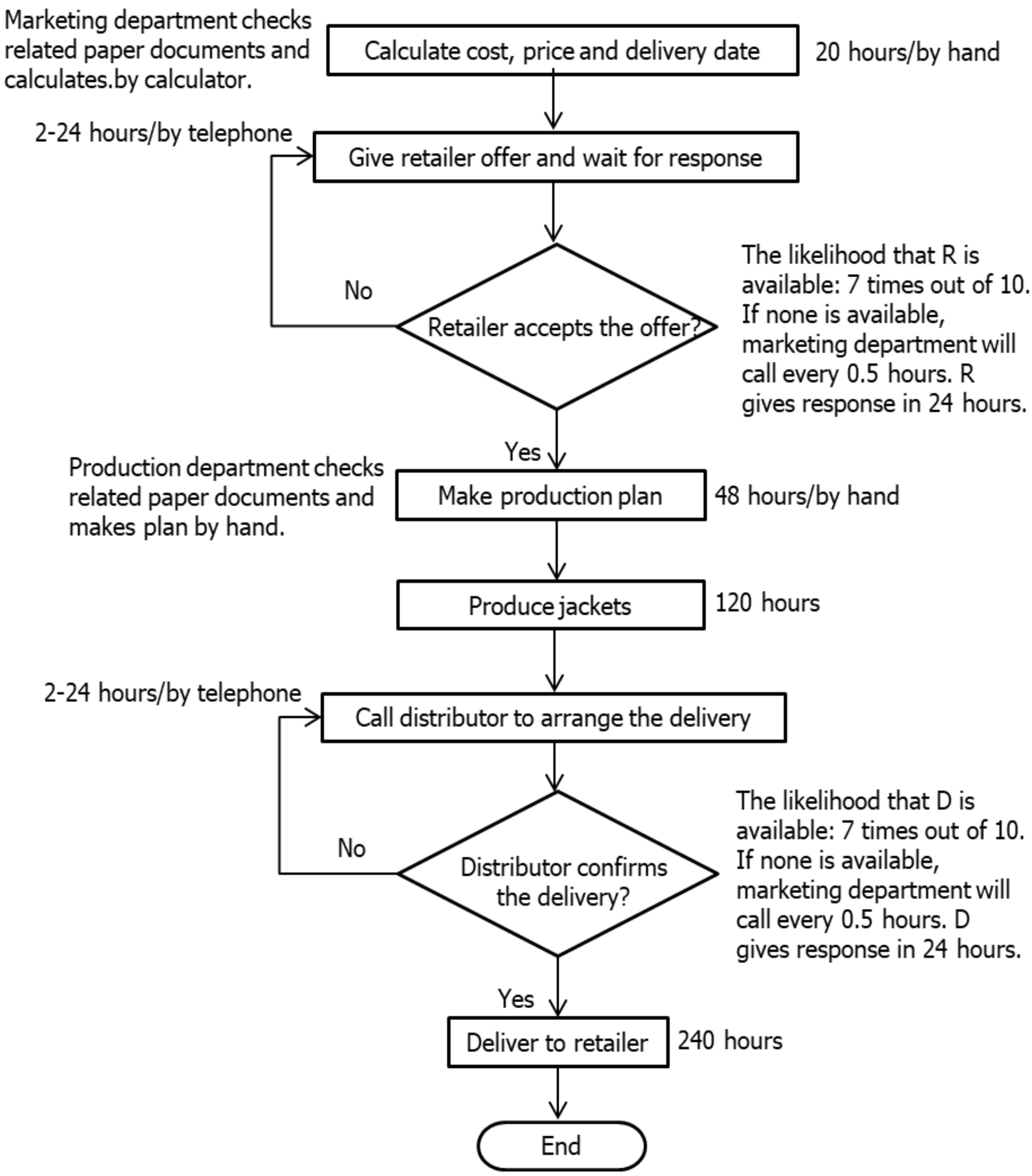
Under this scenario, the manufacturer uses the telephone to exchange information inside the company and with the retailer, three raw material suppliers and the distributor. The time of each step is designed based on the suggestions of six managers. The manufacturer needs 0.1 hours to receive the order and 0-3 hours to call the warehouse to check the stock; the possibility that staff answers the phone is 7/10. The warehouse spends 0.1 hours reviewing the paper document by hand, another 0.1 hours calling the marketing department to give feedback. The marketing department spends 5-24 hours calling each supplier to inquire about the raw material (all six managers say that if the supplier answers the phone, it provides feedback in 5 hours); the possibility that the supplier answers the phone is 7/10. The marketing department spends 2-24 hours placing the order for each supplier; the chance to answer the phone is 7/10. The manufacturer needs another 120 hours to receive raw materials from each supplier (three managers' suggestions are 5 days, two managers' suggestions are 4 days, and one manager’s suggestion is 6 days). The marketing department spends 1-4 hours asking the distributor about the delivery; the possibility that the distributor answers the phone is 7/10. The marketing department spends 20 hours making an offer by hand (6 managers' suggestions are from 18 hours to 22 hours), 2-24 hours calling the retailer and get feedback; the possibility that the retailer answers the phone is 7/10. The production department needs 48 hours to make the production plan by hand (six managers' suggestions are from 1.5 to 2.5 days). When the production department completes the production, it spends 2-24 hours calling the distributor to arrange the delivery; the possibility that the distributor answers the phone is 7/10. About the possibility, four managers’ suggestions are 7/10, and two are 8/10, so the study uses 7/10.

Simulation 1-1: Sufficient raw materials under no e-business

When the marketing department receives an order from a retailer, it will call the warehouse to check raw materials inventory by telephone. The warehouse checks paper documents, confirms it has sufficient raw materials to produce jackets, and lists all raw materials costs. The marketing department calls the distributor to inquire about the delivery costs and date, calculates cost, price, and delivery date by hand, gives the retailer the offer, and waits for the response. When the retailer accepts the offer, the production department will check the related paper documents and make a production plan by hand. The next step is to produce ordered jackets and call the distributor to deliver the goods to the retailer; when the retailer receives the order jackets, the order fulfilment is completed (see Figure 5.12).

Figure 5.12 The order fulfilment flowchart (sufficient raw materials under no e-business)



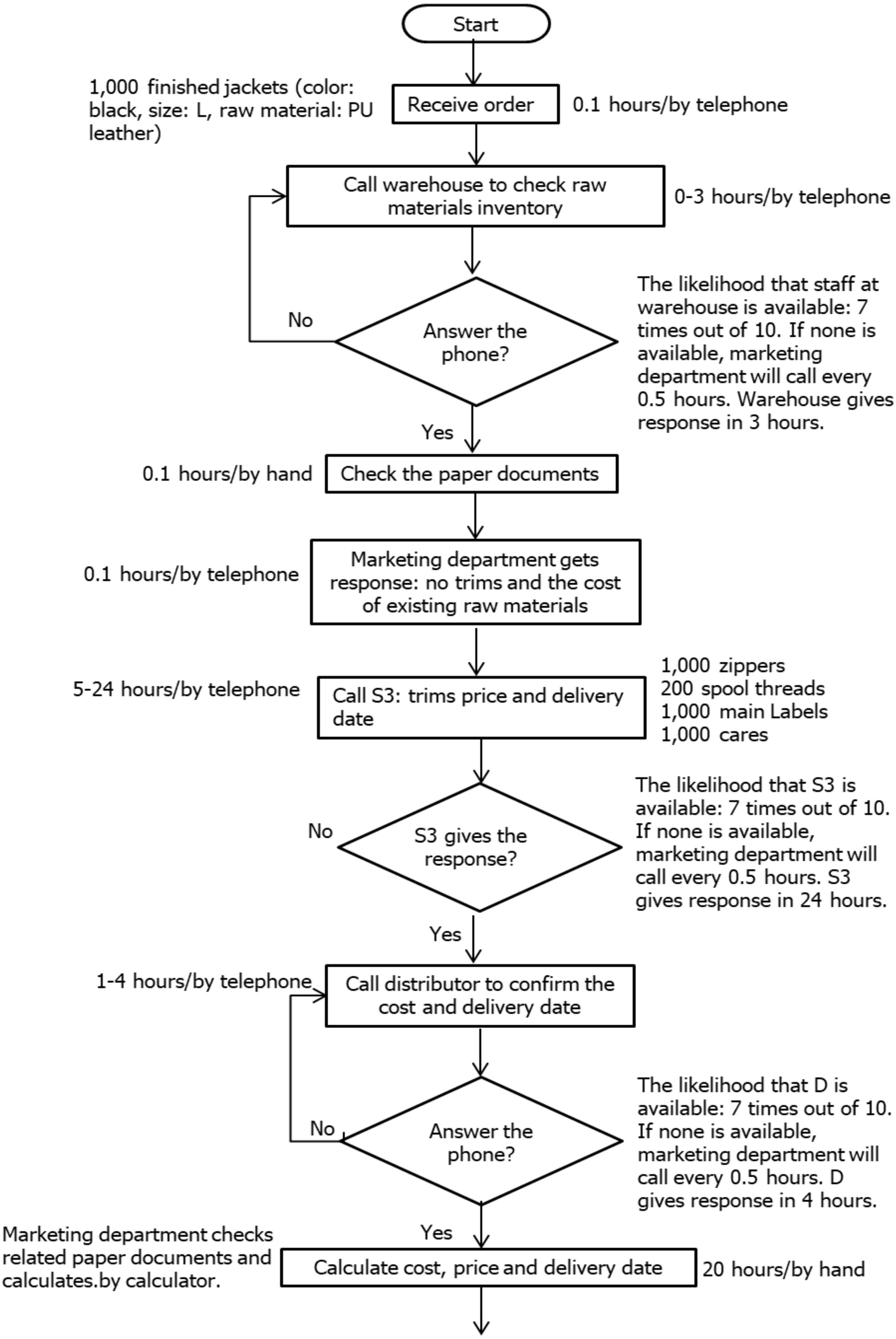


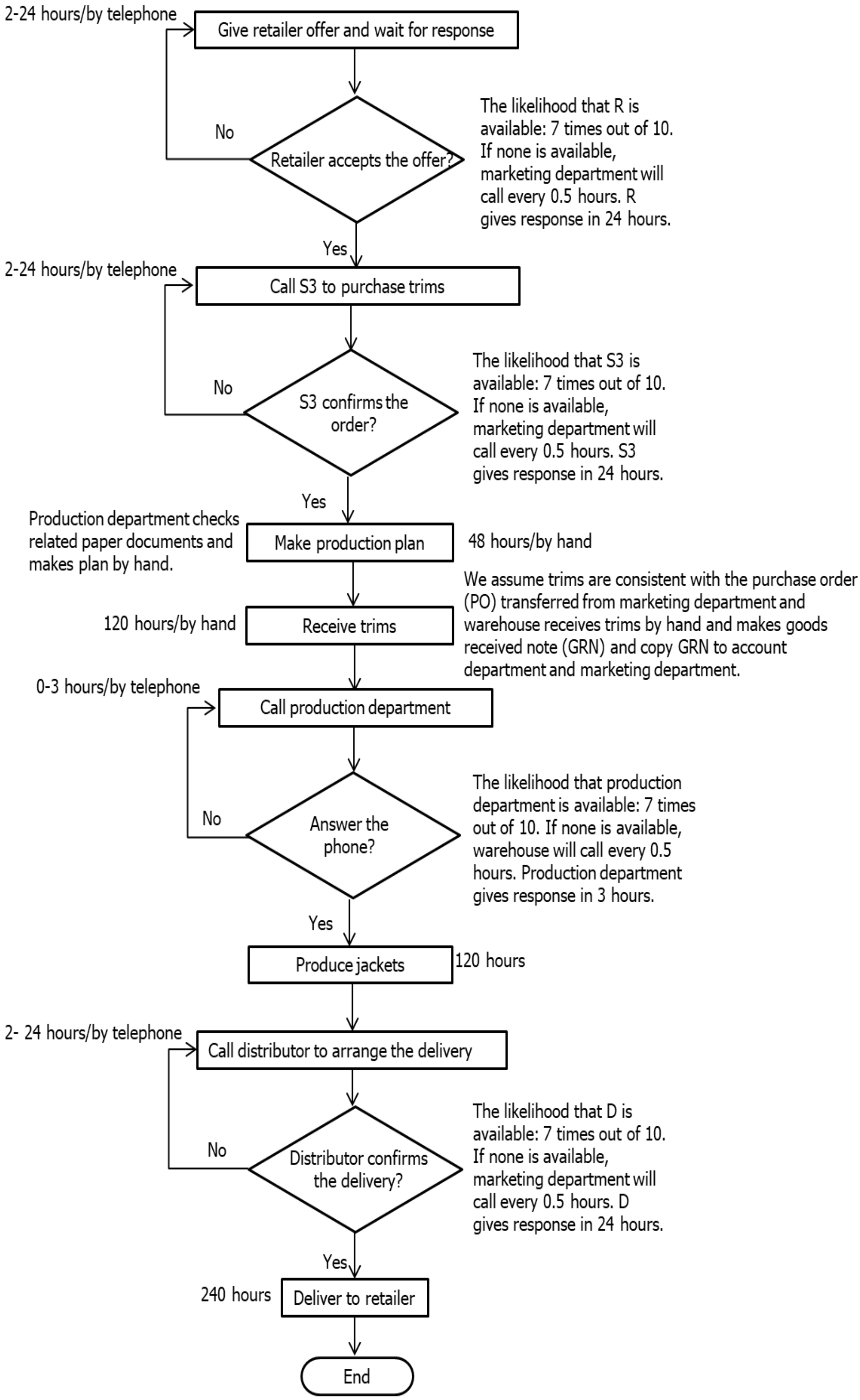
The manufacturer has enough raw materials and trims to produce the jacket in this situation, and it is unnecessary to inquire and purchase raw materials.

Simulation 1-2: Partial raw materials under no e-business

In this simulation, when the marketing department receives an order from the retailer, it will call the warehouse to check raw materials inventory. The warehouse reviews paper documents, confirms it has sufficient leathers and interfacing, but no trims to produce jackets, and lists leather and interfacing costs. The marketing department calls supplier 3 to inquire about the trim price and delivery date. It also needs to call the distributor to ask about the cost and delivery date, calculate the order cost, price, and delivery date by hand, give the retailer the offer by telephone, and wait for the response. When the retailer accepts the offer, the marketing department places the order to S3 to purchase trims; when S3 agrees, the production department will check the related paper documents and make the production plan by hand. When the warehouse receives the trims from S3, the next step is to produce ordered jackets and then call the distributor to deliver the goods to the retailer. When the retailer receives jackets, the order fulfilment is completed (see Figure 5.13).

Figure 5.13 The order fulfilment flowchart (partial raw materials under no e-business)





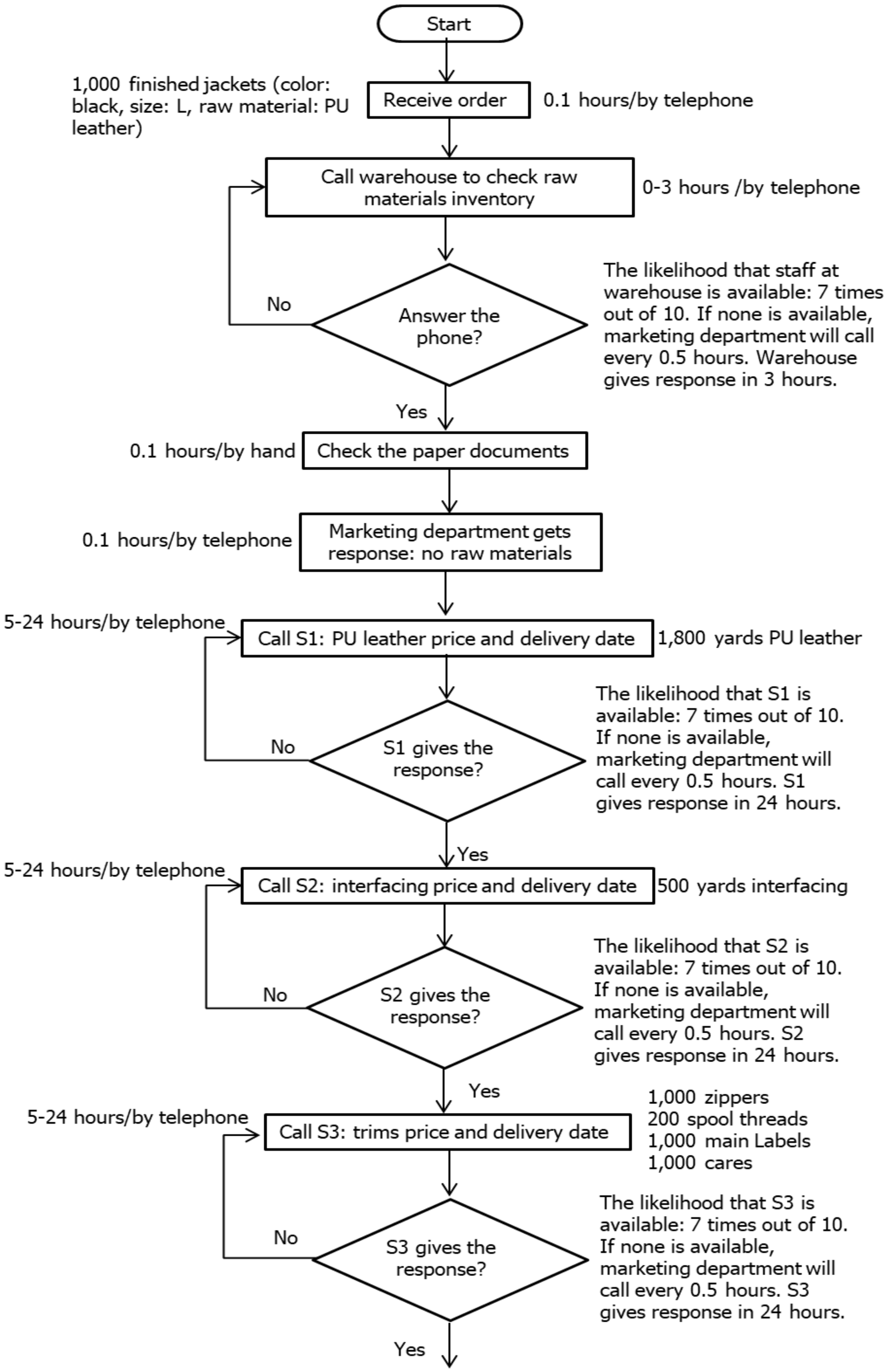
2-24 hours/by telephone
Give retailer offer and wait for response
No
Retailer accepts the offer?
The likelihood that R is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. R gives response in 24 hours.
Yes
2-24 hours/by telephone
Call S3 to purchase trims
No
S3 confirms the order?
The likelihood that S3 is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. S3 gives response in 24 hours.
Yes
Production department checks related paper documents and makes plan by hand.
Make production plan
48 hours/by hand
We assume trims are consistent with the purchase order (PO) transferred from marketing department and warehouse receives trims by hand and makes goods received note (GRN) and copy GRN to account department and marketing department.
120 hours/by hand
Receive trims
0-3 hours/by telephone
Call production department
No
Answer the phone?
The likelihood that production department is available: 7 times out of 10. If none is available, warehouse will call every 0.5 hours. Production department gives response in 3 hours.
Yes
Produce jackets
120 hours
2- 24 hours/by telephone
Call distributor to arrange the delivery
No
Distributor confirms the delivery?
The likelihood that D is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. D gives response in 24 hours.
Yes
240 hours
Deliver to retailer
End

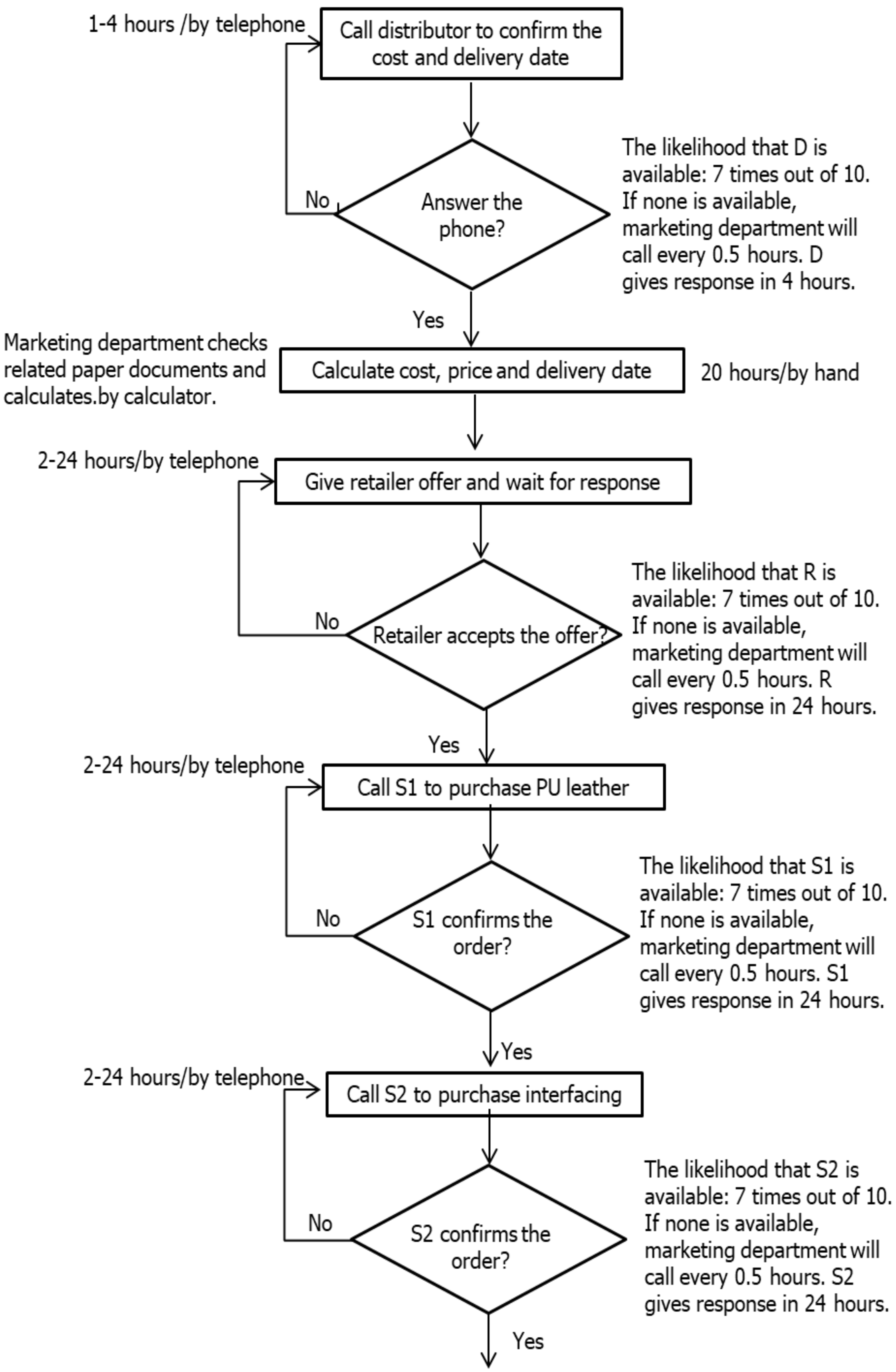
In this flowchart, the manufacturer needs to purchase trims, so it takes 5-24 hours to inquire S3 about the trim, 2-24 hours to place the order, and another 120 hours to receive trims from S3.

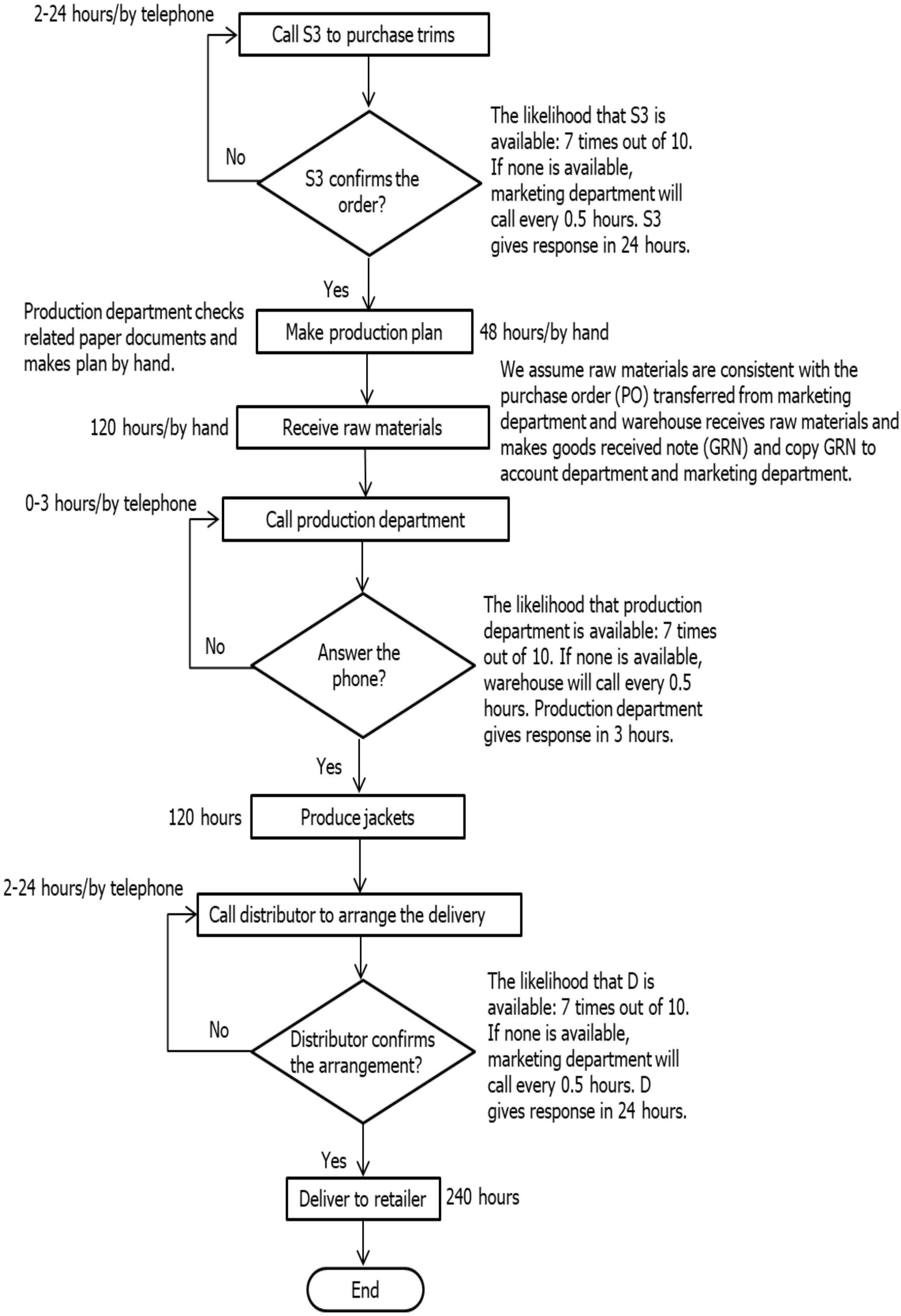
Simulation 1-3: No raw materials under no e-business

In this simulation, the marketing department calls the warehouse to check raw material inventory by telephone when it receives an order from the retailer. The warehouse reviews paper documents and confirms there are no leathers, interfacings and trims to produce jackets. The marketing department calls supplier 1 to inquire about PU leather, calls supplier 2 to ask about the interfacing, and calls supplier 3 to inquire about trims. It also needs to call the distributor to get the delivery costs and date, calculate order costs, price, and delivery date by hand, give the retailer the offer and wait for the response. When the retailer confirms the offer, the marketing department places the orders to S1 to purchase leather, to S2 to purchase interfacing, and to S3 to purchase trims; when S1, S2 and S3 accept the order, the production department will check related paper documents and make the production plan by hand. When the warehouse receives all raw materials and trims, the next step is to produce the order jackets and then call the distributor to deliver the goods to the retailer. When the retailer receives jackets, the order fulfilment is completed (see Figure 5.14).

Figure 5.14 The order fulfilment flowchart (no raw materials under no e-business)




1-4 hours /by telephone
Call distributor to confirm the cost and delivery date
No
Answer the phone?
The likelihood that D is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. D gives response in 4 hours.
Yes
Marketing department checks related paper documents and calculates.by calculator.
Calculate cost, price and delivery date
20 hours/by hand
2-24 hours/by telephone
Give retailer offer and wait for response
No
Retailer accepts the offer?
The likelihood that R is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. R gives response in 24 hours.
Yes
2-24 hours/by telephone
Call S1 to purchase PU leather
No
S1 confirms the order?
The likelihood that S1 is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. S1 gives response in 24 hours.
Yes
2-24 hours/by telephone
Call S2 to purchase interfacing
No
S2 confirms the order?
The likelihood that S2 is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. S2 gives response in 24 hours.
Yes



2-24 hours/by telephone
Call S3 to purchase trims
No
S3 confirms the order?
The likelihood that S3 is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. S3 gives response in 24 hours.
Yes
Production department checks related paper documents and makes plan by hand.
Make production plan
48 hours/by hand
We assume raw materials are consistent with the purchase order (PO) transferred from marketing department and warehouse receives raw materials and makes goods received note (GRN) and copy GRN to account department and marketing department.
120 hours/by hand
Receive raw materials
0-3 hours/by telephone
Call production department
No
Answer the phone?
The likelihood that production department is available: 7 times out of 10. If none is available, warehouse will call every 0.5 hours. Production department gives response in 3 hours.
Yes
120 hours
Produce jackets
2-24 hours/by telephone
Call distributor to arrange the delivery
No
Distributor confirms the arrangement?
The likelihood that D is available: 7 times out of 10. If none is available, marketing department will call every 0.5 hours. D gives response in 24 hours.
Yes
Deliver to retailer
240 hours
End

In this flowchart, the manufacturer needs to purchase all raw materials. It spends 5-24 hours asking S1 about the leather, 5-24 hours to inquire S2 about the interfacing, 5-24 hours to inquire S3 about the trim. When the retailer accepts the order, the manufacturer needs 2-24 hours to place the order for S1 to purchase leather, 2-24 hours to place the order for S2 to purchase interfacing, and 2-24 hours to place the order for S3 to buy trim. The warehouse also needs 120 hours to receive leathers from S1, 120 hours to receive interfacings from S2, and 120 hours to receive trims from S3.

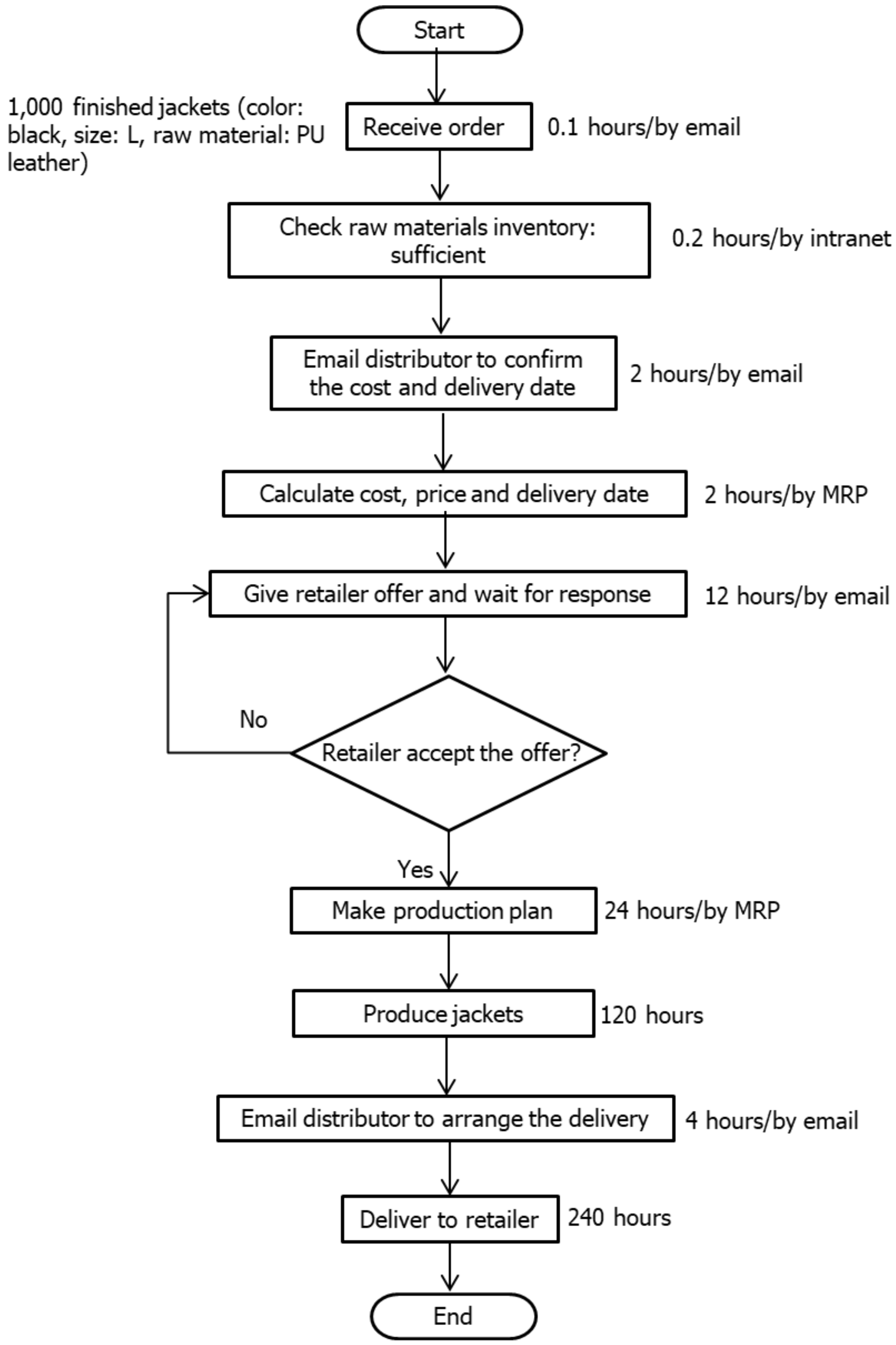
5.3.1.2 Scenario 2: Partial e-business (as Model 2)

Under this scenario, the manufacturer uses intranet and MRP to exchange information among departments inside the company and uses email to exchange information with the R, S1, S2, S3 and D in the supply chain. The time of each step is designed based on the suggestions of six managers. The manufacturer needs 0.2 hours to check the stock by intranet. Suppose it has not enough raw materials to produce the order jacket. In that case, it needs 5 hours to inquire each supplier about raw materials and 4 hours to place the order for each supplier (two managers' suggestions are 4-6 hours). The manufacturer spends 2 hours asking the distributor about the delivery by email (6 managers suggestions are 1.5-2.5 hours) and uses 2 hours to calculate the order costs by MRP (following the No. 6 managers suggestion of using MRP to manage the production). The marketing department needs 12 hours to give the retailer the offer and gets feedback by email (six managers' suggestions are 10-14 hours). Finally, the manufacturer needs 24 hours to make the production plan by MRP (following the No. 6 managers' suggestion of using MRP to manage the production), 4 hours to email the distributor to arrange the delivery (all six managers' suggestions are 4 hours).

Simulation 2-1: Sufficient raw materials under partial e-business

In this simulation, when the marketing department receives the order, it will use the intranet to check raw materials inventory and confirm it has sufficient raw materials to produce jackets. The marketing department emails the distributor to inquire about the delivery costs and date. Then it calculates order costs and price by MRP, emails the retailer the offer, waits for the response. When the retailer accepts the offer, the production department inputs the related information to MRP and makes the production plan. The production department will produce the order jackets and email the distributor to deliver the goods to the retailer; when the retailer receives the jackets, the order fulfilment is completed (see Figure 5.15).

Figure 5.15 The order fulfilment flowchart (sufficient raw materials under partial e-business)

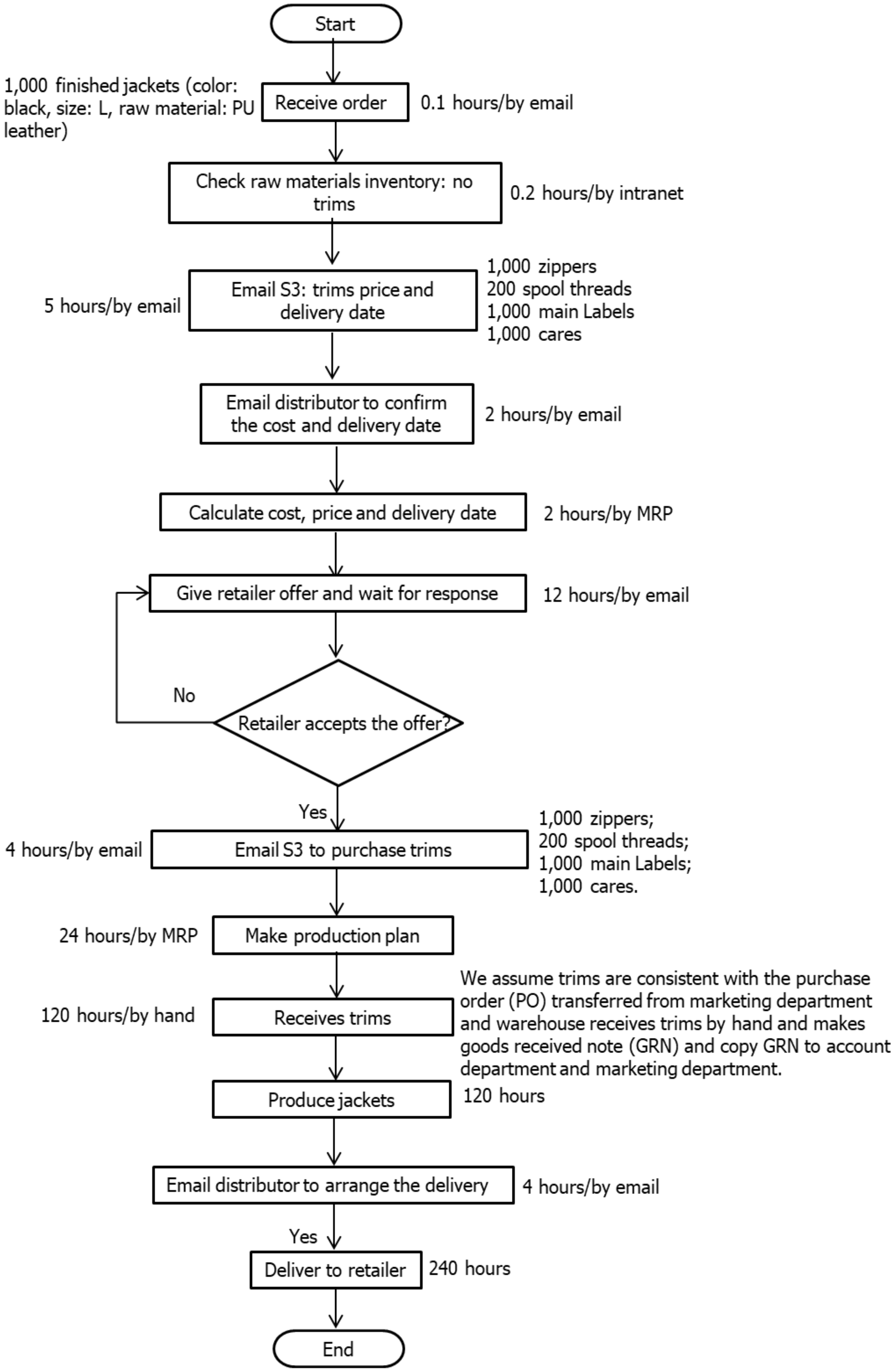


In this flowchart, the manufacturer has enough raw materials and trims to produce the ordered jackets.

Simulation 2-2: Partial raw materials under partial e-business

In this simulation, when the marketing department receives the order from the retailer, it will use the intranet to check raw materials inventory and confirm sufficient leathers and interfacings, but no trims to produce jackets. The marketing department emails the raw material supplier 3 to get the trim costs and delivery date, and then emails the distributor to get the delivery costs and delivery date. Then the marketing department calculates the cost, price, and delivery date by MRP and emails the retailer to provide the offer. When the retailer accepts the offer, the production department will place the order to S3 to purchase trims by email, input the related information to MRP, and make a production plan. When the warehouse receives trims, the production department will produce jackets and email the distributor to arrange the delivery. The order fulfilment is completed when the retailer gets the jackets (see Figure 5.16).

Figure 5.16 The order fulfilment flowchart (partial raw materials under partial e-business)

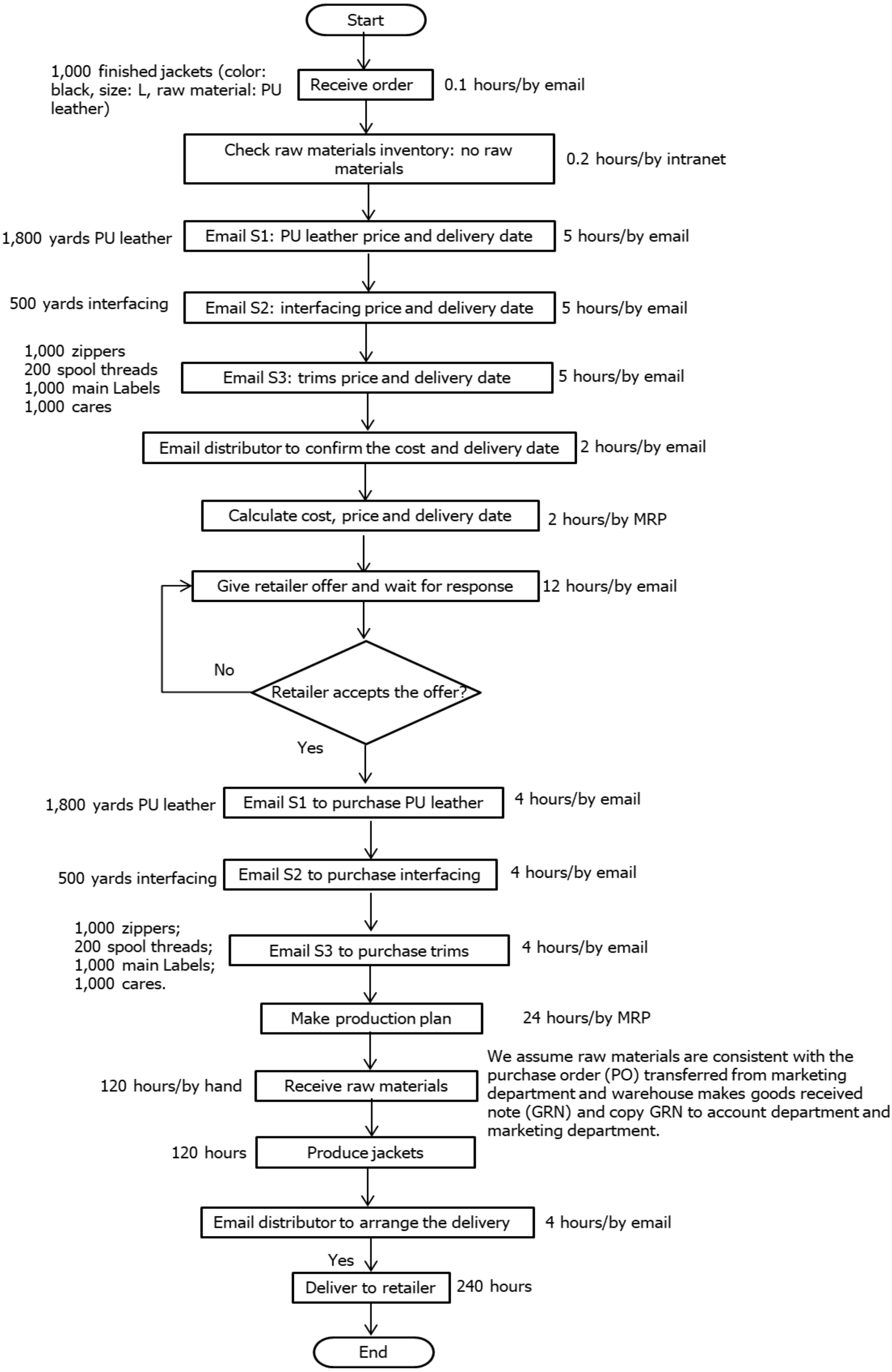


In this flowchart, the manufacturer needs to inquire about S3 the trim, place the order to S3, and receives trims from S3.

Simulation 2-3: No raw materials under partial e-business

In this simulation, when the marketing department receives the order from the retailer, it will use the intranet to check raw materials inventory and confirm there are no leathers, interfacings and trims to produce jackets. The marketing department emails S1, S2 and S3 one by one to get the costs and delivery date of the leather, interfacing and trim, and then emails the distributor to get the delivery costs and date by email. Then the marketing department calculates the order cost, price, and delivery date by MRP and gives the retailer the offer by email. The production department will place the order to S1 to purchase leathers, S2 to purchase interfacings, and S3 to purchase trims when the retailer accepts the offer, inputs the related information to MRP, and makes a production plan. When the warehouse receives ordered raw materials, the production department will produce jackets first and email the distributor to deliver the jackets to the retailer; this order fulfilment is completed when the retailer gets the jackets (see Figure 5.17).

Figure 5.17 The order fulfilment flowchart (no raw materials under partial e-business)



In this flowchart, the manufacturer needs to inquire and purchase all raw materials from S1, S2 and S3 one by one.

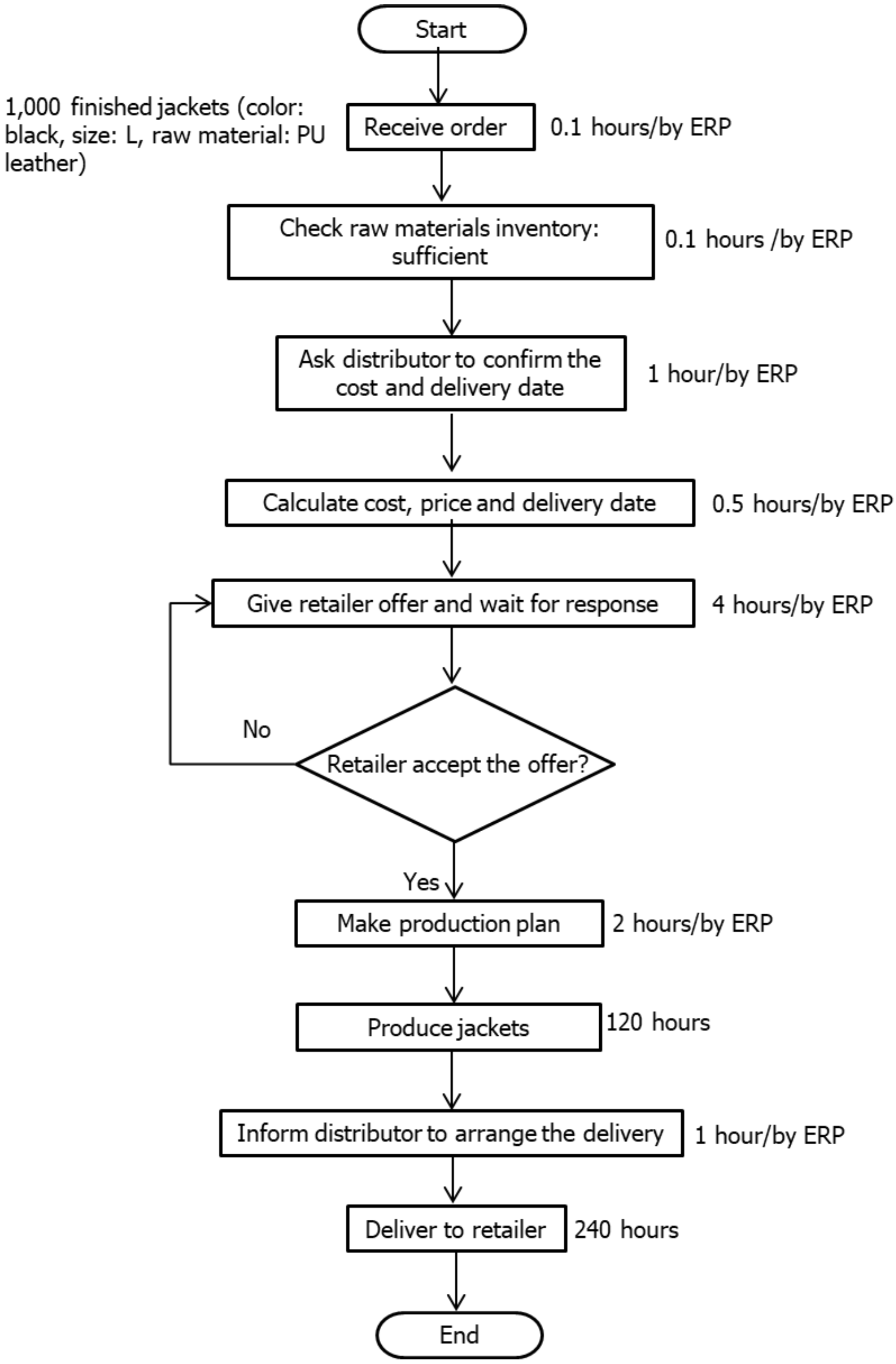
5.3.1.3 Scenario 3: Comprehensive e-business (as Model 3)

Under this scenario, the manufacturer uses ERP to exchange information in the supply chain. The time of each step is designed based on the suggestions of three managers from No.1, No.2 and No.3 companies using ERP systems to manage the operation. The manufacturer needs 0.1 hours to check the stock by ERP. Suppose it has not enough raw materials to produce the order jacket. In that case, it needs 2 hours to inquire about all raw materials, 2 hours to place the order for each supplier by ERP (all three managers' suggestions are 2 hours). The manufacturer spends 1 hour asking the distributor about the delivery by ERP (all three managers' suggestions are 1 hour) and uses 0.5 hours to calculate the order costs by ERP (all three managers' suggestions are 0.5 hours). The marketing department needs 4 hours to give the retailer the offer and gets feedback from ERP (all three managers' suggestions are 4 hours). The manufacturer needs 2 hours to make the production plan by ERP (all three managers' suggestions are 2 hours), 1 hour to inform the distributor to arrange the delivery (all three managers' suggestions are 1 hour).

Simulation 3-1: Sufficient raw materials under comprehensive e-business

In this simulation, when the marketing department receives the order, it will check raw materials inventory by ERP. ERP shows that there are sufficient raw materials to produce jackets. The marketing department contacts the distributor to get the delivery costs and date, then calculates the cost, price and delivery date by ERP. It gives the retailer the offer and waits for the response. When the retailer accepts the offer, the production department will make the production plan using ERP. The next step is to produce ordered jackets and inform the distributor to arrange the delivery. The order fulfilment is completed when the retailer receives the jackets (see Figure 5.18).

Figure 5.18 The order fulfilment flowchart (sufficient raw materials under comprehensive e-business)

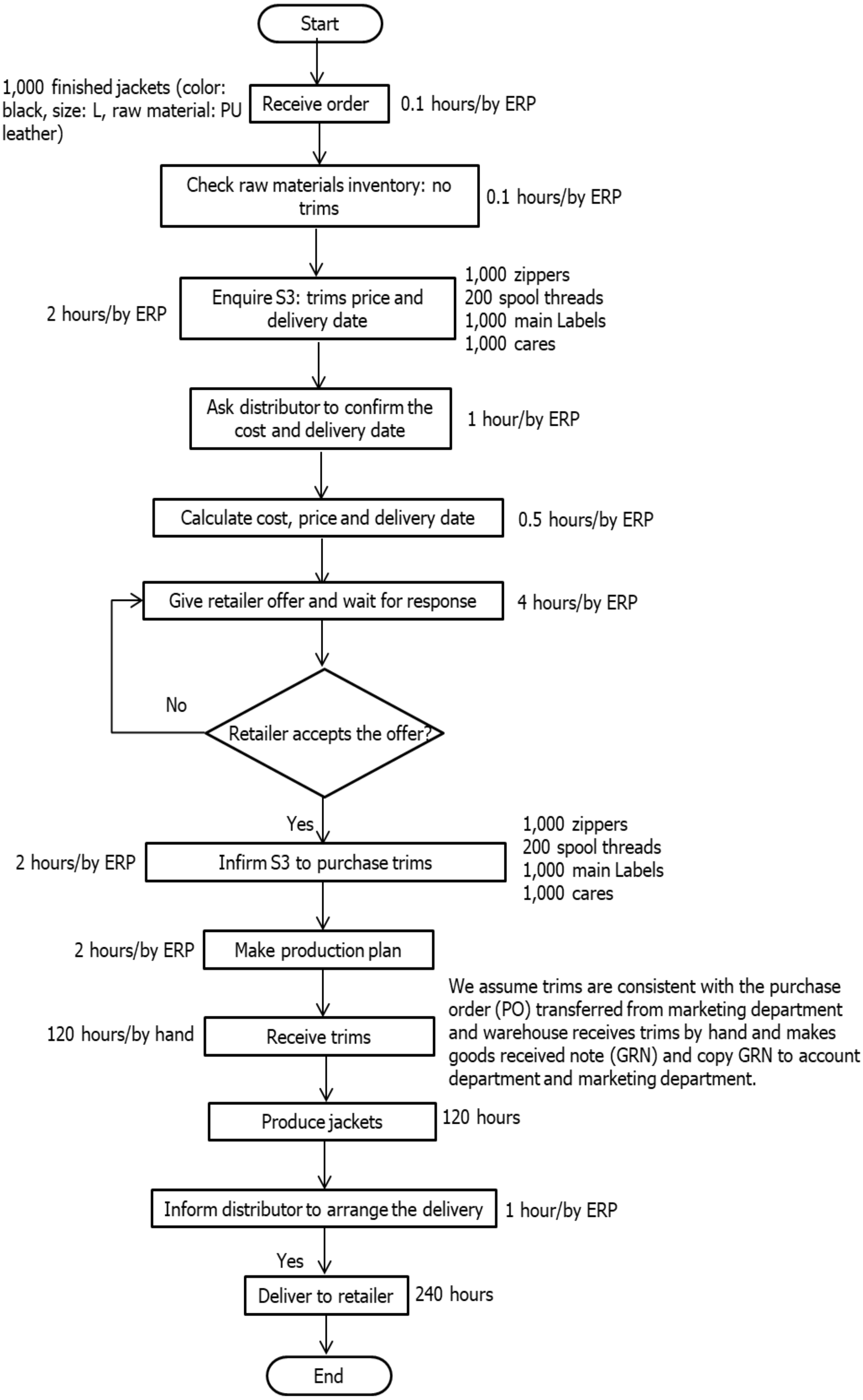


The manufacturer has enough leathers, interfacings and trims to produce the ordered jackets in this flowchart.

Simulation 3-2: Partial raw materials under comprehensive e-business

In this simulation, when the marketing department receives the order, it will check raw materials inventory by ERP. ERP shows there are sufficient leathers and interfacings but no trims to produce jackets. The marketing department contacts raw material supplier 3 to inquire about the trims costs and delivery date, contacts the distributor to get the delivery costs and date, then calculates the cost, price, and delivery date by ERP, and gives the retailer offer. When the retailer accepts the offer, the production department will place the order to S3 to purchase trims and then make a production plan by ERP. When the warehouse receives trims from S3, the production department will produce jackets and inform the distributor to deliver the jackets to the retailer. The order fulfilment is completed when the retailer receives the jackets (see Figure 5.19).

Figure 5.19 The order fulfilment flowchart (partial raw materials under comprehensive e-business)

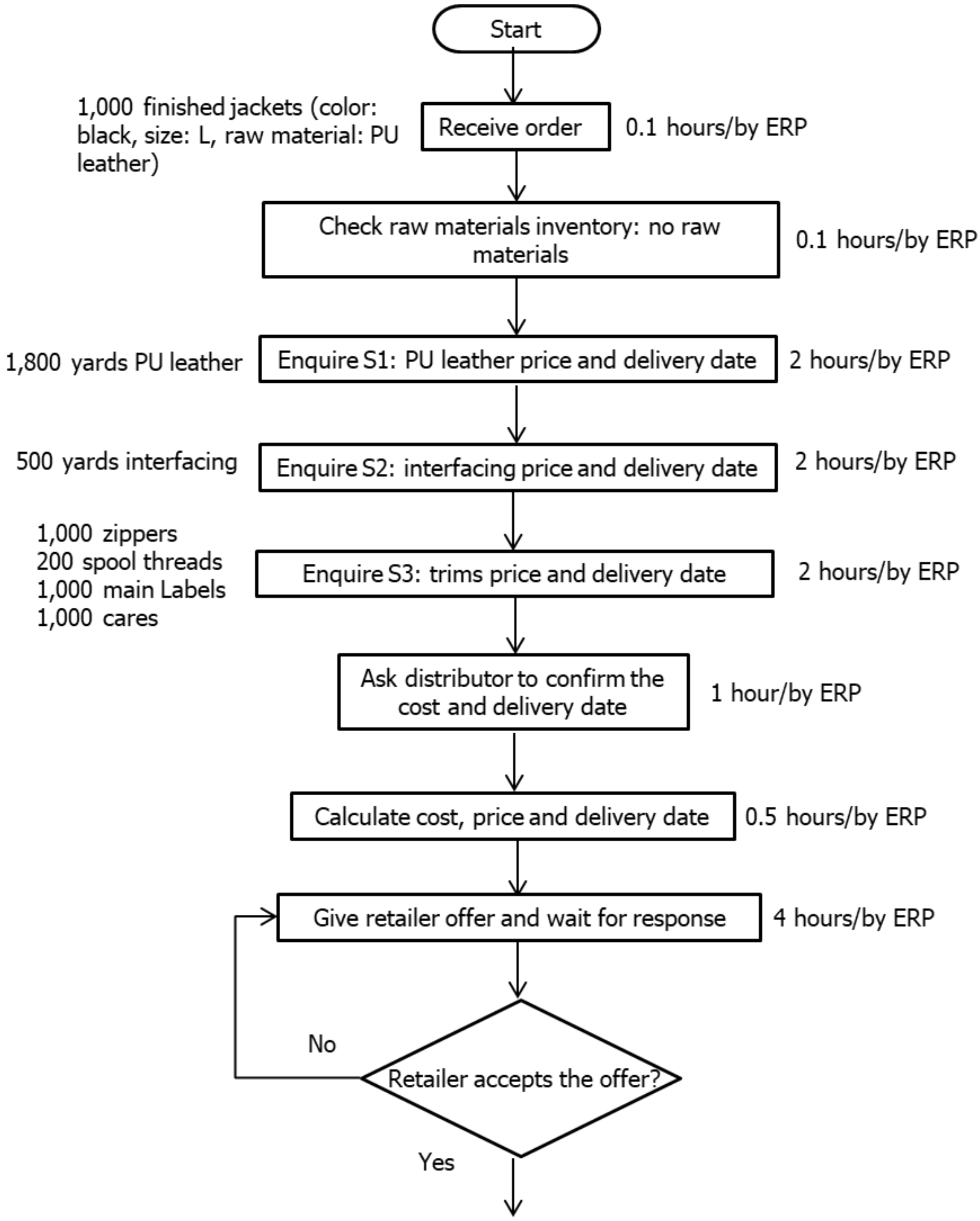


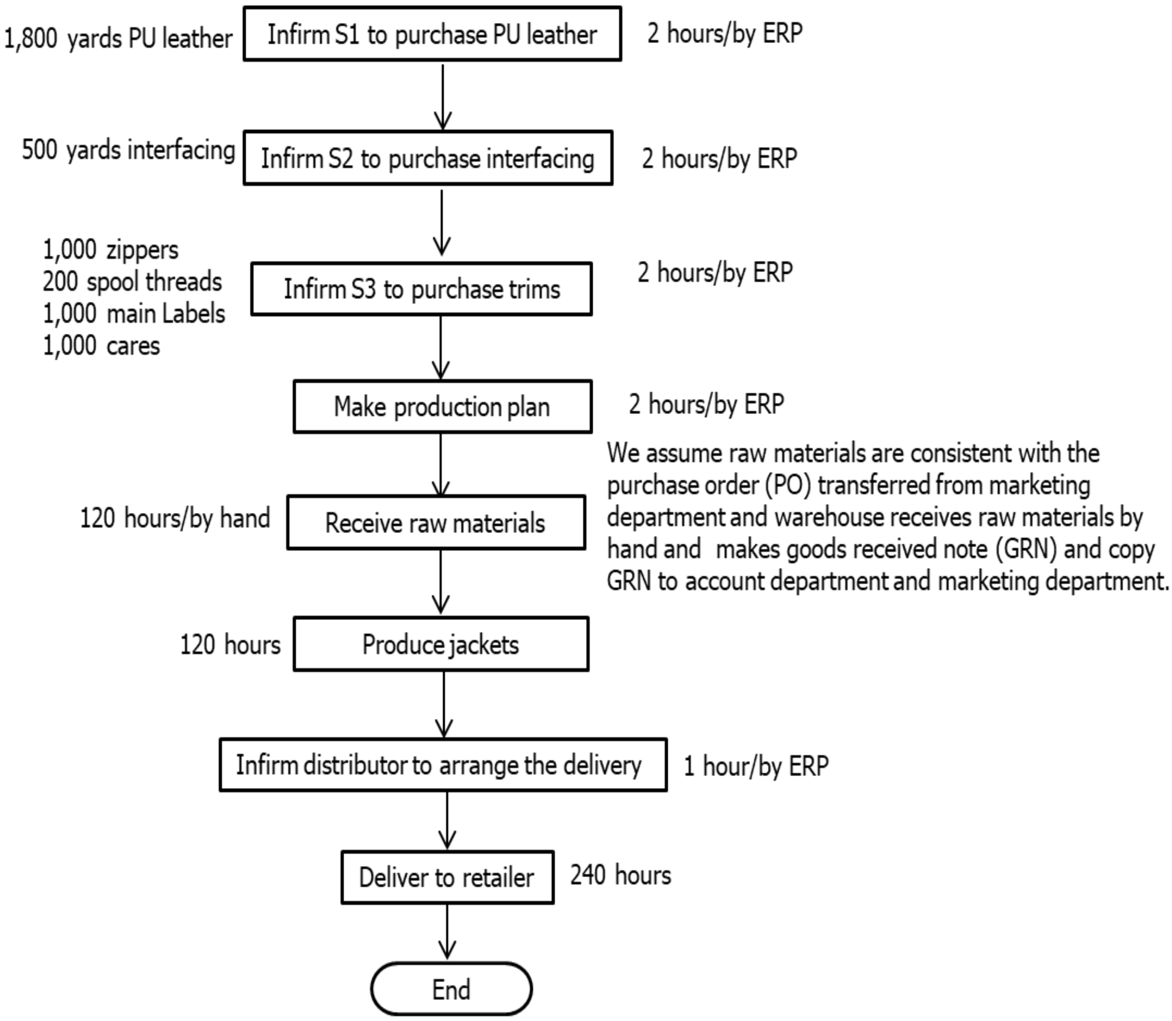
In this flowchart, the manufacturer needs to inquire about S3 the trims, place the order, and then receives trims from S3 by ERP.

Simulation 3-3: No raw materials under comprehensive e-business

In this simulation, the marketing department will check raw materials inventory by ERP when it receives the order. ERP shows there are no leathers, interfacings and trims to produce jackets. The marketing department contacts S1, S2 and S3 one by one to inquire about leather, interfacing and trim costs and delivery date, and contacts the distributor to get the delivery costs and date, calculates jackets costs, price and delivery date by ERP, and gives the retailer the offer, waits for the response. When the retailer accepts the offer, the production department will place the order to S1 to replenish leathers, to S2 to replenish interfacings, and to S3 to replenish trims and make the production plan by ERP. When the warehouse receives leathers from S1, receives interfacings from S2, and receives trims from S3, the production department will produce ordered jackets and inform the distributor to arrange the delivery. When the retailer gets the jackets, the order fulfilment is completed (see Figure 5.20).

Figure 5.20 The order fulfilment flowchart (no raw materials under comprehensive e-business)





The manufacturer needs to inquire and purchase all raw materials from S1, S2 and S3 by ERP in this flowchart.

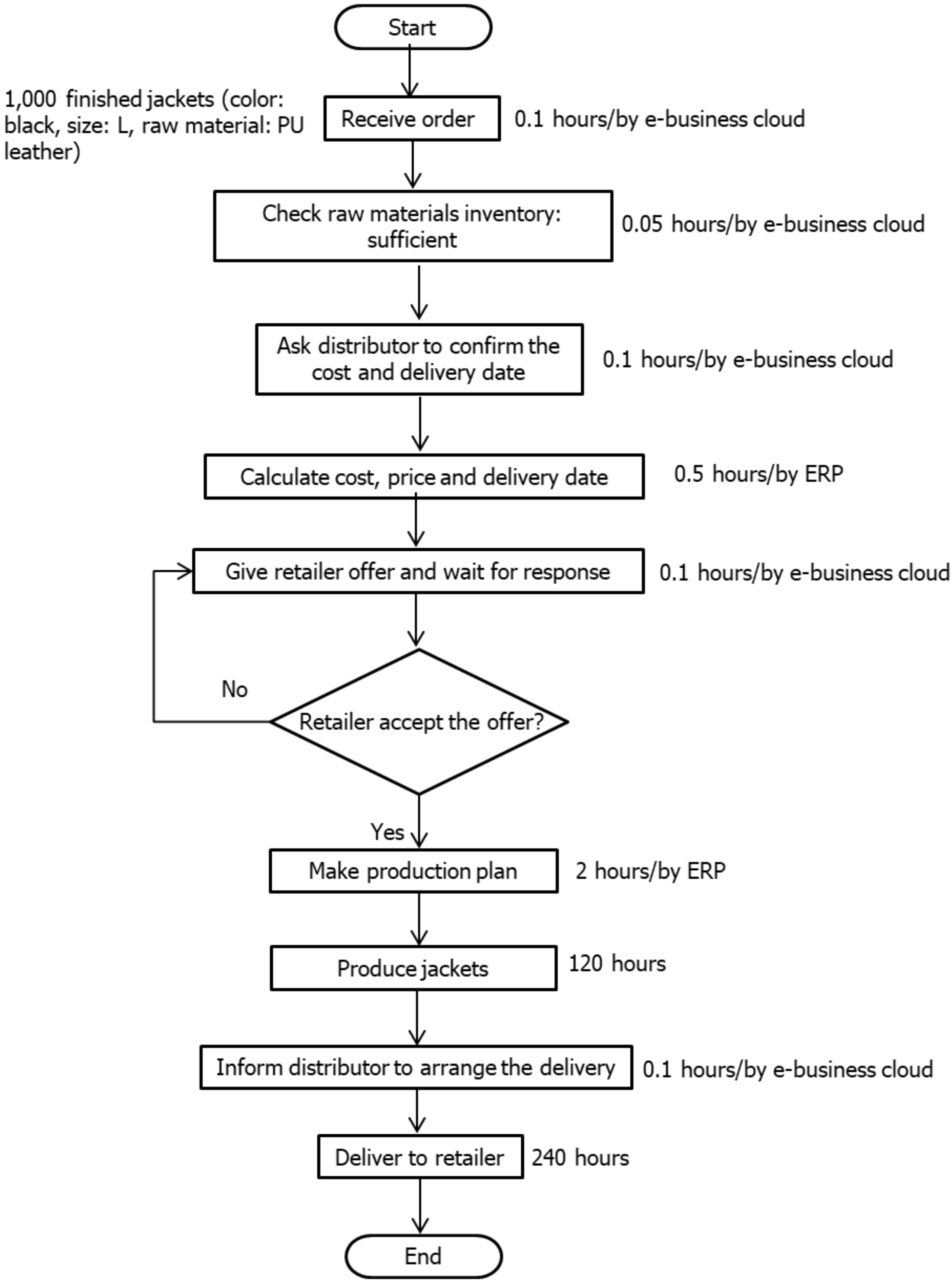
5.3.1.4 Scenario 4: Virtual e-business (as Model 4)

This e-business utilisation level has only been partially modelled in the current literature, and the potential of cloud computing has not been fully developed. Only No.3 company uses cloud computing to communicate with partners; some steps are designed based on No. 3 managers' suggestions. Under this scenario, the manufacturer uses ERP to manage the order and uses the e-business cloud to exchange information with the retailer, raw material suppliers and the distributor. In this scenario, all partners are connected by the e-business cloud. They can share all necessary information and data to fulfil an order by cloud computing. The manufacturer can save much time to exchange information with the retailer, raw material suppliers and the distributor.

Simulation 4-1: Sufficient raw materials under virtual e-business

In this simulation, when the marketing department receives the order from the retailer, the e-business cloud will check inventory and show sufficient raw materials to produce jackets. The marketing department contacts the distributor by cloud computing to get the delivery costs and date and calculates cost, price, and delivery date by ERP, then gives the retailer offer by could. When the retailer accepts the offer, the production department will make the production plan by ERP. The next step is to produce jackets and inform the distributor to deliver them to the retailer; the order fulfilment is completed when it receives the jackets (see Figure 5.21).

Figure 5.21 The order fulfilment flowchart (sufficient raw materials under virtual e-business)

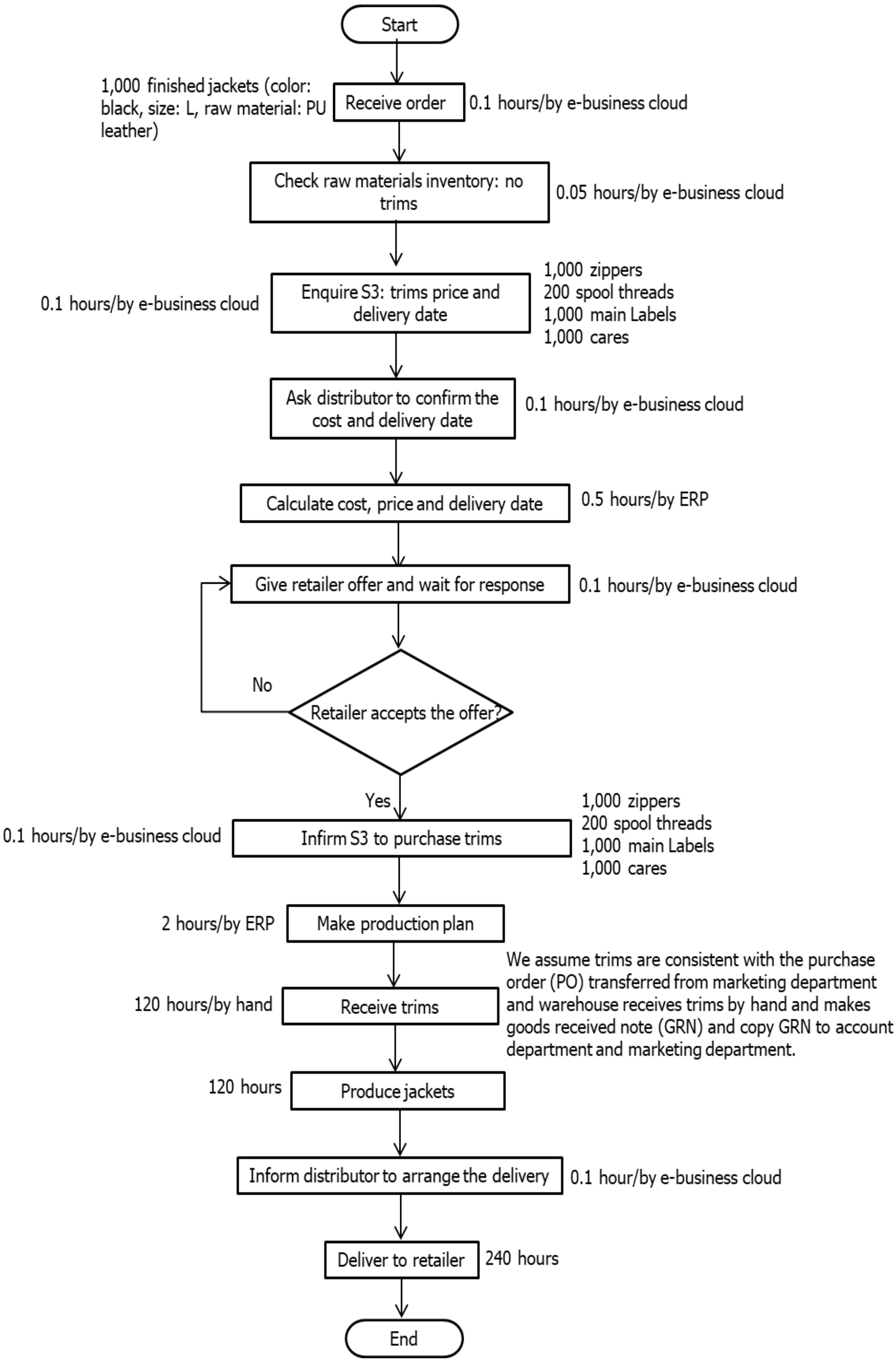


In this flowchart, the manufacturer has enough raw materials and trims to produce the ordered jackets.

Simulation 4-2: Partial raw materials under virtual e-business

In this simulation, when the marketing department receives the order from the retailer, the e-business cloud will check raw materials inventory and find sufficient leathers and interfacings but no trims to produce jackets. The marketing department uses cloud computing to contact S3 to get trim costs and delivery date by e-business cloud. Then, the marketing department contacts the distributor to get the delivery cost costs and date, calculates the cost, price and delivery date by cloud computing, gives the retailer the offer by cloud services and waits for the response. When the retailer confirms the offer, the marketing department will place the order to replenish trims by cloud computing, and the production department will make the production plan by ERP. When the warehouse receives trims from S3, the next step is to produce ordered jackets and inform the distributor to arrange the delivery by cloud computing. When the retailer gets the jackets, the order fulfilment is completed (see Figure 5.22).

Figure 5.22 The order fulfilment flowchart (partial raw materials under virtual e-business)

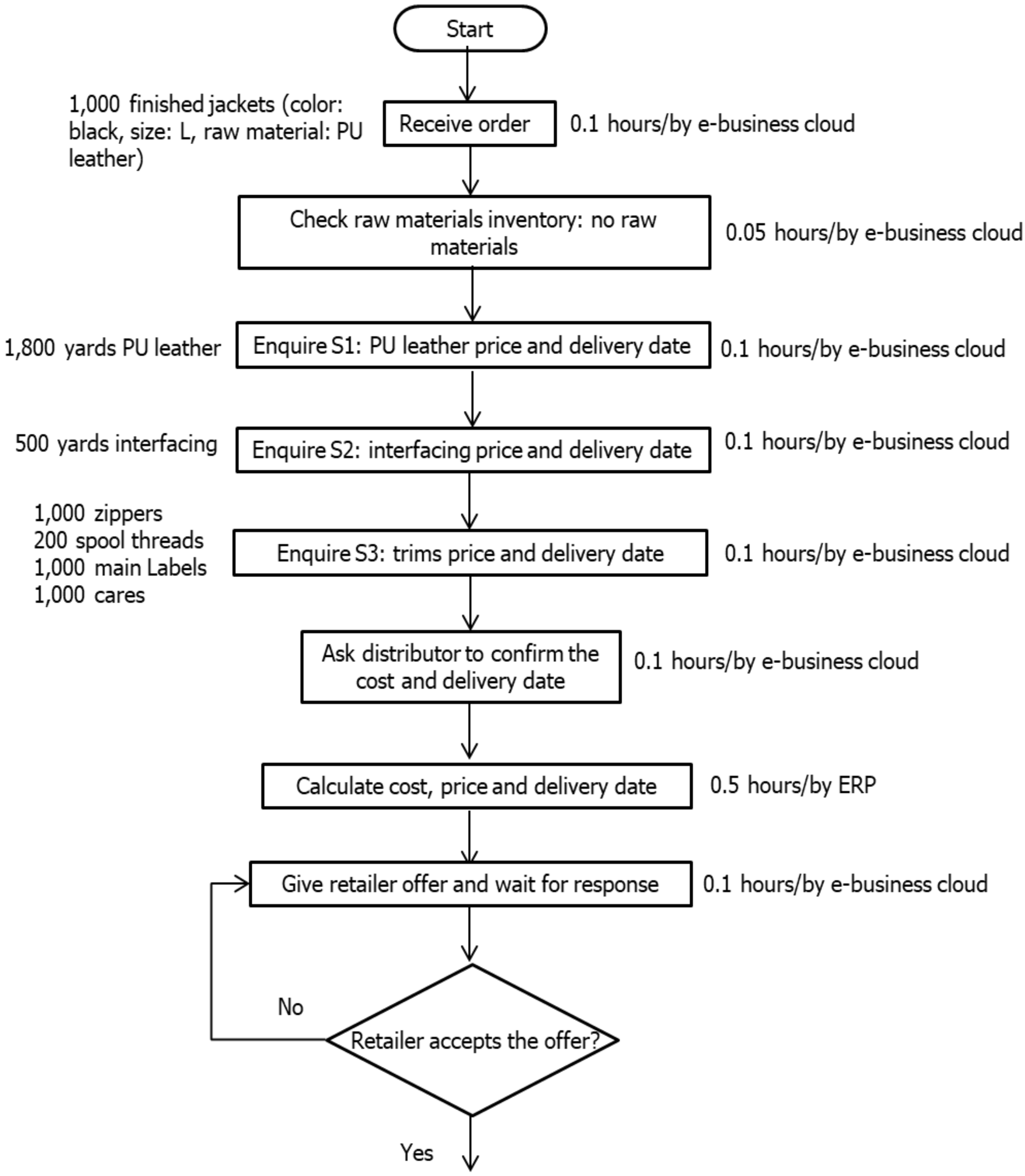


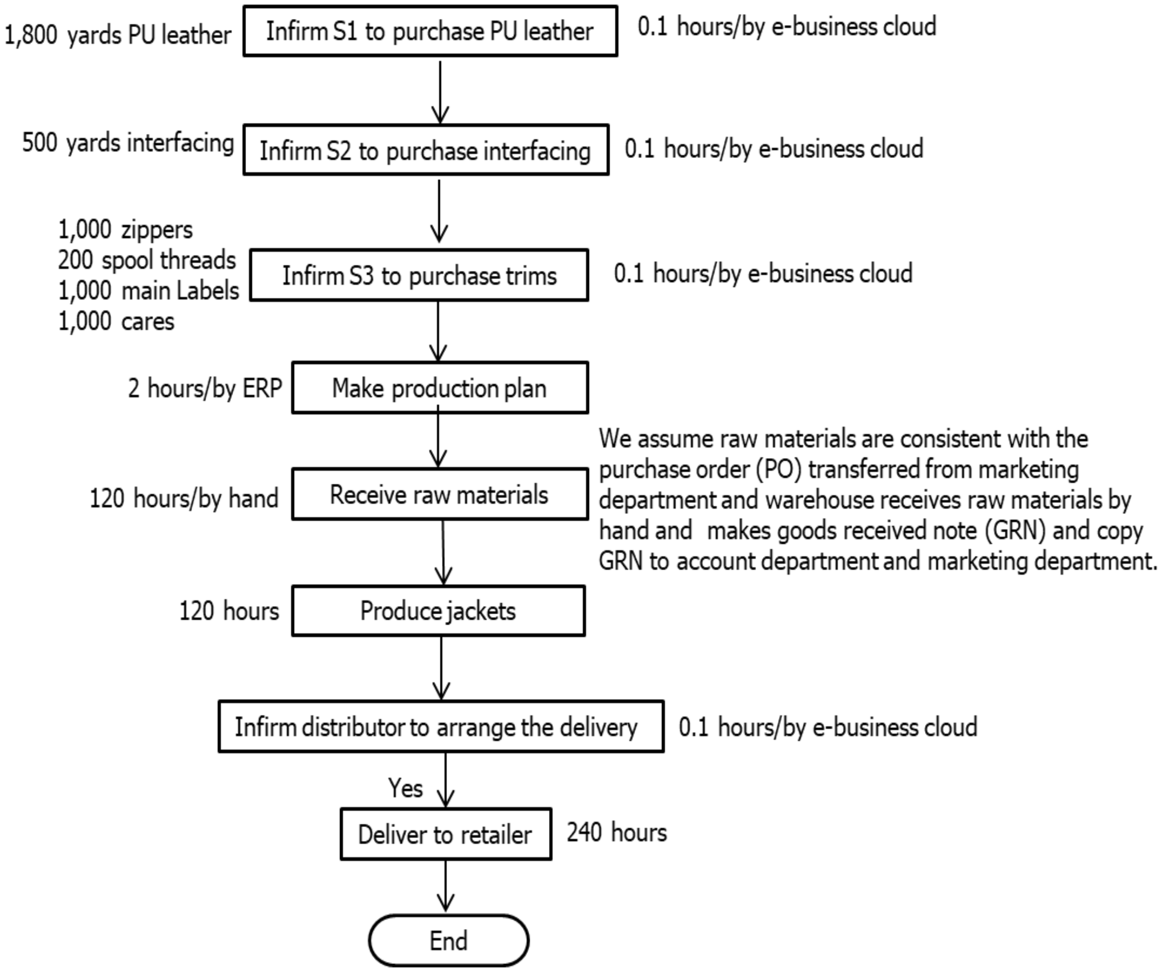
In this flowchart, the manufacturer needs to inquire about S3 the trim, place the order, and receives trims from S3 by cloud computing.

Simulation 4-3: No raw materials under virtual e-business

In this simulation, when the marketing department receives the order from the retailer, cloud computing will check raw materials inventory and find out there are no leathers, interfacings and trims to produce jackets. The marketing department uses cloud computing to contact S1, S2 and S3 to get raw materials and trims costs and delivery date by cloud services. Then, the marketing department contacts the distributor to get the delivery costs and date by cloud computing, then calculates the cost, price, and delivery date by ERP, gives the retailer the offer by cloud computing, and waits for the response. When the retailer confirms the offer, the marketing department will place the order to replenish raw materials by cloud computing. The production department will make the production plan by ERP. When the warehouse receives materials from S1, S2 and S3, the next step is to produce ordered jackets and inform the distributor to arrange the delivery by could computing. The order fulfilment will be completed when the retailer receives jackets (see Figure 5.23).

Figure 5.23 The order fulfilment flowchart (no raw materials under virtual e-business)





The manufacturer needs to inquire and then purchase all raw materials from S1, S2 and S3 by cloud computing in this flowchart.

5.3.2 Experimental Process

Some parameters must be specified before the simulation implementation because these initiated parameters determine agents' actions and behaviours. The order fulfilment process starts when the manufacturer receives an order from the retailer. Initial values of the experimental parameters are shown in the flowcharts of each experimental scenario. All these parameters are designed based on the data provided by managers from six Chinese small and medium size textile & apparel manufacturers and get confirmation from all managers. The experiments can be repeated many times by varying these parameters under four scenarios.

Fifteen runs for each scenario are generated to gain enough statistical significance. Fifty periods of each experiment represent the actual order fulfilment quantities received by the small manufacturer in one year. Two hundred periods of each experiment represent the medium manufacturers' actual order fulfilment quantities in one year.

Four levels of e-business utilisation are implemented in the simulation to identify their respective effects on the order fulfilment process. Scenario 1 represents no e-business (Model 1), scenario 2 represents partial e-business (Model 2), scenario 3 represents comprehensive e-business (Model 3), and scenario 4 represents virtual e-business (Model 4). The time needed for each step in simulation is set to the hour, which means the time to make and deliver products are counted by hours. The study compares four scenarios using different parameters to measure the e-business implementation efficiency in order fulfilment of the textile & apparel supply chain. For example,

T_{ic}: Inventory check time (from receiving the order to marketing department gets a response)

T_{ri}: Raw materials inquiry time (manufacturer inquires raw materials)

T_{oc}: Order confirmation time (from the manufacturer receives the order to the retailer confirms the order)

T_{rp}: Raw materials purchase time (from the manufacturer places the order to it receives raw materials from suppliers)

T_{op}: Order production time (from the manufacturer receives the order to it completes order production)

T_{od}: Order delivery time (from the manufacturer informs the distributor to deliver jackets to the retailer receives ordered jackets)

L: Order fulfilment time (from the start to the end, e.g., lead time)

These parameters are meaningful and essential in practical business situations to measure order fulfilment and supply chain efficiency. These parameters are designed following the textile & apparel order fulfilment process (Frederick and Daly, 2019). They are changeable to enable users to compare simulation results based on different e-business utilisation levels in the textile & apparel supply chain by adjusting the parameter values. Table 5.4 lists propositions, the simulations used and key parameters. The data will be generated from the simulation, and the statistical analysis methods will be used to test propositions.

Table 5.4 Research propositions and the test methods

Propositions	Simulations	Key Parameters	Data and statistical analysis methods
P1. The advancement of e-business utilisation level influences the inventory check time; when the e-business level improves, the time taken to check inventory decreases.	Simulation 1-1 (T_{ic}) (sufficient raw materials under no e-business, see Figure 5.12), 1-2 (T_{ic}) (partial raw materials under no e-business, see Figure 5.13), 1-3 (T_{ic}) (no raw materials under no e-business, see Figure 5.14) Simulation 2-1 (T_{ic}) (sufficient raw materials under partial e-business, see Figure 5.15), 2-2 (T_{ic}) (partial raw materials under partial e-business, see Figure 5.16), 2-3 (T_{ic}) (no raw materials under partial e-business, see Figure 5.17) Simulation 3-1 (T_{ic}) (sufficient raw materials under comprehensive e-business, see Figure 5.18), 3-2 (T_{ic}) (partial raw materials under comprehensive e-business, see Figure 5.19), 3-3 (T_{ic}) (no raw materials under comprehensive	**T_{ic}**: inventory check time (from receiving the order to marketing department gets a response) **Simulation 1-1 (T_{ic}), 1-2 (T_{ic}), and 1-3 (T_{ic}):** 0.2-3.2 hours, includes: Call warehouse: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours Marketing department gets a response: 0.1 hours **Simulation 2-1 (T_{ic}), 2-2 (T_{ic}), and 2-3 (T_{ic})**: 0.2 hours **Simulation 3-1 (T_{ic}), 3-2 (T_{ic}), and 3-3 (T_{ic}):** 0.1 hours **Simulation 4-1 (T_{ic}), 4-2 (T_{ic}), and 4-3 (T_{ic}):** 0.05 hours	The inventory check time for simulation 1-1 (T_{ic}), 2-1(T_{ic}), 3-1 (T_{ic}), and 4-1 (T_{ic}) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum inventory check time, the sum of squares, mean difference, the correlation coefficient between e-business level and inventory check time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be performed to test the null hypothesis 1. Null hypothesis 1: The advancement of e-business utilisation level has no

	e-business, see Figure 5.20) Simulation 4-1 (T_{ic}) (sufficient raw materials under virtual e-business, see Figure 5.21), 4-2 (T_{ic}) (partial raw materials under virtual e-business, see Figure 5.22), 4-3 (T_{ic}) (no raw materials under virtual e-business, see Figure 5.23)		impact on the average time taken to check inventory.
P2. The advancement of e-business utilisation level influences the raw materials inquiry time; when the e-business level improves, the time taken to inquire about raw materials decreases.	Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	**T_{ri}**: raw materials inquiry time (manufacturer inquires raw materials) **Simulation 1-2 (T_{ri})**: 5-24 hours, includes: Call S3 to get trims price and delivery date: 5-24 hours (response rate from S3: 7/10, no response, call back every 0.5 hours) **Simulation 2-2 (T_{ri})**: 5 hours Email S3 to get trims price and delivery date: 5 hours **Simulation 3-2 (T_{ri})**: 2 hours Enquire S3 about trims price and delivery date: 2 hours **Simulation 4-2 (T_{ri})**: 0.1 hours Enquire S3 about trims price and delivery date: 0.1 hours **Simulation 1-3 (T_{ri})**: 15-72 hours, includes:	The raw materials inquiry time for simulation 1-2 (T_{ri}), 2-2 (T_{ri}), 3-2 (T_{ri}), and 4-2 (T_{ri}), simulation 1-3 (T_{ri}), 2-3 (T_{ri}), 3-3 (T_{ri}), and 4-3 (T_{ri}) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum raw material inquiry time, sum of squares, mean difference, the correlation coefficient between e-business level and raw material inquiry time, etc. ANOVA analysis, Boxplots, and Spearman’s rank correlation coefficient will be

		Call S1 to inquire about PU leather price and delivery date: 5-24 hours (response rate from S1: 7/10, no response, call back every 0.5 hours) Call S2 to inquire interfacing price and delivery date: 5-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours) Call S3 to inquire trims price and delivery date: 5-24 hours (Response rate from S3: 7/10, no response, call back every 0.5 hours) **Simulation 2-3 (T_{ri})**: 15 hours, includes: Email S1to inquire about PU leather price and delivery date: 5 hours Email S2 to inquire interfacing price and delivery date: 5 hours Email S3 to inquire trims price and delivery date: 5 hours **Simulation 3-3 (T_{ri})**: 6 hours, includes: Enquire S1 about PU leather price and delivery date: 2 hours Enquire S2 about inquire interfacing price and delivery date: 2 hours Enquire S3 about trims price and delivery date: 2 hours **Simulation 4-3 (T_{ri})**: 0.3 hours, includes: Enquire S1 about PU leather price and delivery date: 0.1 hours	performed to test the null hypothesis 2. Null hypothesis 2: The advancement of e-business utilisation level has no impact on the average time taken to inquire about raw materials.

		Enquire S2 about interfacing price and delivery date: 0.1 hours Enquire S3 about trims price and delivery date: 0.1 hours	
P3. The advancement of e-business utilisation level influences the order confirmation time; when the e-business level improves, the time taken to confirm the order decreases.	Simulation 1-1 (see Figure 5.12), 2-1 (see Figure 5.15), 3-1 (see Figure 5.18), 4-1 (see Figure 5.21) Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (see Figure 5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	**T_{oc}**: order confirmation time (from the manufacturer receives the order to the retailer confirms the order) **Simulation 1-1 (T_{oc})**: 23.2-51.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours Marketing department gets a response: 0.1 hours Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) **Simulation 2-1 (T_{oc})**: 16.2 hours, includes: Check raw materials inventory: 0.2 hours Email the distributor to confirm the cost and delivery date: 2 hours	The order confirmation time for simulation 1-1 (T_{oc}), 2-1 (T_{oc}), 3-1 (T_{oc}) and 4-1 (T_{oc}), simulation 1-2 (T_{oc}), 2-2 (T_{oc}), 3-2 (T_{oc}), and 4-2 (T_{oc}), simulation 1-3 (T_{oc}), 2-3 (T_{oc}), 3-3 (T_{oc}), and 4-3 (T_{oc}) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum order confirmation time, the sum of squares, mean difference, the correlation coefficient between e-business level and order confirmation time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be performed to test the null hypothesis 3.

		Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for a response: 12 hours **Simulation 3-1 (T_{oc})**: 5.6 hours, includes: Check raw materials inventory: 0.1 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for a response: 4 hours **Simulation 4-1 (T_{oc})**: 0.75 hours, includes: Check raw materials inventory: 0.05 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for a response: 0.1 hours **Simulation 1-2 (T_{oc})**: 28.2-75.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours The marketing department gets a response: 0.1 hours Call S3 to get trims price and delivery date: 5-24 hours	Null hypothesis 3: The advancement of e-business utilisation level has no impact on the average time taken to confirm the order.

		(response rate from S3: 7/10, no response, call back every 0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) **Simulation 2-2 (T_{oc})**: 21.2 hours, includes: Check raw materials inventory: sufficient: 0.2 hours Email S3: trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for a response: 12 hours **Simulation 3-2 (T_{oc})**: 7.6 hours, includes: Check raw materials inventory: 0.1 hours Enquire S3 about trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours	

		Give the retailer offer and wait for a response: 4 hours **Simulation 4-2 (T_{oc})**: 0.85 hours, includes: Check raw materials inventory: 0.05 hours Enquire S3 about trims price and delivery date: 0.1 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for response 0.1 hours **Simulation 1-3 (T_{oc})**: 38.2-123.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours The marketing department gets a response: 0.1 hours Call S1 to get PU leather price and delivery date: 5-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours) Call S2 to get interfacing price and delivery date: 5-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours) Call S3 to get trims price and delivery date: 5-24 hours (response rate from S3: 7/10, no response, call back every	

		0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) **Simulation 2-3 (T_{oc})**: 31.2 hours, includes: Check raw materials inventory: sufficient: 0.2 hours Email S1 to inquire PU leather price and delivery date: 5 hours Email S2 to inquire interfacing price and delivery date: 5 hours Email S3 to inquire trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for a response: 12 hours **Simulation 3-3 (T_{oc})**: 11.6 hours, includes: Check raw materials inventory: sufficient: 0.1 hours Enquire S1 about PU leather price and delivery date: 2 hours	

		Enquire S2 about interfacing price and delivery date: 2 hours Enquire S3 about trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for a response: 4 hours **Simulation 4-3 (T_{oc})**: 1.05 hours, includes: Check raw materials inventory: 0.05 hours Enquire S1 about PU leather price and delivery date: 0.1 hours Enquire S2 about interfacing price and delivery date: 0.1 hours Enquire S3 about trims price and delivery date: 0.1 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours	
P4. The advancement of e-business utilisation level influences the raw materials purchase time; when the e-business level improves, the time taken	Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (see Figure 5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	**T_{rp}**: raw materials purchase time (from the manufacturer places the order to it receives raw materials from suppliers) **Simulation 1-2 (T_{rp})**: 170-192 hours, includes: Call S3 to purchase trims: 2-24 hours (response rate from	The raw materials purchase time for simulation 1-2 (T_{rp}), 2-2 (T_{rp}), 3-2 (T_{rp}), and 4-2 (T_{rp}), simulation 1-3 (T_{rp}), 2-3 (T_{rp}), 3-3 (T_{rp}), and 4-3 (T_{rp}) will be generated: the

to purchase raw materials decreases.		S3: 7/10, no response, call back every 0.5 hours) Make production plan: 48 hours Receive trims: 120 hours **Simulation 2-2 (T_{rp})**: 148 hours, includes: Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receives trims: 120 hours **Simulation 3-2 (T_{rp})**: 124 hours, includes: Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive trims: 120 hours **Simulation 4-2 (T_{rp})**: 122.1 hours, includes: Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours Receive trims: 120 hours **Simulation 1-3 (T_{rp})**: 174-240 hours, includes: Call S1 to purchase PU leather: 2-24 hours (response rate from S1: 7/10, no response, call back every 0.5 hours) Call S2 to purchase interfacing: 2-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours)	meantime of each scenario and the standard deviation, minimum and maximum raw materials purchase time, sum of squares, mean difference, the correlation coefficient between e-business level and raw materials purchase time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be performed to test the null hypothesis 4. Null hypothesis 4: The advancement of e-business utilisation level has no impact on the average time taken to purchase raw material.

		Call S3 to purchase trims: 2-24 hours (response rate from S3: 7/10, no response, call back every 0.5 hours) Make production plan: 48 hours Receive raw materials: 120 hours **Simulation 2-3 (T_{rp})**: 156 hours, includes: Email S1 to purchase PU leather: 4 hours Email S2 to purchase interfacing: 4 hours Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receive raw materials: 120 hours **Simulation 3-3 (T_{rp})**: 128 hours, includes: Infirm S1 to purchase PU leather: 2 hours Inform S2 to purchase interfacing: 2 hours Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive raw materials: 120 hours **Simulation 4-3 (T_{rp})**: 122.3 hours, includes: Inform S1 to purchase PU leather: 0.1 hours Inform S2 to purchase interfacing: 0.1 hours Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours	

		Receive raw materials: 120 hours	
P5. The advancement of e-business utilisation level influences the order production time; when the e-business level improves, the time taken to produce the order decreases.	Simulation 1-1 (see Figure 5.12), 2-1 (see Figure 5.15), 3-1 (see Figure 5.18), 4-1 (see Figure 5.21) Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (see Figure 5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	$\mathbf{T_{op}}$**:** order production time (from the manufacturer receives the order to it completes order production) **Simulation 1-1 (Top)**: 191.2-219.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours The marketing department gets a response: 0.1 hours Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Make production plan: 48 hours Produce jackets: 120 hours **Simulation 2-1 (Top)**: 160.2 hours, includes: Check raw materials inventory: 0.2 hours Email the distributor to confirm the cost and delivery date: 2	The order production time for simulation 1-1 (T_{op}), 2-1 (T_{op}), 3-1 (T_{op}), and 4-1 (T_{op}), simulation 1-2 (T_{op}), 2-2 (T_{op}), 3-2 (T_{op}), and 4-2 (T_{op}), simulation 1-3 (T_{op}), 2-3 (T_{op}), 3-3 (T_{op}), and 4-3 (T_{op}) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum order production time, the sum of squares, mean difference, the correlation coefficient between e-business level and order production time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be performed to test the null hypothesis 5. Null hypothesis 5: The advancement of e-business

		hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for a response: 12 hours Make production plan: 24 hours Produce jackets: 120 hours **Simulation 3-1 (Top)**: 127.6 hours, includes: Check raw materials inventory: 0.1 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for a response: 4 hours Make production plan: 2 hours Produce jackets: 120 hours **Simulation 4-1 (Top)**: 122.75 hours, includes: Check raw materials inventory: 0.05 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Make production plan: 2 hours Produce jackets: 120 hours	utilisation level has no impact on the average time taken to produce the order.

		Simulation 1-2 (Top): 318.2-390.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours The marketing department gets a response: 0.1 hours Call S3 to get trims price and delivery date: 5-24 hours (response rate from S3: 7/10, no response, call back every 0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Call S3 to purchase trims: 2-24 hours Make production plan: 48 hours Receive trims: 120 hours Call the production department: 0-3 hours (response rate: 7/10, no response, call back every 0.5 hours) Produce jackets: 120 hours **Simulation 2-2 (Top)**: 289.2 hours, includes:	

		Check raw materials inventory: 0.2 hours Email S3 to get trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for a response: 12 hours Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receives trims: 120 hours Produce jackets: 120 hours **Simulation 3-2 (Top)**: 251.6 hours, includes: Check raw materials inventory: 0.1 hours Enquire S3 about trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for a response: 4 hours Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive trims: 120 hours Produce jackets: 120 hours	

		Simulation 4-2 (Top): 242.95 hours, includes: Check raw materials inventory: 0.05 hours Enquire S3: trims price and delivery date: 0.1 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours Receive trims: 120 hours Produce jackets: 120 hours **Simulation 1-3 (Top)**: 332.2-486.2 hours, includes: Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours Marketing department gets a response: 0.1 hours Call S1 to get PU leather price and delivery date: 5-24 hours (response rate from S1: 7/10, no response, call back every 0.5 hours) Call S2 to get interfacing price and delivery date: 5-24 hours	

		(response rate from S2: 7/10, no response, call back every 0.5 hours) Call S3 to get trims price and delivery date: 5-24 hours (response rate from S3: 7/10, no response, call back every 0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for a response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Call S1 to purchase PU leather: 2-24 hours (The likelihood that S1 is available: 7 times out of 10. If none is available, the marketing department will call every 0.5 hours) Call S2 to purchase interfacing: 2-24 hours (The likelihood that S2 is available: 7 times out of 10. If none is available, the marketing department will call every 0.5 hours) Call S3 to purchase trims: 2-24 hours (The likelihood that S3 is available: 7 times out of 10. If none is available, the marketing department will call every 0.5 hours) Make production plan: 48 hours Receive raw materials: 120 hours Call the production department: 0-3 hours (response rate:	

		7/10, no response, call back every 0.5 hours) Produce jackets: 120 hours **Simulation 2-3 (Top)**: 307.2 hours, includes: Check raw materials inventory: sufficient: 0.2 hours Email S1 to inquire PU leather price and delivery date: 5 hours Email S2 to inquire interfacing price and delivery date: 5 hours Email S3 to inquire trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for the response: 12 hours Email S1 to purchase PU leather: 4 hours Email S2 to purchase interfacing: 4 hours Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receive raw materials 120 hours Produce jackets 120 hours **Simulation 3-3 (Top)**: 259.6 hours, includes: Check raw materials inventory: sufficient: 0.1 hours Enquire S1 to inquire PU leather price and delivery date: 2	

		hours Enquire S2 to inquire interfacing price and delivery date: 2 hours Enquire S3 to inquire trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 4 hours Inform S1 to purchase PU leather: 2 hours Inform S2 to purchase interfacing: 2 hours Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive raw materials: 120 hours Produce jackets: 120 hours **Simulation 4-3 (Top)**: 243.35 hours, includes: Check raw materials inventory: 0.05 hours Enquire S1 about PU leather price and delivery date: 0.1 hours Enquire S2 about interfacing price and delivery date: 0.1 hours Enquire S3 about trims price and delivery date 0.1: hours Ask the distributor to confirm the cost and delivery date: 0.1	

		hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Inform S1 to purchase PU leather: 0.1 hours Inform S2 to purchase interfacing: 0.1 hours Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours Receive raw materials: 120 hours Produce jackets: 120 hours	
P6. The advancement of e-business utilisation level influences the order delivery time; when the e-business level improves, the time taken to deliver the order decreases.	Simulation 1-1 (see Figure 5.12), 2-1 (see Figure 5.15), 3-1 (see Figure 5.18), 4-1 (see Figure 5.21) Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (see Figure 5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	**T_{od}**: order delivery time (from the manufacturer informs the distributor to deliver jackets to the retailer receives ordered jackets) **Simulation 1-1 (T_{od}), 1-2 (T_{od}), and 1-3 (T_{od})**: 242-264 hours, involves: Call the distributor to arrange the delivery: 2-24 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Deliver to the retailer: 240 hours **Simulation 2-1 (T_{od})**, **2-2 (T_{od}), and 2-3 (T_{od}):** 244 hours, includes:	The order delivery time for simulation 1-1 (T_{od}), 2-1 (T_{od}), 3-1 (T_{od}), and 4-1 (T_{od}) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum order delivery time, the sum of squares, mean difference, the correlation coefficient between e-business level and order delivery time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be

		Email the distributor to arrange the delivery: 4 hours Deliver to the retailer: 240 hours **Simulation 3-1 (T_{od})**, **3-2 (T_{od}), and 3-3 (T_{od}):** 241 hours, includes: Inform the distributor to arrange the delivery: 1 hour Deliver to the retailer: 240 hours **Simulation 4-1 (T_{od})**, **4-2 (T_{od}), and 4-3 (T_{od}):** 240.1 hours, includes: Inform the distributor to arrange the delivery: 0.1 hours Deliver to the retailer: 240 hours	performed to test the null hypothesis 6. Null hypothesis 6: The advancement of e-business utilisation level has no impact on the time taken to deliver the order.
P7. The advancement of e-business utilisation level influences the whole order fulfilment time; when the e-business level improves, the time taken to fulfil the order decreases.	Simulation 1-1 (see Figure 5.12), 2-1 (see Figure 5.15), 3-1 (see Figure 5.18), 4-1 (see Figure 5.21) Simulation 1-2 (see Figure 5.13), 2-2 (see Figure 5.16), 3-2 (see Figure 5.19), 4-2 (see Figure 5.22) Simulation 1-3 (see Figure 5.14), 2-3 (see Figure 5.17), 3-3 (see Figure 5.20), 4-3 (see Figure 5.23)	**L**: Order fulfilment time (from the start to the end, e.g., lead time) **Simulation 1-1 (L)**: 433.3-483.3 hours, includes: Receive order: 0.1 hours Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours The marketing department gets the response: 0.1 hours Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back	The order fulfilment time for simulation 1-1 (L), 2-1 (L), 3-1 (L), and 4-1 (L), simulation 1-2 (L), 2-2 (L), 3-2 (L), and 4-2 (L), simulation 1-3 (L), 2-3 (L), 3-3 (L), and 4-3 (L) will be generated: the meantime of each scenario and the standard deviation, minimum and maximum order fulfilment time, the

		every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for the response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Make production plan: 48 hours Produce jackets: 120 hours Call the distributor to arrange the delivery: 2-24 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Deliver to the retailer: 240 hours **Simulation 2-1 (L)**: 404.3 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.2 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for the response: 12 hours Make production plan: 24 hours Produce jackets: 120 hours Email the distributor to arrange the delivery: 4 hours Deliver to the retailer: 240 hours **Simulation 3-1 (L)**: 368.7 hours, includes: Receive order: 0.1 hours Check raw materials inventory: sufficient: 0.1 hours Ask the distributor to confirm the cost and delivery date: 1	sum of squares, mean difference, the correlation coefficient between e-business level and order fulfilment time, etc. ANOVA analysis, Boxplots, and Spearman's rank correlation coefficient will be performed to test the null hypothesis 7. Null hypothesis 7: The level of e-business utilisation has no impact on the average time taken to fulfil the order.

		hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 4 hours Make production plan: 2 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 1 hour Deliver to the retailer: 240 hours **Simulation 4-1 (L)**:362.95 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.05 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Make production plan: 2 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 0.1 hours Deliver to the retailer: 240 hours **Simulation 1-2 (L)**: 560.3-654.3 hours, includes: Receive order: 0.1 hours Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours Marketing department gets the response: 0.1 hours	

		Call S3 to get trims price and delivery date: 5-24 hours (response rate from S3: 7/10, no answer, call back every 0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for the response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Call S3 to purchase trims: 2-24 hours Make production plan: 48 hours Receive trims: 120 hours Call the production department: 0-3 hours (The likelihood that the production department is available: 7 times out of 10. If none is available, warehouse will call every 0.5 hours) Produce jackets: 120 hours Call the distributor to arrange the delivery: 2-24 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Deliver to the retailer: 240 hours **Simulation 2-2 (L)**: 533.3 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.2 hours Email S3 to inquire trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2	

		hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for the response: 12 hours Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receives trims: 120 hours Produce jackets: 120 hours Email the distributor to arrange the delivery: 4 hours Deliver to the retailer: 240 hours **Simulation 3-2 (L)**: 492.7 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.1 hours Enquire S3 about trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 4 hours Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive trims: 120 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 1 hour Deliver to the retailer: 240 hours **Simulation 4-2 (L)**: 483.15 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.05 hours	

		Enquire S3 about trims price and delivery date: 0.1 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours Receive trims: 120 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 0.1 hours Deliver to the retailer: 240 hours **Simulation 1-3 (L)**: 574.3-750.3 hours, includes: Receive order: 0.1 hours Call warehouse to check raw materials inventory: 0-3 hours (response rate from warehouse: 7/10, no response, call back every 0.5 hours) Check the paper documents: 0.1 hours Marketing department gets the response: 0.1 hours Call S1 to get PU leather price and delivery date: 5-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours) Call S2 to get interfacing price and delivery date: 5-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours) Call S3 to get trims price and delivery date: 5-24 hours	

		(response rate from S3: 7/10, no response, call back every 0.5 hours) Call the distributor to confirm the cost and delivery date: 1-4 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Calculate cost, price, and delivery date: 20 hours Give the retailer offer and wait for the response: 2-24 hours (response rate from R: 7/10, no response, call back every 0.5 hours) Call S1 to purchase PU leather: 2-24 hours (response rate from S1: 7/10, no response, call back every 0.5 hours) Call S2 to purchase interfacing: 2-24 hours (response rate from S2: 7/10, no response, call back every 0.5 hours s) Call S3 to purchase trims: 2-24 hours (response rate from S3: 7/10, no response, call back every 0.5 hours) Make production plan: 48 hours Receive raw materials: 120 hours Call the production department: 0-3 hours (response rate: 7/10, no response, call back every 0.5 hours) Produce jackets: 120 hours Call the distributor to arrange the delivery: 2-24 hours (response rate from D: 7/10, no response, call back every 0.5 hours) Deliver to the retailer: 240 hours **Simulation 2-3 (L)**: 551.3 hours, includes: Receive order: 0.1 hours	

		Check raw materials inventory: sufficient: 0.2 hours Email S1 to inquire PU leather price and delivery date: 5 hours Email S2 to inquire interfacing price and delivery date: 5 hours Email S3 to inquire trims price and delivery date: 5 hours Email the distributor to confirm the cost and delivery date: 2 hours Calculate cost, price, and delivery date: 2 hours Give the retailer offer and wait for the response: 12 hours Email S1 to purchase PU leather: 4 hours Email S2 to purchase interfacing: 4 hours Email S3 to purchase trims: 4 hours Make production plan: 24 hours Receive raw materials: 120 hours Produce jackets: 120 hours Email the distributor to arrange the delivery: 4 hours Deliver to the retailer: 240 hours **Simulation 3-3 (L)**: 500.7 hours, includes: Receive order: 0.1 hours Check raw materials inventory: sufficient: 0.1 hours Enquire S1 about PU leather price and delivery date: 2 hours Enquire S2 about interfacing price and delivery date: 2 hours Enquire S3 about trims price and delivery date: 2 hours Ask the distributor to confirm the cost and delivery date: 1 hour	

		Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 4 hours Inform S1 to purchase PU leather: 2 hours Inform S2 to purchase interfacing: 2 hours Inform S3 to purchase trims: 2 hours Make production plan: 2 hours Receive raw materials: 120 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 1 hour Deliver to the retailer: 240 hours **Simulation 4-3 (L)**: 483.55 hours, includes: Receive order: 0.1 hours Check raw materials inventory: 0.05 hours Enquire S1 about PU leather price and delivery date: 0.1 hours Enquire S2 about interfacing price and delivery date: 0.1 hours Enquire S3 about trims price and delivery date: 0.1 hours Ask the distributor to confirm the cost and delivery date: 0.1 hours Calculate cost, price, and delivery date: 0.5 hours Give the retailer offer and wait for the response: 0.1 hours Inform S1 to purchase PU leather: 0.1 hours Inform S2 to purchase interfacing: 0.1 hours Inform S3 to purchase trims: 0.1 hours Make production plan: 2 hours	

		Receive raw materials: 120 hours Produce jackets: 120 hours Inform the distributor to arrange the delivery: 0.1 hours Deliver to the retailer: 240 hours	

The study will conduct ANOVA (Analysis of Variance), Boxplots, and Spearman’s rank correlation coefficient to analyse simulation results. The analyses will test if there is a statistically significant difference between e-business levels and the time taken to fulfil the order, and test the null hypotheses 1, 2, 3, 4, 5, 6 and 7 against the alternative propositions P1, P2, P3, P4, P5, P6 and P7.

As a small textile & apparel manufacturer and a medium textile & apparel manufacturer have different production capabilities, they receive different amounts of orders each year.. Based on six managers’ suggestions, the research designs that a small manufacturer receives 50 orders each year, and a medium manufacturer receives 200 orders each year. The simulation runs 50 times for a small manufacturer and runs 200 times for a medium manufacturer. ANOVA produces a p-value; if p-value<ɑ, the null hypotheses will be rejected. Otherwise, if p-value>ɑ, then the hypothesis (proposition) will be rejected. The α is the significance level; there are different values of α that can be taken, most authors use 5%, and a few other authors use 1%—reducing the α value from 0.05 to 0.01 means reducing a false positive chance. The smaller the value, the more likely significant results can be found. The lower the significance level, the more the data must diverge from the null hypothesis. Therefore, the 1% level is more conservative than the 5% level. For each case, the research will identify the p-value and consider different levels of α to identify “how significant” the results are.

ANOVA is carried out to analyse the data but not the T-test, as the T-test can be used to compare the difference between two independent sample means for a single dependent variable. Still, ANOVA can be used to determine whether samples from more than two groups come from populations with equal means simultaneously. ANOVA is the equivalent of running multiple t-tests. Table 5.5 shows the simulation results used to test seven null hypotheses by ANOVA analysis.

Table 5.5 Simulation results used to test the null hypothesis by ANOVA analysis

To test null hypothesis 1: Average inventory check time (T_{ic})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Sufficient raw materials	Simulation 1-1 (T_{ic})	Simulation 2-1 (T_{ic})	Simulation 3-1 (T_{ic})	Simulation 4-1 (T_{ic})
To test null hypothesis 2: Average raw materials inquiry time (T_{ri})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Partial raw materials	Simulation 1-2 (T_{ri})	Simulation 2-2 (T_{ri})	Simulation 3-2 (T_{ri})	Simulation 4-2 (T_{ri})
No raw materials	Simulation 1-3 (T_{ri})	Simulation 2-3 (T_{ri})	Simulation 3-3 (T_{ri})	Simulation 4-3 (T_{ri})
To test null hypothesis 3: Average order confirmation time (T_{oc})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Sufficient raw materials	Simulation 1-1 (T_{oc})	Simulation 2-1 (T_{oc})	Simulation 3-1 (T_{oc})	Simulation 4-1 (T_{oc})
Partial raw materials	Simulation 1-2 (T_{oc})	Simulation 2-2 (T_{oc})	Simulation 3-2 (T_{oc})	Simulation 4-2 (T_{oc})
No raw materials	Simulation 1-3 (T_{oc})	Simulation 2-3 (T_{oc})	Simulation 3-3 (T_{oc})	Simulation 4-3 (T_{oc})
To test null hypothesis 4: Average raw materials purchase time (T_{rp})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Partial raw materials	Simulation 1-2 (T_{rp})	Simulation 2-2 (T_{rp})	Simulation 3-2 (T_{rp})	Simulation 4-2 (T_{rp})
No raw materials	Simulation 1-3 (T_{rp})	Simulation 2-3 (T_{rp})	Simulation 3-3 (T_{rp})	Simulation 4-3 (T_{rp})
To test null hypothesis 5: Average order production time (T_{op})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**

Sufficient raw materials	Simulation 1-1 (T_{op})	Simulation 2-1 (T_{op})	Simulation 3-1 (T_{op})	Simulation 4-1 (T_{op})
Partial raw materials	Simulation 1-2 (T_{op})	Simulation 2-2 (T_{op})	Simulation 3-2 (T_{op})	Simulation 4-2 (T_{op})
No raw materials	Simulation 1-3 (T_{op})	Simulation 2-3 (T_{op})	Simulation 3-3 (T_{op})	Simulation 4-3 (T_{op})
To test null hypothesis 6: Average order delivery time (T_{od})				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Sufficient raw materials	Simulation 1-1 (T_{od})	Simulation 2-1 (T_{od})	Simulation 3-1 (T_{od})	Simulation 4-1 (T_{od})
To test null hypothesis 7: Average order fulfilment time (L)				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Sufficient raw material	Simulation 1-1 (L)	Simulation 2-1 (L)	Simulation 3-1 (L)	Simulation 4-1 (L)
Partial raw material	Simulation 1-2 (L)	Simulation 2-2 (L)	Simulation 3-2 (L)	Simulation 4-2 (L)
No raw materials	Simulation 1-3 (L)	Simulation 2-3 (L)	Simulation 3-3 (L)	Simulation 4-3 (L)

Boxplots analysis is used to illustrate the difference between e-business levels under three situations graphically. ANOVA analysis result can be used to determine if there is a statistically significant difference between e-business levels and the time taken to fulfil the order, but it cannot confirm if there is a positive correlation or negative correlation between the e-business level and orde fulfilment time, so Spearman's rank correlation coefficient is used to explore the relationship between the e-business level and order fulfilment time under three different situations: sufficient raw materials, partial raw materials, and no raw materials following produce-to-order situation, with the aim of testing if the average time of different steps to fulfil the order decreases when SMEs use more advanced e-business level. The research uses Spearman's rank correlation coefficient but no other correlation methods such as Pearson correlation because average time is a continuous variable and level of e-business is a categorical variable. Pearson coefficient measures the linear relationship between the two variables, i.e., how a straight line can describe these two variables' relationship. Spearman's rank correlation coefficient is a nonparametric measure to describe statistical dependence between two sets of variables. It assesses how the relationship between these two sets of variables can be described using a monotonic function. Many researchers use Spearman's rank correlation coefficient to analyse supply chain management. For example, Jolly-Desodt *et al.* (2006) use it to classify the interactions between performance measures in the textile & apparel supply chain. Renko (2011) uses Spearman's rank-correlation to study the supply chain vertical collaboration. Ibrahim and Ogunyemi (2012) use Spearman's rank correlation coefficient to explore the effect of relationships and information sharing in the supply chain.

Spearman's rank correlation coefficient is a valuable and important method to determine the relationship between ranks obtained in different ways (Chamodrakas *et al.,* 2011). Spearman's rank correlation coefficient is designed by Raju and Kumar (1999). It is a statistical measure to compare the monotonic relationship between paired data. The correlation coefficient r indicates the strength of the relationship between two variables' relative movements; r is constrained as $-1 \leq r \leq 1$. If $r>1$ or <-1, then there is an error in the correlation measurement.

Perfect positive correlation: +1. If r is near +1, there is a positive correlation between e-business level and average order fulfilment time. When the e-business level improves from no e-business to virtual e-business, the average time taken to fulfil the order also increases.

Perfect negative correlation: -1. If r is near -1, there is a negative correlation between e-business level and average order fulfilment time. When the e-business level improves from no e-business to virtual e-business, the average time taken to fulfil the order decreases.

No correlation: 0.0. If r is near 0, there is no correlation between e-business level and average order fulfilment time. Table 5.6 shows the simulation results used in Spearman's rank correlation coefficient analysis.

Table 5.6 The simulation results used in Spearman's rank correlation coefficient analysis

Sufficient raw materials				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Average inventory check time	Simulation 1-1	Simulation 2-1	Simulation 3-1	Simulation 4-1
Average order confirmation time	Simulation 1-1	Simulation 2-1	Simulation 3-1	Simulation 4-1
Average order production time	Simulation 1-1	Simulation 2-1	Simulation 3-1	Simulation 4-1
Average order delivery time	Simulation 1-1	Simulation 2-1	Simulation 3-1	Simulation 4-1
Average order fulfilment time	Simulation 1-1	Simulation 2-1	Simulation 3-1	Simulation 4-1
Partial raw materials				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**
Average raw materials inquiry time	Simulation 1-2	Simulation 2-2	Simulation 3-2	Simulation 4-2
Average order confirmation time	Simulation 1-2	Simulation 2-2	Simulation 3-2	Simulation 4-2
Average raw materials purchase time	Simulation 1-2	Simulation 2-2	Simulation 3-2	Simulation 4-2
Average order production time	Simulation 1-2	Simulation 2-2	Simulation 3-2	Simulation 4-2
Average order fulfilment time	Simulation 1-2	Simulation 2-2	Simulation 3-2	Simulation 4-2
No raw materials				
	No e-business	**Partial e-business**	**Comprehensive e-business**	**Virtual e-business**

Average raw materials inquiry time	Simulation 1-3	Simulation 2-3	Simulation 3-3	Simulation 4-3
Average order confirmation time	Simulation 1-3	Simulation 2-3	Simulation 3-3	Simulation 4-3
Average raw materials purchase time	Simulation 1-3	Simulation 2-3	Simulation 3-3	Simulation 4-3
Average order production time	Simulation 1-3	Simulation 2-3	Simulation 3-3	Simulation 4-3
Average order fulfilment time	Simulation 1-3	Simulation 2-3	Simulation 3-3	Simulation 4-3

5.4 Model Implementation

According to Kendall (1998), researchers should implement the model when the ABM simulation is designed. This study applies the conceptual model to a multi-agent based textile & apparel supply chain to answer the research objectives and test propositions. There are one manufacturer, three raw material suppliers, one distributor, and one retailer in this simulation. In the dynamic supply chain, coordinate behaviour is essential, and the synergy among agents is also important. Therefore, the key point of ABM in the supply chain is that agents can coordinate and complete the task. All nodes in the supply chain must be coordinated closely to carry on business processes. In the architecture, these coordinate behaviours are carried out by messages; these messages involve all data and information flow in the whole supply chain.

Agents are put into an implementation platform to interact with other agents after computer programmes code them. Excellent literature summaries compare and contrast various ABM platforms (Railsback *et al.,* 2006; Smith *et al.*, 2008). Nevertheless, these platforms are somewhat dated because of new software versions. The replacement of software guaranteed a fresh look at the current state of technology development. Given the previous literature reviews of ABM utilisation in supply chain management, this research considers the following platforms: JADE, EMERALD, Swarm and Repast. These four platforms are open sources, which means accessible for use and source code inspection. They are based on an object-oriented language; usually, Java and the programming of these platforms is fit for ABM.

JADE is a software framework based on Java language; it uses a middle-ware following the FIPA regulations and graphical tools to support deployment and debug phrases to simplify ABM. Details of JADE can be found on its website (http://jade.tilab.com). JADE was initially designed by the Research & Development department of Telecom Italia s.p.a. Nowadays, JADE has become an open-source and a community project under the LGPL license and probably the most widespread agent-oriented middleware. As an entirely distributed system, its flexible infrastructures extend add-on modules easily and accelerate the development of complete agent based applications by providing the runtime environment to implement the life-cycle support features which agent needs.

EMERALD is an implementation platform, and agents can exchange positions with other agents and do not need to follow the same rule paradigm. It is built on JADE and is fully FIPA compliant. Kravari *et al.* (2012) use Emerald to study cross-community interoperations. EMERALD supports many logics and languages, for example, Java, JESS, RDF, XML, etc. In the multi-agent systems, EMERALD is the only platform to support trust and reputation mechanisms to study efficient decision-making and trustworthiness (Kravari and Bassiliades, 2015). It is used to discover agents' behaviours on behalf of their clients, such as transactions.

Swarm is one of the oldest agent based modelling platforms. It establishes many foundational concepts in ABM, and several of the new platforms are based on it, such as Repast. Nevertheless, Swarm will not be considered in this research regarding the last version's age and the more recent platform with more friendly environments.

Repast Suite (Recursive Porous Agent Simulation Toolkit) is the other free, advanced, and open-source ABM and simulation toolkit. It is created by the University of Chicago’s Social Science Research division. It is based upon Swarm but implemented by Java language. Repast has several versions, and the latest version is Repast Simphony 2.8.0, which is released in 2020. Details of Repast can be found on its website (https://repast.github.io/). Repast is one of the most used frameworks to build, manage and analyse ABM simulations. Meanwhile, it provides many built-in adaptive features and multiple implementations in several languages.

Kravari and Bassiliades (2015) survey agent platforms to summarise different characteristics of available agent platforms, including the above four platforms. As an industry-driven platform, the survey indicates that JADE is still the most popular full FIPA-compliant agent toolkit in the academic and industrial communities. Moreover, it is written in Java programming language and processes the ABM. The survey indicates that JADE could be more suitable and efficient for the economics/e-commerce application domain than other platforms.

Based on the architecture and agents developed before, this research uses the JADE platform-based simulation programme to study the communication and coordination among agents and generate the data. The agent platform can be allocated across computers, and the deployment can be managed by a remote graphical user interface (GUI). If necessary, the deployment can be changed at run-time by transfer agents from one computer to another. What is worthy of mention is the significant advantages of the JADE used in this study. The programmes are written entirely in the Java language. Java language provides a rich set of programming abstractions so developers can design multi-agent simulations with relatively minimal agent theory skills. Java is suitable for modelling different entities as an object-oriented computer programming language. Details of the Java characteristics can be read in various textbooks (Cosmina, 2018; Juneau, 2017; Parsons, 2020). The fundamental features of the object-oriented paradigms which are particularly suited to ABM are embedded in each agent. For example, one agent can be seen as a class object, and it has unique attributes such as cost variables, product catalogues, inventory level, etc. The agent follows predefined behavioural regulations to take action. These regulations involve what actions to take when receiving a new customer demand, deciding the order level, arranging the production, etc. These behavioural regulations are considered as methods or functions in computer programming terms. The coded model runs in a specific scope or domain, which is

There is one product (jacket) in the system;

There are six agents, one manufacturer, three material suppliers, one retailer and one distributor. More agents can be added into the system in the future implementation;

Raw material suppliers are all equally distanced from the manufacturer, so the transport time is the same;

These assumptions can be relaxed in future simulations.

Chapter 6 Results and Analysis

This chapter implements the model described in the previous chapter and analyses the simulation results. The chapter is organised in two parts: section 6.1 describes the simulation outcomes, and section 6.2 gives difference analysis and correlation analysis based on the ANOVA, Boxplots, and Spearman's rank-correlation in SPSS, intending to test the research propositions and to achieve research objectives.

6.1 Simulation Outcomes

The research uses different simulation results to test seven propositions. All key parameters are shown in Table 5.4. All steps and the original value of parameters are designed based on the discussion with six managers from Chinese small and medium size textile & apparel manufacturers. The AMB simulations are run to test seven propositions; all simulation results are listed in the file "ABM Data (9439748)". 15 runs for each e-business level are generated in simulations, 50 times for a small manufacturer and 200 times for a medium manufacturer in each run to represent the order received each year for small and medium manufacturers. The research uses Run 7 of each simulation result to analyse.

Proposition 1: The advancement of e-business utilisation level influences the inventory check time; when the e-business level improves, the time taken to check inventory decreases.

This study considers two situations to test P1: (1) average inventory check time (sufficient raw materials) for a small manufacturer and (2) average inventory check time (sufficient raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6). The data are only generated for one situation for initial comparison because the parameters are the same for no raw materials, partial raw materials, and sufficient raw materials; thus, the results would be similar for any supplier.

Table 6.1 is the example simulation results of inventory check time for a small manufacturer with sufficient raw materials.

Table 6.1 ABM simulation results (sufficient raw materials for a small manufacturer)

Inventory Check time **Simulation Set 1: Sufficient raw materials for a small manufacturer**			
No e-business (simulation 1-1)	Partial e-business (simulation 2-1)	Comprehensive e-business (simulation 3-1)	Virtual e-business (simulation 4-1)
Hrs	Hrs	Hrs	Hrs
1.07	0.45	0.08	0.04
0.77	0.31	0.09	0.05
0.58	0.41	0.10	0.06
0.67	0.34	0.09	0.04
0.79	0.32	0.10	0.06
1.01	0.43	0.09	0.05
0.64	0.29	0.11	0.05
0.79	0.32	0.10	0.06
1.23	0.46	0.09	0.05
0.74	0.33	0.10	0.02
0.79	0.28	0.10	0.05
0.87	0.40	0.10	0.06
1.11	0.44	0.09	0.05
0.72	0.30	0.09	0.04
0.57	0.42	0.09	0.06
0.66	0.35	0.11	0.07
0.73	0.54	0.11	0.07
1.36	0.28	0.09	0.04
0.79	0.62	0.08	0.05
0.63	0.44	0.09	0.07
0.97	0.41	0.09	0.06
0.74	0.32	0.11	0.03
0.99	0.30	0.09	0.04

No e-business (simulation 1-1)	Partial e-business (simulation 2-1)	Comprehensive e-business (simulation 3-1)	Virtual e-business (simulation 4-1)
Hrs	Hrs	Hrs	Hrs
0.59	0.42	0.11	0.06
0.57	0.58	0.08	0.04
0.74	0.30	0.08	0.03
1.00	0.42	0.11	0.05
0.59	0.29	0.09	0.04
0.78	0.64	0.09	0.05
1.83	0.33	0.11	0.05
0.68	0.29	0.10	0.04
0.57	0.27	0.09	0.04
0.86	0.38	0.08	0.04
0.77	0.32	0.10	0.06
1.22	0.39	0.10	0.06
0.64	0.30	0.10	0.05
0.86	0.46	0.12	0.04
1.18	0.32	0.09	0.04
0.81	0.35	0.10	0.03
1.05	0.32	0.10	0.04
0.57	0.30	0.09	0.05
1.20	0.31	0.11	0.04
1.68	0.44	0.09	0.05
0.92	0.32	0.09	0.07
0.92	0.33	0.11	0.05
0.55	0.32	0.11	0.04
0.70	0.29	0.12	0.05
1.98	0.37	0.12	0.04
0.69	0.35	0.09	0.06
1.93	0.38	0.09	0.05

In simulation 1-1, inventory check time starts from receiving the order, ends at the marketing department gets a response from the warehouse. When the small manufacturer receives an order (0.1 hours by telephone), it calls the warehouse to check raw materials inventory. The time needed is from 0 hours (if the warehouse answers the phone) to 3 hours (the likelihood that the warehouse replies to the phone is 70%). The marketing department will call every 0.5 hours if none is available until the warehouse answers the phone. When the warehouse answers the phone, it will check the paper documents (0.1 hours by hand) and inform the marketing department there are enough raw materials to produce the order jackets by phone (0.1 hours). At simulation 2-1, inventory check time starts from receiving order (0.1 hours by email), ends at checking raw materials inventory (0.2 hours by intranet). In simulation 3-1, inventory check time starts from receiving order (0.1 hours by ERP) and ends at checking raw materials inventory (0.1 hours by ERP). At simulation 4-1, inventory check time starts from receiving order (0.1 hours by e-business cloud) and ends at checking raw materials inventory (0.05 hours by e-business cloud).

Proposition 2: The advancement of e-business utilisation level influences the raw materials inquiry time; when the e-business level improves, the time taken to inquire about raw materials decreases.

This study considers four situations to test P2: (1) average raw materials inquiry time (partial raw materials) for a small manufacturer; (2) average raw materials inquiry time (partial raw materials) for a medium manufacturer; (3) average raw materials inquiry time (no raw materials) for small manufacture, and (4) average raw materials inquiry time (no raw materials) for medium manufacture (see Table 5.5 and Table 5.6). It is unnecessary to inquire about raw materials under a sufficient raw materials situation; only partial raw materials and no raw materials are considered here.

Proposition 3: The advancement of e-business utilisation level influences the order confirmation time; when the e-business level improves, the time taken to confirm the order decreases.

This study considers six situations to test P3: (1) average order confirmation time (sufficient raw materials) for a small manufacturer; (2) average order confirmation time (sufficient raw materials) for a medium manufacturer; (3) average order confirmation time (partial raw materials) for a small manufacturer; (4) average order confirmation time (partial raw materials) for a medium manufacturer; (5) average order confirmation time (no raw materials) for a small manufacturer, and (6) average order confirmation time (no raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6).

Proposition 4: The advancement of e-business utilisation level influences the raw materials purchase time; when the e-business level improves, the time taken to purchase raw materials decreases.

This study considers four situations to test P4: (1) average raw materials purchase time (partial raw materials) for a small manufacturer; (2) average raw materials purchase time (partial raw materials) for a medium manufacturer; (3) average raw materials purchase time (no raw materials) for a small manufacturer and (4) average raw materials purchase time (no raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6). Because under sufficient raw materials situation, it is unnecessary to purchase raw materials, so the study only considers partial raw materials and no raw materials situation.

Proposition 5: The advancement of e-business utilisation level influences the order production time; when the e-business level improves, the time taken to produce the order decreases.

This study considers six situations to test P5: (1) average order production time (sufficient raw materials) for a small manufacturer; (2) average order production time (sufficient raw materials) for a medium manufacturer; (3) average order production time (partial raw materials) for a small manufacturer; (4) average order production time (partial raw materials) for a medium manufacturer; (5) average order production time (no raw materials) for a small manufacturer, and (6) average order production time (no raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6).

Proposition 6: The advancement of e-business utilisation level influences the order delivery time; when the e-business level improves, the time taken to deliver the order decreases.

This study considers two situations to test P6: (1) average order delivery time (sufficient raw materials) for a small manufacturer; (2) average order delivery time (sufficient raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6). The data are only generated for one situation for initial comparison. The parameters are the same for no raw materials, partial raw materials, and sufficient raw materials situation so that the results would be similar for no supplier or any supplier.

Proposition 7: The advancement of e-business utilisation level influences the whole order fulfilment time; when the e-business level improves, the time taken to fulfil the order decreases.

This study considers six situations To test P7: (1) average order fulfilment time (sufficient raw materials) for a small manufacturer; (2) average order fulfilment time (sufficient raw materials) for a medium manufacturer; (3) average order fulfilment time (partial raw materials) for a small manufacturer; (4) average order fulfilment time (partial raw materials) for a medium manufacturer; (5) average order fulfilment time (no raw materials) for a small manufacturer, and (6) average order fulfilment time (no raw materials) for a medium manufacturer (see Table 5.5 and Table 5.6).

6.2 Data Analysis

The data collected from ABM simulation are analysed by ANOVA, Boxplots and Spearman's rank-correlation in SPSS version 22.0 to explore the relationship between order fulfilment efficiency and the level of e-business utilisation. All analysis results are listed in the file "ABM Data (9439748)".

As Laudon and Laudon (2014) indicate, enterprises can use internet-based technology to accelerate specific activities more effectively to obtain competitive advantages. Zhao and Zhao (2018) also insist that information sharing affects supply chain efficiency and effectiveness. The advancement of e-business utilisation level influences the whole jacket order fulfilment time and supply chain management. A higher level of e-business means less time needed to complete the order and the high efficiency of the supply chain. The analysis results support such current knowledge. Below are some vital analysis results used to illustrate the relationship between e-business level and time taken of different steps to fulfil an apparel order and test the propositions.

6.2.1 The Difference Analysis

ANOVA is carried out to test if there is a statistically significant difference between e-business levels and the time taken to fulfil the order. Table 6.2 shows the analysis results of the meantime and the p-value of 30 experiments under four scenarios.

Table 6.2 ANOVA analysis results: meantime and p-value

Proposition	Simulation	Meantime				F	Sig.
		No e-business	Partial e-business	Comprehensive e-business	Virtual e-business		
P1: inventory check time	Sufficient raw materials for a small manufacturer (N=50)	0.902	0.371	0.097	0. 049	236.256	0.000
	Sufficient raw materials for a medium manufacturer (N=200)	0.936	0.364	0.101	0.050	734.437	0.000
P2: raw materials inquiry time	Partial raw materials for a small manufacturer (N=50)	22.541	11.976	6.607	1.017	351.528	0.000
	Partial raw materials for a medium manufacturer (N=200)	21.948	10.741	6.687	1.071	885.958	0.000
	No raw materials for a small manufacturer (N=50)	59.725	37.006	13.687	1.094	273.054	0.000
	No raw materials for a medium manufacturer (N=200)	60.130	36.295	13.164	1.053	1027.439	0.000
P3: order confirmation time	Sufficient raw materials for a small manufacturer (N=50)	73.768	39.372	14.683	2.678	518.093	0.000
	Sufficient raw materials for a medium manufacturer (N=200)	70.865	37.912	14.133	3.271	1694.465	0.000
	Partial raw materials for a small manufacturer (N=50)	72.074	39.383	23.136	2.618	311.561	0.000

	Partial raw materials for a medium manufacturer (N=200)	68.887	36.353	19.675	1.217	1608.036	0.000
	No raw materials for a small manufacturer (N=50)	129.254	55.148	28.192	1.448	441.488	0.000
	No raw materials for a medium manufacturer (N=200)	121.654	52.350	27.775	1.931	1665.912	0.000
P4: raw materials purchase time	Partial raw materials for a small manufacturer (N=50)	216.124	185.175	160.114	123.884	301.044	0.000
	Partial raw materials for a medium manufacturer (N=200)	211.098	181.111	150.323	120.240	2447.587	0.000
	No raw materials for a small manufacturer (N=50)	246.869	193.959	155.832	111.024	365.614	0.000
	No raw materials for a medium manufacturer (N=200)	239.496	186.617	154.511	109.513	2541.520	0.000
P5: order production time	Sufficient raw materials for a small manufacturer (N=50)	224.719	192.973	128.789	116.092	1520.440	0.000
	Sufficient raw materials for a medium manufacturer (N=200)	240.619	191.556	128.616	122.144	5681.193	0.000
	Partial raw materials for a small manufacturer (N=50)	386.941	318.490	281.236	227.123	781.423	0.000
	Partial raw materials for a medium manufacturer (N=200)	383.461	323.313	279.540	225.957	3362.014	0.000
	No raw materials for a small	436.972	335.464	255.172	226.290	775.771	0.000

	manufacturer (N=50)						
	No raw materials for a medium manufacturer (N=200)	428.652	345.823	250.999	221.651	2605.416	0.000
P6: order delivery time	Sufficient raw materials for a small manufacturer (N=50)	238.247	190.971	128.789	123.364	1340.082	0.000
	Sufficient raw materials for a medium manufacturer (N=200)	269.953	253.711	239.982	235.208	1324.208	0.000
P7: order fulfilment time	Sufficient raw materials for a small manufacturer (N=50)	505.851	456.052	375.261	353.577	548.790	0.000
	Sufficient raw materials for a medium manufacturer (N=200)	504.134	451.549	370.474	352.840	2475.884	0.000
	Partial raw materials for a small manufacturer (N=50)	682.154	587.354	489.930	469.643	438.773	0.000
	Partial raw materials for a medium manufacturer (N=200)	683.466	589.446	496.724	469.385	2047.766	0.000
	No raw materials for a small manufacturer (N=50)	715.714	626.530	553.808	488.067	399.619	0.000
	No raw materials for a medium manufacturer (N=200)	706.825	620.828	555.812	486.827	1369.183	0.000

Meantime (average time)

All 30 analysis results show that no e-business level uses the maximum time to complete different steps to fulfil the order; virtual e-business level uses the minimum time to do the work. For example, to check the inventory (P1), inquire raw materials (P2), confirm the order (P3), purchase raw materials (P4), produce the order (P5), deliver the order (P6), and the whole lead time (P7). When SMEs use more advanced e-business to manage the order, they use less time to complete the order. The result agrees with the literature that e-business reduces the lead time (Benitez *et al.*, 2018) and accelerates order fulfilment efficiency (Chandak and Kumar, 2020).

The analysis result shows that small and medium manufacturers' meantimes are almost the same under different situations. Although they accept different orders in the same period, they use nearly the same time to fulfil the order.

The p-value (calculated probability)

F statistic is a value to determine if the means between groups are significantly different. The F test in the ANOVA test also determines a p-value. The p-value or calculated probability can be used to measure if the analysis result is as extreme as the observed result and test if the null hypothesis is true. The p-values of all 30 simulation analysis results are <0.001 (i.e., $p<0.001$), so there is a statistically significant difference between e-business levels and the time taken of different steps to fulfil the order in the supply chain: inventory check time; raw materials inquiry time; order confirmation time; raw materials purchase time; order production time; order delivery time and order fulfilment time.

LSD (Least Significant Difference): LSD identifies if variables of 4 e-business levels are significantly different and provide the notable characteristics of the comparison between different e-business levels.

Fisher's Least Significant Difference (LSD) method is equivalent to a t-test for independent samples in the groups involved in the comparison. Therefore the LSD test is a set of individual t-tests, and as known, each t-test only involves two groups for comparison, but the LSD test can compare more than two groups at the same time. For example, Macchion *et al.* (2014) use LSD to study the production and supply network of the fashion industry. Table 6.3 contains the results of the LSD test to identify if variables of 4 different e-business levels are significantly different and illustrate the notable characteristics of the comparison between e-business levels.

Table 6.3 LSD analysis results to compare characteristics between e-business levels

Proposition	Simulation	Mean Difference between: No e-business and partial e-business	Mean Difference between: Partial e-business and comprehensive e-business	Mean Difference between: Comprehensive e-business and virtual e-business
P1: inventory check time	Sufficient raw materials for a small manufacturer	0.531	0.274	0.049*
	Sufficient raw materials for a medium manufacturer	0.571	0.264	0.051
P2: raw materials inquiry time	Partial raw materials for a small manufacturer	15.934	5.369	5.589
	Partial raw materials for a medium manufacturer	11.207	4.054	5.616
	No raw materials for a small manufacturer	22.719	23.319	12.593
	No raw materials for a medium manufacturer	23.834	23.131	12.112
P3: order confirmation time	Sufficient raw materials for a small manufacturer	34.396	24.689	12.005
	Sufficient raw materials for a medium manufacturer	32.953	23.779	10.862
	Partial raw materials for a small manufacturer	32.690	16.248	20.518
	Partial raw materials for a medium manufacturer	32.534	16.678	18.458
	No raw materials for a small manufacturer	74.106	26.956	26.744
	No raw materials for a medium manufacturer	69.304	24.575	25.844
P4: raw materials purchase time	Partial raw materials for a small manufacturer	30.949	25.060	36.230
	Partial raw materials for a medium manufacturer	29.987	30.788	30.083
	No raw materials for a small manufacturer	91.038	38.127	44.808
	No raw materials for a medium manufacturer	52.879	32.106	44.998
P5: order production time	Sufficient raw materials for a small manufacturer	31.746	64.184	12.696
	Sufficient raw materials for a medium manufacturer	49.063	62.940	6.472
	Partial raw materials for a small manufacturer	68.451	37.254	54.113
	Partial raw materials for a medium manufacturer	60.147	43.773	53.583

	No raw materials for a small manufacturer	101.508	80.292	28.883
	No raw materials for a medium manufacturer	82.829	94.824	29.348
P6: order delivery time	Sufficient raw materials for a small manufacturer	47.276	62.182	5.425
	Sufficient raw materials for a medium manufacturer	16.242	13.729	4.773
P7: order fulfilment time	Sufficient raw materials for a small manufacturer	49.799	80.790	21.685
	Sufficient raw materials for a medium manufacturer	52.585	81.075	17.634
	Partial raw materials for a small manufacturer	94.801	97.424	20.287
	Partial raw materials for a medium manufacturer	94.020	92.721	27.340
	No raw materials for a small manufacturer	89.184	72.721	65.741
	No raw materials for a medium manufacturer	151.013	65.015	68.986

Note: * indicates significance level is 0.179. The rows highlighted are the ones where the mean difference between no e-business and partial e-business is not the greatest among the three pairs of comparison.

Mean difference measures the absolute difference between the mean value of two different e-business levels and explains how much difference between the averages of the two e-business levels (at a significance level of 0.05). See Table 6.3; under 30 different situations, there are 30 groups of analysis results; 20 groups show that the mean difference between no e-business and partial e-business is the greatest score among the three pairs of comparison. The results show the importance of e-business adoption in order fulfilment and supply chain management. The result agrees with the literature that e-business accelerates order fulfilment and supply chain efficiency (Chandak and Kumar, 2020). Small and medium size textile & apparel manufacturers need to realise the importance of e-business adoption in their order fulfilment and supply chain management (Fatimah *et al.,* 2016; Mazzarol, 2015).

1 group shows that the mean difference between comprehensive and virtual e-business is the greatest score among the three pairs of comparison (P4: raw materials purchase time, under partial raw materials for a small manufacturer). 9 groups show that the mean difference between partial e-business and comprehensive e-business is the greatest score among the three pairs of comparison. (P2: raw materials inquiry time, under no raw materials for a small manufacturer; P4: raw materials purchase time, under partial raw materials for a medium manufacturer; P5: order production time, under sufficient raw materials for a small manufacturer, under sufficient raw materials for a medium manufacturer, under no raw materials for a medium manufacturer; P6: order delivery time, under sufficient raw materials for a small manufacturer; P7: fulfilment time, under sufficient raw materials for a small manufacturer, under sufficient raw materials for a medium manufacturer, and partial raw materials for a small manufacturer). The results indicate that under some situations, compared to other e-business levels, comprehensive e-business improves order fulfilment efficiency best. Current literature does not mention it. So small and medium size textile & apparel manufacturers should consider utilising more advanced e-business techniques to replace most basic e-business technologies. They do not need to pursue the most advanced e-business. They should use ERP or SAP but not just email to manage and exchange information with partners in the supply chain.

Only 1 mean difference in P4: raw materials purchase time (under partial raw materials for a small manufacturer) shows that the mean difference between comprehensive and virtual e-business is more evident than between other e-business levels. There are 30 groups of simulation results; it accounts only for 3.33%, so the effects on the analysis results are tiny.

The study analyses 30 simulation results of significant difference, and 29 show that e-business utilisation level affects the jacket order fulfilment time. When the e-business level improves from no e-business to more advanced e-business, the time taken to complete different order fulfilment steps decreases. Only one analysis result is different in P1: the significant difference between the comprehensive e-business and virtual e-business 0.179 is more significant than the 0.05 level (sufficient raw materials for a small manufacturer). The difference in the average time taken to check inventory between the comprehensive e-business and virtual e-business is not significant for a small manufacturer with sufficient raw materials.

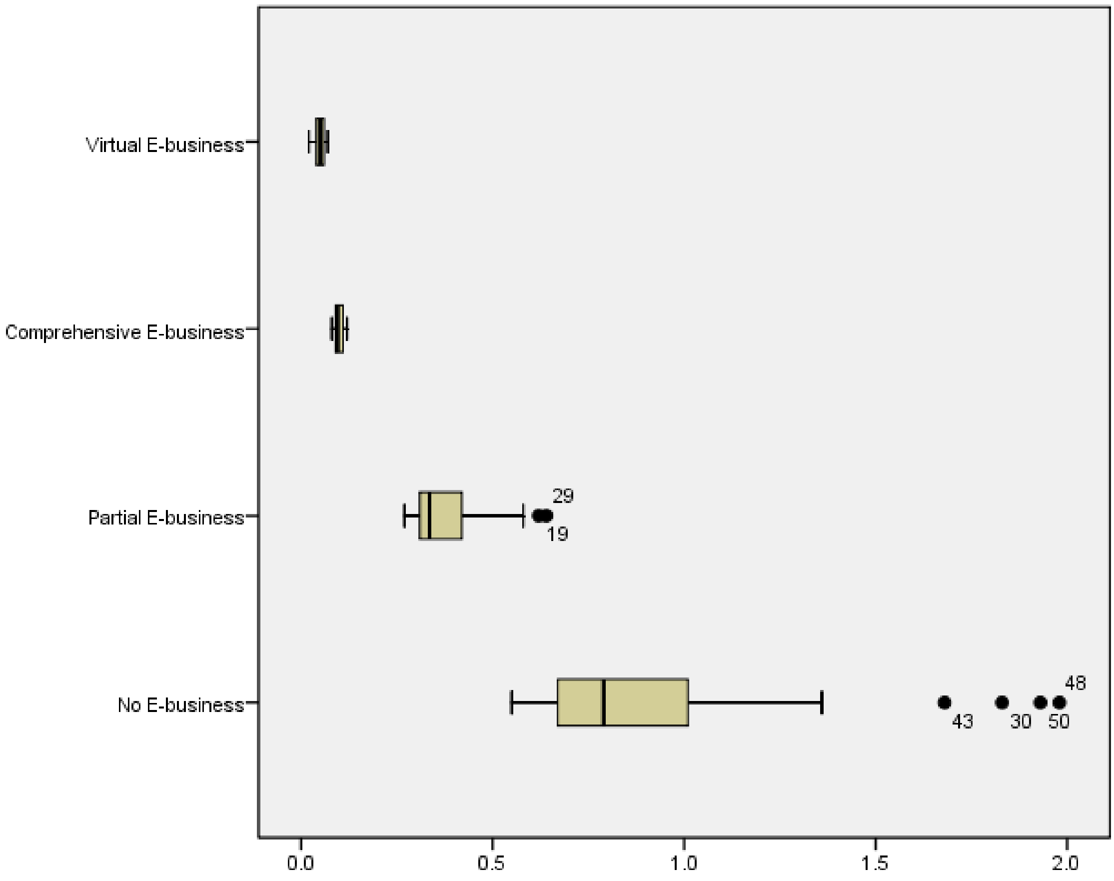
Small and medium size textile & apparel manufacturers should understand the importance of e-business in order fulfilment and supply chain management. Although SMEs may use some basic e-business to manage their order fulfilment and supply chain, such as email, they still need to upgrade the e-business utilisation level from basic e-business to advanced level. The reason is e-business technology develops quickly in such a dynamic world. Therefore, textile & apparel manufacturers have to focus on the new developments of e-business and promptly upgrade e-business utilisation levels based on their current situation to develop their supply chain capabilities and keep competitive advantages.

Boxplots Analysis

This research uses Boxplots analysis to illustrate the differences among four e-business levels of the time taken of different steps to fulfil an order: the minimum time, the maximum time, the first and third quartile, and the median. Boxplots provides the same analysis results as ANOVA, such as the minimum and maximum of each e-business level, the mean of each e-business level, etc. Boxplots analyses show the differences and similarities more clearly than the tables and provide a graphical illustration of the data.

Figure 6.1 is the example of the Boxplots analysis to test P1 for a small manufacturer with sufficient raw materials. Other Boxplots analyses are shown in the file "ABM Data (9439748)". The parallel axis is the time taken to check the inventory, and the vertical axis is the e-business level. The median line of partial e-business lies outside of the box of no e-business, so there is likely to be a difference between these two levels. Meanwhile, the median line of comprehensive e-business lies outside the box of partial e-business, so there is likely to be a difference between these two levels. So when the e-business level improves, the time taken to check inventory decreases.

Figure 6.1 Boxplots for average inventory check time (sufficient raw materials) for a small manufacturer



The interquartile ranges, i.e., the box lengths, illustrate the data dispersions at each e-business level. The more extended box means the more dispersed data, and the smaller box means the less dispersed data, i.e., the observed values tend to be closer to the mean. No e-business box is the longest box; the gap between the maximum and minimum inventory check times is the largest. There are four outside values (indicated by small ·) in no e-business, values beyond the inner fence but not beyond an outer fence. As Figure 6.1 shows, they are the most significant numbers in the set of no e-business; the reason is the time needed for the warehouse to answer the phone affects the time taken to check the inventory. In partial e-business, there are two outside values: the largest numbers in partial e-business; the reason may be how and when the warehouse checks the intranet. There is no outside value in comprehensive and virtual e-business. It confirms the literature that e-business reduces some human errors and improves flexibility (Rinaldi and Bandinelli, 2019). Comprehensive e-business and virtual e-business are much shorter than no e-business and partial e-business because advanced e-business tools guarantee the information exchange between agents at the first time. As Figure 6.1 shows, for a small textile & apparel manufacturer under the sufficient raw materials situation, no e-business uses the maximum time to check the inventory, partial e-business uses less time, and virtual e-business uses the minimum time to check the inventory.

Other 29 Boxplots analysis results under different scenarios are listed in the file "ABM Data (9439748)". All 30 analysis results show that no e-business uses the maximum time to complete the different order fulfilment steps and the whole order fulfilment. No e-business has the most extended interquartile ranges (the box lengths), so there is the opportunity to shorten the lengths. Virtual e-business has the shortest box lengths, and it uses the minimum time to complete the different order fulfilment steps and the whole order fulfilment process. When small and medium size textile & apparel manufacturers use more advanced e-business in supply chain management, they use less time to fulfil the order. SMEs should use appropriate e-business technology and tools to fulfil the order and manage the supply chain.

The ANOVA analysis result can only identify significant differences between e-business levels and the time needed to fulfil the order. It can not distinguish the positive correlation or the negative correlation between order fulfilment time and e-business levels. The Spearman's rank correlation coefficient (R) can identify the positive or negative correlation between e-business levels and the time needed to fulfil the order.

6.2.2 The Correlation Analysis

Spearman's rank correlation coefficient (denoted by r) tests the relationship between e-business level and the time needed for different steps to complete the order.

The coefficient of determination (denoted by r^2) confirms the percentage of the variation in the time taken of different steps to fulfil the order can be attributed to the e-business level.

The coefficient of determination is a crucial output of regression analysis, and it is interpreted as the proportion of the variance in the dependent variable (average time taken of different steps) that is predictable from the independent variable (e-business level). Many researchers use the coefficient of determination to study the supply chain; for example, Bagchi *et al.* (2006) use the coefficient of determination to analyse how information sharing and inter-organisation collaboration affect supply chain integration. An r^2 is the square of the correlation (r); thus, it ranges from 0 to 1. Generally, a higher coefficient of determination indicates a better relationship between the two variables.

An r^2 of 0: the dependent variable cannot be predicted from the independent variable.

An r^2 of 1: the dependent variable can be predicted without error from the independent variable.

An r^2 between 0 and 1: the extent to which the dependent variable is predictable.

An r^2 of 0.10: 10% of the variance in Y is predictable from X; an r^2 of 0.20 means that 20% of the variance in Y is predictable; and so on.

Table 6.4 contains the results to measure the rank correlation, statistical dependence between the rankings of two variables: e-business level and average time of different steps to fulfil the order, and the results of the coefficient of determination.

Table 6.4 Analysis results of the Spearman's rank correlation coefficient (r) and the coefficient of determination (r^2)

Proposition	Simulation	r	r^2
P1: inventory check time	Sufficient raw materials for a small manufacturer	-0.968	0.937
	Sufficient raw materials for a medium manufacturer	-0.968	0.937
P2: raw materials inquiry time	Partial raw materials for a small manufacturer	-0.944	0.891
	Partial raw materials for a medium manufacturer	-0.924	0.854
	No raw materials for a small manufacturer	-0.936	0.876
	No raw materials for a medium manufacturer	-0.936	0.876
P3: order confirmation time	Sufficient raw materials for a small manufacturer	-0.961	0.924
	Sufficient raw materials for a medium manufacturer	-0.960	0.922
	Partial raw materials for a small manufacturer	-0.947	0.897
	Partial raw materials for a medium manufacturer	-0.962	0.925
	No raw materials for a small manufacturer	-0.966	0.933
	No raw materials for a medium manufacturer	-0.967	0.935
P4: raw materials purchase time	Partial raw materials for a small manufacturer	-0.932	0.869
	Partial raw materials for a medium manufacturer	-0.958	0.918
	No raw materials for a small manufacturer	-0.942	0.888
	No raw materials for a medium manufacturer	-0.960	0.922
P5: order production time	Sufficient raw materials for a small manufacturer	-0.931	0.867
	Sufficient raw materials for a medium manufacturer	-0.933	0.871
	Partial raw materials for a small manufacturer	-0.967	0.935
	Partial raw materials for a medium manufacturer	-0.967	0.935
	No raw materials for a small manufacturer	-0.950	0.903
	No raw materials for a medium manufacturer	-0.953	0.908
P6: order delivery time	Sufficient raw materials for a small manufacturer	-0.940	0.884
	Sufficient raw materials for a medium manufacturer	-0.928	0.861
P7: order fulfilment time	Sufficient raw materials for a small manufacturer	-0.934	0.872
	Sufficient raw materials for a medium manufacturer	-0.928	0.861
	Partial raw materials for a small manufacturer	-0.924	0.854
	Partial raw materials for a medium manufacturer	-0.940	0.884
	No raw materials for a small manufacturer	-0.954	0.910
	No raw materials for a medium manufacturer	-0.946	0.895

For example, for a small manufacturer with sufficient raw materials, the correlation coefficient between e-business level and inventory check time r=-0.968, nearly -1, is almost a perfect negative correlation between the e-business level and average inventory check time. The coefficient of determination r^2=0.937 means that 93.7% of the variation in the time taken to check inventory can be attributed to the level of e-business.

As Table 6.4 shows, the minimum Spearman's rank correlation coefficient (r) is -0.968 (P1: average inventory check time, sufficient raw materials for small and medium manufacturers); the maximum r is -0.924 (P7: average order fulfilment time, partial raw materials for a small manufacturer), nearly -1. Both are almost perfect negative correlations between e-business level and the average time taken of different steps to fulfil the order and the whole order fulfilment time. The maximum coefficient of determination (r^2) is 0.937 (P1: average inventory check time, sufficient raw materials for small and medium manufacturers). The minimum r^2 is 0.854 (P2: average raw materials inquiry time, partial raw materials for a medium manufacturer, P7: average order fulfilment time, partial raw materials for a small manufacturer). At least 85.4% of the variation in the time taken to complete the different order fulfilment steps and the whole lead time can be attributed to the e-business level. The result confirms the literature that e-business affects order fulfilment efficiency and supply chain efficiency (Chandak and Kumar, 2020).

Although more advanced e-business utilisation levels can save time to fulfil the order, the time saved most from no e-business to partial e-business. When small and medium size textile & apparel manufacturers use comprehensive or virtual e-business, the time saved is not apparent as from no e-business to partial e-business, so they should consider the potential benefits and investments when planning to use the most advanced e-business. Meanwhile, SMEs cannot save some processing times by adopting advanced e-business. For example, they need 120 hours to produce the ordered jackets; the production time only can be reduced by improving production technology or equipment. The distributor needs 240 hours to arrange and deliver the ordered products to the retailer; the delivery time only can be reduced by using advanced transportation facilities, such as aeroplanes but not trucks or ocean ships. Hence, when SMEs consider implementing the e-business strategy, they still need to improve production technology and shorten the delivery time. The summary of the analysis results is listed in Table 6.5.

Table 6.5 Summary of analysis results

	Propositions	**ROs**
Meantime and P-value	There is a statistically significant difference between e-business levels and the time taken of different steps to fulfil the order. The advancement of e-business utilisation level affects order fulfilment time.	When SMEs use more advanced e-business to manage the order, they use less time to fulfil it. The time saved most from no e-business to partial e-business. When SMEs use comprehensive or virtual e-business, the time saved is not obvious as from no e-business to partial e-business, so they should consider the potential benefits and investments when planning to use the most advanced e-business level.
LSD	The results show the importance of e-business adoption in order fulfilment and supply chain management. The results support P1, P2, P3, P4, P5, P6 and P7.	The results agree with the literature that e-business engagement accelerates order fulfilment and supply chain efficiency (Chandak and Kumar, 2020). Under some situations (P2: no raw materials for a small manufacturer; P4: partial raw materials for a medium manufacturer; P5: sufficient raw materials for small and medium manufacturers, no raw materials for a medium manufacturer; P6: sufficient raw materials for a small manufacturer; P7: sufficient raw materials for small and medium manufacturers, partial raw materials for a small manufacturer), compared to other e-business levels, comprehensive e-business improves order fulfilment efficiency best. SMEs should consider utilising more advanced e-business to replace basic e-business technologies. It is not urgent to pursue the most advanced e-business engagement level.
Boxplots Analysis	No e-business uses the maximum time to fulfil the order, and virtual e-business uses minimum time. A more advanced e-business engagement level means less time to complete the order.	The results agree with the literature that e-business reduces the lead time and accelerates order fulfilment efficiency.
Spearman's rank correlation coefficient	There is a negative correlation between the e-business level and the order fulfilment time. The results support P1, P2, P3, P4, P5, P6 and P7.	When SMEs use more advanced e-business in the supply chain, they use less time to fulfil the order. The result confirms the literature that e-business affects order fulfilment and supply chain efficiency.

To summarise, the advancement of e-business level affects order fulfilment efficiency and supply chain capabilities; for example, from no e-business to more advanced e-business, SMEs use less time to fulfil the order, so all seven propositions are reasonable. The advancement of e-business utilisation level influences the whole order fulfilment time; when SMEs use more advanced e-business levels in the supply chain, the time taken to fulfil the order decreases. The time reduces the most from no e-business to partial e-business. Although the order fulfilment time still reduces from partial e-business to comprehensive e-business and reduces from comprehensive to virtual e-business, the time saved is not apparent as from no e-business to partial e-business. Small and medium size textile & apparel manufacturers need to utilise e-business and upgrade e-business levels. They should carefully consider the potential benefits and investment costs before making the e-business strategy and taking action.

Chapter 7 Discussion and Conclusion

This study provides an in-depth discussion of how Chinese small and medium size manufacturers can use e-business initiatives to improve order fulfilment efficiency and develop supply chain capabilities. The research studies e-business utilisation in textile & apparel supply chain management. To the researchers' best knowledge, this research constructs a conceptual model representing different e-business engagement levels to illustrate the impact of e-business initiatives in order fulfilment and supply chain management for textile & apparel SMEs. ABM and statistical analysis methods are used to collect and analyse the data, which may set an example for SMEs in different industries who attempt to employ e-business initiatives into supply chain management.

This research focuses on e-business utilisation in the textile & apparel supply chain. It provides rich information about the technologies and tools, motivations, perceptions, constraints and barriers to attract or prevent manufacturers from adopting e-business approaches to facilitate order fulfilment and supply chain management. The study allows the proposal of a set of guidelines for the strategic use of e-business technologies for small and medium size textile & apparel manufacturers; additionally, it promotes a theory relating to adopting e-business initiatives for supply chain management.

The study uses the ABM simulation to generate data to examine the impact of e-business on an apparel supply chain and follow previous research works' theoretical conclusions. Two main conclusions can be found. Firstly, a more advanced e-business utilisation level means a shorter time to fulfil the order. It is an opportunity for small and medium size textile & apparel manufacturers to develop supply chain capabilities by utilising e-business initiatives to complete more orders in the same period. SMEs should consider the investment costs if they want to adopt the most advanced e-business level. The efficiency is not obvious from the medium level to the most advanced level. Secondly, e-business adoption follows incremental strategies generally go from limited use inside the organisation to broader use in the supply chain. E-business is not only the instrument for managing order fulfilment efficiently. It is also a valuable technique to connect all partners tightly in the supply chain, accelerate cooperation among partners and improve supply chain efficiency.

This chapter presents a summary of conclusions. Intended contributions and the limitations of this research and future research are identified. The research results are expected to provide theoretical contributions and implicational managerial implications for textile & apparel manufacturers, especially SMEs.

7.1 Research Objectives

RO1 To identify e-business technologies and tools used in the textile & apparel supply chain.

E-business can change the nature of inter-organisational relationships in the supply chain. E-business technologies and tools should ideally enable resource sharing such as information, competencies, and the synchronization of business processes between supply chain partners. Companies can utilise e-business to share information within the company or with supply chain partners to fulfil business processes. A wide diversity of e-business technologies are used in the current textile & apparel supply chain. Many scholars, governments, organisations conduct surveys in Asia, the USA, Europe and Africa to investigate e-business adoption. These researches introduce popular e-business technologies and tools in different industries worldwide (see section 2.3.4 and Table 2.2).

The Chinese government and some official organisations list e-business tools in the textile & apparel industry (China National Textile & Apparel Council; CNNIC Report,2015, 2020; Liu and Wang, 2016). For example, they introduce internet access: website, webpage; software: ERP, MRP, MRP II, EDI, PRM, RFID, CRM, mobile Apps, mobility security software, social media; e-commerce marketplace; search engine; big data; cloud services, 5G, etc. Chinese textile &

apparel manufacturers use social media provided by Chinese companies, such as WeChat, QQ, WeCom. They also use Baidu but not Google as the search engine. The interview focuses on the Chinese small and medium size manufacturers; the result confirmed previous research results: they use the internet, ERP, MRP, mobile Apps, social media, e-commerce, search engine and 5G to connect supply chain partners and fulfil the order.

RO2 To explore the barriers for textile & apparel manufacturers to implement e-business in the supply chain and the benefits of implementing e-business based on literature review and the interview with small and medium size textile & apparel manufacturers.

Many scholars investigate the obstacles for manufacturers to adopt e-business, some main barriers for textile & apparel manufacturers to utilise e-business can be concluded. For example, there are some internal obstacles: employees even executives refuse to accept e-business; the current organisational culture does not encourage innovative ideas; the manufacturer has to reorganise the whole business process; high investment costs on hardware, software, and training on employees; SMEs have insufficient resources to support e-business investment and system upgrade; technical issues, for example, the shortage of well-trained staff; security concerns, and the advantages of e-business adoption will decrease over time even vanish. There are also some external obstacles: less customer demand, the product may not fit for e-business, etc. (see section 2.3.6 and Table 2.4). The interview results support the above studies; for example, high investment costs, insufficient resources, the shortage of professional staff, etc.

E-business technologies can help textile & apparel manufacturers avoid supply chain problems to improve flexibility. Manufacturers can use e-business to transmit orders, deliver notes and invoices, and exchange information online to save time and reduce transaction costs. It is difficult for textile & apparel manufacturers to forecast the demand. By utilising e-business, the retailer can share demand information with the manufacturer and raw material suppliers for the first time. They can understand market demands quickly, replenish inventory frequently, reduce high inventory costs, decrease cycle time and lead time, and improve operational capability and competitiveness. E-business technology can also ease human errors; for example, delivering incorrect products to customers, advanced computer systems or software can reduce human errors. When a manufacturer wants to launch a new product, it can also use e-business to gather helpful information about current and potential raw material suppliers and find new clients in the global market (see section 2.3.5 and Table 2.3). The interview results support the above studies; for example, e-business can attract more customers, reduce costs, forecast market demand, shorten lead time, etc.

RO3 Conduct modelling simulation to:

• Design conceptual model to represent different levels of e-business utilisation (from no e-business to more advanced e-business level) in textile & apparel supply chain;

A four-level e-business conceptual model is established (no e-business, partial e-business, comprehensive e-business and virtual e-business) based on the literature and the confirmation from six managers (see section 5.1).

• Run the simulation based on the conceptual model to understand the effects of varying e-business utilisation levels in an apparel order fulfilment for a Chinese small and medium size apparel manufacturer in textile & apparel supply chain;

The thesis designs twelve flowcharts representing different e-business utilisation levels in a jacket order fulfilment under different situations based on the confirmation of six managers from Chinese small and medium size textile & apparel companies. There are three different situations: sufficient raw materials to produce the order, partial raw materials to produce the order, and no raw materials to produce the order (see section 5.3 and section 5.4).

• Identify how e-business implementation influences textile & apparel order fulfilment efficiency and supply chain capabilities.

When SMEs use a more advanced e-business level, some steps to fulfil the order can be shortened by utilising appropriate e-business technologies and tools (see section 6.2).

RO4 To compare and contrast the research results with the literature to develop the theory of e-business utilisation in textile & apparel supply chain, provide practical suggestions for Chinese small and medium size textile & apparel manufacturers to implement e-business initiatives.

The findings from simulation results and interviews provide insights into the ongoing theoretical interests in e-business initiatives related to supply chain management. The study identifies many issues associated with e-business utilisation in textile & apparel supply chain management. The research results confirm some benefits of e-business adoption for small and medium size textile & apparel manufacturers listed above: accelerate order fulfilment efficiency and supply chain efficiency (Chandak and Kumar, 2020), reduce cycle time and lead time (Benitez *et al.*, 2018), reduce some human errors, improve flexibility (Rinaldi and Bandinelli, 2019), and the obstacles: high investment costs (Zhao and Zhao, 2018), need to reorganise business process (Ciarniene and Stankeviciute, 2015), technical issues (Krishna and Singh, 2018), insufficient resources (Bankole and Olatokun, 2017; Mazzarol, 2015), etc.

Meanwhile, the data analysis results also show some results the current literature does not mention. For example, Chandak and Kumar (2020) insist that e-business can improve supply chain efficiency. Still, they do not study the textile & apparel industry and do not focus on Chinese SMEs. Rinaldi and Bandinelli (2019) study the SMEs' importance in international textile and clothing brands; the study focuses on the relationship but not the specific order process management from the SMEs side. The simulation results show that e-business affects each step to fulfil an apparel order for SMEs. Abdullah *et al.* (2015) insist that SMEs must move toward the highest e-business utilisation level. The simulation results show that although the most advanced e-business level saves time to fulfil the order, the time saved is not obvious as from no e-business to a medium advanced e-business level.

SMEs should use e-business to improve textile & apparel supply chain capabilities. Not only supply chain partners, such as textile & apparel manufacturers, raw material suppliers, retailers, distributors, etc., and some organisations such as government agencies, nonprofit organisations, and other related groups also need to push the e-business adoption. Textile & apparel products have unique characteristics compared with other industries, e.g., labour-intensive, diverse customer demands, short production cycle, etc. The product is seasonal ad easy to be imitated by competitors. SMEs should consider some e-business strategies to improve their capabilities, such as designing network-based e-business strategies, connecting raw material suppliers, distributors and customers/buyers, sharing information, implementing an e-business investment strategy, and integrating e-business strategies. SME should consider if the upstream or downstream integration of e-business fits the current situation, as they are just participants in the whole textile & apparel supply chain.

Based on the findings, the research offers the below recommendations: owners and managers of small and medium size textile & apparel manufacturers need to understand the benefits they can gain from e-business adoption in business process, keep up-to-date with the e-business upgrade, employ ICT specialists to identify the current e-business adoption situation and the further needs of e-business, and push SMEs to adopt e-business. For instance, they need to train employees, even executives, to continuously accept and use advanced e-business tools, improve the environment and infrastructure, and constantly facilitate e-business engagement. They can use 5G to connect to the internet, establish and upgrade the full functionality of the website or App, use cloud services to save cost, secure order processing and finance systems, etc.

Under such a rapidly changing era, small and medium size textile & apparel manufacturers have to depend on the strategic flexibility and capability to survive and develop. The e-business initiative is the appropriate tool to support them to grow rapidly and innovatively. SMEs have some characteristics, such as resource constraints, poor access to finance, lack of professional staff, lack of skills, lower standardisation, less strategic thinking, planning, etc. Chinese small and medium size textile & apparel manufacturers should consider such critical factors to implement e-business strategies:

Attract more customers, search for more raw material suppliers worldwide. SMEs can establish and upgrade websites or Apps to introduce products and services more effectively online and improve convenient usability. Customers and clients can use mobile devices to get information, such as product introductions and exchange information. Chinese SMEs can also join platforms such as Taobao, Tmall, JD, Blogging, or textile & apparel industry platforms such as Tnc, or search engines such as Baidu to introduce the company or display products and services.

Improve the information exchange efficiency inside the company. SMEs can consider using WeChat. WeChat supports users in exchanging information instantly one by one and establishing some groups; each group can involve no more than 500 members. It is free for users, but the documents in WeChat will expire in 72 hours, so users should download and save files before the deadline.

Improve the information exchange efficiency with supply chain partners. SMEs can consider using email and WeCom. Email is free for average users, and documents in most mailboxes will not expire. WeCom only provides services for formal organisations to manage the business in China. It verifies the registered members' identity, guarantees the memberships' reliability. Enterprises need to pay 300 RMB to register and establish official relationships with other enterprises. Users can build different groups to connect all supply chain partners. The files are valid for 180 days in WeChat.

Automate and improve production processes management. SMEs can use MRP or MRP II to manage production processes. MRP focuses on logistic management, intending to complete production and control inventory costs. MRP II integrates resources such as people, money, time, information, data, etc., rationally planning to improve competitiveness. More than 1,000 software companies provide MRP or MRP II in China; the prices are different, from a few thousand to tens of millions RMB. SMEs should select appropriate software based on their strategy design and budgets.

Use cloud service to manage the database. Cloud service helps SMEs store the essential data on the cloud system and use some software by cloud computing. SMEs can use different IT devices to connect the cloud to access, compute data at any time, anyplace. Nowadays, there are two kinds of common cloud services: public cloud and private cloud. Public cloud is the most basic service with low prices; multiple customers share one service provider's system resources. Chinese Textile & apparel SMEs can enjoy professional IT services without any investment in equipment and management. It is an excellent way to reduce costs for them. For example, SMEs pay 2,999 RMB each quarter to enjoy Baidu public cloud services. Suppose SMEs need more advanced private cloud computing services, such as CRM or ERP systems. They need to consider their situation, business strategy design, and budgets first and select appropriate services.

Seek supports from government or textile & apparel organisations. The Chinese government issued many policies to support SMEs development; different local governments implement such policies to support SMEs, such as financial support, tax and fee reduction, innovation guide, and public services support. Many local governments, such as Xinjiang Province, Jiangsu Province, Zhejiang Province and Guangdong Province, provide policies and systems to support textile & apparel industry development. Some Chinese organisations, such as the China Chamber of Commerce for Import and Export of Textiles (CCCT), China National Textile & Apparel Council (CNTAC), and China Textile Commerce Association (CTCA), provide textile & apparel companies necessary guidelines or assistance.

7.2 Theoretical Contribution and Practical Implications

The intended contribution of this study is described below. The overall objective of this study is to develop a broader theoretical perspective on developing small and medium size textile & apparel manufacturers' supply chain capabilities with e-business initiatives. Meanwhile, to gain a deeper understanding of the e-business strategies for Chinese small and medium size textile & apparel manufacturers to implement and generate a comprehensive picture of e-business initiatives in textile & apparel supply chain management. This is obtained through acquiring a richer appreciation of the literature review and the model design and ABM results analysis.

7.2.1 Theoretical Contribution

The first contribution of this study is to focus on the e-business utilisation of small and medium size textile & apparel manufacturers in China. As most previous studies in this research area are conducted in developed countries, a few studies focus on developing countries. It is necessary to understand e-business implementation in small and medium size textile & apparel supply chains in emerging economies. These SMEs face harsh competition from developed and developing countries. As an important emerging economy, Chinese small and medium size textile & apparel manufacturers face enormous pressures from local large size manufacturers and competitors from other countries.

The second contribution of the study is to adopt a combination of research methods and contributes to the theory of e-business initiatives implementation in the textile & apparel supply chain. The study establishes a four-level e-business conceptual model to represent the advancement of e-business utilisation level in a specific textile & apparel order fulfilment, provides a theoretical template for further research in e-business implementation in supply chain management in a broader context. The conceptual model developed in the study can help researchers conduct further studies about e-business engagement in supply chain management of manufacturing industries. Researchers can enrich current literature by adopting the conceptual model to measure e-business utilisation in manufacturing industries.

The third contribution of the research is to use the ABM method to generate the data. The study focus on e-business utilisation in the textile & apparel supply chain, the actual supply chain involves various partners and complicated business processes. It is impossible to collect all data from the real world, so this thesis uses ABM as the data collection method. The research conducts interviews with 6 Chinese small and medium size textile & apparel manufacturers to design and implement ABM. ABM captures emergent phenomena, provides rich and meaningful data, and precisely represents the actual supply chain operations. ABM has been used in economics and business marketing research, but it is still a novel approach to studying the supply chain. Many researchers have made valuable achievements in the supply chain, but only a few have used ABM to study textile & apparel supply chain management in recent years. For example, Felfel *et al.* (2015, 2018) study multi-site textile & apparel supply chain planning and only model one-to-one information sharing between supplier and the retailer/buyer. No researchers have used ABM to simulate an order fulfilment process in the textile & apparel supply chain and study how e-business advancement levels affect SME's supply chain capabilities. This study models information sharing between a manufacturer, three suppliers, one retailer and one distributor. The study uses statistical analysis methods (ANOVA analysis, Boxplots analysis and Spearman's rank correlation) to explore the efficiency of apparel order fulfilment and textile & apparel supply chain. The study tries to combine the ABM and statistical analysis methods to check e-business utilisation in specific product order fulfilment. This study uses ABM to generate data; the data reflect the natural worlds' actual value, as seen from the analysis results. It provides the opportunities to explore a supply chain system closer to reality, the real world.

7.2.2 Practical Implications

Small and medium size textile & apparel manufacturers can benefit from findings when they understand the importance of e-business and start to utilise advanced e-business technologies and tools in supply chain management. This research presents significant implications for Chinese small and medium size textile & apparel manufacturers and government and institutions or organisations linked to the textile & apparel industry. Based on the findings of this research, small and medium size textile & apparel manufacturers, government, and related institutions or organisations (not only in China but also in other similar countries) will understand the effects of e-business on the supply chain capabilities. Executives, government officers, and consultants should understand e-business initiatives and concentrate on e-business utilisation. They also need to consider, design, and implement e-business strategies, policies and plans to support SMEs to survive and develop in such a dynamic market. The research results show that appropriate e-business utilisation can help SMEs accelerate their business process, improve order fulfilment efficiency, and develop supply chain capabilities.

Consequently, SME managers should consider investing in e-business based on their limited resources. Technology vendors should provide different e-business services for SMEs based on their current e-business utilisation level. Government officers can make more specific policies to motivate SMEs to adopt more advanced e-business tools and technologies. For example, introduce the benefits of e-business to SMEs and reduce the barriers for SMEs to use e-business, such as improving public infrastructure services and providing technical or financial support for SMEs. The study confirms that in an emerging economy such as China, small and medium size textile & apparel manufacturers still have opportunities to deploy e-business to develop supply chain capabilities. According to a CNNIC Report (2020), at the end of 2019, there are 2,978 hundred million websites, 3.67 million mobile Apps, and 4.49 hundred million Broadband users in China. At the end of June 2021, there are 9.4 hundred million netizens. The internet penetration rate is 67.1%, so Chinese small and medium size textile & apparel manufacturers have good circumstances to use e-business to develop their supply chain capabilities.

7.3 Research Limitations and Further Work

The main limitation of this research is the simplifying assumption of the order fulfilment and supply chain. The real-world supply chain is more complicated than the model. There is another limitation of this model. The simulation is run just under the produce-to-order situation, and the study assumes that the small and medium size textile & apparel manufacturer receives the order and then arranges the production. This assumption is not very practical because not all SMEs are in such a situation; some may produce goods without the order.

The study uses ABM to collect data because it is impossible to collect all information from the actual supply chain. Small and medium size textile & apparel manufacturers have to face different situations to produce goods, such as resource-to-order, produce-to-order, produce-to-stock, and assemble-to-order, etc. They need to satisfy the various requests from retailers, adjust their production plan at any time, deal with different circumstances. If they produce goods without the order, they have to collect detailed market information and forecast marketing demand accurately.

The model has been much more complex than most models developed in current literature. Current literature assumes only one manufacturer and no more than three retailers (Long, 2015; Naqbi *et al.,* 2018; Pu *et al.*, 2018). The research tried to duplicate a complicated jacket order fulfilment system based on the discussion with actual small and medium textile & apparel manufacturers and has successfully demonstrated and experimented with the significant improvement in the supply chain due to the information exchange among agents.

More agents can be added in the simulation in further research, such as more retailers/buyers, raw material suppliers, etc. The study may consider other production situations in the future, for example, produce-to-stock, resource-to-order, assemble-to-order, etc. Further research can view the model design from the retailer/buyer side. More studies need to be conducted in a real textile & apparel manufacturing company to test if research results are helpful to design and maintain a robust and resilient supply chain from the practical approach.

Appendix: Interview Questions

1. Which kind of e-business tools are your company using or planning to use, for example, email, website, MRP, MRP II, ERP, EDI, cloud service, or other technologies to facilitate the business activities?

2. What type of data or information are partners exchanging with each other within your supply chain?

3. Can you describe each step about order fulfilment, for example, 1,000 jackets, what will you do to complete the order, and how long each step takes?

4. How do you calculate the price and the delivery date?

5. What happens when the warehouse receives raw materials from suppliers? If it does not correspond to the order, what will you do?

6. How long does it take to produce a batch of products, for example, 1,000 jackets?

7. How do you deliver finished products to your customers, and how long does it take to deliver the order products, for example, 1000 km?

8. What barriers hinder your company from implementing another e-business solution in the supply chain, such as ERP?

9. You said your company would use new e-business technology in the near future, so what benefits do you expect from it?

10. How did you exchange information with partners before you used e-business? Can you describe the detailed steps and time needed for each step, please?

11. I designed four levels of e-business utilisation: no e-business, partial e-business, comprehensive e-business, and virtual e-business, and twelve flowcharts to represent an apparel order fulfilment (1,000 jackets) under three different situations, sufficient raw materials, partial raw materials, and no raw materials to produce the order, so there are twelve various flowcharts, I will explain them one by one, can you read them and give me some suggestions to improve them, please? For example, the order fulfilment steps, the time of each step, etc.

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