Integration of Lean Six Sigma with Multi Agent Systems in the Food Distribution Industry in Small to Medium Enterprises (SMEs)

A thesis submitted for the Degree of Doctor of Philosophy

By

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ABSTRACT

The service industry worldwide continues to face unprecedented challenges in decision-making and in managing the operations involved in delivering products at low cost and ever-faster delivery speeds. These pressures exert an even greater impact upon small- and medium-sized enterprises (SMEs) involved in this industry who, influenced by globalisation, have to respond by handling the dynamic complexity within their operational supply chain. Many larger firms have implemented Lean and Six Sigma (LSS) and end-to-end integrated real-time information systems (RTI) that provide the information and the mechanisms needed to support flexibility and prompt decision-making. The recent emergence of new technologies such as multi-agent systems (MAS) provides enhanced capability to address complexity and decision-making with greater ease of use at a reduced cost.

Whilst the application of Lean and Six Sigma are supported by significant published research, the application of integrated LSS and MAS in food distribution, especially in SMEs, is not. This study seeks to provide research to address this shortcoming for SMEs within the food distribution sector within Saudi Arabia, how this integrated approach can offer considerable performance improvement in SMEs and provide a base for further contributions in this field.

This research undertook an empirical case study in Saudi Arabia to test the application of LSS in a food distribution SME. This approach demonstrated a significant improvement in the Six Sigma for late delivery. A single-stage MAS application extended this improvement, demonstrating that there is value in its application. The study conducted a survey of 39 firms in this sector to gain an insight into their current practices and challenges.

The findings indicated there was a lack of Lean and Six Sigma principles adopted and that a lack of use of interconnected real-time systems to support decision-making and complex operational SCs. These findings identified the opportunity to design a conceptual framework with a stepped approach that integrated LSS with MAS, which was then developed on a Java-Assisted DEvelopment Framework (JADE) platform and tested using real-world data in an SME empirical case study. The results of the sequence of applications and the final simulations proved that this integrated Lean multi-agent system (LMAS) solution offered such substantial improvements in quality, time and costs that the SME considered that those factors justified making its implementation a priority.

Declaration

I, Fahed Algassem, confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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List of Research Outputs

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Integration of Six Sigma and Lean Manufacturing Principles into FSC SMEs. The Annual Research Student Conference. (Poster)

Integration of Six Sigma and Lean Manufacturing Principles into FSC SMEs. The Annual School Conference ResCan2013. (Poster).

Contents

List of Figures

List of Tables

List of Nomenclature

ACC	The Agent Communication Channel
ACL	Agent Communication Language
AMS	Agent Management System
CAS	Complex Adaptive System
CI	Continuous Improvement
CSCMP	Council of Supply Chain Management Professionals
DEFRA	The UK Department for Environment, Food and Rural Affairs
DF	Directory Facilitator
DMADV	Define, Measure, Analyse, Design, Verify
DMAIC	Define, Measure, Analyse, Implement, and Control
EDI	Electronic Document Interchange
FIFO	First-In-First-Out
FIPA	Foundation for Intelligent Physical Agents
FSC	Food Supply Chain
FSCNs	Food Supply Chain Networks
GDN	Goods Delivery Note
GRN	Goods Receiving Note
GSCF	Global Supply Chain Forum
JADE	Java Agent Development Framework
JIT	Just-In-Time
LIFO	Last-In-First-Out
LMAS	Lean Multi-Agent System
LSS	Lean Six Sigma
MAS	Multi-Agent System
MTO	Make-To-Order
MTS	Make-To-Stock
ROA	Returns On Assets
ROI	Returns On Investments
RTIS	Real-Time Information Systems
SAGIA	Saudi Arabian General Investment Authority
SC	Supply Chain
SCM	Supply Chain Management
SIPOC	listing Suppliers, Inputs, Processes, Outputs and Customers
SME	Small- and Medium-Sized Enterprises
TILAB	Telecom Italia Lab
TQM	Total Quality Management
TQC	Total Quality Control
VOC	Voice Of the Customer
VSM	Value Stream Mapping
WTO	World Trade Organisation
5S	Sort, Set, Safe, Skill, Standardise
7W	Defects, Inventory, Transportation, Waiting, Over-processing, Motion, Production

1. INTRODUCTION

1.1 Introduction

This chapter provides the rationale and layout structure for the integration of Lean Six Sigma (LSS) and Multi-Agent Systems (MAS) within SMEs in the food distribution sector in order to address key issues affecting their operational efficiency and the effectiveness of their SCs. This chapter also describes the dissertation's research background, the pilot study, the problem statement, aims and objectives, research questions, and scope and structure of the thesis.

1.1.1 Background

Manufacturing and service organisations including SMEs across the world are facing unprecedented challenges in delivering products of the best quality with low costs and at faster delivery speeds. Production, efficiency and product quality are essential measures of customer satisfaction and company success in the global competitive market. In this challenging business environment, the accelerated competition among firms has forced them to focus on strengthening their quality initiatives as a means of enhancing their SCs. A significant focus in both the industry and research has been on seeking solutions to obtain higher production efficiency and better product quality. Therefore, some firms have adopted advanced management tools such as LSS, Total Quality Management (TQM) and Total Quality Control (TQC), Agile Manufacturing, Lean Manufacturing, Kanban and, more recently in the field of artificial intelligence, MAS.

The food supply chain (FSC) is a close cooperation of interdependent companies that manage the flow of goods and services that add value to the agricultural and food products they trade. The objective is to maximise customer value at the lowest possible cost (Folkerts and Koehorst, 1998) and minimise the inefficiencies that cause bottlenecks, such as the lack of coordinated actions, problems with information, excess inventories, unmet consumer demands, etc., which can all be attributed to issues with information flows (Mangina and Vlachos, 2005). The reengineering and optimisation of SCs remain a major concern for food companies (Mangina and Vlachos, 2005). Van der Vorst et al.'s (2009) investigations determined that real-time information systems were an essential requirement for efficient and effective FSCs. Substantial research has shown that information technology is the most effective tool for addressing operational inefficiencies and enhancing company productivity and thus competitiveness (Andersen, 2001; Lambert and Stock, 1993; Stratopoulos and Dehning, 2000; Zhang and Lado, 2001). The use of advanced information technologies has introduced considerable structural changes in FSCs (Clark and Hammond, 1997; Fearne and Hughes, 2013). These include an increase in collaboration within the SC that has enabled automated stock replenishment and deliveries to occur but places more responsibility on the producers (Mangina and Vlachos, 2005).

In the modern globalised economy, supply chain management (SCM) has swiftly become the most significant element of production-based firms' success. According to Nabhani and Shokri (2007), businesses that manage their SCs efficiently tend to thrive, while those which do not may not survive for long. Each of the LSS and SCM methodologies have their advantages and disadvantages. Implemented individually, they reach a point of diminishing returns in measuring performance, so it is likely that value is to be extracted by combining them to achieve further improvements. Salah et al. (2011) stated that LSS and SCM have several features in common in terms of how they concentrate on processes and solving customer problems in order to achieve customer satisfaction; they also complement each other and can be integrated. This applies generally in business, including food distribution SMEs, regardless of their type and size.

The intelligent agent system presents an alternate technology for SCM that enables distributed collaboration, autonomy and intelligence (Barbuceanu et al., 1997; Nissen, 2001; Swaminathan et al., 1998). Ben Mahmoud et al. (2009) suggested that it would be helpful for logistics chain management to employ MAS within its methodology and to use tools to help designers address areas such as information sharing, supplier evaluation, feedback and communications. The researcher therefore proposes in this thesis to synthesise the current research within LSS, SCM, Kanban and MAS to address potential improvement in operational efficiency and effectiveness within food distribution services in SMEs.

1.2 Problem Statement

The food industry is characterised by a large percentage of SMEs (Mangina and Vlachos, 2005), and research has shown that SMEs experience many of the same operational difficulties as larger firms but have limited resources and skills needed for the adoption of the best practices and technology used by larger firms in Saudi Arabia.

There is a gap in published research on the application of LSS techniques and the use of real-time systems in the food industry SMEs in Saudi Arabia. This study sets out to address this gap and demonstrate how an integrated approach using Lean Six Sigma related techniques alongside MAS can address these issues of limited resources and skills within the Saudi SME food distribution sector and can demonstrate improved performance, using an empirical case study of an SME in the Saudi Arabian food distribution sector.

1.3 Aim and Objectives

This research aims to improve the global competitiveness of SMEs in the Saudi Arabian food distribution sector and to overcome the operational supply chain management issues which they face in relation to quality, lead times, costs and resources, through the introduction of LSS techniques integrated within a real-time information system using MAS. To achieve this aim, the researcher has set out the following objectives:

- To understand the main obstacles faced by SMEs and the critical factors in quality initiatives needed to maintain quality standards within the food distribution industry;
- To demonstrate the benefits of LSS related practices and real-time systems for SMEs in the food distribution sector;
- To determine the key constraints and issues faced by food distribution SMEs in Saudi Arabia, their current operational practices, and the nature and level of quality initiatives adopted;
- To establish a framework and operational model (LMAS) that integrates LSS, related techniques, and MAS to significantly improve SCM operational performance and efficiency in SMEs.

1.4 Research Questions

This research seeks to answer the following questions:

- What are the current operational practices and performance issues experienced by SMEs within the food industry in Saudi Arabia?
- Can the application of LSS practices improve the operational efficiency of the SC of an SME within the food distribution industry sector in Saudi Arabia?
- Can the integration of LSS with related stock techniques using MAS make a significant contribution to the operational performance of SMEs in Saudi Arabia?

1.5 Scope

This research focuses on developing a framework for integrating Lean and Six Sigma with other related techniques in SMEs in the Saudi food distribution industry SC. It also proposes the integration of MAS, a new domain paradigm in information and communication technology, with the objective of collecting data to compare and investigate firms before and after introducing the framework.

1.6 Structure of the thesis

The remainder of the thesis is organised into eight chapters. A brief overview of each chapter is presented below:

CHAPTER 1: INTRODUCTION

This chapter introduces the reader to the topic area, describes the background to how this research topic was chosen, and explains the scope of the intended aim, objectives and the problem statement that shape the thesis structure. Finally, it lays out the research questions for this study to address gaps in the current knowledge revealed by the literature review and interviews.

CHAPTER 2: LITERATURE REVIEW

This chapter presents a review of previously established knowledge and the methodology and the scope of the literature review of the operational practices in SCs and the challenges faced by SMEs in the food distribution sector, with a focus on Saudi Arabia. The relevance of Lean and Six Sigma principles in improving operational quality, lowering costs and addressing time factors within the SCs of food distribution firms are all discussed. The emergence of new technologies and programmes such as MAS using Java and how these can be relevant to real-time information systems in the food distribution SCs of Saudi Arabian SMEs are outlined. A pilot study was conducted to assess the relevance of the concepts found in the literature review to the SMEs of the food industry of Saudi Arabia and their awareness of these concepts, and to determine the feasibility of the scope and aim. The chapter concludes with the identification of the research gap that this study seeks to address.

CHAPTER 3: METHDOLOGY

This chapter presents the research methodology and design adopted, including the selection of research methods, data collection techniques and tools applied in the different phases of this research.

CHAPTER 4: APPLICATION OF LEAN SIX SIGMA

This chapter investigates the effectiveness of the LSS methodology in a case study in a food distribution SME, using relevant tools to identify defects and their causes and then apply the best solution to improve the delivery process.

CHAPTER 5: QUESTIONNAIRE ANALYSIS

This chapter presents the analysis of the empirical study questionnaire to establish the critical factors and variables that influence SMEs' operational performance and how LSS and MAS methodologies can support SMEs in addressing these issues. Finally, it proposes a framework for an integrated model using an MAS for SMEs in the Saudi Arabian food industry.

CHAPTER 6: DEVELOPMENT OF THE LEAN MULTI-AGENT SYSTEM

This chapter explains the development of a conceptual framework which is used to develop an LMAS platform to address the critical issues that hinder the operational effectiveness of SMEs. This conceptual model and its development integrate Lean, Kanban, 5S and 7Wastes with quality assurance into the MAS. A simulation method is proposed and the verification of the developed model is described.

CHAPTER 7: RESULTS AND DISCUSSION

This chapter presents the results of the developed LMAS platform and discusses how these results can help to resolve the critical issues identified in the literature review and the empirical case study to improve SMEs' operational efficiency and enhance customer satisfaction.

CHAPTER 8: CONCLUSION AND FURTHER WORK

This chapter concludes that the integration of LSS with the emergent MAS can be an effective solution to support SMEs in the food distribution sector of Saudi Arabia by improving their operational practices, increasing their capabilities and providing quality assurance in their SCs, while enhancing customer satisfaction, reducing costs and eliminating time delays by following the quality philosophy of "doing things right the first time", ensuring successful initial outcomes.

1.7 Summary

This chapter has introduced the purpose and rationale for this thesis and the methodology used to identify research in the literature review, and has described the pilot study of SMEs needed to define the aim, objectives, problem statement and formulated research questions. The literature review that follows intends to investigate published research on how LSS principles and the MAS can support SMEs in overcoming the challenges they face in their SC operations.

2. LITERATURE REVIEW

2.1 Introduction

To understand more completely the challenges faced within the operations of SMEs in the food distribution sector and the current practices needed to improve SCM operations, the scope of this literature review began with a search on SMEs including Saudi Arabia, SCM, the food distribution sector, quality improvement techniques of Lean and Six Sigma and finally MAS. Cases in which some of these fields overlapped, such as SMEs, SCM, and food distribution were of particular interest to the research. The scope and order of the literature review included research in 220 published papers covering the following broad areas:

- The nature of SME challenges faced in food distribution in Saudi Arabia;
- SCM: to understand the extent of operations and the current practices to manage the flow of goods within the FSC;
- LSS: understanding the application of these tools and the advantages and limitations of their application in the food distribution industry;
- MAS: to understand the emergence of MAS and JADE as a platform for modelling SCs chains in the food distribution sector, including potential benefits and constraints.

2.2 Small- and Medium-Sized Enterprises Background

SMEs are at the heart of modern economies. They are often suppliers for large organisation which means that their 'footprint' is far greater than it would initially seem (Antony et al., 2005). In many countries SMEs are the backbone of the economy; an immense amount of activity takes place within their walls, and they provide an income for a considerable number of workers thus helping to develop national and global economies (Bahaddad et al., 2012). Statistics indicate that SMEs make up 90% of all companies in most economies globally and provide 40–80% of all jobs, contributing meaningfully to the GDPs of many countries (Elasrag, 2012). According to Al-Habib (2012) SMEs have much to offer to the economic growth of both developed and developing economies. These businesses do much to generate employment, providing a significant proportion of low-income groups with employment, and fill the demand for low-cost goods and services domestically. If the SME sector is thriving, this will have a positive effect on the entire country's economy.

SMEs in developing countries are in their formative stages; in contrast the private and public sectors in the US and other developed countries already offer their SMEs considerable support which has enabled them to mature and impact positively on their country's economy (Al-Habib, 2012). It is thought that there are 19.3 million micro-enterprises and SMEs in the European Union (EU), approximately 90% of all EU enterprises. Furthermore they provide jobs for around 65 million employees, two-thirds of all those in employment (Bahaddad et al., 2012). Antony et al. (2005) have also drawn attention to the significant role played by SMEs in the economy of the UK and the industrialised world overall. At the beginning of 2004 there were approximately 4.0 million business enterprises in the UK, more that 99% of which were SMEs. In the UK SMEs employ about 58% of the total workforce. SMEs in Saudi Arabia make up approximately 95% of all Saudi enterprises (Al-Mahdi, 2009). It can be seen that SMEs are key players and exert a great deal of influence in economies throughout the world. This should cause a radical reassessment of how SMEs can be supported, locally, regionally, and globally (Bahaddad et al., 2012). After studying the previous literature on SMEs Antony (2005) summed up some of the strengths and weaknesses of SMEs in Table 2.1.

There is no universal definition of SMEs and they are defined differently in different countries. Three sets of characteristics are usually the basis of such definitions: the number of employees, the amount of paid-up capital, and the annual revenues (Carter and Jones-Evans, 2006, Kumar et al., 2009). The cut-off values for these criteria vary from one economy to another, with developed economies such as the USA, Japan, the EU and the UK having higher values for paid-up capital and annual revenues than economies of developing economies (Kureshi et al., 2009). Furthermore Verhees and Meulenberg (2004) describe an SME as a firm '*that is run and controlled under the direct supervision of the owner*'. In general terms SMEs can be defined as non-subsidiary, sovereign firms, with fewer employees than a certain number which varies according to country. Thus SMEs in the USA are firms with fewer than 500 employees, in the EU the limit is 250, while in other countries, it is 200 employees. Businesses with less than 50 employees are described as small firms, and businesses with ten or less are micro-enterprises (Carter and Jones-Evans, 2006).

Table 2.1: Strengths and weaknesses of SMEs (Antony, 2005)

SMEs' strengths	SMEs' weaknesses
Flexible, hence changes can be introduced fairly quickly	Low degree of standardisation and formalisation
Flat with few layers of management and fewer departmental interfaces	Focus is on operational matters rather than planning
Top management highly visible and hence provides leadership by example	There is a chance that management may lay off employees when their work becomes superfluous. This makes SMEs have to work harder to retain high calibre staff
Absence of bureaucracy in management teams	Limited investment in IT
Tend to have high degree of employee loyalty	No incentive or reward programs in many cases due to budget and resources constraints
Managers and operatives are more likely to be directly involved with the customers	Lack of strategic planning and inspiring vision
Rapid execution and implementation of decisions	Responsible for many facets of the business and many decisions. Decisions are generally made for short-term profitability
Training likely to be focused	Lack of skills, time and resources; no specified training budget
Culture of learning and change rather than control	Incidence of "gut feeling" decisions more prevalent; often operate in a fire-fighting mode for survival
People-oriented	Not systems-oriented
More responsive to market needs and more innovative in their ability to meet customer demand	Extent of training and staff development in SMEs is limited and informal
Likely to deploy improvements quickly and gain rapid benefits	Adamant and dictatorial nature of owner can damage new initiatives
Loose and informal working relationships and absence of standardisation	Formation of strategy process is intuitive rather than analytical

2.2.2 Small- and medium-sized enterprises in Saudi Arabia

There is no clear and agreed definition of SMEs in Saudi Arabia. According to the Council of Saudi Chambers (Council of Saudi Chambers, 2006) and the Saudi Arabian General Investment Authority, SMEs in Saudi Arabia are considered to be small if they have less than 60 employees, and to be medium-sized if they have between 60 and 99 employees (Bahaddad et al., 2012, Merdah and Sadi, 2011). In this research the SME is considered to be micro if it has between one and nine employees, small if it has between 10 and 49 employees and medium-sized if it has between 50 and 100 employees. Merdah and Sadi (2011) consider that SMEs are in the position to take on a range of important roles. They can sell their own product (usually finished goods), act as subcontractors for large enterprises, or supply large enterprises with raw materials. During the Second Forum of SMEs in Saudi Arabia the Board of Directors of the Chamber of Commerce and Industry in Riyadh estimated that SMEs make up 90% of all enterprises in the country. The Minister for Commerce and Industry has reported that there were a total of 650,000 commercial enterprises in 2006.

Nowadays SMEs face even greater challenges because they have to compete in the global economy. Merdah and Sadi (2011) state that new rules and responsibilities have been introduced through the multilateral trading system since Saudi Arabia became the 149th member of the World Trade Organisation (WTO) on the 11th December, 2005. There has been more competitive pressure on large firms but particularly on SMEs since the Saudi Arabian market opened up to foreign investors. SMEs need to adjust to these changes and respond to them. SMEs have been forced to respond more quickly in this new economic climate and to become more flexible operationally, tactically, and strategically and at the same time integrate business functions and manufacturing, production and service operations so as to meet the challenges which have arisen due to globalisation. Mitsuo Otsuki (2002) lists the main problems that SMEs in Saudi Arabia encounter : lack of funds, shortage of skilled human resources, lack of management and marketing skills, lack of use of modern technologies, problems with costs and raw materials purchases, and the lack of information. They must supply the products which consumer's desire and which meet their needs, they must improve productivity and competitiveness so as to meet the challenges which have arisen due to globalisation, must improve technology transfer, and must encourage investment in SMEs.

Therefore, SMEs compete in the same environment as larger firms. They have to execute the same functions and fulfil the same requirements for customers, but with fewer resources and reduced access to information. All of that constrains their ability to consider and adopt more modern methods and technologies that could improve their operations, ensure quality and enhance customer satisfaction so that they can compete more effectively.

2.2.3 The current state of quality in the Saudi food industry

When Saudi Arabia joined the World Trade Organisation in 2005, the government reduced import tax from 13% to 5%. Aggressive competition from foreign companies was already threatening local companies, and this reduction in import tax made the situation more problematic. International firms imported additional high-quality products which obliged Saudi businesses to improve the quality of their products to an international level while continuing to price them competitively (Alsaleh, 2007, Alsmadi et al., 2012).

The Saudi food industry appears to have been especially affected by international competition. The 2014 statistics of the Saudi Factories Directory of Commerce and Industry, (2015) shows that the food industry makes up 14% of the entire Saudi industrial sector. There are 926 food factories with 187,172 employees, and their assets are worth 99,384.5 million. This is all the more remarkable as the country has little agriculture; as a result the Saudi food industry must import raw foods for processing and packaging from other agriculture countries (Alsaleh, 2007). At present almost US$ 2 billion worth of processes and manufactured food products are imported (Alsaleh, 2007). Competition from foreign food imports has reduced the market share of local firms in Saudi Arabia, indicating that the local businesses must take serious steps to improve the quality of their products and services.

In the last ten years the Saudi food sector along with the rest of Saudi industry has paid careful attention to quality. Saudi businesses now take pride in improving quality standards in their organisations with many companies displaying any quality accreditations they may have in their advertising and on their labels. As well as the positive effect of such quality improvements on food safety and on the long-term well-being of society they also increase the likelihood that the Saudi food industry will endure in the open glo bal market of tomorrow. It is necessary to depend on automated, modern practices which will undoubtedly result in considerable improvements in quality, but not at the cost of production optimisation and productivity. Preserving competitive product cost in an open market is a further aspect of quality that must be taken into consideration in the future when evaluating the position of the Saudi food industry (Alsaleh, 2007).

In his study Alsaleh (2007) evaluated the competitiveness of the Saudi food industry by considering the application of quality tools. According to the study such advanced tools of quality as TQM and Six Sigma were not widely accepted in the surveyed organisations even though they have a positive impact on their competitiveness. The food industry showed a positive attitude towards quality with 60% of the businesses surveyed expressing an interest in new types of quality tools. This positive stance paves the way for further attempts to increase awareness of the new quality tools.

The results of a recent survey on the current situation regarding the adoption and implementation of Six Sigma in Saudi Arabia by Alsmadi et al. (2012) showed that even though Lean and Six Sigma are the focus of business thinking, they have not attracted much attention in developing countries, and this is indeed the case among Saudi firms. Furthermore as little data is available about its application in developing countries, there is a need for more to be known on the subject. Alsmadi also claimed that research on the implementation of LSS in SMEs would be extremely advantageous, not only to future research but also to Saudi business, and that longitudinal studies should be carried out to examine firms prior to and after the implementation of Six Sigma.

Furthermore, the advent of advanced and emergent systems including e-manufacturing present opportunities for SMEs worldwide to compete more effectively. In Saudi, however, the SME first have to establish a basis for LSS practices in order to effectively integrate operational systems before they can embrace and embed the concept of e- manufacturing sustainability.

The papers reviewed indicate that there is a gap in the application of LSS in SMEs in Saudi Arabia, which will increasingly constrain the ability of these firms to meet the increasing demand for quality by their consumers and consequently increase their exposure to international competition.

2.3 Supply Chain Management Background

In today's competitive business environment where companies are constantly striving to discover methods of fulfilling the ever-increasing expectation of customers at a reasonable cost, SCM becomes significant and demands serious attention from the research community. The companies that find out how to better manage their SCs are the ones that will succeed in the global market place. Businesses must identify uncompetitive areas of their SC process and areas where customer expectations are not being fulfilled, must set goals for improvement and must speedily put into practice any needed changes (Jain et al., 2010). SCM is the management of different levels of internal or external organisational transactions, that is to say of goods and information flow (Shokri et al., 2010). As it involves managing information systems, customer service, purchasing, sourcing, transportation, production scheduling order processing, inventory management, warehousing, and marketing, it becomes clear that SCM impacts hugely on the efficiency of any business, and food distribution businesses attract a great deal of attention (Nabhani and Shokri, 2007). Academicians are paying much attention to the development and functioning of SCs which has resulted in a proliferation of definitions and phrases. The following sections deal with definitions of the SC from a range of authors and scholars.

2.3.2 Supply chain management

According to Nabhani and Shokri (2009) an SC is the overall network of a firm's activities and shows connections between supplier, warehouses, factories, stores and customers. The activities comprise material flow as well as services, information and funds. Ayers (2001) describes the SC as a life cycle process which includes information, physical goods, and financial lows, and which strives to meet end-consumer requirements with goods and services from a variety of connected suppliers. According to Mentzer et al. (2001) '*a supply chain is defined as a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer'*. Figure 2:1 represents the main stages of the SC for a typical SC business entity along with the main stages and their indices.

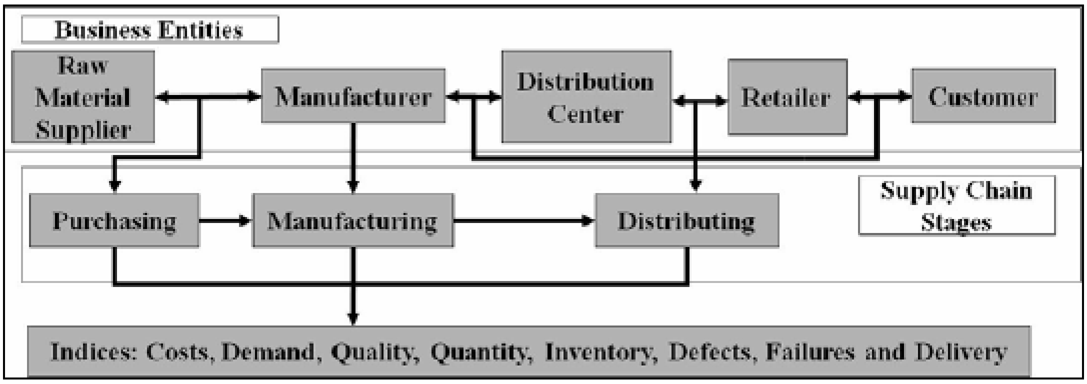


Figure 2.1: Integrated SC entities and stages (Antony et al., 2006)

The term SCM originated with Procter and Gamble at the beginning of the 1980s as they tracked their goods as they made their way through the distribution channel (Saleh, et al., 2011). According to Fawcett and Magnan (2001) a simplified SC is represented in Figure 2.2. A significant draw-back for SCM is that there is no generally accepted definition of the term (Naslund and Williamson, 2010). Although there is no commonly accepted definition, the ones which have been suggested have some features in common. Some of these are that systems include end-to-end coordination and focus on integrating with other entities on the chain to provide value for the end customer. Nevertheless SCM is more than merely new business practices. Instead it can be viewed as a strategic shift in the governing principles and culture which are at the heart of the company, which is then carried over into its dealings with external partners, to bring about a shared culture of optimisation of efficiency (Tan et al., 2002, Ellram and Cooper, 1990).

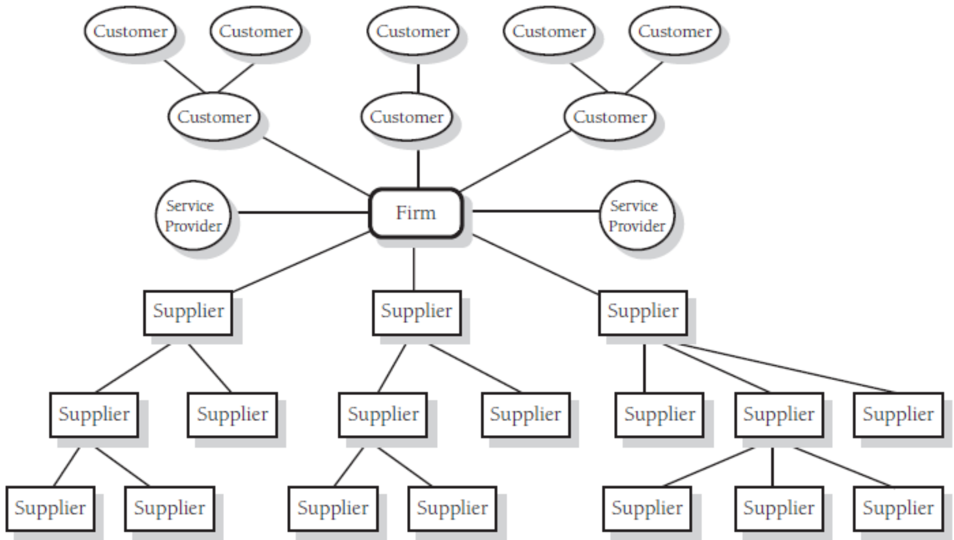


Figure 2.2: A simplified SC according to Fawcett and Magnan (2001

According to Tan et al. (2002) SCM is a new management philosophy which can be seen as an initiative which concentrates on coordinating manufacturing, logistics, materials, distribution and transportation and on how companies draw on their suppliers' capabilities to increase their competitive advantage. This chain connects the processes from different organisations, all the way from raw materials to end user, and can be lengthened to include after-sale services and recycling. Kannan and Tan (2005) and Chan and Chan (2006) described SCM as being to do with integrating processes and optimising the endeavours of all members of the chain to achieve better quality, responsiveness, pricing, and material flow and to add value for customers and to bring down the cost of materials. Lummus et al. (2001) consider that managing information systems, purchasing, customer service, sourcing, transportation, scheduling production, processing orders, managing inventory, warehousing, and marketing are all parts of SCM. It is a strategic management tool which can be drawn on to increase customer satisfaction in general and to enhance a business' competitiveness and profitability.

The Council of Supply Chain Management Professionals describe SCM as "*encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies*" (www.cscmp.org). Furthermore the Global Supply Chain Forum defines SCM as '*the integration of key business processes from end user through original suppliers, that provides products, services, and information that add value for customers and other stakeholders*' (Lambert and Stock, 1993).

Many other authorities have defined SCM. It has been described as a system which is made up of such components as suppliers, production facilities, distribution services, and customers, which are all connected with the feedforward flow of materials and the feedback flow of information (Gunasekaran et al., 2001). SCM makes every effort to supply and distribute the final product all the way from the supplier which supplies the supplier to the customer of the customer, using warehousing, order management, distribution across all channels, and delivery to the customers (Lummus et al., 2001). Mentzer et al. (2001) consider SCM to be the systemic, strategic coordination of traditional business functions and tactics across the business functions of a specific company and across businesses in the SC itself, with the aim of enhancing the performance of specific companies and of the SC overall. It has been mentioned previously that a significant difficulty for SCM is that there is no generally accepted definition. Table 2.2 shows the different definitions of SCM from various researchers.

Table 2.2: Different definitions of SCM

Author	Year	Definition
Ellram and Cooper	(1990)	*"An integrated philosophy to manage the total flow of a distribution channel from supplier to ultimate customer".*
Novack and Simco	(1991)	*"The supply chain management covers the flow of goods from supplier through manufacturer and distributor to the end-user".*
Scott Westbrook	(1991)	*"Supply chain is used to refer to the chain linking each element of the process from, raw materials through to the end customer".*
Cavinato	(1992)	*"The supply chain concept consists of actively managed channels of procurement and distribution. It is the group of firms that add value along product flow from original raw materials to final customer".*
La Londe and Masters	(1994)	*"SCM is the transfer of the customer requirement and cost-effective value through management coordination of the flow of products, services, and accurate information through suppliers to customer.*
Ganeshan and Harrison	(1995)	*"A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials intermediate and finished products, and the distribution of these finished products customers".*
Lee and Corey	(1995)	*"The integration activities taking place among a network of facilities that procure Raw Material, transform them into intermediate goods and then final products, and deliver Products to customers through a distribution system".*
Porter	(1997)	*"SCM is an activity for approaching a clear line of sight from the suppliers to customers through integration of clients and vendors to create value-added, better quality, and customer satisfaction, and bring out new goods and process technology".*
Christopher	(1998)	*"The supply chain is the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer".*
Lambert et al.	(1998)	*"A supply chain is the alignment of firms that bring products or services to market".*
Tan et al.	(1998)	*"The simultaneous integration of customer requirements, internal processes, and upstream supplier performance".*
Handfield and Nichols	(1999)	*"A supply chain encompasses all activities associated with the flow and transformation of goods from the raw material stage, through to the end user, as well as the associated information flows".*

2.3.3 Benefits of supply chain management

SCM can be considered a group of approaches that can efficiently integrate SC entities to produce and distribute the right quantities, at the right time, to the right place, hence keeping system-wide costs as low as possible while maintaining adequate service requirements (Simchi-Levi, 2005). The benefits of SCM can bring have raised interest especially the returns on investments (ROE) and returns on assets (ROA). The final aim of SCM is to increase profitability by adding value and introducing efficiencies which results in greater customer satisfaction (Stock and Boyer, 2009, Tan et al., 1998). The assumption is that when the SC is enhanced, all SC members will reap benefits. Fewer redundancies, lower inventory levels and lead times, and diminished demand uncertainties will translate into decreased costs. Furthermore better process performance bring about better product quality, customer service, responsiveness to the market, and access to the target market (Lambert et al., 2005). Over a period of time SCM has been key to many businesses' success. Indeed at the moment the strategy of most successful organisations is closely linked to its SC practices. Soni and Kodali (2008) list the following benefits of SCM practices:

- Lower levels of uncertainty, errors, delays, and loss throughout the SC;
- Less duplication of processes, information, practices, stock, etc.;
- Operations which offer no or less value for customers are reduced or eliminated;
- Efficiency and productivity are improved, which results in lower costs;
- Lower stock levels;
- Shorter response times;
- Improvements in demand-triggering mechanisms;
- Quicker and most flexible response to customer demands;
- Improvement in information sharing and highlighting; and
- Better adaptation of technology.

A review of the current literature indicates that organisations can benefit in several ways from introducing SCM. Earlier studies have assessed organisations' performance on the basis of a range of criteria, for example financial and non-financial situation, performance in relation to innovation, market share, and levels of satisfaction among employees and customers. These criteria can be used as performance indicators and are also valuable in assessing the benefits of SCM (Talib and Rahman, 2010). Building on this discussion, this section summarises the most significant benefits of SCM along with some of the less important ones:

- Lower product cost, better product quality, quicker response and a greater market share can be the results of a better use of chain resources in an SC. If organisations benchmark SC performance against the organisation's best practice this offers the motivation for improvement which should ultimately result in more sales (Talib et al., 2010).
- When organisations cooperate closely with suppliers they reap benefits in connection with the products, processes and technological innovations, for example new product development, training, workforce development, market requirement and so on. Both customers and suppliers profit from this, and the relationship between the organisation and suppliers also improves as there is a closer 'control' of the SC (Hello and Szekly, 2005). A further advantage is that a close relationship pays dividends when there are any urgent orders as the supplier will try to accommodate them, thereby increasing customer satisfaction (Zahedirad and Shivaraj, 2011).
- SCM also focuses on customer relations. If a close partnership with customers is in place, there will be more cooperation with customers. More cooperation with customers will bring down the risk of late design changes and changes to orders which impact on the organisation's delivery performance (Talib et al., 2010).
- The SC offers the most widely recognised benefits in connection with cost reduction and control (Fawcett and Magnan, 2001). Such SCM tools as e-marketing, e-procurement, ECR, QR, and JIT allow organisations to cost their products and services more accurately. Organisations can use these to calculate real-time and to update information about their buyers and suppliers in key accounts (Rao, 2006).
- Strategic planning also allows there to be greater integration between various departments within an organisation by means of effective communication and information-sharing systems. This breaks down barriers between departments and puts in place an integrated plan throughout the entire organisation (Talib et al., 2010).
- Customer service and responsiveness has given most SCM organisations competitive advantage in the marketplace. When an organisation offers superior service and reacts rapidly to customers' needs it will obtain an advantage (Talib et al., 2010). The four most important benefits of SCM, ranked according to the cumulative scores, are all connected to improved customer service. The most important benefit is responsiveness to customer requests, then on-time delivery and then greater customer satisfaction. A further benefit is that SC integration also brings down lead times for order fulfilment (Fawcett and Magnan, 2001).

- By its very nature, SCM enhances communication and thereby provides better-quality customer service and value. Sustaining superior relationships of cooperation between those inside and outside of the chain results in better SC communication (Talib et al., 2010).

2.3.4 Barriers faced by small- and medium-sized enterprises in supply chain management

Mayer et al. (1995) point out that SC integration entails the efforts of all members of the entire chain. This is a group made up of suppliers, distributors, service providers, manufacturers, retailers and customers or end users. Trust is the key word for all the members of this group and is essential before integration into a reliable chain can be achieved. Trust is present if members have confidence in each other and are prepared to share risks, relying on their exchange partners' integrity. If members do not trust each other, there will be difficulties in connection with information sharing, forecasts will not be accurate, technologies will not be adopted; this will impact on the whole chain, and the SCM system will not function effectively.

This means that even though there are environmental drivers for SCM and many benefits to offer the rate of adoption is lower than expected. There are various possible causes for this, for example fragmented approaches, no integration, no management support, problems with measurement and with information not being available, insufficient information systems. These can all stand in the way of organisations putting into practice a holistic approach to SCM (Monczka and Morgan, 1997). Some of these barriers are due to SCM's multidisciplinary character with the various organisations that make up an SC focusing on different elements of it. This can make it problematic to create a common vision regarding the SC. This is compounded by senior management who struggle to grasp the concept of SCM or do not fully support it. The final result produces inconsistencies in approach both within the chain itself and within the actual organisations (Meehan and Muir, 2008).

Ab Rahman et al. (2008) carried out studies between 2007 and 2008. The primary study of eleven SMEs in 2007 showed significant barriers to putting SCM into practice to be factors such as limited expertise in implementing SCM, problems with load time, higher costs, network development, and achieving customer satisfaction. The later study which took place in 2008 was of five large companies. This study demonstrated that issues such as whether SCM concepts are understood and that there is cooperation with other parties in developing the SC. Additionally, Management support and data transformation play important roles in the implementation of SCM. These studies indicate however, that lack of expertise and interest on the part of some of the parties in SCM, especially if there is little management support, are significant factors and may directly influence the capability of companies to fully espouse SCM practices.

Meehan and Muir also examined barriers which might hinder SMEs in Merseyside in putting SCM into practice. Here it was interesting to note that the barriers do not outweigh the recognised benefits even though there are some constraints, and there is consistency of opinion. The respondents cited the lack of skilled individuals who could oversee and direct SC development as the most important barrier. Whilst this relates to available technical skills it is also a more general issue of limited staff resources that SMEs experience. Lack of 'power' also stands in the way of SMEs adopting SCM. This refers to an overall lack of ability to influence others in their SC in spite of their joint focus on customer service and relational considerations and the lack of interest from other SC members to participate in SC development programmes. This lack of leadership and interest impacts greatly on the ability to take on and power these SCM initiatives through. Meehan and Muir (2008) also draw attention further obstacles that SMEs encounter; lack of experience in the management of improvement programmes, lack of trust between members of the SC, lack of experience in or knowledge of electronic trading, and geographical distance from customers or suppliers.

Zahedirad and Shivaraj (2011) similar survey of 152 Indian SMEs considered a range of industries to identify barriers and benefits. The results highlighted four significant obstacles: lack of an SCM team, lack of clear guidelines, lack of training in SCM and lack of support from top management. This was summarised overall as lack of management . The research data indicates that human considerations are at the root of the most significant obstacles to implementing SC collaboration successfully. Indeed Fawcett et al. (2008) found that many managers thought that employees in their organisations were suspicious and therefore resisted the SCM. In summary, SMEs are faced with a wide range of barriers that include lack of expertise and technical skills that are part of a lack of information, tools and equipment generally. However, the most significant barrier is their attitude to change, lack of management expertise and sophisticated approaches to information.

2.3.5 Food supply chains

Nowadays FSCs are intricate networks which reach across the globe; they lead from farm to consumers and entail producing, processing, distributing, and disposing of food. The desire of consumers that fresh food should be available throughout the year has resulted in food markets becoming globalised (Ahumada and Villalobos, 2009). FSCs vary considerably in extent and complexity and their members range from subsistence farmers who produce their own food to people living in cities who buy their food at supermarkets. The UK Department for Environment, Food and Rural Affairs describes the FSC as being made up of four stages: food manufacture, food wholesale, food retail, and non-residential food catering (DEFRA, 2006). Folkerts and Koehorst (1998) consider a FSC to be a set of interdependent companies that aim to produce superior customer value at as little cost as is feasible by cooperating closely to manage to movement of goods and services down the value-adding chain of agricultural and food products. According to Myoung et al. (2001), for the FSC to function smoothly, all those involved in production, distribution, and consumption must trust one another and it must benefit each to share information. Van der Vorst et al. (2009) observe that FSCs consist of organisations which produce and distribute animal- or vegetable-based products. These can be subdivided into two categories:

- FSC networks for fresh agricultural products, for example fresh vegetables and fruit. These chains are mainly made up of growers, auctioneers, wholesalers, importers and exporters, retailers and specialty shops, and their logistics service suppliers. The main processes involved are handling, (conditioned) storing, packing, transportation, and trading.
- FSC networks for processed food products, for example portioned meats, desserts, snacks, canned food products. These chains are mostly made up of growers, importers, members of the food industry such as processors, retailers and out-of-home segments and their logistics service suppliers. In these types of chains, consumer products with added value are produced from agricultural products which are the raw materials. In some cases the conservation processes results in consumer products that are scarcely perishable, which means that the FSC design is simpler and quality change models are not usually necessary.

Food industry is featured by a large proportion of SMEs conducting food activities (Mangina and Vlachos, 2005). Food distribution firms provide the link between food manufacturers and end consumers. This type of business has key features of the type which characterises a service industry in that a range of activities take place which add value to the product for the customer (Nabhani and Shokri, 2007). Important activities of a food distribution firm include procurement, inventory, warehousing, order processing, and customer service (Nabhani and

Shokri, 2009). Food distribution SMEs can have two distinct features in the SC, 'food' and 'service'. It may be problematic to apply the concept of quality in food distribution SMEs because various complicated components such as 'food attributes', 'supply chain', 'culture', and 'leadership' interact in the business (Nabhani and Shokri, 2007). It is less straightforward to implement SCM practices in smaller companies because it may be complex and difficult to analyse the operational objectives (Nabhani and Shokri, 2009). Figure 2.3 illustrates the complex flow of information and goods and the effectiveness of food distribution which all impact on the overall efficiency of the chain. Food distribution has been placed at the centre of the chain which means that it is more problematic to deal with upstream and downstream components to achieve the desired quality and service attitude (Nabhani and Shokri, 2007).

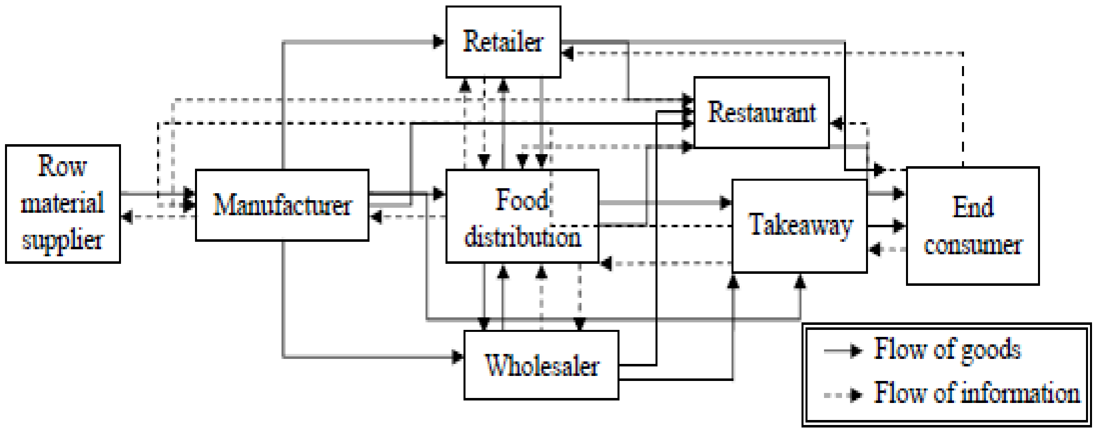


Figure 2.3: The complexity of the flow of information and goods in the food chain (Nabhani and Shokri, 2007)

Key processes for food distribution SMEs include order processing, flexibility, inventory reduction, lead-time reduction, Total Cash Flow, JIT operations, transportation, customer satisfaction, and customer service (Nabhani and Shokri, 2007).

The core elements that drive the processes within the value chain can be categorised as the flow paths (goods and information) and information sharing (connectivity) and have a direct impact on the effectiveness of the operations which is measured by profitability, customer satisfaction and improved decision making. Therefore, the most significant determinant is that the supply chain needs to integrate the flow of goods with the flow of information for optimal performance.

In order to consider the efficiency of the flow paths and connectivity, this study will need to identify the key determinants; these are the critical factors and the conditional variables that will influence the flow paths and connectivity respectively. As the review will concentrate on efficiency, the overall performance within time is an essential element.

2.3.6 Developing the Initial Framework

The supply chain is based upon connecting the goods and the information flow within operations. The information system needs to process and track three resources, human, financial, and stock or goods movement. These three resources are essential for the integration of the goods value stream - the interrelationship of the processes, sequence of tasks, the interfaces and the coordination. The supply chain also includes a planning and forecasting system, which needs to keep a record of the history of the supply and demand, and computes, forecasts and plans future supply decision-making. The coordination that correlates all of these three resources therefore is triggered by the sequence of tasks which all have time dependency.

The scope of the framework will need to address the two key elements that directly impact upon the efficiency of the operations and value chain:

1- The goods flow or how material flows through the key functions of the value chain from request/order to customer fulfilment. The framework will therefore consider the following critical success factors of an efficient material flow - process design, quality, and time. This will need to include a value stream map of the order of the key processes to be automated, taking into the account the duration for each activity within each process as well as the elapsed time, to complete the function and the entire process. The lead-time ladder between each activity, from source to goods despatch before delivery, must be effectively measured in order to provide the content for the information flow.

2- The information flow will be the record of the above flow and will be supplemented with the details of the order, goods (quantity, specification, size etc.) and the relationship to (a) supplier/suppliers. In addition, the information flow will include the decision-making data.

The initial framework can now be presented in Figure 2.4 below.

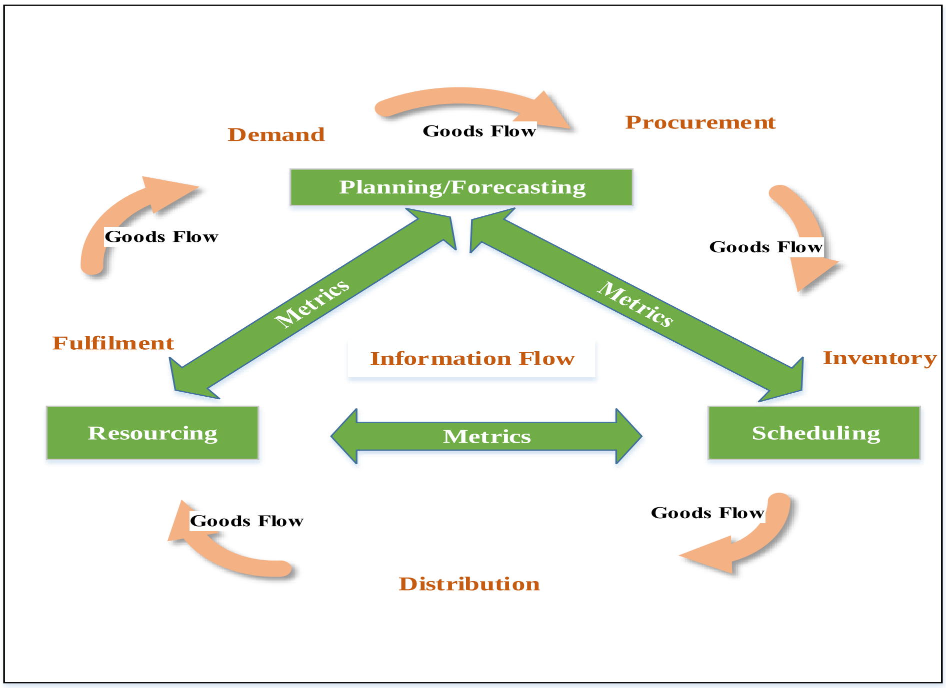


Figure 2.4: The initial framework integrating the flow of goods and information in the supply chain

In all the literature reviewed, however only one paper applied Six Sigma to food distribution. This indicates that there is a gap in the application of LSS practices in the SCM of food distribution sector SMEs. Furthermore, the researcher was not able to find published literature on the SCM of SMEs in Saudi Arabia, highlighting this as a gap in the research.

2.4 Lean and Six Sigma Background

During the second half of the twentieth century, Lean and Six Sigma were the two most important structured process improvement methodologies. They each evolved separately; Lean concentrates on process speed and eliminating waste, and Six Sigma, like its forerunner TQM, aims to eliminate process variation which leads to defects. Ignorance regarding these matters and their repercussions has meant that improvement programmes have produced different measures of success. The researcher holds that the methodologies must be closely examined and analysed so as to better understand and to be a greater chance of success. In this chapter therefore the principles of Lean and Six Sigma will be considered and the need and benefits of LSS integration.

2.4.2 Lean

2.4.2.1 Lean overview

The principles of Lean were developed from the Toyota production system (Antony, 2011) during the 1950s (Lee et al., 2008). There are two concepts at its heart: ‘just-in-time’ (JIT) and

‘Jidohka’. Lean can be seen as a modernised version of JIT as they have a common attitude to change. They each concentrate on the process, specifically on adding value and eliminating waste (Näslund, 2008). In Lean the emphasis is on eliminating waste to result in less variation, shorter cycle times, quicker flow and greater customer ‘value in use’ (Sinclair et al., 2005). The focus of Lean is on efficiency with the objective of producing products and services at the least cost and as quickly as possible. Lean strategy provides a set of tried and tested tools and techniques which will bring down lead times, set up times, and equipment times and will reduce inventories, scrap levels and the amount of reworking needed alongside other hidden sources of waste (Antony, 2001).

Lean methods and tools can change wasteful processes into Lean processes which are value-added and driven by customers. In Toyota Motors Taiichi Ohno and Shigeo Shingo created many Lean tools (Snee, 2010). Even though they may not appear sophisticated, these tools and methods can successfully be used to improve different processes.

By and large scholars recognise five basic principles in Lean. These have their roots in Womack and Jones’ original Lean principles as set out in their ‘Lean thinking”. The principles are: specify value, identify the value stream, smooth process flow, production based on pull, and perfection through elimination of ‘muda’ or waste (Womack and Jones, 1996). Achieving the goal in Lean of eliminating waste entails establishing the value of a process by differentiating between value-added activities or steps and non-value-added activities or steps and cutting down waste (Arnheiter and Maleyeff, 2005, Antony, 2011). When all the activities along the value stream add value, this results in ‘perfection’.

In Lean there are various sorts of waste as can be seen from Table 2.4. Scholars have listed either seven (Womack and Jones, 1996, MacInnes, 2002, George, 2002) or eight types (McAdam, 2003; Jacobson and Johnson, 2006). According to Pepper and Spedding (2010) there are eight types of waste: over-production, defects, unnecessary inventory, inappropriate processing, excessive transportation; waiting; and unnecessary motion. Kilpatrick (2003) added a further one – underutilised people. These eight types of waste which are shown in Table 2.3 are related to what customers value. A Lean initiative utilises value stream mapping to reveal waste and find its value.

Table 2.3: Types of Waste (MacInnes, 2002, McAdam and Donegan, 2003, Womack and Jones, 1996, Jacobson and Johnson, 2006)

Type of Waste	Description
Defects	Any part of the service that does not conform to customer needs
Inventory	Any work in process that exceeds the amount required to meet customer needs
Transportation	Any movement of materials or information
Waiting	Any delay between the end of one step and the beginning of the next step
Over-processing	Any action that adds more value than the customers wants.
Motion	Any movement of or by people that does not directly advance the progress of work
Production	Producing more than what is needed for immediate use
Unused Human Resources	Having excess workforce for the process

2.4.2.2 Benefits of implementing Lean

The Lean methodology offers several benefits to businesses. The overarching benefit of Lean is the ability to see cost and lead time reduction opportunities where you never saw them before (George 2003). The crucial feature of Lean Manufacturing is to reduce waste by cutting out non-value-adding activities, by applying Lean principles at all points in the SC, by enabling an unbroken flow of products to take place without any bottlenecks, by allowing demand to control production (demand-pull instead of supply-push), and by giving the most importance to quality. This usually leads to a lack of backlogs and production being matched to forecast. Benefits include better customer service and lower procurement and plant-floor costs (Lee et al., 2008).

Another benefit of Lean practices is to lower lead times (Arnheiter and Maleyeff, 2005, Kilpatrick, 2003). These can be so low that it is possible to deliver on time using ‘make-to-order’ (MTO) production. Even with high-volume consumer products companies which cater to large supply and distribution channels where a make-to-stock (MTS) approach is necessary, lower lead times result in better replenishment times which reduces inventories in the entire supply network and means that the SC can react more accurately to demand uncertainties (Arnheiter and Maleyeff, 2005).

A further feature of Lean is that variability in demand, manufacturing and supplier is decreased wherever possible. Manufacturing variability involves variation in task times (downtime, absenteeism, operator skill levels etc.) as well as variation in product quality characteristics (length, width, weight etc.). Task time variation can be reduced by the introduction of standardised work procedures. Supplier variability involves uncertainty regarding quality and delivery times. Partnerships and other types of supplier-producer cooperation are frequently used to bring down levels of supplier variability (Arnheiter and Maleyeff, 2005). Kilpatrick (2003) summarises the benefits of implementing Lean into three general categories: Operational, Administrative, and Strategic Improvements. The administrative and strategic benefits of Lean are both exciting. Some of the benefits of Lean are set out in the following Table 2.4.

Table 2.4: Lean's Benefits (Kilpatrick, 2003; Snee, 2010)

Administrative Improvements	Operational Improvements	Strategic Improvements
• Reduction in order processing errors • Streamlining of customer service functions so that customers are no longer placed on hold • Reduction of paperwork in office areas • Reduced staffing demands, allowing the same number of office staff to handle larger numbers of orders • Documentation and streamlining of processing steps enables the out-sourcing of non-critical functions, allowing the company to focus their efforts on customers' needs • Reduction of turnover and the resulting attrition costs • The implementation of job standards and pre-employment profiling ensures the hiring of only "above average" performers	• Reduced lead time (cycle time). • Increased productivity • Reduced work-in-process inventory • Improved quality • Reduced space utilisation	• Sales volume increased • New customers • Greatly improving cash flow

Todoruţ et al. (2010) consider the most important benefits which the Lean model offers are the better use of resources, a shorter product development cycle, better quality at a lower price, more flexibility, and an ecological production system. To summarise, Lean involves five minimisations and five maximisations as is shown in the following Table 2.5.

Table 2.5: The five minimisations and five maximisations (Todoruţ et al. ; 2010)

The five minimisations	The five maximisations
Minimisation of material handling.	Maximisation of use
Minimisation of distances by avoidance of walking	Maximisation of flexibility
Minimisation of efforts.	Maximisation of the production flow
Minimisation of disorder.	Maximisation of visibility
Minimisation of storage.	Maximisation of communication.

2.4.2.3 Lean shortcomings

According to Nagendra and Das (1999) cited by Halgeri et al. (2010), the Lean methodology does have some draw backs and does not always provide solutions. Some companies which have started to use the Lean methodology have improved their inventory turns, and work in progress and lead time, and other companies have shown great improvements, however in only a few areas (George, 2002). This demonstrates that Lean is not infallible but that it has some failings. Shamou (2011) explains the most significant shortcomings:

- A stable master schedule must be in place before Lean's key features can be used to the full. Therefore current processing must be compatible with capacity. Dealing with unforeseen changes or a rush of unexpected orders can be a problem.
- In addition if lead times, change this can also lead to difficulties. Often manufacturers who operate in such an environment will not attempt to use Lean methodologies.
- A further possible draw-back is that electronic transaction data cannot be shared with and communicated to the business operations and other areas of the organisation. With Lean there is very little information flow (Halgeri et al., 2010).
- Lean quality is not judged in terms of the customer's needs or wants but purely in relation to eliminating waste. In Lean the 'zero defect' principle means that quality targets have been reached if there is no scrap or reworking in the process. One of the five Lean principles is defining value (Womack and Jones, 1996); however this does not mean that quality will automatically result as value is defined so as to distinguish between value-adding and non-value-adding activities, not to assess whether the customer is satisfied or delighted.

2.4.3 Six Sigma

2.4.3.1 Six Sigma overview

Bill Smith, an engineer at Motorola, developed Six Sigma in the middle of the 1980s (Snee, 2010). He aimed to identify and eliminate sources of defects or errors in business processes by zeroing in on process outputs which customers perceive as critical. Six Sigma programmes are made up of various improvement projects in different areas and with varying degrees of complexity (Parast, 2011, George, 2002). According to Kivela and Kagi (2009) the programmes are designed to bring down the defect rate of a product or service to 3.4 per million (see Table 2.6). There is in fact no one common definition of Six Sigma but there are several which are each based on specific points of view, for example that of Motorola and of General Electric (Schroeder et al., 2008). The principles of Six Sigma can be applied to move the process average, to help create strong products and processes and to cut down extreme process variation which can result in low quality. The close relationship between bringing down process and product variation and raising business value, expressed in cost, yield, and quality, is at the heart of Six Sigma (Sinclair et al., 2005). Its goal is a business environment where there is no error (Moosa and Sajid, 2010). Furthermore, according to Antony (2011) Six Sigma can be significant in creating an understanding of the cause and nature of what is actually taking place during the process steps. Kwak and Anbari (2006) describe it as a business strategy that concentrates on enhancing business systems, productivity, financial performance, and on understanding customer requirements. Customer focus is the most important consideration in Six Sigma, and improvements are understood in terms of how they impact on customer satisfaction and value (Pande et al., 2002).

Table 2.6: Measure of defect (Pande et al., 2002)

Sigma level	**Defects per million opportunities**
6	3.4
5	233.0
4	6,210.0
3	66,807.0
2	308,537.0
1	690,000.0

Parast (2011) considers that Six Sigma differs from other process improvement programmes such as TQM, Lean, and the Baldrige model in that it can offer an organisational context which allows problem solving and exploration throughout the organisation. Although Six Sigma programmes are rooted in the quality movement they differ from programmes such as the Lean systems or ISO-900 in that they have a limited time-frame, measurable and quantifiable goals, and a project structure (Mi Dahlgaard-Park et al., 2006). According to Shamou (2011) Six Sigma's successes show that it is a powerful improvement methodology. Impressive cost savings as well as increased customer satisfaction and profitability mean that many companies and businesses turn to Six Sigma. Indeed it has several characteristics which other improvement programmes do not have, for example it is capable of dealing with process variation. There are two approaches in Six Sigma: DMAIC which stands for 'Define, Measure, Analyse, Implement, and Control' and DMADV ('Define, Measure, Analyse, Design, Verify') (Tariq and Khan, 2011). Kumar et al. (2009) consider that the DMAIC approach, which seeks to '*decrease variation in the process by identifying and improving specific areas'*, is best able to recognise problems and deal with them. Tariq and Khan (2011) observe that the five phases of DMAIC are crucial in improving processes. In the Define phase problems are defined in terms of customer and project goals. The Measure phase measures current processes and gathers relevant data. The source of problems is identified in the Analyse phase and all factors are examined. In the Improve phase current processes are optimised using various data analysis techniques. Finally in the Control phase the process is controlled and any problem that arises is corrected before any error or defect can develop.

2.4.3.2 Benefits of Six Sigma

The reduction and prevention of defects which impact on the quality of products and processes are considered the most important benefits which Six Sigma offers (Tjahjono et al., 2010). It concentrates on the improving product quality by tackling process variation. According to Shamou (2011), variation results in defects, one type of waste. Six Sigma alone tackles process variation which means that it impacts directly and rapidly on quality. A further feature of Six Sigma is that Unlike the other process improvement methodologies, Six Sigma is directly connected to corporate financial targets (Antony, 2004). The second generation of Six Sigma (1994 – 2000) focused on bringing down costs and was implemented by General Electrics, Du Pont and Honeywell and other well-known organisations (Tjahjono et al., 2010). With Six Sigma the cost of quality can be brought down to a level of less than 1% of sales which compares favourably to the level with Four Sigma which is 15% (Mi Dahlgaard-Park and Bendell, 2006). Table 2.7 shows how the level of Sigma influences the percentage net income.

Table 2.7: Cost of quality (O'Rourke, 2005)

Sigma Level	Defects Per Million Opportunities	Cost of Quality
2	308,357 (Non-competitive companies)	Not applicable
3	<1% of sales	25-40% of sales
4	6,210 (Industry average)	15-25% of sales
5	233	5-15% of sales
6	3.4 (World class)	<1% of sales
Each sigma shift provides a 10 percent net income improvement		

Another benefit is that Six Sigma is a business strategy and methodology that brings greater customer satisfaction through increased process performance (Snee, 2010, Thomas et al., 2008). It is to be expected that errors will sometimes occur in processes, but if hundreds or thousands of processes and operations are involved, this will reach a significant level (Trybus, 2005). Six Sigma should then be implemented to recognise process variation root causes, identify the solution, and introduce control measures (Shamou, 2011). Finally Six Sigma is an effective way of measuring process capability and performance which allows the performance of a business process to be benchmarked and to be compared with other processes and with industry standards. It has become a generally accepted measure of quality (Shamou, 2011). Conventionally Six Sigma has been related to reducing defects and costs in the manufacturing sector. It has been reported that applying Six Sigma projects in service companies also results in various benefits (Antony, 2004, Antony et al., 2007):

- Greater customer satisfaction;
- Lower defect rate in service processes;
- Less variability in key service processes;
- Improved culture with a mind-set of continuous improvement of service process performance;
- Lower process cycle time resulting in faster service delivery;
- Lower service operational costs; and
- Greater market share.

2.4.3.3 Six Sigma weaknesses

Six Sigma has its limitations and is not a faultless methodology. Organisations must be aware that Six Sigma does not provide the answers to all business issues, and may not be the most relevant management strategy for every organisation. For Six Sigma to be sustainable, organisations must analyse it and take into account its strengths and weaknesses, and implement the Six Sigma principles, concepts and tools correctly (Kwak and Anbari, 2006). As value stream improvement is not one of its aims, Six Sigma does not deal with the issue of process lead time directly. It is hence to be expected that there will be no lead time improvement when companies implement the methodology (Shamou and Arunachalam, 2009). Six Sigma does not give quick results but it can take between six and eight months before a solution to be developed with a Six Sigma project. The most time consuming part of the process is data collection, and this can result in delays which will be unacceptable to businesses which are under threat (Shamou, 2011). In edition sometimes solutions driven by the data can be costly so that only a small component of the solution is eventually put into effect; sometimes the entire project can be shelved if it is too expensive for the business to implement (Shamou, 2011).

In the face of the limitation in publications on Six Sigma in the food distribution sector, the research investigated the challenges of Six Sigma in related service sectors. There is a range of difficulties when Six Sigma is applied in the service industries, some of which are related to data collection. Antony (2004) and Antony et al., (2007) list some of the potential difficulties and challenges as follows:

- It is less straightforward to collect data for analysis;
- It is less straightforward to measure customer satisfaction in a service context;
- In a service-focused organisation it is difficult to find processes which can be assessed as defects per million opportunities;
- There is comparatively more resistance to change in a service context than in a manufacturing one;
- Because a larger sample size is necessary for statistical validity reasons, the data collection process takes longer;
- Flowcharts and process maps are not generally used in service processes;
- Individual measurements are often used in service processes; this means that subgroups must be defined in terms of a particular interval of time (i.e. a week or month);
- Service processes are easily affected by noise or other factors which cannot be controlled;
- In service industries most data is collected manually in face-to-face interactions;
  Most decisions in services are based on 'human judgement' and on fluid criteria;
- Usually service processes are affected by human and organisational changes to a greater extent than are changes to manufacturing processes.

2.4.4 Comparing Lean and Six Sigma

There are advantages and benefits to be gained by businesses from both Lean and Six Sigma, and they must choose which one is most suitable. Antony (2011) compiled the opinions of various important academics and practitioners in the field. Professor Sung Park, researcher at National Seoul University in South Korea observes that both Lean and Six Sigma stress process flow. However while Six Sigma concentrates on achieving process flow with minimum variation, Lean focuses on process flow with minimum waste with the aim of improving speed and raising productivity. Six Sigma concentrates on bringing down costs by systematically dealing with issues with the cost of poor quality items in different processes, while Lean aims to reduce cost by removing all types of non-value-added activities and eliminating waste. Professor Goh, working as a research at the National University of Singapore, considers that there are more refined ideas and tools or techniques. Unlike Six Sigma, Lean is formalised and past experience is codified. Professor Rae Cho, Clemson University, USA, and Dr Phil Rowe, Burton Consulting Group describe Six Sigma as using more statistical tools and being more suitable for complex problems with unknown solutions. However Mr Alessandro Laureani, Master Black Belt from Hertz Corporation, has observed that it can be advantageous to start with Lean when trying to enlist the cooperation of staff members at the early stages of the process as Lean tools are mostly less complicated than Six Sigma ones, and will also offer results more rapidly which can be shown to the management.

Provided the processes are not too complex and the company not too large, it will then be possible to progress to the second stage and to use the Six Sigma statistical tools to deal with the more complicated problems which have no obvious solution. Many companies are impressed by the results achieved using one or other of the methodologies but do not take into account the fact that their situation could be different and therefore the outcomes could be different. It is essential that companies carry out thorough research to find out which methodology will be most appropriate for their business needs. They must take into account their business processes, the nature of their product, the type of problem (significant waste, safety issues, compliance with regulations) and the source of any problem (process variation, design).

When Lean and Six Sigma are closely examined it becomes clear that they complement each other even though they concentrate on different improvement goals. Table 2.8 contains a comparison of Six Sigma and Lean and details how they complement each other. Because of the dynamic nature of competition in the global market it is becoming increasingly important that industrial core intrinsic technologies be developed. It is necessary for companies to maintain their intrinsic technologies and constantly upgrade them so as to acquire sustainable competitive advantage. They must also upgrade their management technologies and be aware of recent developments and how these can be incorporated into the company's present system or they will not be able to continue to exist in the market even if they have got advanced intrinsic technologies. When the two methodologies are combined the results will be superior to the outcomes that would result from one alone. The integrated approach is superior to earlier ones because it integrates the process elements (process capability, process management, statistical thinking) and the human elements (leadership, customer focus, cultural change etc.) of process improvement. Companies frequently neglect integrating these aspects into their processes and quality improvement initiatives which means that they do not achieve the radical improvements which they desire (Antony, 2011).

Table 2.8: Extracted Comparison of Lean and Six Sigma by Andersson et al. (2006) and Todoruţ et al. (2010)

Programme	**Lean**	**Six Sigma**
Origin	The quality revolution in Japan and Toyota	The quality revolution in Japan and Motorola.
Approach	Project management	Project management
Length of Projects	1 week to 3 months	2 to 6 months
Theory	Remove waste	Reduce variation (No defects)
Process view	Improve flow in processes	Reduce variation and improve processes.
Tools	Analytical tools	Advanced statistical and analytical tools
Application	Primarily manufacturing processes	All business processes
Training	Learning by doing	Learning by doing
Methodologies	Identify value Identify value stream Flow Pull Perfection	Define Measure Analyse Improve Control
Focus	Flow focused	Problem focused
Assumptions	Waste removal will improve business performance. Many small improvements are better than systems analysis.	A problem exists Figures and numbers are value System output improves if variation in all processes is reduced
Primary effect	Reduced flow time	Uniform process output
Secondary effects	Less variation Uniform output Less inventory New accounting system Flow-performance measure for managers Improved quality	Less waste Fast throughput Less inventory Fluctuation-performance measures for managers Improved quality
Criticisms	Statistical or system analysis not valued. The SC is not applicable in all industries.	System interaction not considered. Processes improved independently. Does not improve customer satisfaction

Professor Jiju Antony, speaking from his experience as a research and a practitioner, advocates an integrated approach, considering that this will give lasting results. A well-balanced approach which draws on both Lean and Six Sigma approaches is most likely to deal with all key issues and problems. When Six Sigma and Lean are put into effect at the same time this will allow all sorts of people to be included in improvement activities which will help the organisation to become more effective and to gain competitive advantage. Lean and Six Sigma which are two significant process improvement methodologies have developed independently from each other during the last few decades.

2.4.5 Lean Six Sigma

There are many definitions regarding LSS which recognised in the literature, however there are four main classifications. The first defines Six Sigma as a complement to Lean (Tjahjono et al., 2010) and synthesises the best practice Six Sigma techniques that eliminate waste and improve processes in one overarching approach to enhance the performance progress (Zhang et al., 2012; O'Rourke, 2005; Salah et al., 2011; Polk, 2011; Todoruţ et al., 2010; Mader, 2009; Jing, 2009; Taylor, 2008). Nonetheless by adopting this seamless integration it is difficult to fully demonstrate that the final outcomes are superior to the respective individual implementations (Shamou, 2011).

The second classification considers that LSS is a management philosophy which benefits customers, suppliers, employees and shareholders. Additionally, George (2002), Shamou and Arnachalam (2009) and Snee (2010) described it as a methodology which aims to achieve maximum shareholder value by rapidly improving customer satisfaction, quality, operational process and flexibility, reducing cost and increasing bottom-line savings. Furthermore, Salah et al. (2010) and Polk (2011) add that this focus reduces variation rates, and eliminates activities that do not add value. Todoruţ et al. (2010) conclude that LSS achieves its goal of delighting the customer with products and services of an excellent standard at competitive prices by eliminating losses from production and reaching Six Sigma production levels.

The third classification views LSS as both a business strategy and a methodology, with Snee (2010), Thomas et al. (2008) and Basu (2004), considering it that brings together statistical and business processes into an integrated model of process, product and service improvement, delivering operational excellence. Spector (2006) considers that LSS is most successful in improving processes and is frequently applied in top performing organisations as a powerful approach that tackles problems without the burden of introducing separate individual systems

(Salah et al., 2011; Zhang et al., 2012). DMAIC and DMADV are used alongside Lean to accomplish bottom line results. It is put into effect on a project-by-project basis (3-6 months). Antony et al. (2004) observe that a combination of the discipline and systematic approach of Six Sigma with the speed and agility of Lean results in more effective solutions when striving for business and operations excellence.

Finally, the last classification considers LSS as a business culture. Here, the success of LSS depends on both the operational element and the top management of the organisation. According to Spector (2006) LSS is most helpful in improving processes when it is rolled out with the direct support of the board in top performing organisations. Hilton and Sohal (2012) describe LSS as a philosophy of improvement that provides management with the structure and tools to tackle both human and process organisational factors issues (Jacobson and Johnson, 2006) and as such has been more successful than earlier approaches. Moreover, it acknowledges that LSS is a useful leadership development tool as it better fits leaders for their role as leaders of change (Snee, 2010). In conclusion, to quote Welch and Welch (2005), "*Perhaps the biggest but most unheralded benefit of Six Sigma is its capacity to develop a cadre of great leaders*."

2.4.6 The need to integrate Lean and Six Sigma

Lean and Six Sigma are clearly based on two different drivers. Lean is based on the wish to raise the product flow velocity by eliminating all non-value-added activities while Six Sigma has its roots in the desire to guarantee final product quality by concentrating on very high conformance levels. It is important for the supporters of one system to learn from the supporters of the other (Snee, 2010). Nevertheless organisations which have implemented Six Sigma or Lean may sooner or later come to the point of diminishing returns (Arnheiter and Maleyeff, 2005, George, 2002). In spite of Lean and Six Sigma having developed separately, several articles advocate an integrated approach (Clegg et al., 2010). It is essential to tackle improvement systematically for any improvement of performance in terms of quality, cost, lead times for delivery which individually and collectively influence customer satisfaction.

Six Sigma and Lean go hand in hand and complement each other (Lee and Choi, 2006). Most practitioners hold that the two methodologies are mutually complementary with the use of both methods together allowing all sorts of problems in processes to be tackled with the most suitable toolkit resulting in even more dramatic improvements than could be achieved through the use of only one method (Todoruţ et al., 2009). Similarly Pepper and Spedding (2010) argue that the fusion of Lean and Six Sigma is potentially an extremely powerful tool. If Lean's cultural elements and Six Sigma's data driven investigations are combined, the result could be an indisputable and ongoing approach to implementing organisational change and improving processes. Furthermore Snee (2010) observes that an integrated system for the management of projects must be developed, and not separate systems for Lean or Six Sigma projects. Only then will there be a common improvement methodology. Most of the current literature implies Lean and Six Sigma are the optimal combination for process improvement (George, 2002; Arnheiter et al, 2005; Shamou and Arunachalam, 2009; Antony, 2011; Zhang et al, 2012; Salah et al., 2011; Snee, 2010).

Recently several companies have acknowledged the benefits of implementing Lean and Six Sigma at the same time. Often they had started applying Six Sigma and had made efforts over several months reducing lead time; they then recognised that they had in effect been implementing Lean (George, 2002). By combining Lean and Six Sigma, both systems' deficiencies were overridden; thus the organisations could obtain their desired outcomes more quickly and effectively, and furthermore they were successful at all levels and for all sizes of projects, ranging from point improvements on the shop floor all the way up to multifaceted projects where complex analyses were necessary (Salah et al., 2011). Figure 2.5 shows the types of improvements that may take place in organisations where Lean or Six Sigma has been implemented, and the additional improvement that an integrated programme would bring. The horizontal axis shows the customer's point of view and their perception of value which includes quality and delivery performance. The vertical axis shows the cost to the producer for providing the product or service to the customer. In both systems improvements take place, but after a certain point these begin to level off (Arnheiter and Maleyeff, 2005).

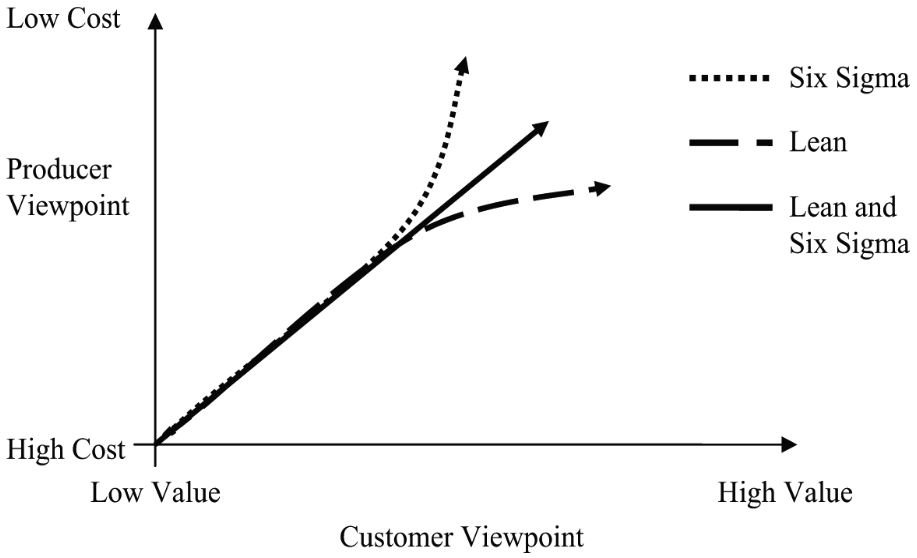


Figure 2.5: Summary of the nature of improvements (Source: Arnheiter and Maleyeff, 2005)

According to Pepper and Spedding (2010) when Lean is adopted and Six Sigma is not, the tools which are needed to achieve the optimum level of improvement are lacking. On the other hand when Six Sigma is introduced and Lean is not, the improvement has a range of tools available but lacks the strategy or structure needed to use them in a system. Bevan et al. (2006) consider that '*combining common sense Lean and common science Six Sigma offers the potential to achieve uncommon results*'.

Even though Lean and Six Sigma have been in existence for more than twenty-five years, a considerable number of companies still have little idea of what they are (Salah et al., 2011). Bendell (2006) and Pepper and Spedding (2010) consider that LSS has not yet fully developed into a specific area of academic research. Although it has been of great use in manufacturing and service sectors and in large and small organisations, research is still in its initial stages (Zhang et al., 2012), and O'Rourke (2005) observes that there is not much research on developing, critiquing, or comparing actual practical applications of LSS.

A recent survey by Alsmadi et al. (2012) on the degree that organisations in Saudi Arabia have adopted and implemented Six Sigma indicates that little notice has been paid to Lean and Six Sigma in developing countries even though these methodologies are on the cutting edge of current business thinking. This confirms Antony and Desai's (2009) claims that Lean and Six Sigma have not been assimilated into organisational culture in spite of it being necessary to do so to obtain sustainable results.

There are constant changes in customer needs which are continually increasing. Furthermore LSS has been useful in SME organisations as Zhang et al. (2012) have pointed out. Nevertheless there is still room for more research in this area so as to develop the theoretical background of the implementation of LSS in SMEs. Hoerl and Gardner (2010) hold that it is necessary to examine the LSS tools and techniques to make it a complete fit in both the service and the manufacturing sector. It is also necessary to look at the integration of Lean and Six Sigma as presented in the literature scientifically and systematically and to gain a comprehensive view of how they are integrated. The obvious conclusion is that as LSS is still a comparatively recent methodology, it has yet to become popular, indicating a lack of confidence among organisations, a situation which will only change when more research is available which will then increase confidence levels among manufacturers (Shamou, 2011).

2.4.7 Benefits of integrating Lean and Six Sigma

When Lean and Six Sigma are integrated this results in greater flexibility in problem solving and offers two possible approaches, Kaizen and DMAIC, to use when tackling with problems, according to the kind of problem or project involved (Shamou and Arunachalam, 2009). Figure 2.6 shows Snee’s (2010) analysis of the improvement objectives and needs of organisations. Whether more Lean tools or Six Sigma tools are used depends on which types of problems an organisation may have. Familiar problems which organisations may face include needing to:

- Rationalise process flow so that it is less complex, there is less downtown, a shorter cycle time, and less waste;
- Raise the level of product quality;
- Deliver products of a consistent standard;
- Bring down costs of processes and products;
- Lower levels of process variation to bring down waste, for example waste due to defective products;
- Achieve better process control to keep processes stable and predictable;
- Identify the sweet spot in the process operating window; and
- Develop strong processes and products.

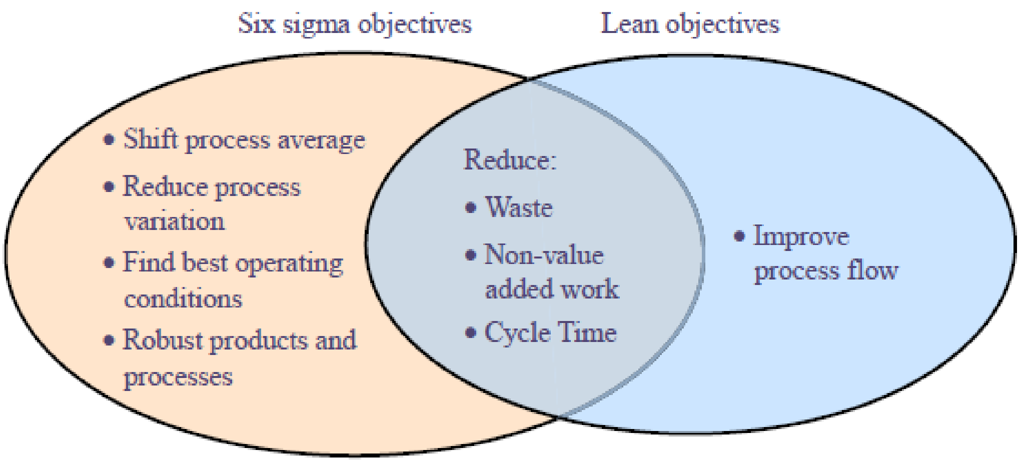


Figure 2.6: Improvement objectives and needs of an organisation, (Snee, 2010)

This research adopts the views of George et al. (2007) who maintain that LSS allows companies to thrive in the new business environment where customer expectations include no defects and rapid delivery at low cost. When these two practices are brought together the results are rapid, standardised processes which reduce costs and improve quality (Polk, 2011).

Lean and Six Sigma are two well-known strategies for business process improvement which can offer striking improvements in cost, quality and time by concentrating on process performance (Antony et al., 2005, Taylor, 2008). By raising levels of customer satisfaction rapidly, LSS maximises shareholder value (Nabhani and Shokri, 2009). Arthur (2007)and Nabhani and Shokri (2009) believe that quality, cost and on-time delivery are the most important drivers of customer satisfaction in the food distribution sector. This means the three main objectives can be expressed as:

- To raise product quality by having a better perception of customer needs and introducing the process that will fulfil them;
- Bringing down cost by eliminating waste and using resources more effectively;
- Bringing down lead-time with better process design, by eliminating all types of waste, and by sustaining constant material flow.

When the two tools are used in combination, it is highly likely that all three objectives will be achieved. It is necessary to use a standard operational framework to implement Lean and Six Sigma before organisations can benefit fully from both strategies (George, 2002). For this reason, the DMAIC process is used for the main functional system when implementing LSS

(Thomas et al., 2008). The conceptual development of the LSS framework can be seen in Figure 2.7.

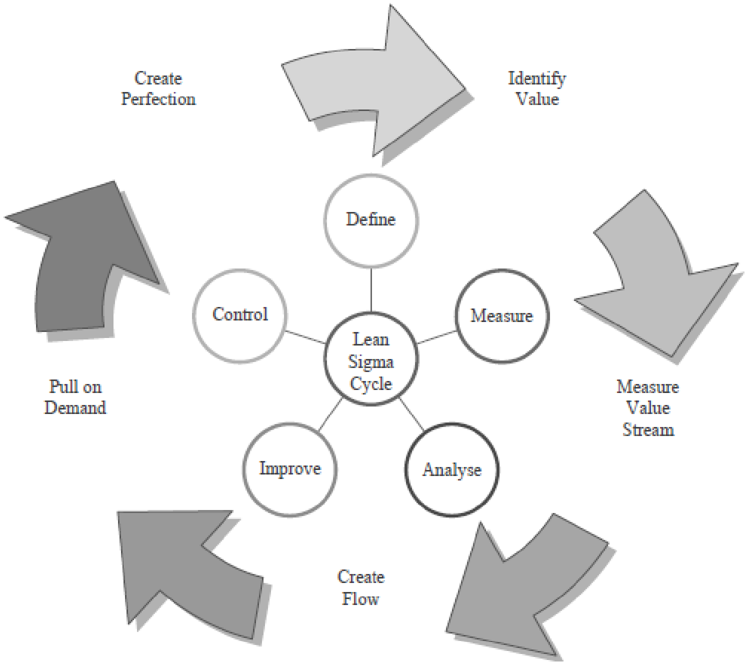


Figure 2.7: The conceptual development of the LSS framework (Source: Thomas et al., 2008)

According to Todoruţ et al. (2010) an integrated approach to process improvement using the LSS approach will:

- Use value stream mapping (VSM) to produce series of projects suitable for the application of Six Sigma or Lean tools;
- Introduce Lean principles initially to gain momentum; the Six Sigma process will come into play later when more complicated issues must be addressed;
- Adapt the substance of the training to the situation of the particular organisation. It may be advantageous for some companies to apply Lean principles to housekeeping while others may already have done so and will benefit from more advanced tools.

2.4.8 Supply chain management and Lean Six Sigma

It is not easy to implement SCM, because it is extremely difficult to design and operate an SC and keep total system-wide costs down, while at the same time keeping total system-wide service levels elevated. This is further complicated by the challenges associated with making accurate customer demand forecasts that arise from the difficulty of balancing supply and demand and the tremendous differences in inventory and back-order levels in the SC, inaccurate forecasts, and uncertainty about delivery lead times and the number of manufacturing defects which can cause further problems (Simchi-Levi, 2005). SCM on its own simply does not have the appropriate analytical tools for problem solving and may not be flexible enough to adjust to complexity in SCs and changes in market segments and demand (Amer et al., 2007). It is vital for the success of an organisation and its suppliers that wasteful activities be eliminated and total SCM costs be reduced by employing continuous improvement methodologies and up-to-date electronic systems (Dasgupta, 2003).

Continuous improvement and SCM are directly related (Salah et al., 2010). Understanding SC dynamics and relationships is an essential driver of business performance (Salah et al., 2011). The important issue of how to integrate SCM with other operational performance initiatives such as Lean is still being investigated and developed (Ballou et al., 2000, Ferrin et al., 2002), as is its integration with Six Sigma and LSS (Salah et al., 2011). In the face of mounting competition, suppliers are forced to look at SCM systems to provide high-quality products at the lowest possible costs, with there being a direct link between continuous improvement and SCM (Salah et al., 2010). Inventory, transportation costs and SC partners are all central to developing SCM. Here, key JIT and LSS concepts come into play. These include adding value for customers, reducing the number of defects, making value flow to customers more rapidly, pulling rather than pushing, selecting a few excellent strategic suppliers, bringing down inventory levels and waste and improving delivery times by delivering less more frequently and to final point of use (Salah et al., 2011).

Parveen and Rao (2009) consider that an integrated approach to Lean Manufacturing from the perspective of the Lean SC is necessary if complete leanness throughout the SC is to be achieved. The Lean approach to SCM is also known as the Lean logistics approach; it aims to reduce inventories, waste and lead times (Foster and Ganguly, 2007). An important concept in Lean Manufacturing, which is emphasised in the enterprise VSM exercises which are employed to develop SC processes (Foster and Ganguly, 2007), is to consider things from the perspective of the enterprise SC as a whole rather than individual processes or entities (Salah et al., 2011). The implementation of Lean Manufacturing in SCM incorporates the principles of JIT. The right products must be delivered on time and at a low cost. JIT delivery is extremely dependent on suppliers and is fundamental for successful JIT production. The Lean SC allows small amounts to be produced economically and thus enables producers to bring down inventory and production costs and satisfy customer demands (Vonderembse et al., 2006).

Integrating Six Sigma with SCM can bring with it advantages such as DMAIC project discipline, sustainable results and a widely recognised human resources framework which uses the belt system and strong quantitative analysis (Mo Yang et al., 2007). Responding to dissatisfaction with Six Sigma and SCM efforts, Samsung combined the two to improve its operations and efficiency (Samsung, 2007). According to Dasgupta (2003) it is not easy to measure, monitor and improve the performance of an SC and its entities using only the traditional strategic criteria of cycle and lead times, delivery performance, total SCM costs, rolled throughput yield, inventory levels, etc. He therefore suggests a structured methodology using Six Sigma metrics to offer a common scale, such as defects per unit or Sigma-level.

To sum up, various scholars have deliberated on the integration of LSS with SCM. The tools of Six Sigma provide assurance that high-quality products are developed using capable processes, while Lean tools make sure that there is an efficient flow throughout the SCM's different areas, such as inventories, demand quantities, schedules, etc. LSS tools are generally designed to decrease costs, waste and non-value-adding activities, and thereby to satisfy all customers throughout the SC. The Lean approach considers mistake proofing. It asks the 'five whys' to get to the root cause of the problem and identify the influencing variables that need to be addressed within the process design. Influencing variables that directly affect the flow of goods include the physical attributes of location, space, placement and storage. One of the most fundamental, but powerful cornerstones of Lean are the five Steps of 'Seiri', 'Seiton', Seiso, Seiketsu and Shitsuke, a tool that introduces standard operational practices to ensure efficient, repeatable, safe ways of working. The Toyota production system represents the two main implementation frameworks. The 5S seeks to introduce discipline and a systematic work method that ensures both the efficient and safe flow of goods in and out, and which, through discipline and order, has a direct impact on productivity, visual management, safety management, and on minimising destruction, and therefore significantly reducing wastes in terms of time, resources and goods. Furthermore there is an emphasis on the use of visual factors to allow the timely identification of problems for faster and proactive resolution (Hopp and Spearman, 2004). The systematic nature of LSS tools, however, requires knowledge and cooperation between the people working within it; it requires ongoing training to develop and sustain the skills and the constant measurement of the lead and lag times between tasks.

Essentially, the Lean approach requires the transition from waste thinking that is reactive, not measured, and not defined, to a shift in mindset where each aspect of waste is defined and a threshold/standard is set with the intention of eliminating the root cause. LSS promotes good relationships with suppliers and customers in various areas such as partnership and problem solving (Salah et al., 2011). These good relationships and the problem-solving focus demand that the quality of decision-making between the SC partners regarding schedules, forecasted demands and inventories are managed effectively and will require that the information is shared on a timely basis for real-time decisions within the internal and external SCs.

2.4.9 Principles of the Kanban Systems

Finally, the goods and information flow is connected by the inventory system which is the representation of the physical store and the movement of goods within the virtual store – the data that relates all aspects of the stock, stores and movement. Where the inventory system is driven by demand or pull, the Kanban system provides a best practice model for efficient and effective stock management. The key principles of Kanban is that the movement and storage of goods is based on a visual colour-coded system; it augments the JIT approach by controlling the direction and flow of the goods between the departmental functions, using the set visual cues that trigger an alert to action.

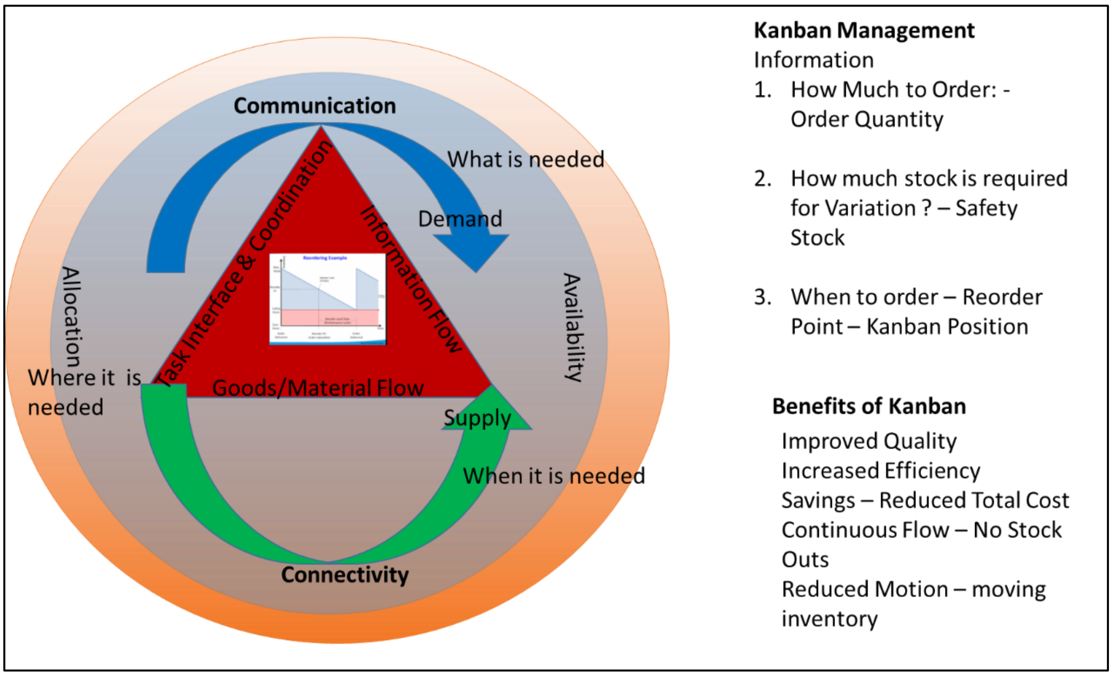


Figure 2.8: The adapted basis of the proposed Kanban system

2.4.10 Integration of Lean with the Kanban Systems

The Kanban system is combined effectively with JIT to deliver significant benefits as well as to provide a standardised approach. The Kanban system is governed by three set quantity levels that are calculated and standardised for each separate stock item. These calculation algorithms are categorised as follows:

- How much stock to order – a standard order quantity that is calculated as an average from the recent history of orders /customer demand for the product.
- This average takes into account variation over the period selected which then becomes the buffer/safety zone. These two calculations produce the maximum threshold – the maximum quantity or level of stock that should exist in the store at any point in time
- When to order is a vital element of Kanban and Kanban requires the calculation of the re-order point which, when it is reached, activates the visual coding system as an alert to place an order before the buffer/safety zone is reached. The re-order point takes into account the average lead-time for orders to be received and includes variation.

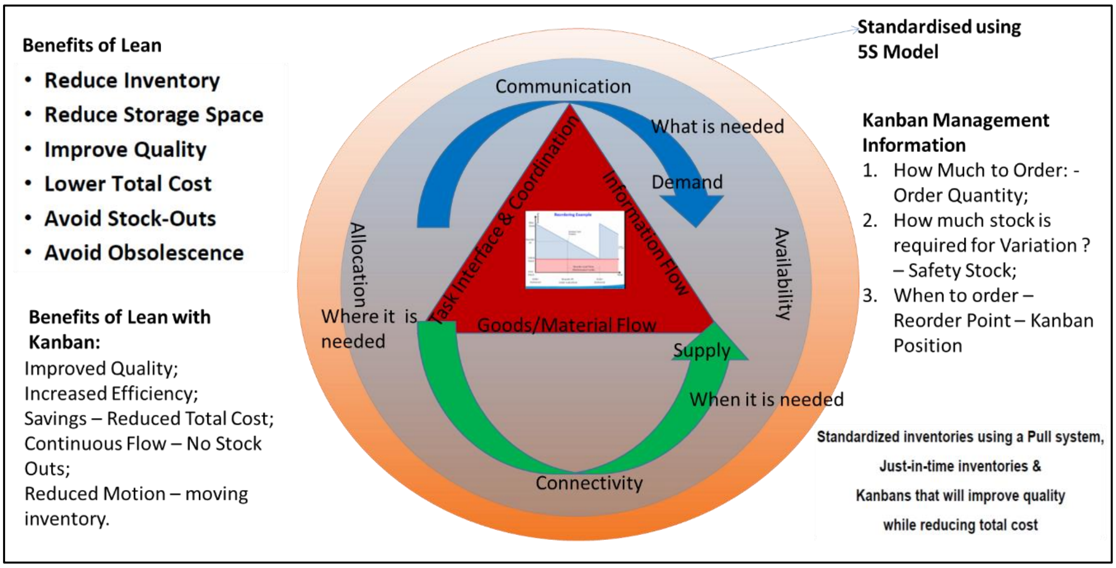


Figure 2.9: The propose Kanban approach

2.4.11 The Proposed Kanban Cycle

The use of the visual cards that are triggered by the three key stock levels controls the ordering, supply and fulfilment cycle. The Kanban card system improves the continuity of stock supply in a way that is consistent with demand/pull and reduces the incidence of overstocking as well as the frequency with which the organisation runs out of stock. The associated advantage is a saving in costs associated with both stock outages and surplus. The length of time stock remains in store is managed to avoid obsolescence and reduce the likelihood of deterioration as well as breakages or damage. Furthermore, as the receipt of stock is anticipated using the visual card cues it is easier to plan resources, space and availability in order to reduce the likelihood of stock waiting too long in the receiving depot. The location of stock is controlled by bin cards and specific allocation so the likelihood of the stock being misplaced or getting lost in the stores is minimised. So Kanban directly contributes to the improvement of quality.

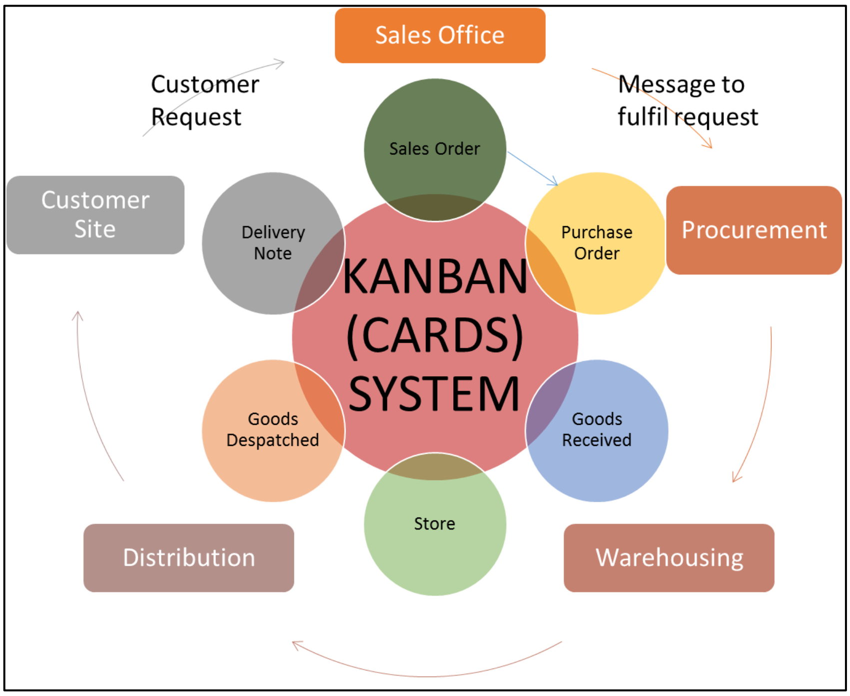


Figure 2.10: The integration of the Kanban cycle in the flow of goods and information

Once the Kanban system is in place and the re-order point determined, this order is fulfilled (pull) immediately by the store's inventory when the customer places it. This results in faster lead times, more customer satisfaction and a greater ability to meet variations in demand. When stock reaches the classified re-order point this acts as an automatic alert (push) to re-order. Assuming the calculations are correct there will be sufficient stock in store to satisfy and fulfil further customer demand before receiving the ordered stock. The Kanban card/colour flag information system alerts all functions and departments regarding the status of the goods flow and connects them with each other, which promotes more effective resource scheduling.

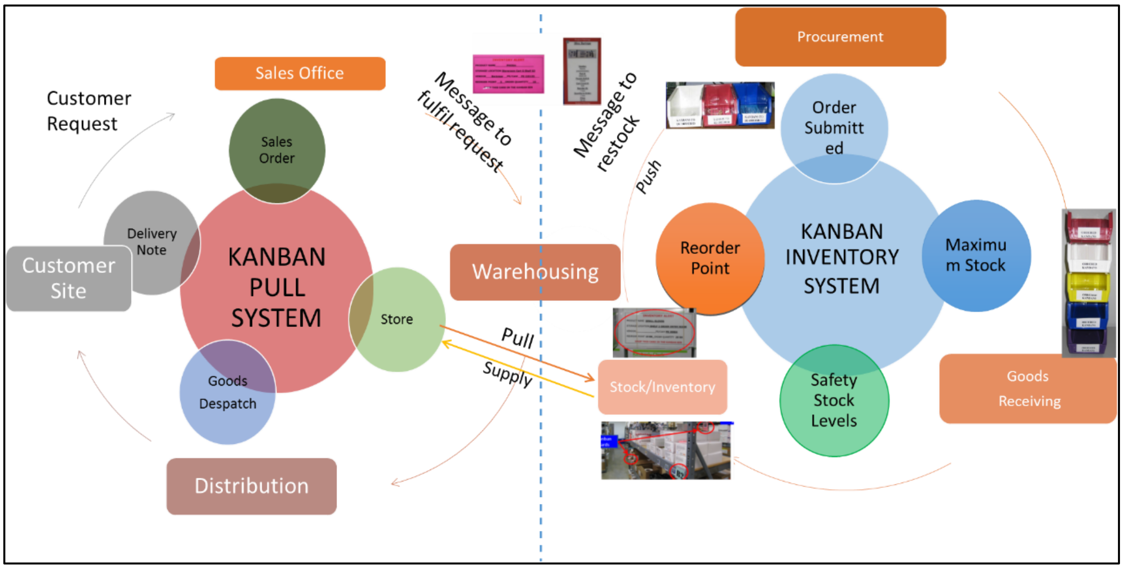


Figure 2.11: The integration of the pull and push of Kanban into the goods and information flow.

However this requires a networked real-time information system. Whilst many large firms benefit from these networked systems, the published literature indicates that SMEs have not done so, primarily because of the cost and need for skilled resources.

Mangina and Vlachos (2005) argue that poor information flow is the largest cause of SC inefficiencies and that intelligent agents may remove such inefficiencies by providing the needed visibility and flexibility to the system. However, MAS with its intelligent agents provides the visibility and flexibility to address the identified issues. The agent-based option is in fact the most appropriate solution tool and can support SMEs with its low cost, ease of application, ease of use, low maintenance demands and speed of delivery. The system can be written in many programming languages, which makes it more easily accessible to SMEs; it is more customisable than the many other costly specialised packaged systems. The published literature reviewed here indicates that there is a gap in the application of LSS using MAS in food industry SMEs.

2.5 Multi-Agent System Background

The increase in networked information resources necessitates information systems which can be distributed through a network and interlinked with other systems. These types of systems cannot be readily developed using traditional software technologies as these have limitations in relation to distribution and interoperability (Bellifemine et al., 1999). (Jennings, 2001) and Park and Sugumaran (2005) claim the majority of complex real world problems can be solved with distributed environments. According to Maturana et al. (2004), cited in Park and Sugumaran, (2005), an extensive distributed system can be developed by identifying reusable software components, customising them to new requirements, and integrating them with newly developed software. Agent-based technologies appear to offer a potential solution to the problems accompanying realising such systems as they have been developed to deal with distribution and interoperability (Genesereth and Ketchpel, 1994). Paolucci et al. (2008) consider that agent technology is appropriate when modelling distributed and concurrent applications which require a high level of cooperation and/or competition with asynchronous communication. Because of this, different communication and coordination protocols have been developed.

2.5.2 Agent

Since the middle of the 1990s the concept of the agent has become more and more important in studies relating to computer applications (Um et al., 2010). After their introduction, software agents were considered a subfield of Artificial Intelligence. It is significant that a whole range of terms have been used to describe agents, for example software components, control units, problem solvers, computer programs, decision-making entities, and so on (Papadopoulou, 2013). For some time there was only one definition of an agent with several definitions coexisting (Ferber and Perrot, 1995). The absence of any generally accepted definition of a software agent can be traced back to cross-fertilisation in the research carried out in many areas (Papadopoulou, 2013).

The term 'agent' implies the notion of agency, or someone assigning to someone else a task to be completed on their behalf (Papadopoulou, 2013). To extend the analogy Wooldridge (2009) describes an agent as a computer which is situated in a certain environment and which is able to carry out autonomous action in this environment so as to achieve its design objectives (Figure 2.12).

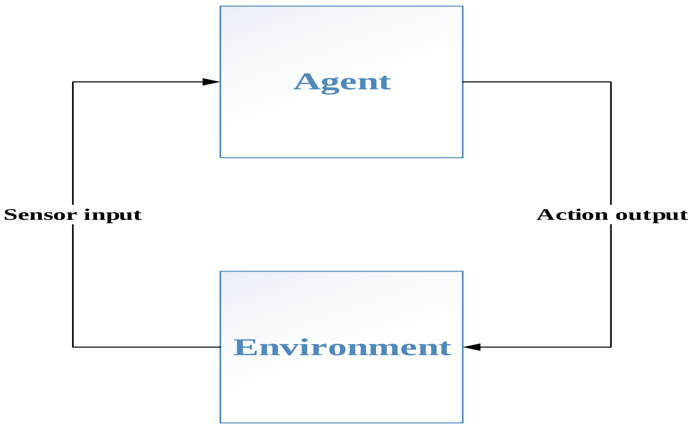


Figure 2.12: Agent

Intelligent agents are a new type of software systems development and are used in a wide and increasingly diverse range of applications (Moyaux et al., 2006). Mangina and Vlachos (2005) claim that the term agent refers to software problem-solving entities which are positioned in a specific environment and have particular functions, and which are designed to process inputs which arise related to the problem domain. According (North and Macal, 2007) every agent has an individual, specific set of attributes and behavioural features which determine their diversity and heterogeneity. Behavioural characteristics include perceptual tools which sense the environment, decision-making protocols, plan projection mechanisms which assess the probable outcomes of decisions, and adaptation and learning capabilities.

Moyaux et al. (2006) consider that researchers currently agree on Wooldridge and Jennings' (1995) definition which is that the term 'agent' describes a hardware- or, more often, a software-based computer system with the following features:

- Autonomy: that is the agent is a computer system, which is located in some environment and is capable of acting without the intervention of humans (or other agents) and should have a degree of control of its own actions and internal state;
- Social ability: Agents can interact with other agents (or humans) by means of agent communication language (ACL) in the way described by Labrou and Finin (1997);
- Reactivity: Agents are aware of their environment and react in a timely way to changes that take place in it;
- Pro-activeness: Agents do not merely act in their environment but can also take initiative. The application domain in which agent technology is applied is critical as it is always necessary to maintain a balance between risk and trust when working with software-based systems.

If an agent were to work in isolation, it would not be able to cooperate with other agents and make up for the imperfect knowledge which its designer has given it and would therefore not deliver many of its supposed advantages. The most effective implementations of agent technology are to be seen in models based on communities of intelligent agents (Papadopoulou, 2013). Julka et al. (2002) consider an agent to be an independent, multi-threaded object which communicates with other agents by means of messages. Each agent has its unique name which acts as its address. This allows agents to communicate with each other regardless of their location within a computer network. Agents are able to send messages to other agents on the basis of these properties. An agent's task is described in terms of one of more activity classes which are contained within the agent. The agent can carry out multiple tasks at each specific time; each of these constitutes an instance of a particular activity. Rady (2011) suggests that technically agents have enough knowledge and inferential capability to act in a way that would be described as 'intelligent' if a human were to do so. Within the organisation, agents are given enough authority to make commitments on behalf of users. This allows the agents to act according to same principals and abide by the same corporate rules, policies and procedures as would people in the organisation.

2.5.3 Multi-agent system

Agents are often organised in MAS (Paolucci et al., 2008). Mangina and Vlachos (2005) observe that in an MAS, several autonomous intelligent agents combine efforts together (Mangina and Vlachos, 2005). A MAS attempts to solve complex problems with the entity agents by means of their collaborative and autonomous properties (Liau, 2003). (Serugendo et al., 2011) describe an MAS as a set of interacting agents situated in a common environment which cooperate to finish a common, coherent task. Here, each agent is striving to accomplish its individual set of objectives which may be in variance with each other. Rady (2011) describes MAS as a computer program with problem solvers located in interactive environments, each of which are able to act flexibly and autonomously, and which carry out socially organised actions which may or may not be directed towards predetermined objectives or goals. Um et al. (2010) observe that within the MAS different sorts of agents show varying levels of problem-solving capabilities in different problem domains. MAS architectures differ according to the complexity of problem domains, i.e. system design, number of agents, and number of variables which determine the agents' decision-making behaviour. It is especially important to have effective coordination mechanism in place in relation to these which can regulate agents' interactions. There are, indeed, many multi-agent development tools in existence.

The overall goal of MAS is to construct systems which interlink separate developed agents and thus allow the ensemble to act beyond the capacity of any one agent. MAS strive to solve entire problems by cooperating with each other. Thus MAS are able to contribute to finding solutions to complex problems and can make decisions or support humans in their decision-making. This means that agents are particularly useful when coordinating SCs (Saberi and Makatsoris, 2008). Agent-based technologies will not realise their full potential or become common unless there are standards which support agent interoperability which are used by agent developers and until there are adequate environments for the development of agent systems (Bellifemine et al., 1999). Nevertheless, using a common communication language is not sufficient to support interoperability between different agent systems. FIPA's work to standardise systems has moved towards facilitating interoperability between agent systems, because, as well as working on the ACL, FIPA has specified the key agents needed to manage an agent system and the ontology needed for interaction between systems and has defined the transport level of the protocols. JADE is a software package which makes it easier to develop agent applications which comply with FIPA's specifications for interoperable intelligent MAS.

2.5.4 Java-assisted development framework

The Foundation for Intelligent Physical Agents (FIPA) is an international non-profit association of companies and organisations who are working together to establish specifications for generic agent technologies. The FIPA is working on developing generic technology which can be applied in different areas, not just in one, and is a set of basic technologies which developers can combine to create complex systems with high levels of interoperability (Bellifemine et al., 2001). The FIPA is founded on two basic assumptions. First it should not take long reach a consensus and to achieve the FIPA standard; here FIPA should not hinder progress but should promote it, even before industry makes any commitments. Second, only the external behaviour of system components should be specified; the agent developers should determine implementation details and the internal architecture. Indeed the internal architecture of JADE is propriety, although it will comply with the interfaces laid down by the FIPA (Bellifemine et al., 2001).The specifications of the FIPA illustrate the reference model of an agent platform.

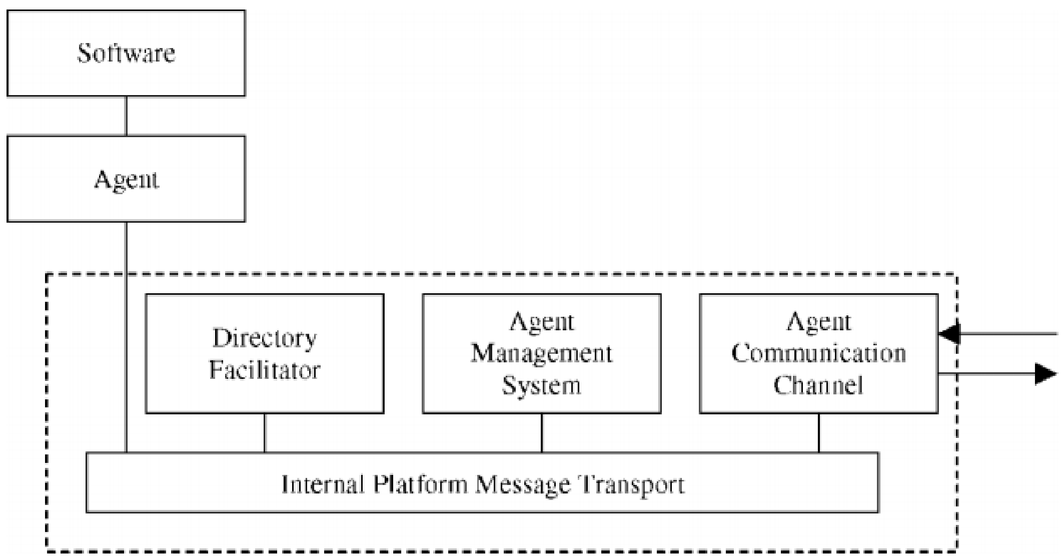


Figure 2.13: FIPA reference model of an agent platform (Bellifemine et al., 2001).

They characterise the roles of various key agents who are needed to manage the platform, and describe the agent management content language and ontology. Three mandatory roles are recognised as playing a role in an agent platform. The Agent management system is the agent that has supervisory control over accessing and using the platform. It also maintains a directory of resident agents and supervises their life cycle. The agent communication channel opens up channels of communication between agents inside and outside the platform. The agent communication channel is the default method of communication and provides a routing service which is reliable, methodical, and accurate. The directory facilitator is the agent that transmits yellow page services to the agent platform (Bellifemine et al., 1999). Naturally the specifications also characterise the ACL. The basis of communication between agents is message passing, that is agents send individual messages to each other to communicate. The FIPA ACL is a standard message language which specifies the semantics, encoding, and pragmatics of the messages. It does not detail a specific mechanism for transporting messages. As different agents may use different platforms and utilise different networking technologies, the messages are encoded in a textual form. The assumption is that the agent is able to transmit this textual form (Bellifemine et al., 2001).

The JADE platform is widely accepted for use in the development of MAS and is FIPA-compliant. JADE, or the Java Agent DEvelopment Framework, has been developed by the Telecom Italia Lab (TILAB) in Italy in collaboration with the FIPA, to facilitate the development of agent applications for interoperable intelligent MAS (Nikraz et al., 2006). JADE is designed to make development easier and at the same time guarantee that there is compliance to the standards by means of a complete set of system services and agents (Bellifemine et al., 1999). In the design phase the emphasis is on the JADE platform and the concepts which it presents (Nikraz et al., 2006). JADE is basically a middle-ware as it is written completely in the programming language Java and uses various types of Java technologies; it supplies a set of graphical tools to support debugging and deployment which makes it easy to implement MAS. The agent platform can be spread out over multiple machines whatever the underlying operating system, and a remote graphical user interface used to control the configuration. The designer concentrates on the JADE platform in the design phase and, as it is not necessary to painstaking modify the results of the design phase for use in a chosen agent platform, can then immediately progress to implementation. Naturally this affords designers considerable savings in time and also offers them a better defined path to follow towards implementation (Nikraz et al., 2006). Bellifemine et al. (1999) list several features which JADE provides for the agent programmer which support this:

- FIPA-compliant agent platform; this includes the agent management system, the agent communication channel, and the default directory facilitator;
- Distributed agent platform: it is possible to divide the agent platform into several hosts. Normally only one Java application and thus only one Java Virtual Machine is used in each host. Agents are introduced as one Java thread and Java events are utilised for effective, lightweight communication between agents on the same host;
- Several FIPA-compliant additional directory facilitators can be set in motion at run time so as to construct multi-domain environments; here a domain is a logical set of agents whose services are advertised by a common facilitator;
- Java API to send/receive messages to/from other agents; ordinary Java objects are used to represent ACL messages;
- FIPA97-compliant IIOP protocol to connect various agent platforms;
- Light-weight transport of ACL messages in the same agent platform; this is made possible by the messages being transferred encoded as Java object, not strings. This gets around marshalling and un-marshalling procedures;
- Library of FIPA interaction protocols ready for use (Details in 'Interaction Protocols' section);
- Graphic-user interface which manages several agents from the same agent. Activity in each platform is monitored and recorded. It is possible to use this administrative GUI to perform all life-cycle operations for agents, for example creating a new agent, or suspending or terminating an existing agent.

2.5.5 Multi-agent systems in the supply chain

Globalisation and the advance of electronic business is causing SCM to grow in importance. Numerous changes in products, suppliers, and customers mean that SCs are dynamic (Ahn et al., 2003). An SC is a dynamic process which entails a complex flow of materials, funds, and information through a range of functional areas within a company and between companies (Yuan et al., 2001). Because of the dynamics of the SC, coordinated behaviour is crucial for its effective integration (Um et al., 2010). An advanced information technology and information system is needed for the successful management of SCs. Information systems ranging from enterprise resource planning to newly-developed advance planning and scheduling systems and e-commerce solutions have been developed for the SCM (Rady, 2011). Nevertheless SC information systems are not sufficiently adaptable for these new developments as it is costly and time-consuming to re-customise and then re-implement them (Ahn et al., 2003; Rady, 2011). Furthermore, electronic document interchange has not been widely accepted as a medium for electronic trade among business world communities as a whole as it represents an obstacle for small companies (Cingil and Dogac, 2001).

There are many benefits which multi-agent and up-to-technology can bring to collaborative, autonomous, and intelligent systems in distributed environments, meaning that it is one of the most suitable options for complex SCM (Swaminathan et al., 1998). For this reason, MAS has become the new paradigm when conceptualising, designing and implementing software systems, allowing many of the restrictions of existing information systems for the SCM (Julka et al., 2002). MAS is considered to be an up-to-date technology which can improve or replace technologies in transactional as well as analytical information technologies (Moyaux et al., 2006). Of late various researchers have used the intelligent agent approach to support SCM. Some of them concentrated on real-time management of SCs, while others used rule-based mechanism and constraint relaxation approaches to model agents' behaviour (Yung et al., 2000). Um et al. (2010) consider the SC to be made up of a set of intelligent software agents; each of these takes responsibility for one or more areas of the SC as well as interacting with each other to plan and execute their responsibilities.

Ahm et al. (2003) divide studies on agent-based SCM into three groups. The first focuses on the area of coordination, modelling different kinds of companies and their capabilities as individual agents whose interactions aim to achieve efficient cooperation. The second type concentrates on simulating SCs with agent-based models with the aim of investigating the performance of agent-based SC architectures and the impact of various strategies and constraints. The third type examines the way virtual SCs can be flexibly organised by MAS.

The basic principles behind SCM and agent technology allow new perspectives for FSCs to be developed. Even so only a small amount of research has been carried out to examine the use of intelligent agents to tackle food distribution problems. Mangina and Vlachos (2005) have presented a model of intelligent FSCs that increase efficiency in the SC. Their model of a beverage supply network shows that products can develop intelligence to direct themselves throughout the entire distribution network. Krejci and Beamon (2012) further emphasis some of the challenges faced when choosing the most suitable model to represent the components of an FSC in an MAS model. They presented examples from the literature which demonstrate the way other researchers have dealt with these issues and closed by considering the advantages and disadvantages in relation to realism and data requirements of each type of solution. El Yasmine et al. (2014) suggest the use of a multi-agent model to create a near-optimal solution which reduces costs and time needed to a minimum in the agri-food industry process from start to finish. They developed an AUML model which shows how MAS functions within the SC. To compare the results on duration and cost of fulfilling clients' orders, a heuristic model was used in the dynamic case which solved problems with optimisation, while a mathematical model was used in the static case.

An examination of the research of other scholars revealed and confirmed many of the benefits and limitations of MAS. According to Rady (2011) some of the advantages are: 1) allows efficient and rapid simulation as a result of asynchronous functioning; 2) robustness and liability – should one agent fail, others can take their place; 3) scalability and flexibility which allow the system to be modified to deal with a problem; 4) greater cost effectiveness as implementation is more straightforward than with mathematical methods; 5) reusability of agents – this can come about through the work of experts – and innovation which allow new technological applications to be developed; 6) useful, should little information be available.

Three of the most significant limitations of MAS are: 1) agents with oversized granularity; 2) few opportunities for interaction; and 3) inadequate mechanisms for modelling organisational structure. Nevertheless, it is possible to reuse modules which are generic in other applications, meaning that there are obviously advantages when applications are developed using agent-based technologies. Furthermore there are issues with complexity and with the characteristics of such problems. However MAS provides the most acceptable and comprehensible solutions when problems are mainly distributed or there is no analytical solution (Carvalho and Custódio, 2005). However, despite the advantages of using MAS to model FSCs, there are very few existing MAS models of multistage FSCs in the literature (Krejci and Beamon, 2012).

2.5.6 Modelling food supply chains with multi-agents systems

Modern consumers have come to expect more from the processes used to produce their food in terms of integrity, quality, safety, diversity and sustainability, all of which puts substantial pressure on the associated information services. The standards and methods used to control and guarantee food quality are paramount for SC performance. As well as being a performance measure in its own right, product quality is also closely linked to other characteristics such as integrity and safety (Van der Vorst et al., 2009). FSCs differ radically from other product SCs, with the most important distinction being that the quality of food products changes continually and fundamentally during the entire SC through to the time of actual consumption (Yu and Nagurney, 2013). Widodo et al (2006) estimate that between 20% and 60% of any country's fresh agricultural products go to waste or are otherwise lost. Mangina and Vlacos (2005) stated that the distinctive characteristic which sets the food industry apart from other sectors is that current food quality and safety standards demand traceability; all products and agricultural supplies are monitored at all stages of the SC. In addition, because food is extremely perishable, it is essential that its SC is maximally time-efficient. As a result, there is a great demand to automate the SC by means of advanced information and communications technologies like electronic data interchange. The developments in information technology and the higher level of competition in recent years have altered the business environment in the food industry (Fearne and Hughes, 2013). Specialised handling, transportation and storage technologies are often necessary for food products (Rong et al., 2011).

The FSC is vital for society (Marsden et al., 1999). The development of more efficient methods for producing food are the subject of attention because food is literally essential for survival, and these systems are subject to a tremendous amount of pressure (Krejci and Beamon, 2012). As Van der Vorst (2006) observes, it is vital that FSCs be examined in the context of the full complexity of their network structures. According to Mangina and Vlachos (2005), the vast majority of supply inefficiencies that cause bottlenecks, such as the lack of coordinated actions, problems with information, excess inventories, unmet consumer demands, can all be attributed to issues within the information flows. The food industry is developing into an interconnected system with a wide range of relationships. The formation of (virtual) FSCs in the form of alliances, horizontal and vertical cooperation and forwards and backwards integration in the market place shows this (Van der Vorst et al., 2005). These challenges highlight the need to manage FSCs effectively so that they will be profitable. For this reason, they have attracted a greater amount of attention of late (Yu and Nagurney, 2013). Modelling FSCs is one way of increasing efficiency in food production, and such models have an even greater potential application in the face of the current major challenges in relation to food production and distribution (Krejci and Beamon, 2012).

FSC models are vitally important as they give decision-makers the tools they need to evaluate and design FSCs which will ensure sustainable productivity. These models allow organisations to take decisions that better support long-term human and environmental well-being.

Nevertheless, for them to be helpful, they must be flexible while still able to represent accurately the basic elements of FSCs. Mathematical optimisation is normally used to model the food production stage of an FSC. Many current optimisation models are static, deterministic linear programming (LP) models, designed only to maximise income or profit within the context of farm input costs and availability (Krejci and Beamon, 2012). Discrete-event simulation has also been used to model food systems. While this can be used to model time dynamics and stochastic behaviour explicitly, it is unable to model the sociological processes that affect individual FSC actors' decision-making (Higgins et al., 2010).

Recent research implies that FSCs should be modelled as complex adaptive systems in order to portray the dynamic, stochastic and multi-faceted elements of an FSC (Higgins et al., 2010; Meter, 2006). A complex adaptive system (CAS) is a system of interconnected autonomous entities that choose to survive and which, over time, collectively evolve and self-organise (Pathak et al., 2007). MAS can be used to model the heterogeneous, self-sufficient, intelligent and interacting actors that make up a CAS, meaning that MAS is especially suitable for modelling an FSC, as it allows decision-making, interactions and adaptations of autonomous FSC actors to be described clearly. Nevertheless, some elements of FSCs are especially hard to model in detail as there can be extreme data requirements (Krejci and Beamon, 2012).

However, despite its importance, there are few papers published on modelling in MAS in FSCs, while those that do exist analyse only a single stage within the chain. This indicates there is a gap of modelling the complexity in the multiple stages in the SC, which is essential if it is to support the integration of LSS practices within an SME.

Therefore in this study the researcher proposes to extend the initial framework using MAS as the integrating information and intelligence tool.

2.5.7 Multi-Agent System

A multi-agent system can help a distributed SCM environment to operate in a more efficient coordinated manner. Agent technology provides a natural way to design and implement distributed intelligent manufacturing environments and provides software architecture for managing the supply chain processes and specifications. A multi-agent system (MAS) is a community of collaborative and autonomous intelligent agents, combined as a loosely coupled network of problem solvers, in a common but distributed environment. These agents are constantly communicating and interacting to solve problems beyond the scope of individual participating roles. Each agent completes a common and coherent task. In doing so, each agent seeks to achieve their own objectives and then can be expected to compete as well as cooperate with the other agents. In this way, the MAS function exceeds the traditional linear software application approach in its ability to handle conflict and contention whilst retaining focus on aim. A key advantage of MAS is that the agent is delegated responsibility for physical participants (roles) within the business process. As SCM tends to be a complex distributed environment even within the SME, there are multiple players both internal and external to the organisation. The agent approach is suited to modelling the coordination and complexity within the interplay and coordination of these players, as well as incorporating the expected standards, sequence, priority of goods flow from producers, and suppliers in the food industry, through to wholesalers and retailers. The advantage of the agent is that it can map the physical flow whilst also providing the messaging and information trail through the flow with asynchronous communication. As problem-solvers that are able to cooperate as well as compete, multiple agents promote flexibility within the system and provide information visibility.

2.5.8 Conceptual Framework for Integrating LSS with MAS

The literature review has facilitated the development of the initial conceptual framework that has at its center the focus on the three critical factors within the supply chain – quality, process and time – that are integral for the flow of goods and information. The LSS principles are supported by related lean techniques and tools that promote a systematic disciplined flow of goods within the value stream. The Kanban system is an integral facet that directs the flow throughput as well as regularly maintaining a JIT status update, pushing visual messages to order when stock reaches thresholds, and pulling stock as needed to fulfil customer orders. Additionally the flow of goods and the performance indicators of the logistics systems are presenting information and comparisons to thresholds established autonomously. The MAS maintains the continuous and real-time communication of messages (information), coordinates the tasks whilst also connecting the entire flow, coordinates resources with process management and decision-making, and presents the actual results against plans, schedules and forecasts Throughout the goods flow, transaction cycle and environmental conditions, quality information is being collected, compared and reporting against the thresholds set for waste and the allocation of the resources in a simultaneous manner, presenting a real-time gauge "dashboard" for each responsible role as well as the interdependencies between the roles. This continuous review of the performance and thresholds provides a feedback loop to the critical factors and the variables to promote and encourage decisions and changes that contribute to continuous improvement. The integration of all these components is represented in the conceptual model in Fig 2.14 below.

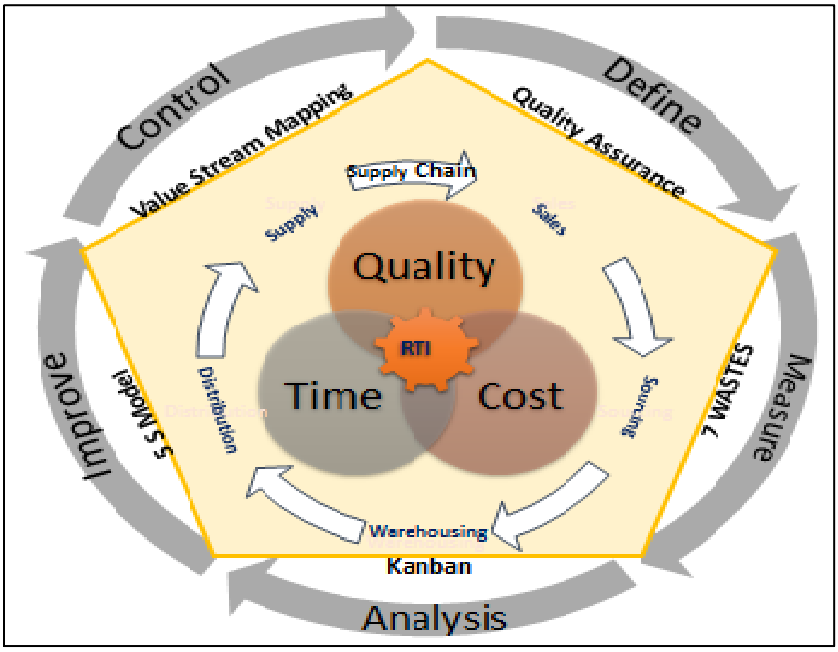


Figure 2.14: The conceptual integrated framework

The literature review of seven published papers on food distribution initially identified the operational practices and issues summarised in Table 2.9. The literature review indicated that there was a gap in the research, so the research review was extended and identified two further papers in 2014. The review excluded papers that did not focus on FSCs or food distribution, or did not present any issues that merited follow-up or exposed important gaps. Following the literature review, a pilot study was then conducted to determine whether these concepts are relevant to the SMEs and identify any related problems which were in fact present in SMEs in Saudi Arabia.

2.6 Pilot Study

Following the completion of the literature review, the researcher identified a gap in the literature on SMEs' using the combined practices of Lean and Six Sigma and the use of MAS in the food distribution industry. The researcher chose to address the gap by conducting a field pilot study to understand and evaluate the current situation more deeply in terms of operational practices and issues within SMEs' SCM in the food distribution sector in Saudi Arabia. Specifically, this pilot study aimed to find out:

- What were the operational problems faced by SMEs in Saudi Arabian food distribution operations?
- What kind of quality initiatives are used by SMEs in the Saudi food distribution sector?
- Do SMEs within Saudi Arabia's food distribution industry use any electronic real-time information systems?

To identify the most common problems and issues faced by SMEs in operational practice, the researcher conducted semi-structured, face-to-face interviews with a sample of experienced managers and quality professionals responsible for the SC operations in food distribution industry SMEs in Saudi Arabia. In addition, the researcher compared the problems and issues identified in the research literature with the first-hand experience of these practitioners.

The interviews were conducted with experienced personnel from within the food distribution industry of Saudi Arabia. The interviewees were from six independent SMEs based in different locations across the city of Riyadh. Four distributors also manufacture their own goods in addition to importing goods. Two specialised in food distribution only. From the interviews, the researcher was able to identify several operational considerations, significant factors and issues identified by the interviewees, as listed in Table 2.9. These Semi-structured interviews were conducted with managers and quality assurance professionals for two reasons:

- First, to gain the information required about operational problems, quality initiatives and information sharing systems in Saudi food distribution SMEs.
- Second, to understand if the findings of the literature review were borne out in practice by these experienced personnel and if there were further issues not identified in the literature review.

The interviewees were asked closed questions that related to the most common problems, quality initiatives and information-sharing systems they have experienced. Using a prompting technique, the researcher sought to facilitate each interviewee's consideration of additional problems that the interview had not yet identified, such as those raised by previous interviewees and issues identified in the literature review. Table 2.9 presents a comparison of the frequency of occurrence of problems and issues in the literature review compared with those raised in face-to-face interviews.

Table 2.9: Comparison of the frequency of occurrence of problems and issues

		Frequency	
		Literature (L)	Interviews (I)
	Problems Identified	(Total count =9)	(Total count =6)
Quality	Low level of quality	8	6
	Wrong payment	1	-
	Wrong offloaded items	1	-
	Variations in the weight	1	-
	Bullwhip effect	1	-
	Food safety	3	5
	Temperature	2	2
	Incorrect quantity delivered	-	1
	Incorrect items delivered	-	1
	Incorrect invoices handed over	-	1
Time	Late delivery	1	3
	Non-value added time in warehouse operations	1	-
	Lead time	3	5
Information /Goods Flow Path (Connectivity	Inventory level	3	1
	Poor booking in system	1	-
	Communication	2	2
	Information flow	2	3
	Transportation	1	1
	Breakdown of refrigerated truck	-	1
Cost	Cost	2	4
	Efficiency	2	1
Flexibility	Flexibility	2	-

Table 2.9 shows that the top three problems by frequency of mention from the literature review were low level of quality, lead time and food safety. The top three in the interviews were similar, only with food safety occurring more often than lead time. Both groups had cost as the fourth largest concern. The interviews, however, raised the issues of late delivery and information flow significantly more than the literature review. In both the literature review and the face-to-face interviews, issues related to inaccurate information appeared in the form of poor booking in system, low level of quality, late delivery, incorrect payment, incorrect offloaded items in the literature review, and incorrect quantities, items delivered and invoices in the face-to-face interviews. All of these issues relate to effective communication and information systems, which is consistent with the issues identified as communication and information flow concerns that appeared in both research approaches.

The most common response of many interviewees was that they did not have quality initiatives in place. Four had heard of LSS and were considering or planning to implement Lean and Six

Sigma, but only one had implemented an ISO standard. Half the interviewees advised that they did not have electronic information systems. Only three had implemented electronic information systems, one in all departments, one in sales and management only and the other only in management.

The literature review research and interviews identified quality as the most significant problem that presented itself; knowledge and application of LSS techniques would help to address many of the issues identified. Second, lead time and cost can be considered interdependent. Further issues such as incorrect delivery, invoicing and offloading depend upon a reliable and accurate information system; if this were in place, it would reduce cost, save time and avoid negative impacts on customer satisfaction. In addition, information systems could be applied to address effective recording of supplier product details and to measure the consistency of product quality and related factors that currently impinge on quality. This would help the decision-makers identify the causes of quality problems and address them more promptly and accurately.

Therefore, the pilot study enabled the researcher to gain a better understanding of the current problems experienced by SMEs in the SCs in the food distribution industry. The research from the literature review and the face-to-face interviews made it apparent that the combined application of LSS techniques and effective operational information systems could make significant positive contributions to reducing the number of quality issues and improve the dependability of the operations. The main study therefore intends to understand how these related problems within an SME's SC operations can be reduced with integrated LSS techniques and MAS and thus increase quality, customer satisfaction and reduce time lost and costs.

2.7 Research Gaps

The study of the literature review indicates that SMEs in the food industry face the same challenges as larger firms, but, whilst larger firms are able to adopt best practices and technology to overcome these challenges, the SMEs have more limited resources and skills and are less able to adopt similar best practices and technology. There are several gaps in the published literature. These gaps do not consider SMEs and their SCs, SMEs in the food industry generally and SMEs in the food industry of Saudi Arabia:

- The current operational practices in Saudi Arabia food industry SC;
- The implementation of integration of Lean with Six Sigma (LSS);

- A structured framework for implementing LSS in service organisations;
- Full consideration of modelling of MAS within FSCs;
- Integration of Lean concepts, Kanban, 5S and 7W with MAS;
- Finally, the combined implementation of LSS with MAS in the food distribution industry.

Therefore, this study seeks to address this gap and demonstrate how this integrated approach using Lean Six Sigma related techniques with MAS can improve performance in SMEs and provide a base for further contributions in this field.

2.7 Summary

In this chapter, an analysis has been given of Lean and Six Sigma respectively, two of the improvement methodologies most frequently utilised by manufacturers; their benefits, limitations and strengths, along with the tools used in them, are examined. The analysis outlines the differences and similarities in the two methodologies to allow an informed choice to be made regarding Lean and Six Sigma. Furthermore, the analysis considers the integration of Lean and Six Sigma and the rationale for combining these practices; an expanded definition of LSS with the benefits of integration is discussed. The analysis proposed that the full benefits of these tools is gained only when there is a timely flow of accurate and up-t-date information inside the SC and all of its partners, which requires a networked system that facilitates the decision-making of forecasted inventories, demand and scheduling. However, whilst large firms use these systems to manage their internal and external SCs, SMEs find it difficult to benefit from them because of cost and lack of resources. The proposed lower cost and ease of use of MAS makes it a more viable option for SMEs, allowing them to integrate LSS more effectively within their constraints. However, the current gap in the published literature on LSS and MAS in food distribution makes it difficult for SMEs to access the background knowledge required to garner these potential benefits.

3. METHODOLOGY

3.1 Introduction

This chapter aims to describe the method and procedures which were employed for the data collection and analysis. The chapter details the research design and approach, the pilot study and the main study, the research strategy and the methods used for data collection and analysis.

3.2 Research Methodology Overview

The aim of the present research is to create a greater understanding of existing practices in the Saudi Arabian food industry's SC. To do so, the application of LSS and MAS are examined in a case study in an SME in the food distribution sector. These processes allow the research to develop the framework of an integrated methodology which then results in a robust system for food distribution industry SMEs. The researcher can then focus on the research's philosophical stance and explain the choice of the methodology used in the research. Research can be categorised as two types, basic or fundamental research and applied research. In the second category, a study is carried out to examine a known problem and to make certain recommendations on how to address it. In contrast, basic research aims only to add to current knowledge (Sekaran, 2006). As the researcher is aware of the significance of this dissertation's potential contribution to knowledge in the field, it falls to the basic category.

The general aims and objectives of any research determine the choice of research methodology and data analysis technique. Tolmie et al. (2011) claims that the choice of the most suitable research design and data collection tools is more crucial than the choice of data analysis tools. The use of the terms 'research methodology' and 'research design' can be misleading, as the two are often thought to mean the same. The research design forms the basis of a system which is used to collect and interpret data, while the research methodology is only concerned with how the data is collected (Bryman and Bell, 2015). Karlsson (2002) observes that the objective of the methodology is to demonstrate to the reader that the study has been planned and carried out robustly. In relation to the choice of how to carry out research and of which method to use, Robson (2002) observes that there is no absolute rule which determines the choice of research approach or the time scale of that research. Based on the empirical data which has been collected, the data analysis is carried out and conclusions reached in such a way as to establish the reliability and validity of the study and thus to assess its quality.

3.3 Research Philosophy

It is vital to identify the research philosophy, as this points towards the beliefs and perspective which underpin the way that the knowledge is collected, brought together and analysed (Mahfouz, 2011). The various types of research philosophies are examined in the literature and it is therefore possible to use these to inform and guide this study's investigative elements. A research philosophy reflects researcher's the fundamental set of beliefs regarding the world around us. Burrell and Morgan (1979) report that two assumptions, 'ontology' and 'epistemology', are the basis of the thinking behind these beliefs. Ontology is linked to the 'real' or 'natural' world, and the realist does not considers social phenomena to be dependent on social participants, so ontology will lead to knowledge being appreciated. In contrast, epistemology is concerned with the study of knowledge as such and identifying what knowledge is. Epistemology can provide answers to questions regarding how things actually work and the best way to obtain knowledge (Lincoln and Denzin, 1994).

If researchers understand the philosophical issues at play, that will enable them to decide on the correct research design for their research objectives (Easterby-Smith et al., 2002). It is essential to be aware of the specific philosophical assumptions or paradigms underlying any study before starting it (Creswell, 2003). Neuman and Kreuger (2003) use four paradigms to categorise the philosophical stance: positivism, post-positivism, realism and constructivism. Positivism stresses that only phenomena that can be observed and measured can be regarded as knowledge; it depends on the degree of measurable substantiation which has a great deal of control over phenomena. In constructivism by contrast, phenomena are described from the perspective of participants who are closely linked to the phenomena being examined (Collins and Hussey, 2003). Constructivism considers knowledge to be subjective and to include beliefs and personal values, the social context and sometimes the historical background (Schwandt, 2000). In constructivism, knowledge invariably changes according to the time period and context, meaning that constructivism is a dynamic research philosophy. On the other hand, positivism presents the knowledge and information about the research subject as fact and is based on actual observations, objectives and phenomena that are indisputable measurable (Mahfouz, 2011).

The findings of this study will describe the underlying basis of FSC operations in SMEs in Saudi Arabia at present and after the integration of LSS and MAS. As the data collected are both historical and numerical, the results will not be influenced by any human factors. In addition, the researcher has no links with the subject under scrutiny and is not related to it any sense. This research can be classified under the positivist paradigm, as the results are to be examined objectively. Once the research philosophy has been recognised, it is essential to choose the proper research approach to be able to identify suitable methods for research and data collection. Blaxter et al.'s (2010) method has been used to develop the research design for this study. It draws on three principles to arrive at the appropriate framework: research family, research approach and data collection.

3.4 Research Family

Jankowicz (2005) describes the research approach as "*a systematic and orderly approach taken towards the collection and analysis of the data so that information can be obtained from those data*". The three best-known types of approaches are the qualitative, quantitative and mixed-method approaches. The choice of research approach is based on the objectives and aims of the research. The next section considers the main characteristics of the different methods and compares them.

3.4.1 Quantitative approach

Nau (1995) describes the quantitative method as a method that is designed to find out 'how much' or 'how often'. Creswell (2013) believes that this approach is most appropriate when the main goal is to recognise the factors which may impact on the results and to identify the best predictors of the results or the effectiveness of an intervention. In addition, if tests are conducted when the quantitative approach is used, the techniques must be explained in terms of 'operations', such as investigative laboratory experiments and mathematical modelling. The data analysis will be shaped by statistical principles. When little information is available from previous research on the subject being studied, qualitative research is the more appropriate approach and allows a better understanding to be developed.

3.4.2 Qualitative approach

This approach is characterised by the recognition of the significance of descriptive data obtained from recorded narration and is typified by being closely associated with the field or with real-world scenarios. The qualitative approach has a range of features, although the main consideration is on obtaining data on everyday events which take place naturally in normal settings. Data obtained using the qualitative approach is usually rich and holistic and is extremely likely to be complex. This technique provides explanations which enhance the understanding of the subject and offer opportunities which encourage the social adoption of decisions that have been agreed on. It further contributes by helping develop concepts, policies and social awareness (McMillan, 2001). However, Cornford and Smithson (2006) observe that the qualitative approach has specific disadvantages. Because the data collected is extremely complex and rich, the analytical process can be problematic. Even more crucially, the data can be open to interpretation and there can be misgivings that the interpretations of both interviewee and researcher may be biased. Finally, the situation overall is active as the environment and circumstances can continually vary, potentially impacting on the validity of the study and its verification.

3.4.3 Mixed method

Several authors have agreed in describing quantitative and qualitative methods as polar opposites. Thus, Ticehurst and Veal (2000) suggest that the merits and values of each approach are consistently in line with different philosophical stances. Saunders (2003) shares this view of the two research approaches being at opposite ends of a scale. These scholars have observed that adherents of qualitative research constantly criticise the quantitative approach, arguing that its inflexible methodology often does not support a more extensive and nuanced explanation of actual phenomena. However, trends in research are no longer as polarised in relation to the distinctions between quantitative and qualitative research approaches (Mahfouz, 2011). The tendency is now to walk somewhere between the two approaches when trying to represent the complexity of real-world cases (Creswell, 2003). Different authorities have stressed this and observed that if researchers concentrate exclusively on one specific research approach, they may not capture the larger picture under study (Waring, 1996). In order to take into account a broader sweep of aspects of research and its parameters, it is necessary to bring together both quantitative and qualitative research approaches (Crotty, 1998).

Fielding and Schreier (2001) accept that a blend of both approaches may, on occasion, actually be complementary. It is debatable whether quantitative research is consistently objective in contrast to qualitative research, which usually produces a significant analysis (Laurie and Sullivan, 1991). Different expressions can be used for the mixed-method approach, such as the integrating, quantitative or qualitative approach or the multi-method approach or multi-methodology (Tashakkori and Teddlie, 2010). In mixed-method research, quantitative and qualitative data may be collected concurrently or sequentially , depending on the design and sequencing of the research. However, mixed-methods research remains fairly uncommon in the research literature (Knox, 2004).

However, in this research a blend of both approaches meant that the data could be triangulated; it also helped avoid any weaknesses, biases or limitations which might have presented themselves if only one approach had been used. In addition, drawing on both approaches meant that the data collected were stronger and more comprehensive. A qualitative method has been adopted on a small scale, as the research utilised semi-structure interviews in the pilot study. The results of the overall research are deductive and based on numerical output, steered by MAS and the questionnaire results. Thus this research can be classified as quantitative.

3.5 Research Approach

It is essential to choose a research method which matches the research approach and philosophy in order to achieve the research objectives (Yin, 2013). The choice of research methods depends on how clearly they allow the research questions to be answered and how effectively study objectives can be met. Action research is suited to social science studies, as it is a match for researchers who are carrying out research at their own workplaces and who are attempting to bring about improvement in the work of themselves and their co-workers (Blaxter, 2010). An experiment-based approach is employed when the most important aim of the research is to bring about deliberately and dynamically some change in the state, situation or understanding of participants in order to bring about change in their performance.

On the other hand, case studies can be used to create rigorous and exhaustive knowledge relating to a single case or a certain number of associated cases (Robson, 2002). Case studies enable researchers to bring to light underlying problems in the phenomenon which is being examined. Case studies are of most use in answering questions of ‘how’ and ‘why’ (Yin, 1994). This feature of case studies allows an understanding to be developed of the meaning in the context of the assumptions, beliefs and perspectives which the researcher determines (Meredith, 1998). The case study is now considered one of the most significant research strategies, especially in relation to the development of a new theory (Flynn et al., 1990). Considering the industrial perspective of this study, an experimental method will be adopted for this research. A sample from the industry is used to gain information and test the concepts.

3.5.1 Research Methodology Overview

There are several theoretical framework configurations or modelling approaches (for example, pattern-oriented modelling (POM)); however this study is focused on SMEs distributed over a large region in Saudi Arabia, and these have limited information records, so it was considered to be most cost effective to use a direct approach. This study adopts a staged approach to conduct the research through a case study and a survey of a sample from the industry:

Stage 1: Literature review and conduct of a pilot study in an SME. A literature review is completed to gain an understanding of the issues faced within the SC of the food distribution industry and how current knowledge and practices of LSS and MAS are being used to address these issues. Initially, a field pilot study was carried out to gain an understanding of the issues faced by SMEs and the operational methods and real-time systems they use to maintain quality standards within the food distribution industry of Saudi Arabia.

Stage 2: A case study in Saudi Arabia: Conduct an empirical case study on a SME in Saudi Arabia to identify the most challenging issues faced and analyse, by using the DMAIC cycle, whether the application of LSS concepts can deliver significant improvements. Propose an initial conceptual framework.

Stage 3: Conduct a survey in this sector in Saudi Arabia to propose a conceptual framework: This stage seeks to obtain a more comprehensive understanding of the nature of SMEs and their operational practices in this industry sector in Saudi Arabia and gain a more representative understanding of the challenges faced. The researcher will design a questionnaire and conduct a survey of SMEs in Saudi Arabia.

Stage 4: Develop a MAS, perform a simulation with live data: This stage intends to use the combined results of the empirical case study experiment and the results of the questionnaire to improve the conceptual framework. Depending on the findings of the case study results and the questionnaire analysis, the researcher will assess whether the application of an integration of LSS and MAS can address the problems faced and improve operational practices.

Stage 5: Update the model, design and develop operating procedures: After validation by a sample of relevant managers and owners from Saudi SMEs in the food distribution industry, an integrated LSS and MAS model will be designed using Java-based programming on the JADE and Eclipse platforms. Finally, this model will be tested using a manual simulation of real-world data collected from an operating SME in Saudi Arabia’s food distribution sector.

Stage 6: Compare simulation to actual performance and validate findings with interviews: In this final stage, the analysis of the findings from the tests conducted will be compared with the original actual baseline results to identify the extent of operational improvements. The results will be discussed with mangers and customers of the facility and the FSC.

3.5.2 Empirical data collection

Interviews, archives, questionnaires and observations can all be used to obtain empirical data for case studies (Yin, 1994). It is accepted that combining methods and sources when collecting data can increase the validity and reliability of evidence (Voss et al., 2002). This section therefore details the different methods and techniques employed in the data collection process.

3.5.3 Literature review

Previous academic research offers an indispensable platform from which to identify the most recent and most relevant knowledge in the area being studied. It contains a collection of related information which has been brought together and analysed in other studies, thus offering an invaluable supply of knowledge. It is made up of raw data that has not been processed previously and of compiled data which has already been summarised or analysed (Saunders et al., 2009). In addition, this data can provide a vital foundation for identifying the relevant requirements from the literature and developing the platform on which findings from empirical research can be compared and assessed. For this reason, literature on quality management, Lean, Six Sigma, SMEs, FSCs and MAS was reviewed in order to obtain preliminary information and then to establish the key functions and benefits of applying the relevant concepts to SC performance. Nevertheless, a literature review alone was not enough to provide all that was needed for the first stage of this study; furthermore, the literature review showed that there was insufficient relevant information on food distribution and on SCs specific to Saudi Arabia.

Within the research, the analysis of the literature review sought to identify those issues which food distribution SMEs faced and which were included in the literature review. In all, ten peer-reviewed papers from the literature review were chosen and used to pinpoint the generic requirements which should be modelled. The papers were selected according to the issues they covered.

3.5.4 Pilot study interview

It is often useful to conduct a pilot study before the start of a full-fledged research study. This gives the researcher the opportunity to explore any issues which might present challenges at a later stage. It also enables the researcher to fine-tune the practical aspects of the research before its implementation. According to Thabane et al. (2010), it is important to conduct a pilot study; this will also increase the chance of the main study being successful, as the pilot study will have drawn attention to any areas which might present problems in the main research project.

The researcher interviewed several SME managers prior to formulating the survey questions so as to gain a general understanding of the existing food distribution situation. The data collection method chosen for the pilot study was interviews, which provided the information needed on operational problems, quality initiatives and information-sharing systems in Saudi food distribution SMEs.

Research in the social sciences most frequently uses interviews to collect relevant data. Interviews allow holistic insights on the subject under scrutiny to be gained through face-to-face discussions with experts and practitioners (Easterby-Smith et al., 2002). This method was chosen as the primary data collection method for this study, due to its being a very effective means of collecting rich, empirical data and insights about the phenomena of interest (Easterby-Smith et al., 2002). Interviews can be classed as three types: unstructured, semi-structured and structured. Robson (2002) describes the differences between these categories as follows:

- Structured interviews: pre-determined questions using a pre-set text. Structured questionnaires and interviews differ only in that interviews use questions that allow open-ended responses.
- Semi-structured interviews: while the questions may be pre-determined, the order is not and may be altered depending on what the interviewer considers most appropriate. The text of the questions can be changed and further explanations sought and offered.
- Unstructured interviews: Here the interviewer generally has an area of interest, although there may be interconnections within the subject area. This type of interview may be completely informal.

3.5.4.1 Data collection

The researcher carried out the pilot study in June 2013. Face-to-face interviews were conducted with field experts who had an extensive knowledge of the existing food distribution situation in Saudi Arabia. These interviews further validated the information obtained from the literature review, while adding important elements. With semi-structured interviews with an open-ended questionnaire format, interviewees are able to reflect on their experiences and can express their opinions freely in relation to each question. This approach also allows the researcher to manage the sequence of the interview effectively; to do this an interview guide consisting of a pre-defined list of questions is used (Bryman and Bell, 2015). As the goal is to construct a theory, the choice of the semi-structure interviews gave the author the necessary flexibility to investigate specific areas of interest and ideas which came to light during the interviews, while at the same time maintaining the focus of the study. The semi-structured interviews were carried out with experts, managers and industrial practitioners in the SME food distribution sector in Saudi Arabia. The interviewees were questioned on their most common problems, quality initiatives and information-sharing systems. Six interviews were conducted before saturation was reached. Interviews were only conducted with individuals who had had substantial experience in the area of food distribution in SMEs. Details on the interviews and interview are given in Table 3.1. Questions were asked on difficulties in food distribution and possible explanations for these issues. In the final interview phase, the researcher used a prompting technique to draw the attention of interviewees to problems that had been identified by other interviewees or in the literature. This prompting technique served to confirm the significance of such problems. Semi-structured interviews enabled the interviewees to develop themes and offer wider perspectives on issues and problems for food distribution SMEs in Saudi Arabia.

Table 3.1: Interview and interviewee details

Interviewee	Position	Interview method	Date	Length of interview
1	Deputy director	Face-to-face	16/01/2013	20-30 min
2	Company manager	Face-to-face	20/1/2013	20-30 min
3	Owner	Face-to-face	21/1/2013	20-30 min
4	Sales manager	Face-to-face	22/12013	20-30 min
5	Owner	Face-to-face	23/1/2013	20-30 min
6	Company manager	Face-to-face	24/1/2013	20-30 min

3.5.5 The questionnaire

It was important for data from food distribution SMEs to be collected and analysed so that the research could build up an understanding of the extent of their SCM operations and to reveal any problems or issues with implementation, to assess the degree of their success and achievements and identify any areas for improvement in their existing practices. The results from the analysis were used as key inputs for developing a novel LSS and MAS integration framework. The survey methodology was chosen on the basis of its suitability for describing, highlighting and measuring specific features within a substantial population. This methodology is appropriate in research when a positivist approach is being used and the primary data must be collected from various places (Easterby-Smith et al., 2002). As examining a representative sample rather than the entire population is less expensive, the survey is recognised to be one of the most cost-effective research methodologies. It is also a widely used research methodology in operations management literature (Mahfouz, 2011). As well as being commonly used for data collection in survey research, the questionnaire can also be employed in action research and case study methodologies (Oppenheim, 2000).

The questionnaire developed for this research is quantitative and has progressed through several steps. First, the survey questionnaire was constructed, then a contact list a created and then the companies were contacted. In the next stage the responses were collected; these were then analysed and, finally, the conclusions were formulated. This process was based on a thorough review of the existing literature, deep discussions with the research participants (both academics and practitioners) and a clearly formulated conceptualisation of the research objectives. The survey aimed to develop a more comprehensive understanding of the nature of SMEs and their operational practices in this industry sector in Saudi Arabia and to gain a more representative understanding of the challenges faced. The scope of the questionnaire was a range of micro- to medium-sized SMEs, but did include some large firms; it had the objective of collecting data to compare SMEs and large organisations in terms of their practices, implementation and performance. The questionnaire structure can be categorised as follows: demographic data, operations value stream, quality assurance, information sharing and managing performance indicators.

3.5.5.1 Data collection technique

Questionnaires can take several different forms; they can be self-administered or group-administered, formal, sent out by post or conducted over the telephone. This flexibility plays a significant role in questionnaires being the most commonly used method of data collection (Silverman, 2013). A postal questionnaire was chosen in this research as the most appropriate but was distributed electronically. Although there are some disadvantages to this data collection technique, this was nevertheless judged to be the optimal choice for the survey. Some questionnaires were administered face-to-face at the request of the participants. The existing literature was employed to design the questionnaire, which was made up of five sections.

3.5.5.2 Construction of the questionnaire

Silverman (2013) provides five pointers to follow when developing questions to improve the layout of a questionnaire and increase the response rate:

1- Place personal data questions at the beginning of the questionnaire and allow the respondent to choose whether or not to answer them;
2- Present questions in a logical sequence which bears in mind the logic of inquiry and the participant's probable responses;
3- Divide the questionnaire into sections with headings to make it clear to the respondent what information is being elicited;
4- Modify the questions so that they are as clear as possible, based on feedback from the pilot questionnaire;
5- Choose the most appropriate type of questions (open-ended or closed).

In order that more questions could be answered and the survey more easily processed and analysed, the questions had to be easily understood so that participants could respond quickly; hence, most questions were closed, which also had the advantage that the interviewer did not have to be present. The most significant disadvantage of closed questions is that they impose a bias on respondents, who are limited to answering from pre-set answers (Silverman, 2013). As the survey was designed to obtain factual data, the use of closed questions was necessary in most cases.

To improve the organisation of the questionnaire layout, the funnel approach was used. Here broad questions were asked initially, after which the scope of questions was narrowed down. The final questionnaire of 54 questions is displayed in Appendix A (English) and Appendix B (Arabic translation).

The first section was designed to collect data on business demographics (influencing variables). Here multiple-choice questions were used to investigate the nature and scope of the firms' operations and gain an insight into their perceived needs for improvement. The next section examined the operations value stream (SCM flow paths), which is made up of two elements: goods/material flow and warehousing. Multiple-choice questions were used to provide the scale of the operations and key information regarding inventory, stock movement and equipment status, as well as the extent of the practices adopted in the management of these areas. The third section was designed to analyse quality control and assurance based on the application of the core principles of quality control. The questions aimed to find out in which functions the most defects and errors occurred, what quality initiatives and practices had been adopted for the operation and the interviewees' views on quality control in their firm. The fourth section aimed to analyse the scale of each operation's sales and procurement operations, the level and type of information systems used for sharing between these functions, how effective those systems are and what problems the interviewees experienced with them. The questions in the final sections covered managing performance indicators. This section required the respondent to rate the importance of several measures in their operations and to prioritise the benefits measured in order of importance.

3.5.5.3 Data collection

The survey of 54 questions commenced in May 2015, after confirmation of the ethics code attached in Appendix C. The survey had to be completed within a one-month period. To improve the response rate, the researcher contacted respondents ahead of time to ask whether they would be willing to participate. Details on the participating companies are given in Table 3.2. Copies of the survey were distributed to the chosen companies electronically and personally. The first response came in after two days; after a week had passed, phone calls were made and e-mails sent out to remind participants to send back the questionnaires, which elicited further responses. It was originally hoped that two weeks would be sufficient for the survey, however the slow response rate forced the researcher to extend this once in order to obtain the minimum number of responses. On 15 June 2015 the survey was closed with 39 responses from 27 companies. The response rate appeared to be slow, but data analysis commenced as soon as the minimum number of responses had been obtained.

Table 3.2: List of respondents

Company	Size Class	Number of workers	Number of responses
Company 1	SME	2-9	1
Company 2	SME	2-9	1
Company 3	SME	2-9	1
Company 3	SME	10-49	1
Company 4	SME	10-49	1
Company 5	SME	10-49	2
Company 6	SME	10-49	2
Company 7	SME	10-49	2
Company 8	SME	10-49	2
Company 9	SME	10-49	1
Company 10	SME	10-49	2
Company 11	SME	10-49	1
Company 12	SME	10-49	2
Company 14	SME	50-100	1
Company 15	SME	50-100	1
Company 16	SME	50-100	2
Company 17	SME	50-100	2
Company 18	SME	50-100	2
Company 19	SME	50-100	2
Company 20	SME	50-100	1
Company 21	SME	50-100	2
Company 22	SME	50-100	2
Company 23	SME	50-100	1
Company 24	Large	More than 100	1
Company 25	Large	More than 100	1
Company 26	Large	More than 100	1
Company 27	Large	More than 100	1
Total			**39**

3.5.5.4 Data validation

The structure of a survey, the question layout, types of questions used and the robustness of any pilot trials all impact on its reliability and validity (Saunders and Thornhill, 2003). The questionnaire was pre-tested in four different food distribution organisations prior to distribution. The results of the pilot test drew attention to some minor issues which were corrected at once. The four respondents who participated in the pilot test were managers with high levels of experience in the food distribution sector. Their feedback on the layout and clarity of the questions and ease in filling out the questionnaire was taken into consideration, and the survey questionnaire was modified accordingly. The pilot test indicated that an average of 10 minutes was sufficient to fill out the questionnaire.

3.6 Tools

3.6.1 Multi-agent system

Chapter 2 presented and discussed MAS and the use of JADE, a software package which uses Java programming. It enables MAS to be easily implemented using middle-ware that complies with the FIPA specifications and uses a set of graphic tools which support the debugging and deployment phases. Eclipse is an open source community that concentrates on constructing an open development platform consisting of extendable frameworks, tools and runtimes used to build, deploy and manage software throughout the lifecycle. This software development platform enables the software developer to quickly build new Java applications; JADE is a Java-based development platform and service set which allows an environment with plug-in components to be more easily developed. The organisation of this study has been based on proposals by Nikraz et al., (2006), who have been published on the JADE site by TILAB.

3.7 Summary

This chapter describes the application of the methodology adopted to collect data and analyse the nature of the SME operations and the challenges they face within their SC. The study adopted a mixed method of quantitative and qualitative approach, supported with an experimental elements. The data collection techniques included literature review, pilot study, questionnaire with semi-structured interviews and an empirical case study. The data collected helped to understand the nature of the scope and scale of the operations and practices in SMEs and to identify the challenges that they face. The findings of the questionnaire and empirical case study were used to develop a conceptual framework of LSS and MAS. This conceptual framework was then developed within MAS and tested using manual simulation that was verified. The results of the simulations were validated by interviews.

4. EMPIRICAL CASE STUDY TO ASSESS THE BENEFIT OF LEAN SIX SIGMA IN AN SME

4.1 Introduction

This study conducted an empirical case study over a 6-month period to investigate whether the LSS methodology and processes can demonstrate a significant improvement in overcoming the major operational performance challenges of an SME in the food distribution industry of Saudi Arabia.

4.1.1 Case study overview

The case study was conducted by the researcher in Riyadh in a medium enterprise that had been in operation for more than 20 years. First of all the appropriate assurances were given and approval to conduct the case study received by the owner /manager. The SME activities include manufacturing, receiving and processing orders, invoicing, storage, loading and delivering products to food outlets. It supplies chilled and dry products such as rice, pasta, cereals, coffee, spices, cocoa and others. The company faces many problems and difficulties in the process of delivering food, two of the most prominent being delays in the delivery of orders and low levels of quality, leading to customer dissatisfaction with the service provided. Customers have made negative observations and complaints, suggesting the potential for financial losses due to loss of customers. Prior to starting this LSS project to improve the quality of service at the company, the total cost of late deliveries was calculated, to justify the running of the project. Multiplying the number of dissatisfied customers who have complained by average revenue per customer indicates a potential loss in custom of 720,000 SR (£120,000). The decision has therefore been made to use the LSS methodology to try to bring down the number of complaints.

4.2 Implementing the Lean Six Sigma Methodology

The researcher brought together a small project team consists of four members; the scope of the case study is to achieve a reduction in the number of complaints about the delivery process and quality of goods The organisation of the case study had been based on proposals by George and George (2003), George et al (2005) and Nabhani and Shokri (2009. Suitable statistical tools have been applied in a synergistic and integrated application of LSS methodology to use customer requirements as a means of pinpointing defects and their causes, then to apply the best solution to enhance the delivery process. A range of tools and technologies in the various phases of LSS methodology have been applied according to the process and resources concerned. Table 4.1 shows the tools which have been applied in each phase of LSS within the

DMAIC cycle framework. The effectiveness of the methodology was assessed using the empirical case study of a food distribution SME in Saudi Arabia.

Table 4.1: Tools and technologies which have been applied

DMAIC	TOOLS
Define	Project charter, Interviews, SIPOC Diagram, Data Collection, Pareto Chart.
Measure	Data Collection, Brainstorming Strategy, Histogram, Process Map, Process Capability Calculation, Sigma Level Calculation, VSM analysis calculation, VOC Identification.
Analyse	Fishbone Diagram, Cause & Effect Matrix, Pareto chart, Brainstorming Strategy, Quality function deployment method.
Improve	Brainstorming Strategy, VSM Analysis Calculation, Process Map, Implementation Plan.
Control	Control chart, Time Series Plot, Data Collection, Process Capability Calculation, Sigma Level Calculation.

4.2.1 Phase 1: Define

The implementation of this project began with the 'define' stage, where a project charter was established. Definitions were established of prerequisites such as the goals of project, its scope and the resources required, providing a basis on which the subsequent stages could proceed. Various people were assigned to roles in different places in order to organise the structure of the project, whose aim was to reduce the number of complaints about the delivery process. According to George and George (2003), the basic principle of LSS is that a defect is anything that makes a customer dissatisfied, such as poor quality, high cost and long lead times. The first step in dealing with these problems is to take a process view of how the firm meets customer requirements. The tool for building a high-level map of such a process is a SIPOC diagram (Figure 4.1), listing suppliers, inputs, processes, outputs and customers. A SIPOC diagram was drawn up to identify potential internal and external customers and to specify their requirements for the distribution process and what the inputs and outputs should be. The output of processes was used to assess the quality standards, so that improvements could be made on the basis of an analysis of inputs and process variables. Requirements and values were identified on the basis of product, time, quality and quantity.

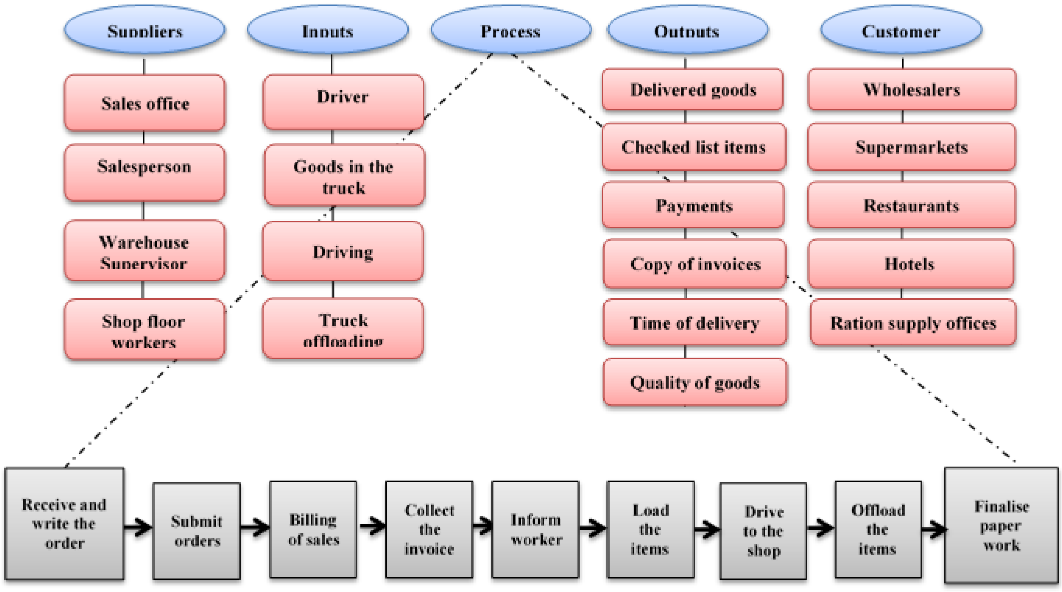


Figure 4.1: SIPOC diagram

The team also commissioned a customer service team member to compile customer statements so that the voice of the customer (VOC) could be determined. VOC is a process which allows service or product quality to be assessed; it supplies information which allows SC stakeholders to see how improving products and services quality management can enhance the performance of the entire chain (Mowat and Collins, 2000). If the customer's comments are not correctly understood, the entire programme can fail, especially in a food sector, where the customer's perception of quality is variable (Nabhani and Shokri, 2009). A sample of customers was asked about their satisfaction with the service provided by the company and the main problems that they had faced or noted when their orders were fulfilled. Examination of the complaints indicated that the problems related to delivery were incorrect billing, late delivery, supply of a reduced quantity, substandard items delivered, and incorrect products or quantities delivered. A Pareto chart (Figure 4.2) was then used to identify the problems related to delivery which occurred most frequently. This shows that 50 percent of all complaints related to delivery were about late delivery, meaning that this was the problem having the greatest impact.

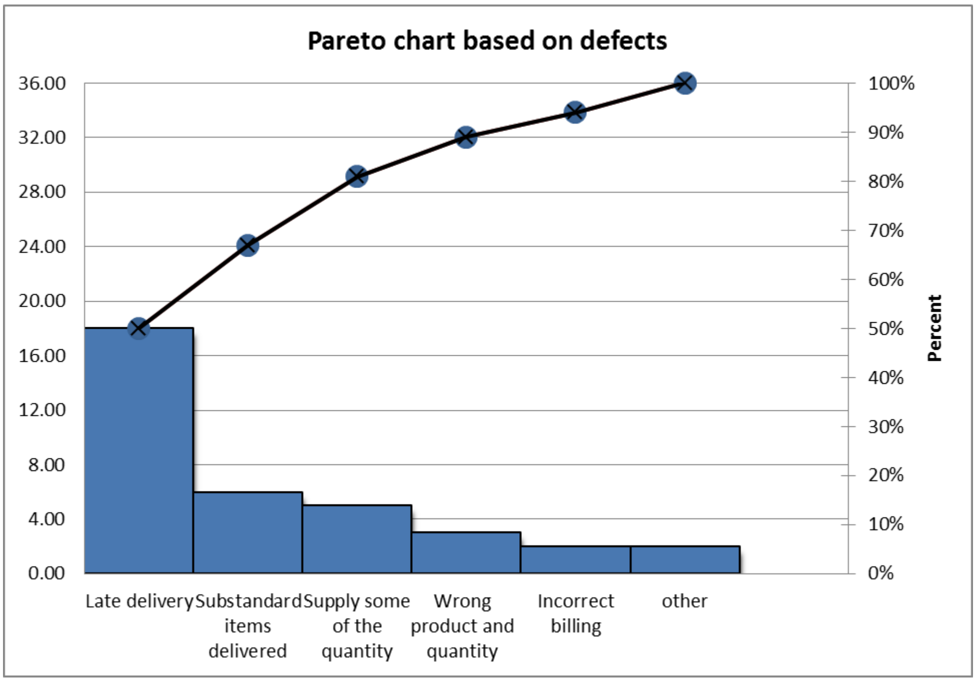


Figure 4.2: Pareto chart based on defects

A Pareto chart based on costs was used for deeper analysis (Figure 4.3). Costs were determined on the basis of two main considerations: the average cost of the possibility of losing a customer and the calculated cost per defect in the service provided.

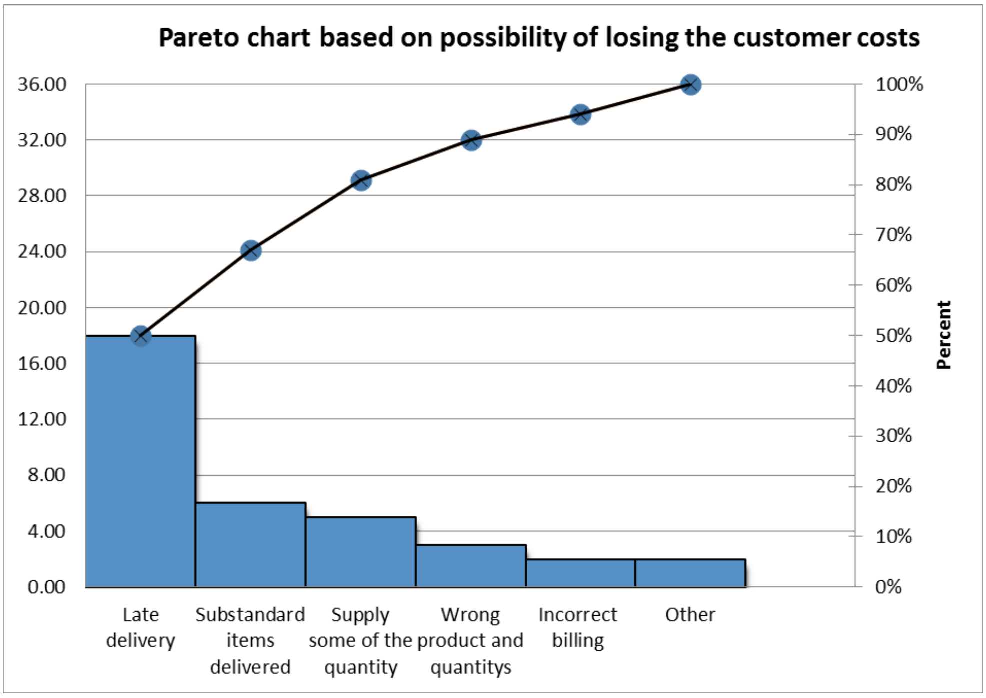


Figure 4.3: Pareto chart based on possibility of losing the customer costs

Looking at the Pareto chart used to calculate the cost based on the above considerations it can be seen that both give almost the same result, i.e. that late delivery and substandard items delivered were respectively the most costly problems. Based on the above, the problem of late delivery is the most significant problem in terms of the number of observations and complaints, and of cost, so the next step was to concentrate on late delivery to identify its causes and potential solutions.

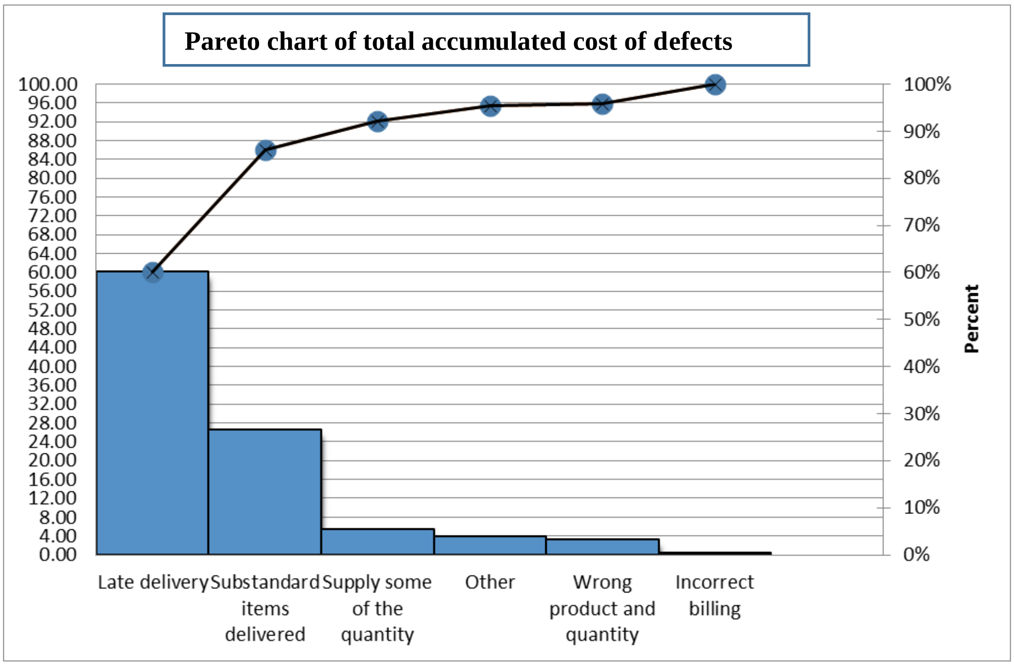


Figure 4.4: Pareto chart showing the accumulative total cost of defects

4.2.2 Phase 2: Measure

At the measuring stage, the current process was measured. Late delivery was used as the critical-to-quality variable (CTQ-Y), with the defect being late delivery. The next stage was at the company's distribution centre, where data on the delivery times for a sample of 100 journeys were collected daily for four weeks. The number of late deliveries (average of delivery + 5 percent) was calculated. This was set as the upper specification level and no lower specification level was set, since the shorter the time for service processing, the better the service quality (Su et al., 2006). The data collected are summarised in Table 4.2.

Table 4.2: Data collected for the cycle time

Mean / hour	Standard deviation	Variance	USL	Capability process index	Sigma level
23.002	2.050	4.201	24.15	0.187	1.7

Since cycle time was identified as the CTQ, a data collection plan was developed. Key measures and sources of data must be identified for proper data collection to take place. The key sources were warehouse manager reports, driver delivery reports and the customer complaints database, where mistakes or complaints about each process were logged. Data were collected every day. The database, which had been produced using the customer complaints, was analysed to identify the key variables which affected delivery time (Figure 4.5). The customer complaint database indicated that delivery-related variables were the number of shops, traffic problems, lateness by customer, lateness by sales office and spent loading time. Figure 4.5 shows that 'lateness by sales office' was the variable appearing most often in the customer complaint database. It was necessary to verify this further. The main objective was to reduce as far as possible the number of causes of this defect.

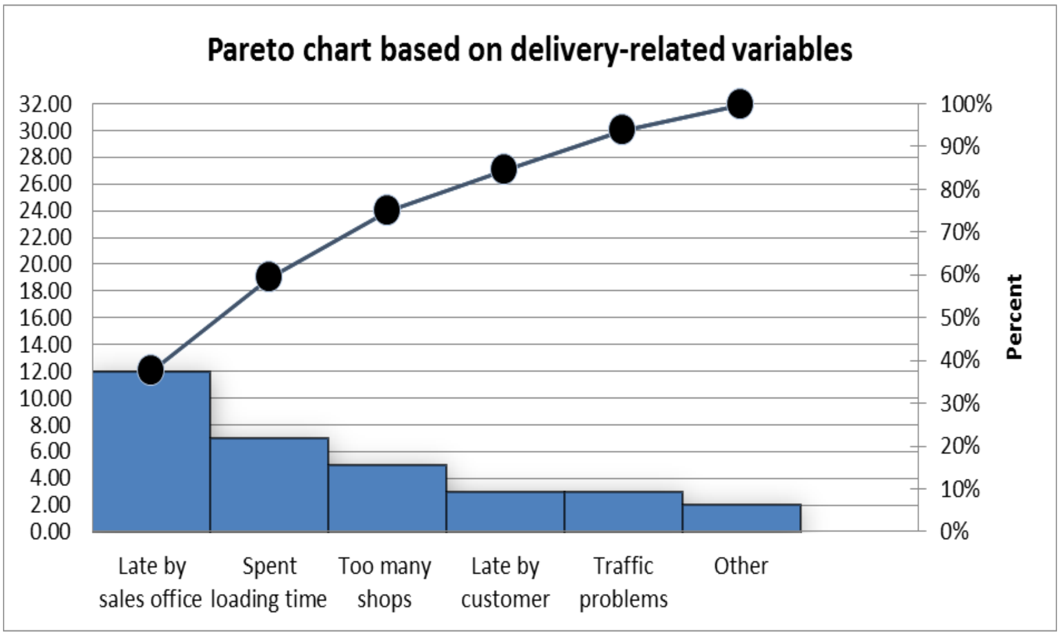


Figure 4.5: Pareto chart based on delivery-related variables

A value stream map (VSM) analysis was carried out to verify the result of the Pareto analysis. A current-state VSM was drawn, as depicted in Figure 4.6, the intention to identify and remove any non-value-added steps.

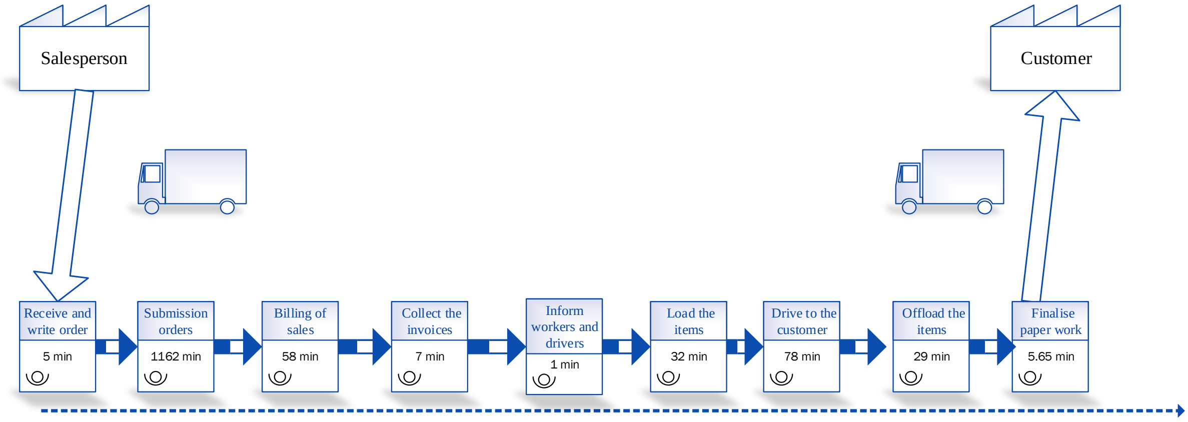


Figure 4.6: A current-state value stream map

Next, a future-state VSM was drawn (Figure 4.7) by removing from the process any non-value-added step, then identifying any potential for reducing the cycle time in each of the other steps.

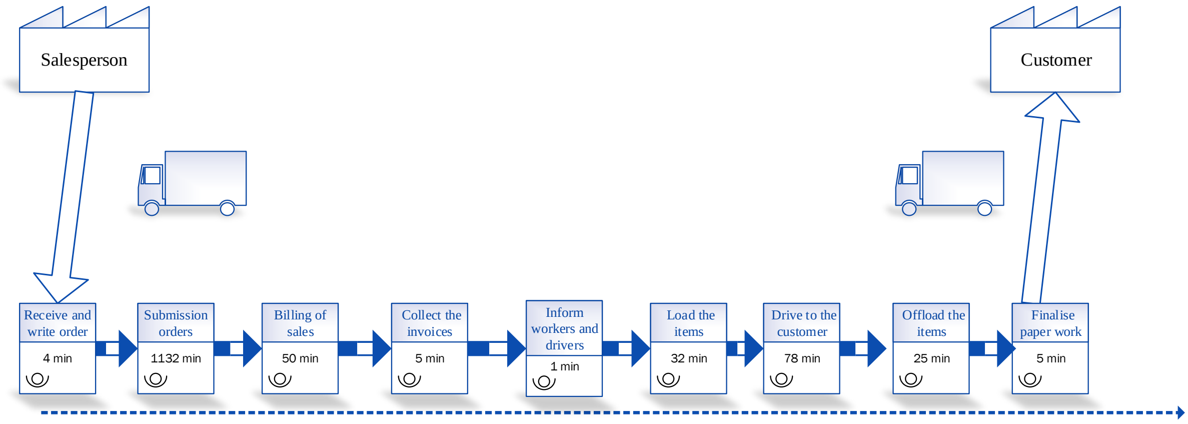


Figure 4.7: A future-state value stream map

In this case, as the major problem was late delivery, the analysis undertaken sought to identify the cause of late delivery and post the analysis of whether there are any non-value added steps related only to this issue.

4.2.3 Phase 3: Analyse

A comparison between the average time data between the steps of the current-state and future-state value stream maps, there are two areas that demonstrate improvement the on billing of sales went from submission of orders 1165 to 1132 mins and the billing of sales 58 mins to 50 mins. The Pareto chart in Figure 4.5, indicates that lateness by the sales office was the most important cause of the defect. The root causes of the problem of late delivery can be identified by using the fishbone diagram shown in Figure 4.8. The effect scores for the variables were entered after brainstorming and a fishbone diagram was drawn up.

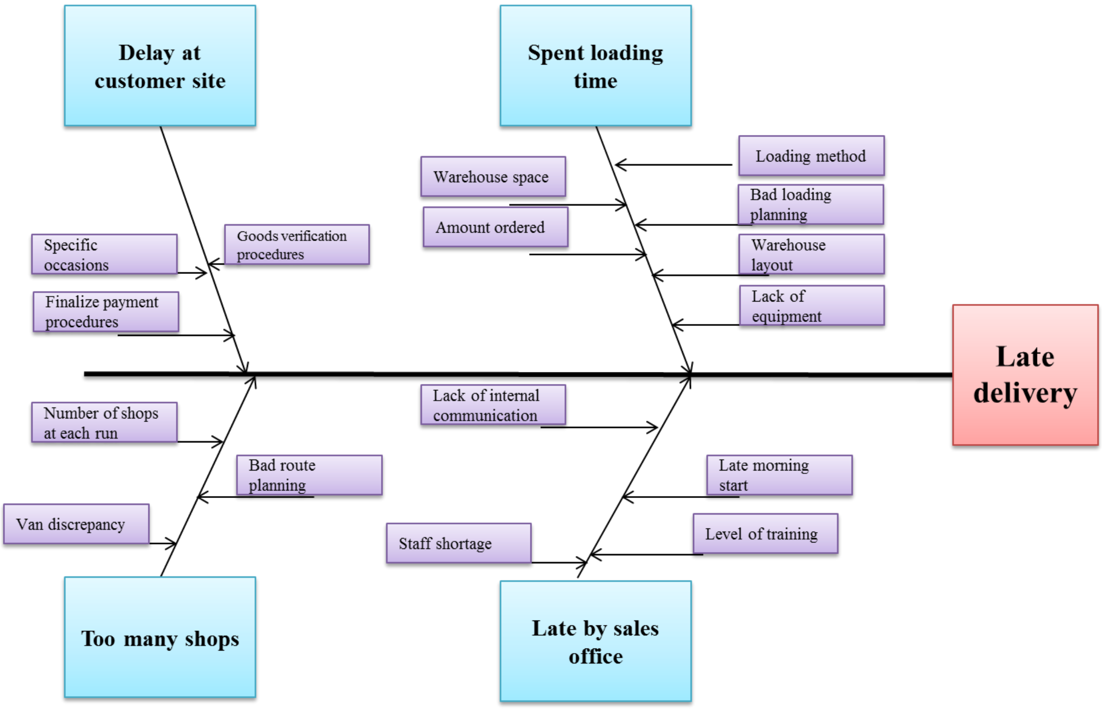


Figure 4.8: Fishbone diagram

Possible sources (Xs) were chosen for further analysis with a cause and effect XY matrix (Table 4.3), using the CTQ-Y variables, so that the possible sources of the three elements could be identified and the number of potential causes narrowed down. Table 4.3 thus lists potential causes of the three main variables and identifies the most critical ones. The importance score of each variable shows how important the variable was considered by the customer. Here, the X most closely associated with the variable was given a value of 9 and then 3, while those with no relationship were given a value of 0. The four causes with the highest scores, i.e. those having the most effect on lateness by the sales office, were chosen as the key sources of the defect, to be given further consideration, so that suitable solutions could be implemented during the improvement and implementation stages.

Table 4.3: Cause & Effect XY Matrix

	Output variables (Y's)	Late by sales office	Spent loading time	Too many shops		
	Importance score	9	**3**	**1**	Weighted score	Total rate
Input/process variables (X's)						
Number of shops		0	**9**	9	36	5.7
Warehouse layout		0	9	0	27	4.3
Staff shortage		0	3	0	9	1.4
Bad route planning		0	0	9	9	1.4
Truck situation		0	3	9	18	2.8
Bad loading planning		3	9	9	63	10
Loading method		3	9	9	63	10
Warehouse space		0	9	0	27	4.3
Late morning start		9	9	9	117	18.6
Amount of orders		3	9	3	57	9
Lack of internal communication		0	3	3	12	1.9
Specific occasions		0	**9**	9	36	5.7
Lack of equipment		3	9	9	63	10
Level of training		3	9	0	54	8.6
Goods verification procedures		0	3	9	18	2.8
Finalise payment procedures		0	3	9	18	2.8
Total					627	

According to Table 4.3, there are four sources, identified as possible causes of the three variables which had already been chosen as the CTQ-Ys for delivery time, were bad loading planning; loading method; late morning start; and lack of equipment

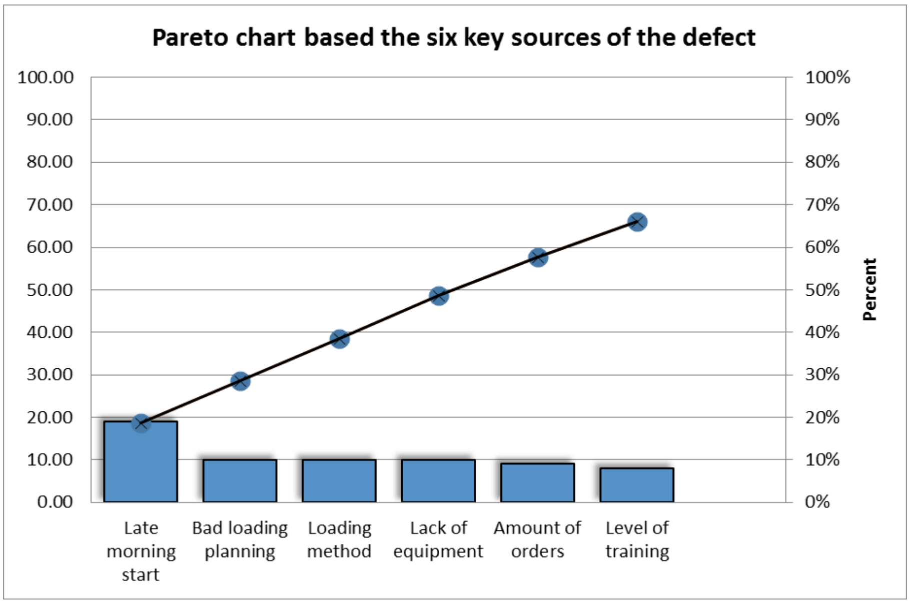


Figure 4.9: Pareto chart based the six key sources of the defect

4.2.4 Phase 4: Improve

Based on the results of the analysis phase and after determining clearly the reasons for the delay, the team agreed on how to develop the best solution to help reduce or eliminate these problems. These solutions must be internal, in order to facilitate the process of implementation and control; they must be inexpensive and they must produce direct and impressive results. The team members, working with the warehouse manager, drivers, salespeople and sales department, categorised the solution as comprising two key stages: changing daily hours of work and improving operations management. This categorisation was selected to cover all the causes of defects that should be focused on so that appropriate solutions could be developed, at low risk and without cost. It had already been suggested that delivery time could potentially be reduced by changing the daily hours of work, improving the loading method and loading planning, and using trolleys to carry the items in order to help deliver the services in the right quality and quantity at the right time. It was recognised that these solutions were not in themselves the most beneficial in reducing or eliminating the causes of the defects; rather, they were required in order to apply other solutions, while their impact was seen to extend to addressing some other problems. It was also considered that they would have a significant direct or indirect impact on the efficiency of the delivery process and the reduction of delivery time.

4.2.4.1 The current situation

The working hours of the company are currently divided into two periods: 8-12 (morning) and 3-7 (evening). These times were determined to conform with the working hours of the majority of customers. Salespeople have to visit customer daily in their workplaces to collect orders and identify items and quantities required. The pressure to meet with clients means that sales people are out of the office most of the working day. The best time for a salesperson to meet customers such as wholesalers and take their orders is from 8pm to 10pm, as the customers are busy until evening when they can identify what they actually need from the days sales and request that the salesperson deliver these items the next day. So, salespeople often only finish their tour after 10pm sometimes later, by which time their own company’s official working hours are over. Salespeople then have to wait until the following morning at 8am before they can submit the order to the sales department for each customer. The next step is for the sales department to issue an invoice for each customer, stating items and prices. Meanwhile, delivery drivers, warehouse workers and the warehouse manager are waiting for all statements and invoices to be issued. The warehouse manager then collects the invoices and takes them to the warehouse for the orders to be processed and the appropriate route for each driver to be determined. The warehouse has two separate sections, so that the pungent odours of some items such as spices and coffee do not contaminate other food items. Items are identified and handled manually throughout the warehouse, then loaded onto trucks by hand, which takes considerable time and effort, with the risk that items will be dropped and damaged during loading and unloading, affecting quality. Once each truck has been loaded with goods from one section of the warehouse, it moves to the second for the rest of the items to be loaded, which is again costly in time and effort. When each truck has been loaded, the goods and quantities are reviewed by the warehouse manager and the driver, then the driver signs a receipt before leaving to deliver the goods.

4.2.4.2 Improvement implementation

It was decided that requiring some employees to begin the working day slightly earlier and improving operations management would be likely to reduce delivery time, so we worked on two parallel paths at the same time. First, it was agreed that the sales office, salespeople and warehouse team would begin work at 7 am, when salespeople would give the lists of items and quantities required by customers, including their addresses, to the sales office. The sales office staff would then print an invoice for each customer, stating the quantity of items required plus the delivery address. As before, the warehouse manager would take copies of these invoices from the sales office to the warehouse, in order to prepare and process the orders. After identifying the items required, workers would use a large trolley to collect them from all parts of the warehouse, therefore eliminating the non-value added steps of carrying each item separately, thus saving time and preserving the quality of the goods. The trolley could also be pushed from one section of the warehouse to the other, thus eliminating the need for trucks to be loaded in two separate operations. When each driver arrived at the loading bay, all of his orders would be prepared and ready for loading onto the truck, without the need to wait. It is worth mentioning that the company plans to purchase a forklift truck to make the loading of goods even faster, smoother, more flexible and effective.

4.2.5 Phase 5: Control

At this first stage, a control plan was applied for the delivery time; this requires the use of the control chart, c-chart to measure the delivery time for internal operations management and ensure that the process is under control. The results of the improved status are demonstrated in the Figure 4.10 below. The histogram presents the normal distribution of the indication of need for further improvement. The control charts indicate the number of orders that are outside the control parameters and the fluctuating variances within the process. In this phase, this control plan should be repeated constantly.

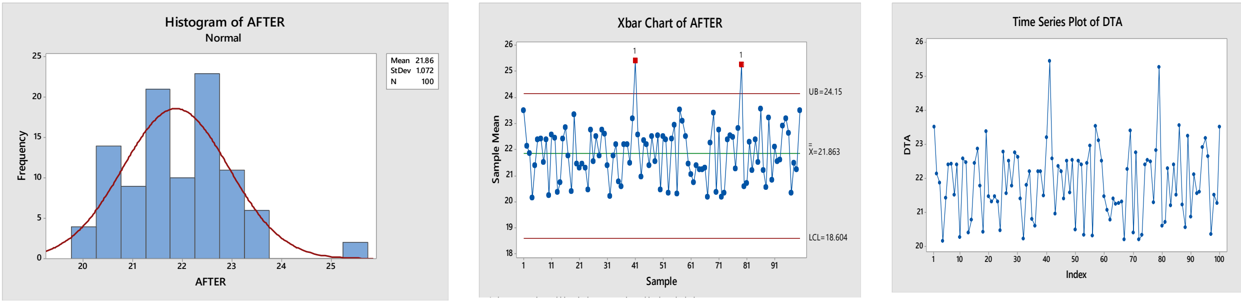


Figure 4.10: Distribution graphs after LSS improvement

4.3 Results

In this empirical case study, the researcher achieved a significant level of success in reducing the cycle time required to deliver orders to customers during working hours, which helped to reduce delays in delivery significantly and increase customer satisfaction, thus reducing the likelihood of a loss of customers due to dissatisfaction. Although the direct focus of the solution was on addressing the causes of delivery delays, it contributed indirectly to raising the quality of goods delivered and reduced the number of customer complaints about delivery of substandard goods, as the new trolleys helped significantly in reducing the risk of dropping items and damaging them while they were being taken to the trucks. The results of the data analysis indicate that changes in hours of work, loading plan and loading method brought down the number of defects by 95% from 10.5 to 0.5 per week, causing an improvement in the Sigma level from 1.7 to 3.55, which produced a considerable improvement in the overall operations of the SME. An important finding of the study was that there was a reduction in average delivery time by 1.138 hours after the application of LSS methodology.

Therefore, an 80% reduction in customer complaints has been achieved from the baseline with the application of LSS; the reduction in complaints from the 50% to the 10% level equates to nearly £48,000 in potential cost benefits for the business. Reducing the total cost lowered the cost per defect by 48%, which was a large gain for the SME.

Table 4.4: Results of implementation LSS

	Before improvement	After improvement
Average time/minutes	23.002	21.8633
Sigma level	1.7	3.55
Financial benefit	-£120.000	£48.000
Actual capability process index	0.187	0.713

4.4 Summary

The case study identified that the SMEs in Saudi Arabia face a wide range of operational difficulties which affect their food distribution supply chain. The application of the DMAIC approach identified several major issues of which late delivery was the most significant. The initial measure of Six Sigma was improved from 1.7 to 3.55. Furthermore, as an 80% reduction in customer complaints equates to approximately £48,000 saving, that lowered the cost per defect by 48%. These significant improvements demonstrate the effectiveness of the LSS approach.

The researcher decided to use the case study to assess whether any further operational gains could be achieved with the introduction of a simple MAS programme which specifically addressed late delivery. The MAS programme was developed to simulate their processes. The results demonstrated a significant improvement in late delivery but did also contribute indirectly to quality issues. In view of this success it was clearly demonstrated that in principle the integration of LSS methodology and an MAS programme in this specific case can be usefully implemented in SMEs in other service industries to enhance operational performance and efficiency. In order to assess whether the principles of LSS and the MAS platform could be applied more universally to support SMEs with similar issues, the researcher conducted a survey of SMEs in the food distribution sector in Saudi Arabia. Using the information gained from such a survey allowed the researcher to propose an initial framework that integrates LSS and MAS.

5. ANALYSIS OF THE QUESTIONNAIRE

5.1 Introduction

This chapter presents the empirical study to understand the nature and scope of SMEs and their operational practices in the food distribution industry in Saudi Arabia. The aim is to identify the critical factors and variables that influence their operational performance and determine the extent to which LSS and MAS methodologies can support SMEs in overcoming the operational challenges they face and improve their performance in this competitive industry. Finally, the goal is to propose a framework for an integrated model using both LSS and MAS for SMEs in the food industry in Saudi Arabia.

5.2 Survey Approach

In this study, a questionnaire was used to collect the data. The survey was formulated according to Oppenheim's (2000) guidelines for the layout of questionnaires. Then the questionnaire was distributed to 60 SMEs in the central business district of Riyadh by hand and email, and 39 questionnaire responses were obtained from 27 companies. The data analysis was conducted and findings were evaluated to determine the critical factors, variables, and the relationship between performance and practices. Based on the findings discussed, recommendations for improvements are proposed.

5.3 Results Analysis, Findings and Discussion

The intended outcome of this survey was to better understand the SMEs and their operating practices; to identify the challenges they face and whether using LSS methodologies could introduce improvements which would increase SMEs' operational performance. An additional goal was to determine whether compliance with these practices can be made sustainable by embedding them in the SME operations using MAS. Furthermore, the aim was to determine whether MAS can bring about a significant improvement in the operational efficiency and effectiveness of the supply chain. The analysis of the results of the survey are discussed below together with the findings. The questionnaire consisted of five sections.

5.3.1 Respondent demographic

Section 1 of the questionnaire sought to understand the size, scope and nature of SME ownership in the food distribution industry. The respondents were asked to provide demographic information. The questions required the respondents to indicate the size and scope of the SME SC operations, the number of employees, level of turnover and type of ownership.

The respondents were asked to indicate the scale and nature of their trading operations, customer base, suppliers and distribution, and understand what the respondents consider to be critical measures of their business performance, what improvements they consider are needed, and the most significant obstacles they face. In addition, the respondents were also asked to identify what obstacles they face in the operations of the supply chain.

The key findings and results are summarised as follows and the complete set of analysis tables is included in Appendix D. Each table is referenced according to the question in the section. Table 5.1 provides a summary of the main demographic data collected from Tables 1.1, 1.2 and 1.3 in Appendix D.

Table 5.1: Summary of range based on size of turnover and number of employees

Size Class	**Employees**	**Company Annual Turnover (Real)**	**Position of Respondents**	**Number of Companies**
Table Appendix D	Table 1.1	Table 1.2	Table 1.3	Survey Respondents
Micro	2–9	Less than 2 million	Owners	3
Small	10–49	2–10 million	Owners and Managers	16
Medium	50–100	11–20 million	Owners and Managers	16
Large	More than 100	More than 20 million	Managers	4
Other	-	Missing	-	-
				39

The company size is based on the number of employees and size of turnover respectively. Thirty-two of the firms are small to medium, with a turnover of 2–20 million and with 10–100 employees. Three large firms have turnovers exceeding 20 million and more than 100 employees. Three are micro firms with a turnover of less than 2 million and 2–9 employees. The analysis of the demographics in Table 1.4 indicates that the majority (84.6%) are locally owned.

Table 5.2: Section 1 Respondent Demographics of Ownership, Years of Operations and Customer Location

Ownership status	Age of company	Where their customers are (Sales)
Table 1.4	Table 1.5	Table 1.6

	Frequency	Percent
Locally owned	33	84.6
Part of a Multinational Organization	4	10.3
A Joint Venture	2	5.1
Total	39	100.0

	Frequency	Percent
Less than 12 months	----	----
1-2 years	----	----
2-5 years	----	----
5-10 years	6	15.4
10+ years	33	84.6
Total	39	100.0

	Frequency	Percent*
Local	37	94.9
Europe	1	2.6
China	1	2.6
India	5	12.8
Africa	6	15.4
Other	5	12.8
No. of participants	39	

Table 1.5 shows that these are all established firms and that the majority can be considered mature as they have been operating for more than 10 years. Table 1.6 indicates that 95% primarily sell locally, whilst 15.4% also sell to Africa and 12.8% to India or other countries not specified. Only 2.6% sell to Europe or China respectively. The majority of the companies procure and sell their goods to more than two countries. Less than half source their goods locally in Saudi Arabia, 28.2% source them within the Gulf and 35.9% in Africa, India and Asia; as seen in Table 1.7 (Appendix D), over 92% of the respondents source their goods in the rest of the world. From this we can establish that the respondents share the same characteristics in the sales and procurement part of their supply chain operations.

Furthermore, a summary of the Tables 1.8 to 1.10 in Appendix D indicates the scale and complexity of the distribution, storage, and warehousing operations. Table 1.8 shows that over 60% distribute their goods to customers countrywide, whilst 28.2% distribute them only in the same city. Table 1.9 indicates that 66.7% are manufacturers, and 90% have warehouses and distribution centres; practically all have depots. Therefore, irrespective of size, they were all operating the same SCM scope of operations in procurement, sales, storage and distribution.

Table 1.10 indicates that 46.2% operate a fleet of between 6 and 20 delivery vehicles and 35.9% operate a fleet of more than 20 vehicles. Only 7 firms have a fleet of 5 or fewer vehicles, and these are mostly micro- and small companies. As can be seen in Table 1.11, only 28.2% operate a continuous delivery rotation/shift system of which 4 are small and 8 are medium companies in terms of turnover and operate 6 to 20 delivery vehicles. 25.6% sometimes adopt a rota system. According to Table 1.12, only 25.6% have adopted standardised and documented procedures throughout the firm, whilst 46.2% have some level of documentation and standardisation; 28.2% have not introduced any at all. Similarly, Table 1.13 shows that 41%

have no training for their staff, 17.9% have had one training session for their staff, whilst 20.5% train them often, and 17.9% train them regularly. These demographic findings indicate that firm size does not influence the adoption of operational practices such as rota systems, standardised processes, or training.

5.3.1.1 Need for Improvement

The respondents were asked if their operations needed improvement; Table 1.14.1 indicates that 89.7% of the respondents believe there is a need to improve them. Only 5.1% stated they did not know if there was a need or that there was no need for improvement. In Table 1.14.2 respondents identified the following areas as those that require improvement. Here stock availability was an area of improvement for 82.9% respondents. This was followed by lower costs (71.4%) and the quality of the products (62.9%). Tables 1.14.1 and 1.14.2 established that there was no correlation between the responses and the size of the companies. Table 1.15 indicates the frequency with which the respondents ranked the key indicators; here quality, stock availability and lower costs were the top 3 most important ones. Delivery time ranked 4th, followed by lead times and flexibility. Table 1.16 shows the functions of the organisation that were considered to need the most improvement in order of importance. The quality of products was the primary area deemed in need of improvement, and inventory was ranked second. In third place was sales, and warehousing was ranked fourth. Fifth was transport, and sixth was purchasing, followed by administration. .

Table 5.3: Section 1 Respondents rank key performance indicators and functions needing improvement

Table 1.15

Statement		Least Important.---Very Important					Mean	Std. Deviation	Rank
Lead Times	Freq.	10	14	11		3	3.74	1.11	5
	%	26.3	36.8	28.9		7.9			
Delivery Time	Freq.	18	15	1	2	1	4.27	0.96	4
	%	48.6	40.5	2.7	5.4	2.7			
Quality	Freq.	28	8	2			4.68	0.57	1
	%	73.7	21.1	5.3					
Lower Costs	Freq.	26	9	2	2		4.51	0.82	3
	%	66.7	23.1	5.1	5.1				
Stock Availability	Freq.	27	4	6			4.57	0.77	2
	%	73.0	10.8	16.2					
Flexibility	Freq.	12	9	12	3	2	3.68	1.16	6
	%	31.6	23.7	31.6	7.9	5.3			
Mean for total							**4.26**		

Table 1.16

Statement		Least Improvement----Most Improvement					Mean	Std. Deviation	Rank
Sales	Freq.	21	9	6	1	1	4.26	1.00	3
	%	55.3	23.7	15.8	2.6	2.6			
Purchasing	Freq.	8	11	12	2	1	3.68	1.01	6
	%	23.5	32.4	35.3	5.9	2.9			
Warehousing	Freq.	12	11	7	2		4.03	0.93	4
	%	37.5	34.4	21.9	6.3				
Transport	Freq.	7	15	9	3	1	3.69	0.99	5
	%	20.0	42.9	25.7	8.6	2.9			
Inventory	Freq.	19	11	3	1	1	4.31	0.96	2
	%	54.3	31.4	8.6	2.9	2.9			
Quality of Products	Freq.	21	10	4	1		4.42	0.81	1
	%	58.3	27.8	11.1	2.8				
Administration	Freq.	2	4	16	9	2	2.85	0.94	7
	%	6.1	12.1	48.5	27.3	6.1			
Mean for total							**4.00**		

5.3.1.2 Obstacles

Question 17 was open-ended and gave respondents the opportunity to identify and provide details of the obstacles they face in their operational SC; these are grouped as follows:

Quality of Products: Problems included low standards in the quality of raw materials, and production levels that were not meeting the quality requirements, short expiry periods for goods, maintaining food safety, a low level of food quality, and shipment and customs delays resulting in damaged or perished goods or goods being past their expiry date.

Inventory: This involved high levels of stock, not having the required variety of items or the options to order and stock them, delays and extended lead times, managing short expiry periods for goods, the variations between the Arabic and the civil calendar events, and import shipments being subject to custom delays.

Sales: This included not being able to satisfy the demand, there being too many options and the complexity of the variety of items needed to satisfy demand.

Warehousing: Many of the respondents cited the shortage of workers in their warehousing function, the low skill levels of workers and poor communication within the workforce, as well as problems with not working as a team.

Other: Respondents noted high operation costs, poor cash flow and late payments, and exporting goods being subject to shipping conditions and customs delays.

5.3.1.3 Summary of Section 1 of the Survey Findings

Correlation analysis of Table C1-1 and C1-2 (Appendix D) identified that the size of the firm does not correlate to the scale and scope of sourcing and distribution, nor to the nature of the problems experienced. In addition, the Chi-square test was used; this indicates how likely it is that an observed distribution fits the distribution that is expected if the variables are independent, and is referred to as a "goodness of fit" statistic. The Chi-squared test confirmed that, as a business grows in turnover, the most significant adaptation response for the business is an increase in the size of the fleet and in the standardisation and documentation of procedures so as to deal with the increasing complexity. Moreover, the general scope and nature of the SCM operations is the same for large and small businesses. The results of the one-way analysis of variance (ANOVA; F-test) determined that there was no significant difference to the size of the firm between the respondents' opinions regarding efficiency measures and areas of improvement which could be linked. Furthermore, flexibility is not considered a significant factor.

The results from the demographics section show that small and large firms all operate the same value stream, from the initiation of the process with the salesperson, through procurement, goods receiving, warehouse and goods dispatch, to the transport to the end customer. Similarly, they all measure the same critical factors of performance in their SC operations and share the same opinion on what they consider the most significant obstacles.

However, it is reasonable to say that larger firms do need to standardise their operations to address size increases and their more complex SC. As larger firms import and export to more countries, they have a more complex sourcing function. Generally, larger fleets are needed to accommodate the wider distribution of goods and transportation. The respondents identified their most critical factors and those needing the most improvements as quality, followed by stock availability, and then lower costs. Furthermore, the SMEs confirmed the obstacles that they face in their SC operations as the quality of products, inventory, sales, and warehousing. The issues of quality of products and the function of inventory are clearly raised throughout this section as the areas requiring the most significant improvement and involving the greatest obstacles.

The results indicate that the size of the firm (turnover or number of employees) does not influence the scale of their sourcing operations or how many countries they source from or sell their products in. However, the results indicated that the size has a significant influence on the size of the company and the size of the fleet and that there is also a significant influence on the size of the operations and the level of standardisation of procedures/documents implemented within the SME.

5.3.2 Operations value stream (Supply chain management and goods flow path)

The intent of section 2 is to gain an understanding of the scale, nature and scope of the supply chain functions and the goods flow path within SMEs in the food distribution industry. This section is split into two sub-sections.

The first sub-section collected data on the flow of goods within the SMEs from order to delivery, highlighting the length of time products are held in stock and where stocks or raw materials stored, whether the organisation has a specific reorder policy and whether they hold buffer stock or maintain safety stock levels to prevent outages. The survey also collected data on stock management policies and practices used to control stock movement. Finally, the study collected information on the problems companies face with waste or damaged stock. In the second sub-section of section 2, the survey collected data on the warehouse management practices of the SMEs. The questions sought to establish how capacity is managed within the warehouse, the extent of stock movement between storage sites, the level of quality inspection of goods and the distinct functions performed within the warehouse and the impact of downtime on their operations. The key findings and results are summarised as follows; the complete set of Tables 2.1.1 to 2.1.9 is included in Appendix D.

Table 5.4: Summary of Stock and Stock Management

Stock Storage Time	Number of Unique Stock Items	Stock Reorder Policy
Table 2.1.1	Table 2.1.2	Table 2.1.3

Table 2.1.1

	Frequency	Percent
1-3 days	4	10.3
3-7 days	2	5.1
7-14 days	8	20.5
30 days or more	25	64.1
Total	39	100.0

Table 2.1.2

	Frequency	Percent
1 – 10	4	10.3
11- 20	9	23.1
21 – 40 items	14	35.9
More than 40	12	30.8
Total	39	100.0

Table 2.1.3

	Frequency	Percent
When no stock exists	1	2.6
When stock reaches a set level	31	79.5
To fill an order	6	15.4
Other	1	2.6
Total	39	100.0

Table 2.1.1 shows that 64.1% of the respondents hold stock goods for 30 days or more, 15.4% have a stock turnover of less than a week, and only 20.5% have a turnover of less than 14 days. 66.7% of the respondents stock more than 21 items, yet 30.8% of the SMEs, 9 of which are small firms with 3 of these small firms having factories, stock over 40 items. According to Table 2.1.2 only the 4 micro firms hold less than 10 items in stock. The respondents all operate a stock/product item catalogue that comprises a wide variety of goods in various sizes and host multiple brands. In Table 2.1.3 79.5% of respondents reorder when their stock reaches a set level and 15.4% will source to fill an order. The results of these tables indicate that all the SMEs generally maintain and manage a relatively complex level of inventory.

Tables 2.1.6 to 2.1.9 are included in Appendix D and are summarised here. Tables 2.1.6 shows that 5% of the firms store their goods in general holding areas and 25% (only one of which is a micro firm, while two are small, three medium and three large) allocate their goods to specified bins, while 28.2% do not have specified bins at all. In Table 2.1.5 87.2% of the respondents, hold buffer stock; this applies this to all the stock for 41% and to some of the goods for 46.2%. Only micro firms do not hold any buffer stock. In regard to stocking methods, Table 2.1.7 shows that 59% adopt first-in-first-out (FIFO), and only 10.3% use last-in-first-out (LIFO). Some of the firms adopt both FIFO and LIFO but for different products. Regarding waste, according to Table 2.1.9, approximately 72% of the respondents reported disposing of unsold products frequently, whilst 15.4% do so on a regular basis. Only 5 firms (12.8% - '4 medium in turnover and one large firm') do not dispose of any unsold products. The results of Tables 2.1.6 to 2.1.8 indicate that there is no consistent practice adopted for managing the flow of goods in and out of the warehouse. Furthermore, goods are not allocated a specific holding bay or location. The lack of consistent practices in this regard increases the likelihood of damaged goods - whether as a result of poor packing or because goods will expire before they are shipped to customers. This propensity is confirmed by the results of Table 2.1.9.

The second part of this section is to determine how the respondents manage the quality of stock through stock levels, stock movement and storage in their warehousing function. The summary of the findings is presented herein; the detailed results from Table 2.2.1 – 2.2.8 are included in Appendix D. Table 5.5 provides a comparison between how full the warehouse is kept and stock movement.

Table 5.5: Comparison between warehouse levels and the movement of stock (Tables 2.2.1-2.2.3)

Comparison Between Warehouse Levels and Movement of Stock	**Size of Firms by Turnover**					
Warehouse Levels and Days in Stock with Stock Turnover from 1–2 times	**Micro**	**Small**	**Medium**	**Large**	**Total**	**Total %**
Warehouse levels in excess of 75% and items in stock for more than 30 days	1	5	3	2	11	44
Warehouse levels in excess of 51–75% and items in stock for more than 30 days	2	3	3	1	9	36
Warehouse levels in excess of 30–50% and items in stock for more than 30 days			2		2	8
Warehouse levels in excess of 30–50% and items in stock for more than 7-14 days	1	1			2	8
Warehouse levels in excess of 51–75% and items in stock for less than 3 days	1				1	4
Total	**5**	**9**	**8**	**3**	**25**	100

41% of the respondents maintain inventory levels within the warehouse at between 51% and 75%; 35.9% are stocked at levels of 75% or more, and 23.1% keep warehouse levels between 30–50%. 64.1% of the respondents have a separate location for receiving their goods within the warehouse, 64.1% only move their stock up to a maximum of twice, and of these, 16 have factories, whilst 25.6% move their stock around 3–6 times and 10.3% more than 6 times. Table 2.2.4 indicates 56.4% have depots and warehouses in the same city, whereas 12.4% are country-wide. The rest practice regional distribution. These findings highlight the fact that relatively high stock movements in conjunction with a lack of a consistent specific allocation of stock to a bin and FIFO policy further evidences the wastage associated with destroying products and associated costs.

If we compare the movement of stock with the length of time in stock and how full the warehouse is, then from the analysis of Table 5.5 it is clear that the movement and level of stocking is not size related. Therefore, turnover or employee sizes are not influencing factors. Additionally, without a specific warehouse allocation standard, goods are not easily located and are therefore not available to the customer. As few firms undertake regular stock counts, they will find it harder to ensure that they have the level of stock that they actually need and identify when stock reaches its set level. Therefore, overstocking is likely to be used to compensate for not being able to locate stock easily; alternately, it is most likely that firms will run out of stock will even though stock may exist but cannot be found or accessed or is damaged, and thus is not available.

Finally, the last part of this section analyses the effectiveness of the transport and tools used within the warehousing and distribution centres. Table 2.2.6 shows that 10.3% of the firms always have problems, whilst the rest of the respondents indicated they frequently have problems with the downtime of vehicles. In Table 2.2.7 53.8% indicated that the mean time between equipment failures incidents is 30 to 180 days and for 10.3% is more than 180 days. Only 12.8% experience consistent problems on a monthly basis. Table 2.2.8 in Appendix D indicates that for 51.3% it takes more than one hour to repair equipment and for 43.6% it takes more than one day. These findings reinforce the time and productivity losses associated with downtime for transport; when this is considered in the light of the stock movements between depots, factories and warehouses, it can be seen that this has a considerable “knock on” effect within the flow of goods, extending lead times, delivery time, decreasing productivity within the operations, and increasing costs.

5.3.2.1 Summary of Section 2 of the Survey Findings

As described in the first sub-section in relation to the goods flow results, with the exception of micro firms, the respondents appear to have a relatively complex stock/product catalogue, with high levels of stock holding. The majority store their stock in a general holding area without using specified bin locations. Whilst they hold some buffer stock, this is not the case for all their stock, but the firms tend to reorder when their stock reaches a set point. However, only some adopt a FIFO policy for all their stock, some adopt it for some stock and others use a mixture of LIFO and FIFO. A significant minority have no stock policy. This definitely contributes to the need to dispose of unsold products regularly. The results from warehousing in Section 2 demonstrate that the majority of the firms maintain very high levels of stocking to ensure stock availability. This increases issues with space constraints in their warehouses.

The limitation on space, the lack of specific allocated bins and the limited use of a stock method policy means that over a third of respondents move stock 3–6 times internally to alternate areas when warehouse space has been exceeded. This very likely contributes to 70% of the firms indicating that most damage to goods occurs in the warehousing and goods dispatch stages. This could also contribute to the need for frequent and regular disposal of unsold products. Since the respondents noted that a significant concern was the low level of skills among as well as the shortage of workers in the warehouses, and since 43.6% experience equipment outages lasting for more than one day, this makes the management of the limited space even harder to address. All these issues influence the quality of the stock; the stock policy method directly influences the management of expiry dates and contributes to incorrect orders and pricing, which was the respondents' third area of concern in quality assurance. The combination of all these would explain that the second-most consistent main obstacle experienced is stock shortages. If the quality is affected and the goods have to be disposed of, this will reduce the availability of stock and contributes to the finding that 61.5% of the respondents are concerned because of partial deliveries.

Therefore it appears that the result of these practices is that SMEs are making additional unnecessary purchases and experiencing high levels of waste because of the regular disposal of excess and damaged goods. All of this directly contributes to the obstacles identified in the respondent demographics section, which are stock quality, availability and cost.

5.3.3 Quality control assurance

Section 3 of the questionnaire sought to collect data on how the SME respondents manage the levels of quality within their operational SC, where the respondents experience the most defects and quality related issues, and whether the SMEs adopt any recognised quality-related practices. Further, the survey established the parts of the supply chain where most quality defects and errors occur. The detailed results from the survey are recorded in Tables 3.1 to 3.7 in Appendix D.

Table 5.6: Questionnaire Section 3 Quality Control Assurance, Questions 3. 1 to 3.3

Table 3.1

	Frequency	Percent*
Goods Receiving	9	23.1
Warehousing	19	48.7
Goods Dispatch	9	23.1
Transportation	20	51.3
Customer Site	17	43.6
Missing	1	2.6
No. of participants	39	

Table 3.2

	Frequency	Percent*
Goods Receiving	32	82.1
Warehousing	31	79.5
Goods Dispatch	15	38.5
Transportation	11	28.2
Customer Sit	11	28.2
No. of participants	39	

Table 3.3

	Frequency	Percent*
Goods Receiving	30	76.9
Warehousing	24	61.5
Goods Dispatch	11	28.2
Transportation	6	15.4
Customer Site	4	10.3
No we don't spend too much time	5	12.8
We do not inspect goods	3	7.7
No. of participants	39	

The summary of the key findings in Table 3.1 which are incorporated in Table 5.6 are that respondents consider transportation (51.3%), warehousing (48.7%) and the customer site (43.6%) as the top three stages where goods are damaged or become defective. 23.1% of respondents consider that goods dispatch and goods receiving present the most quality issues. As goods dispatch forms part of warehousing for all respondents, this means that warehousing and goods dispatch together represent the areas where 71.8% of the problems are found, making this the most significant area for quality issues.

Table 3.2 identifies where the respondents conduct the most inspections and take measures to comply with regulations. Food, environmental, and hygiene standards are mainly inspected in goods receiving (82.1%) and warehousing (79.5%). The emphasis on inspection then drops with only 38.5% of respondents inspecting at goods dispatch, 28.2% for transportation and 28.2% at the customer site. Most of the micro and some of the small firms do not have a separate goods dispatch area. Table 3.3 indicates that respondents reported that they spend too much time inspecting goods with the following top three areas: 76.9% in goods receiving, 61.5% in warehousing and 28.2% in goods dispatch. 12.8% do not consider this activity a waste of time; however, 7.7% (3 firms) do not inspect goods. 15.4% consider it a waste of time to inspect at transportation and 10.3% do so at the customer site even though this 15.4% includes three firms that are identified in Table 3.6 as ISO compliant.

Table 5.7: Questionnaire Section 3 Quality Control Assurance Question 3. 4 to 3.6

Table 3.4

	Frequency	Percent*
Lost Invoices or orders	9	23.1
Mistakes on invoices or requisitions	17	43.6
Incorrect Orders to Suppliers	1	2.6
Incorrect supplies to Customers	11	28.2
Stock shortages	33	84.6
Delays in receiving orders, goods or deliveries	22	56.4
No. of participants	39	

Table 3.5

	Frequency	Percent*
Poor quality	17	43.6
Incorrect order or price	16	41.0
Partial Delivery	24	61.5
Missing	1	2.6
No. of participants	39	

Table 3.6

	Frequency	Percent*
Continuous flow	----	----
ISO 9000	23	59.0
Lean	----	----
Six Sigma	----	----
Kanban	----	----
TQM	----	----
Food Certification Marks - Fair Trade	----	----
Freedom Food	----	----
Other	9	23.1
None	13	33.3
No. of participants	39	

In Table 3.4 84.6% of respondents consider stock shortages as the most significant cause of defects/errors, 56.4% consider delays in the receipt of goods to come second, and 43.6% respondents consider mistakes on invoices or requisitions to come third. In Table 3.5, 61.5% of the respondents indicated that they are most concerned with partial delivery. 59% of the firms adopt ISO 9000 as a quality process, but only 23.1% have introduced other quality systems; however, 33.3% do not have any quality certification at all.

5.3.3.1 Summary of Section 3 of the survey findings

Section 3, Quality Assurance, indicates that the majority of the group of respondents experienced the most quality issues in warehousing and transportation. The most significant defects are related to stock shortages and partial deliveries, followed by administrative errors, incorrect orders and requisitions. However, the greatest concern is partial deliveries followed by poor quality. Most inspections are conducted when goods are being received and during warehousing, but respondents reported wasting too much time inspecting goods in these functions. In summary, it is the practices of storage and sorting within the warehouse that result in the most significant problems: product quality and stock availability.

Therefore, unless a specific allocated bin and stock method policy is maintained rigorously to manage storage and sorting in the warehouse, then it is likely that the respondents will find it difficult to achieve good results in their most important performance measures which are, rated in order, customer satisfaction, better quality and lower costs.

5.3.4 Information sharing

Section 4 comprised 11 questions that sought to understand the main considerations regarding the flow of information and how effectively this records the flow of goods (section 2), the performance demands upon the SME, the decisions made and how this supports the productivity of the operational supply chain within the SME. This survey collected data that indicates the growth of information and data on procurement and sales administration and the mechanisms used to handle the quantity and processing of data related to new suppliers, customers in one year, suppliers, and customer orders they process. The survey sought to identify the preferred communication methods for trade and the related use of real time information systems.

This section of the survey provides insight into the dynamic nature of information growth and coordination in the SMEs and the perception of the effectiveness with which their systems support them in managing this. It also gave an indication of the SME respondents' view of where most of the administrative and information related productivity issues occur. The results of the section are detailed in Tables 4.1 – 4.12 in Appendix D

The summary of the key results shows that the size of the firm does not exert an influence on the scale of the growth of data. Table 4.1 indicates that almost half (46.2%) of the firms appoint more than 10 new suppliers in a single year and Table 4.2 indicates that 84.6% of the firms gain more than 10 customers in a year; only 2.6% (1 large firm) acquire less than 5 new customers in a year. In Table 4.3 and Table 4.4 just over half of the respondents' purchasing teams order regularly from more than 20 suppliers, and over 71.8% receive orders from more than 20 customers.

Table 5.8: Section 4 Flow of information in purchasing and sales function (aggregating Tables 4.1 to 4.4)

Table 4.1 New Suppliers in one year

	Frequency	Percent
Less than 5	11	28.2
6- 10	10	25.6
More than 10	18	46.2
Total	39	100.0

Table 4.2 New Customers in one year

	Frequency	Percent
Less than 5	1	2.6
6- 10	5	12.8
More than 10	33	84.6
Total	39	100.0

Table 4.3 Regular Suppliers

	Frequency	Percent
1-10	6	15.4
10 -20	13	33.3
more than 20	20	51.3
Total	39	100.0

Table 4.4 Regular Customers

	Frequency	Percent
Less than 10	1	2.6
11-20	10	25.6
more than 20	28	71.8
Total	39	100.0

Tables 4.5 and 4.6 (see Appendix D) appear to indicate that the growth in suppliers and customers and their related data does not appear to be influenced by the size of the firm nor does it appear to alter the manner in which the firms capture the initial information. In Table 4.5, 69.2% of the firms' customers place their sales orders through the salesperson, followed by 53.8% who place their orders over the phone and 46.2% via email; 35.9% still use a fax machine to place their orders. In Table 4.6, 71.8% of the respondents' purchasing function use email to place their purchase order, while 56.4% use the telephone.

In terms of the application of RTI, Table 4.7 reflects that 92.3% use an electronic real-time system. Only 3 micro firms do not use any real-time information (RTI) system. In Table 4.8 86.1% indicates that RTI is used for sales orders; 77.8% use it for procurement, 55.6% for inventory, and 50% (18 firms) use it in the warehouse. 17 firms (including three micro firms) do not use it at all for inventory and warehousing. Three medium and two small firms do not use it at all for warehousing. 55.6% of firms that use it for inventory also use it for warehousing.

In terms of productivity gains from integrating the RTI systems and sharing the information amongst the supply chain functions, only one small firm integrates their procurement, inventory and warehousing systems. However, further analysis of the respondents' questionnaires indicated that only 25.6% of the firms have real-time systems for **all** their functions, of which 15.4% are small and medium. In Table 4.10, despite their RTI systems, 64.1% share the customer order internally face-to-face, however 28.2% do so by telephone and 41% (16 firms) by email. Thirty-one firms (79.5%) use paper as well.

Table 5.9: Questionnaire: Level of RTI application and perception of effectiveness among SME respondents (Aggregate of Tables 4.9 to 4.10)

Table 4.9

	Frequency	Percent
Not effective	----	----
Partially	14	38.9
Just OK	13	36.1
Very Effective	9	25.0
Total	36	100.0

Table 4.10

	Frequency	Percent*
Face to face	25	64.1
Telephone	11	28.2
Email	16	41.0
Paper	31	79.5
Fax	2	5.1
No. of participants	39	

Table 4.11

	Frequency	Percent*
Delays	29	74.4
Gets Lost	3	7.7
Wrong person	2	5.1
Inaccurate	19	48.7
Not Completed	11	28.2
No. of participants	39	

In terms of perceived effectiveness of their RTI systems, in Table 4.9 there were only 25% (9 firms) where respondents classified their RTI as very effective. A more detailed analysis of the individual responses indicated that of the nine firms, four (two medium, one small and one micro) use the system for sales orders only, do not use paper and only share information via email. However, two large firms still also use paper and email together. One of these is a medium firm that considers their RTI to be effective but does not use RTI for sales orders and shares sales information only by paper and face-to-face. One medium and one small firm both use RTI for sales orders but do not use email; the small firm uses only paper and the medium uses paper and the telephone. In Table 4.11 74.4% experience delays in sharing information, with 48.7% receiving inaccurate information; 28.2% find that actions are not completed, 7.7% (three firms) find that orders get lost and two firms (one micro) note that they often go to the wrong person.

The results from the final two questions address the main issues with information flow and sharing or coordinating the information between functions and departments. Despite high usage of RTI systems the respondents are not gaining the full benefits because the systems are not integrated across the functions. So the benefits gained through automated processing and storage are, by a significant measure, lost because the way that information is being shared results in significant breakdowns of information flow with delays, inaccuracies and misallocation or loss of data.

The respondents in Table 4.12 (Appendix D) rate the order of the functions that firms experience the most issues with regarding information sharing as follows: inventory, sales and distribution. 75% (27 firms) rated inventory as the function that gives them the most information-sharing issues; however, two firms (8.4%) indicated only minimal issues with inventory, and one firm had no issues. Second, 71.1% rated sales as the most important issue; two large firms that indicated this is the only issue they have. 15.8% indicated they have no or minimal issues with sales. Third, 61.1% rated distribution as their most important issue. 42.9% indicated warehouse and procurement as the functions with which they have the most issues. Finally, 15.4% firms reported having minimal issues.

5.3.4.1 Summary of Section 4 of the survey findings

The results of Section 4 indicates that the use of a real-time system is not sufficient to ensure that effective productivity and performance is sustained within the operations. The results show that, whilst the majority of firms use real-time systems for sales orders and procurement, only 55.6% use IT for inventory, and 50% use it in the warehouse. Three-quarters of the respondents experience delays in sharing information between departments because 64.1% share the customer order internally face-to-face and 28.2% by phone. It appears that the limited integration of a real-time system increases the likelihood of errors, waste, and issues with quality and cost for all firms, particularly SMEs, results in more isolated silos of data across the organisation, and reduces the ability to manage limited resources of space and skills. It also increases the frequency of decisions which must be made and increases the likelihood of incorrect decisions or delayed decision making.

The firms introduce a significant number of suppliers and customers and manage a relatively large and complex number of stock items. The lack of RTI integration between the purchasing and sales function and inventory and warehousing limits the capability of the firm to share, manage and maintain information control stock management policies between sales, inventory and purchasing and to enable the warehouse to manage the flow of goods and resources. 17 out of 39 firms (8 SMEs – two micro, three small and three medium firms) experience significant difficulties in managing expiry dates, a stock policy and a standardised warehouse with specific stock bins. The lack of RTI further increases the issues that 80% of the small and micro firms have with constrained warehouse resources (Table 5.5) and with managing the space and storage of goods, which leads to the disposal of unsold products; this appears to happen frequently, in some cases on a regular basis..

Information sharing appears to be inadequate for the needs of the firms, which indicates that there is in fact limited benefit due to the use RTI in managing the flow of information effectively across the functions in order to protect the accuracy and integrity of the data, ensure prompt and accurate sharing of information, and promote a timely response.

5.3.5 Managing performance indicators

The final section, Section 5, of the survey collected data from two questions to establish how the respondents measure performance in their operations and what they consider the most important benefits that they seek to obtain through the management of their operations. The responses are presented individually in order as follows.

The first question of Section 5 asked respondents to rank in order of importance a set of given performance indicators that included costs, training, delivery times, quality, and customer satisfaction. The results are presented in Tables 5.10

Table 5.10: Questionnaire Section 5 - Order of important performance indicators

Statement		**Not Important------Most Important**					**Mean**	**Std. Deviation**	**Rank**
Lower cost	Freq.	27	6	4	1	1	4.46	0.97	3
	%	69.2	15.4	10.3	2.6	2.6			
Training staff	Freq.	9	10	12	3	3	3.51	1.19	5
	%	24.3	27.0	32.4	8.1	8.1			
Quicker delivery times	Freq.	18	15	2	2		4.32	0.82	4
	%	48.6	40.5	5.4	5.4				
Better quality	Freq.	28	8	1	1		4.66	0.67	2
	%	73.7	21.1	2.6	2.6				
Customer satisfaction	Freq.	29	8	1	1		4.67	0.66	1
	%	74.4	20.5	2.6	2.6				
Mean for total							**4.34**		

The results in Table 5.10 list the most important performance measures in the opinions of the 37 firms as customer satisfaction; only 2 firms consider this unimportant. In second place, 36 firms consider better quality the most important measure; only 2 firms think this is not important. In third place, 33 firms rated both lower costs and quicker delivery times as most important. Finally, 19 firms consider training to be the most important measure of performance. The second question of Section 5 asked the respondent to rate in order of importance a set of perceived benefits that they seek to obtain that related to profitability, reduced waste, improved workflow, quality attitude, increased flexibility, reduced customer complaints, improved productivity, reduced inventory, and improved quality.

Table 5.11: Questionnaire Section 5 : Order of importance of perceived benefits

Statement		Not Important------Most Important					Mean	Std. Deviation	Rank
Increased profitability	Freq.	30	7	2			4.72	0.56	2
	%	76.9	17.9	5.1					
Increased flexibility	Freq.	8	16	8	4	2	3.63	1.10	11
	%	21.1	42.1	21.1	10.5	5.3			
Reduced waste	Freq.	19	15	4			4.39	0.68	3
	%	50.0	39.5	10.5					
Quality attitude	Freq.	13	13	11	1		4.00	0.87	8
	%	34.2	34.2	28.9	2.6				
Improved workflow	Freq.	10	14	9	3	2	3.71	1.11	10
	%	26.3	36.8	23.7	7.9	5.3			
Reduced customer complaints	Freq.	17	17	4	1		4.28	0.76	6
	%	43.6	43.6	10.3	2.6				
Reduced inventory	Freq.	18	14	7			4.28	0.76	6
	%	46.2	35.9	17.9					
Improved delivery times	Freq.	21	10	7			4.37	0.79	4
	%	55.3	26.3	18.4					
Improved productivity / efficiency	Freq.	17	17	4			4.34	0.67	5
	%	44.7	44.7	10.5					

Statement		Not Important------Most Important					Mean	Std. Deviation	Rank
Improved communication	Freq.	11	17	6	4		3.92	0.94	9
	%	28.9	44.7	15.8	10.5				
Improved product quality	Freq.	32	6	1			4.79	0.47	1
	%	82.1	15.4	2.6					
Mean for total							**4.23**		

Table 5.11 shows respondents' prioritisation of the benefits from most important to unimportant, indicating that many firms were not able to distinguish a hierarchy of benefits. Instead they placed four or five items in the position of either most important or very important. Table 5.11 indicates that 39 firms rated improved product quality as most important. Second is increased profitability. In third place is reduced waste, fourth is improved delivery times and fifth is improved productivity and efficiency. Reducing inventory and reducing customer complaints were rated as sixth and seventh; quality attitude was eighth. Improved communication was ninth and improved workflow completes the Top 10 list. Four large firms identified that all the benefits listed are very important, indicating the complex interdependencies that exists in the SC operations. Two small, one micro and two medium firms listed all the benefits as equally important.

5.3.5.1 Summary of the findings from Section 5 of the survey

Summing up, the results in Section 5, Managing Performance Indicators, show that customer satisfaction, better quality and lower costs accompanied by quicker delivery times are the most important performance measures for all the firms. The size of the firm does not appear to be an influencing factor. Whilst all the firms appear to be managing their operations to achieve a complex mix of benefits simultaneously, compared to large firms, small and micro firms predominately agreed that flexibility, workflow and communication are not as important.

Therefore, the critical factors that exert the most influence on the continuity of the flow of goods within an SME organisation are stock availability and lower cost. These are both linked to improved product quality. Furthermore, the variables that exert a significant influence on the three critical factors of quality, cost and time have a direct effect on the flow of goods and the flow of information. In the flow of goods, the process of the initiation and handover between respective functions requires a standardised and consistent interconnected process within all the functions; if the process within one or more of the functions is compromised, then this will have a domino effect throughout the entire SC performance.

5.4 Overview of the Survey Findings

The results of the survey indicate that the majority of respondents from the SMEs have not adopted the best practice for stock management and consequently face significant barriers/obstacles or limitations related to their operational functions that directly influence the flow of goods in the SC of all the firms, irrespective of their size.

The most significant limitations are the lack of standardisation in their operational procedures, the lack of specifically labelled bins and specific stock allocation, and the inadequate use of a stock method policy. All of these are sorting approaches relating to managing space and skills, both of which are constrained. The effects are experienced as over-stocking and over-utilisation of storage facilities that impinge upon and hinder the flow of goods within the warehouse.

The high levels of stock put further pressure on goods receiving and warehouse operations to carry out more quality assurance examinations, however respondents consider it a waste to spend a lot of time inspecting in goods receiving and warehousing. The overall result is higher costs due to the high levels of waste, errors, delays, and defective and damaged goods, which directly compromises all the performance measures. The introduction of the 5S and 7W techniques of LSS would support the firms in overcoming many of these issues.

The survey has established that, because the firms stock large quantities of a wide-ranging scope of products, managing movement and storage becomes more complex, and contributes to the prevalence of variations in product quality, especially as there is poor communication and a lack of interconnectivity between departments. The introduction of a significant number of new suppliers and customers annually places a high level of demand on the use of RTI systems to capture, track, record and monitor. Whilst the majority use their systems for independent functions, purchasing, sales, etc., the majority do not have an integrated system that allows the information to flow through the organisation in a timely fashion, ensuring the right functions and departments know sufficiently well in advance of the expectations for their services. As such, 56.4% indicate that they experience delays in the receipt of goods; this has a direct impact on stock availability, and therefore results in partial deliveries.

Furthermore, the results indicate that forecasting demand management is one of the most significant obstacles, one which is aggravated by the need to satisfy all the seasonal variations required for the events within the Arabic and civil calendars. The underlying source of these errors can be attributed to the manually intensive approach which has been adopted in the order to fulfilment management process, which increases time delays and manual errors at the start of the flow of goods stream. The sharing of customer orders internally and manually explains why such high levels of inaccurate information are transferred between departments and contributes to actions not being completed so that orders and invoices get lost between departments. Therefore, SMEs need to adopt real-time systems that integrate all the functions.

In the light of the existing operational practices and the way they contribute to influencing the obstacles, it is easy to see why these obstacles in the functions that drive the flow of goods and the flow of information in SMEs can severely compromise operations. The next consideration is how to improve these practices.

5.5 Recommendations

It has become evident from the analysis that an SME in food distribution operates a standard SC process in a predominantly manual environment. There is evidence of a lack of sufficient resources and of quality issues related to the way goods are stored, tracked and moved through the warehouse which results in high levels of defects, unsold goods disposal, and stock shortages. Furthermore, there is evidence that respondents experience loss of information, delays and errors because the information systems in place are not integrated within all functions and or do not interconnect. The SMEs in this sample are not taking advantage of many modern operating practices and quality initiatives, for example LSS and emergent RTI systems, that could effectively support their inherent growing dynamic complexity and manage their costs.

If the SMEs introduced mechanisms such as the Kanban inventory system, quality assurance and 5S and 7Waste techniques within the Six Sigma approach, this would overcome many of the constraints due to limited warehouse space and skill shortages and substantially improve the maintenance of product quality and stock availability. The demonstrated improvements are detailed in the Recommended Framework (Section 5.5.1) that follows. Introducing a set of standards that direct the optimal use of space and the allocation of available skills by effectively organising the warehouse into areas for specific stock and allocating the skills to specified areas and tasks with set standards of how to complete the tasks; furthermore, leveraging the benefits of a real-time MAS, would improve collaboration and coordination between functions in a seamless way that would provide clear timely instructions and prompt the relevant required action by the appropriate personnel, allowing them to manage and maintain the feed-forward and feedback flow of demand and supply within the enterprise. Therefore, key resources could more effectively forecast seasonal variations in demand and manage the dynamic changes introduced with new suppliers, new customers and associated shipping delays.

The emergence of alternate technologies such as an MAS provides a solution that can promote the implementation and compliance with LSS practices and facilitate collaboration and intelligent decision-making in a complex dynamic distributed environment, to address the typical obstacles experienced by SMEs at a lower cost.

5.5.1 Recommended Framework

The initial conceptual framework proposes four layers of intervention in the supply chain of an SME's operational practices. These interventions correspond to the recommendations made in this study; it is contended that these will contribute to overcoming the challenges faced by SMEs and provide a basis for continuous improvement in the effectiveness and efficiency of their supply chain as well as reducing costs and time delays.

The empirical case study provided an opportunity to test in principle the relevance of the integration of LSS and MAS when addressing the major issue 'late delivery times'. The findings of the survey of SMEs provide an opportunity to 'litmus test' the conceptual model by assessing the practical necessity and value-adding contribution of the integration of LSS and MAS into the operational practices of SMEs to achieve significant improvements in the three critical factors, quality, time and cost, and therefore in customer satisfaction.

5.5.2 Proposed conceptual framework

The conceptual framework is underpinned by the three critical factors which were confirmed by the literature review and the survey in Table 1.15 to be integral to the operation of an effective supply chain; these are quality, time and cost.

Figure 5.1: Critical factors of the value stream in food distribution

The conceptual framework's stages are arranged in two phases as follows:

5.5.2.1 Phase 1

Stage 1: The Six Sigma DMAIC process is applied in order to understand and identify all problem areas within the complete value stream that need to be improved. The framework proposes that the first intervention should be to adopt on an ongoing basis the Six Sigma DMAIC approach for problem solving within the entire SME supply chain to address these issues and then to resolve issues regarding the quality, time and cost factors and optimise them.

Stage 2: Value stream mapping is used to assess which variables in the flow of goods (Section 2) and information flow paths (Section 4) have the most significant influence on the quality, cost and time factors.

Stage 3: The model proposes that the next intervention should be to adopt the LSS techniques to resolve or mitigate the influencing variables in the goods flow path to overcome the issues identified in Section 2 and Section 3.

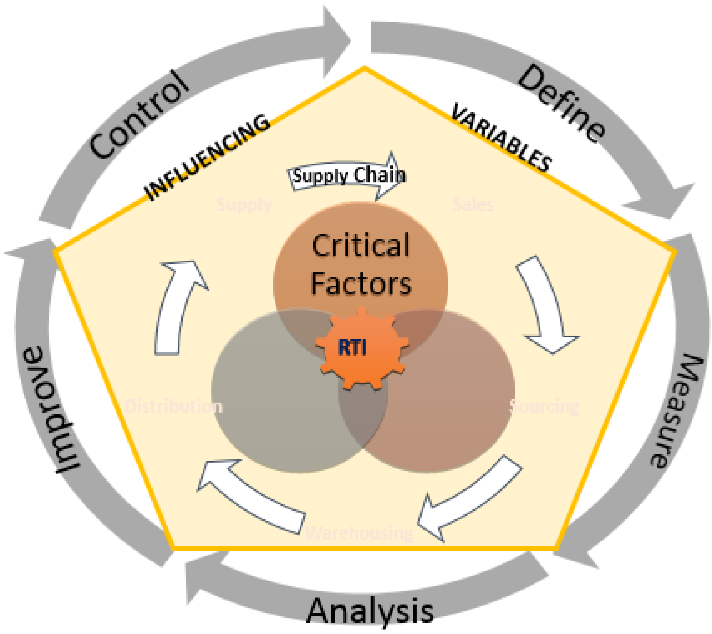


Figure 5.2: Using the DMAIC process to identify the influencing variable that impact on the supply chain critical factors

These variables are a result of the main issues and obstacles experienced by SMEs day to day and were identified as the main limiting factors which limit their operational effectiveness; they are presented in Fig 5.3.

Figure 5.3: The main issues (influencing variables) and obstacles that limit the operational effectiveness of SME supply chains

Stage 4: In site tests, Lean methods and techniques are used in the goods flow path to minimise the influencing variables identified in Section 1, 2 and 3. This study proposes the adoption of the following Lean techniques that support the quality assurance focus and overcome the issues the SMEs indicated to be significant in Section 2 and 3. Value stream mapping to the supply chain is carried out to promote increased integration of the value stream processes and optimise the alignment of the supply chain tasks and activities involved in sourcing, storage, sales, distribution and supply to the end customer. 5S (Sort, Set, Safe, Skill and Standardise) is adopted to optimise the warehouse environment and avoid issues with overstocking and damaged goods; Kanban and a stock management policy is used to prevent overstocking and expiry of products and to integrate quality checks regularly at goods receiving, despatch and at the delivery or the customer site.

The results of the effective adoption of these techniques will reduce many of the costs and time lost associated with the 7 physical Wastes, for example duplicate activities, stock defects, overstocking, waiting for stock to arrive, and avoiding unnecessary transportation. However, one of the main barriers that SMEs face is that they do not have sufficient time to communicate (Section 1 and Section 4) and supervise these requirements in house, nor do they have the skills and resources to either introduce or train their human resources or maintain the complex decision-making that such an integrated alignment of methods and techniques requires. Therefore, the SMEs cannot justify the additional expense and time this would entail.

The second phase of the final model proposes to addresses this critical stumbling block with the proposed introduction of an integrated RTI system (Section 5) based on MAS that can integrate all of these intervention and provide the additional "skilled" resources needed for supervision, communication and decision-making.

Figure 5.4: The integration of Phase 1) LSS and Phase 2) RTI into the framework

5.5.2.2 Phase 2 – Introduce RTI

Stage 5: Design and test the application with an integrated RTI using MAS to address the influencing variables in the information flow path and support the SME as it introduces and maintains compliance with the recommended LSS processes proposed in Phase 1.

The application of the LSS conceptual model proposed thus far is inhibited at this stage because the SMEs lack the resources, capability and money to sink into investment in these and similar quality-related best practice techniques as confirmed by the survey. The final stage of the conceptual model proposed is to overcome this limitation due to the main constraint which is related to the lack of skilled resources and time which hinders the connectivity and coordination required for the SMEs to adopt best practices with all of the associated issues.

The recommendation is to add the capability of intelligent agents from MAS-enabled applications to manage the complexity and decision-making of the proposed conceptual model. These agents can enhance the skills and the resource capability within the SMEs and facilitate the coordination and connectivity needed.

Figure 5.5: MAS integrated in LSS conceptual framework - final framework

The process design of an MAS-enabled application will facilitate the multifaceted integration of LSS features, quality, process, cost and time, as well as the influential variables related to space and stock management, using Kanban, 5S and 7W techniques within all the functions, from sales to warehouse, to manage the flow of goods and information simultaneously.

The use of instruction-based autonomous intelligent agents can address firms' limiting factors in relation to space, stock, and capacity and skills capability; it is appropriate to take into account the scale of the facilities as well as spatial considerations to maintain a design-sorted environment with unique, labelled location bins to hold the required economic mix of inventory, and to reference the expiry dates. These agents use instruction-based processes and decision-making priorities, which are essential for directing the picking and packing of the stock and which therefore increase the capacity and capability of the workers. This also supports the consistent implementation of a stock method policy and reduces quality deterioration due to poor sorting, stacking and goods expiring.

Agent technology automated notifications would constantly encourage adherence to set standardised processes and tasks that control the location and movement of stock from goods receiving to warehouse stores and then to goods dispatch and therefore overcome limitations in available skills. The use of mandatory system checklists for inspectors, pickers, packers, drivers and cleaners introduces quality assurance and control, as required information about the conditions and state of the store, stock, expiry dates or tools is shared per key transaction, which prompts escalation notifications that alert management to problems as an early warning system in relation to quality or related issues. Simultaneously, the system can escalate non-conformance, variations and time-related information to multiple departments and functions, such as the need for stock replenishment when minimum set stock levels are reached, having taken into account the safety stock levels. Additionally, the introduction of new customer orders can prompt the system to anticipate the effect on stock levels and propose new replenishment stock levels for approval. The system can instantly recognise and notify the warehouse when customer orders exceed in-house stock levels and simultaneously prompt an order replenishment notice that considers what goods may still be in transit from a previous order or a shipment. This would significantly reduce excessive overstocking, the unnecessary movement of goods between depots and warehouses and the use of general holding areas.

At each stage of the process and on a periodic basis, the agent can independently make decisions, and, after analysing trends and patterns collectively or independently, inform managers and workers of goods received delays, new stock unit additions, and stock mix changes, which, when combined with the exception notification function, can escalate management's attention and decision-making in a timely fashion. Therefore, with prompt and timely action, the ongoing state of the environment, stock mix and levels, as well as the condition of the goods can be maintained at an appropriate standard. Furthermore, autonomous agents have the ability to dynamically integrate multiple dimensions of information and constraints into the transport function. This would instruct the packing and loading order of goods into specified delivery vehicles best suited for the type of goods or size of the load, whilst also indicating a preferred delivery route. This would reduce the likelihood of the deterioration of stock quality during the transportation and unpacking of goods at subsequent sites, including with the end customer.

The above proposal would enable an organisation to monitor and identify suppliers that continuously provide goods that do not meet the desired quality standards, such as those that are consistently returned by customers and/or are frequently disposed of. Eliminating such suppliers at an early stage would reduce level of consequences in relation to inferior quality and resulting costs to the business and improve customer satisfaction. Furthermore, customers who consistently place extraordinary demands in relation to quantities needed, place orders at short notice,, or return goods can also be identified early and through positive sales engagement, can be managed effectively without compromising stock availability, scheduling urgent orders at higher costs, or loss of revenue due to non-payment. The SMEs' final issue is forecasting demand with seasonal variations. Using MAS intelligence, trends and patterns in purchases, disposals and sales over specified periods can be analysed more scientifically to calculate continuous variations in levels of stock. Stock can be flagged for attention in advance to prompt further intervention to take advantage of bulk price seasonal deals, or, at the end of seasons, to adjust levels, which will avoid quality deterioration and disposal of goods when warehouses are overstocked.

5.6 Summary

The proposed final framework demonstrates how the state of the critical factors reported by the respondents (quality, stock availability and lower cost) can be improved by better managing the influencing variables, space, skill and storage, by creating a more standardised and interconnected environment facilitated by an autonomous intelligent system. Effective stocking and storage will significantly reduce defects in, damage to, and disposal of unsold stock. It will reduce wasted inspection time, and overstocked warehouses and more optimally leverage the available resources and personnel. The introduction of an intelligent real-time system can help firms to collaborate and coordinate functions and reduce waste and, with a complex decision-making capability, promote a more standardised SC feed-forward and feedback loop in a timely fashion. The management resources need to focus on exceptions and escalations instead of the detailed daily transactional processes, and delegate a more detailed emphasis on quality into the system. The proposed framework which integrates Lean principles can enable firms to improve their operational efficiency.

This framework which has been developed using an MAS will then be tested as a demonstrate to assess the effect of contributing this type of additional capacity and to assess the extent of the benefits and the extent it helps to overcome constraints due to limited personnel and support staff with lower skills levels. The model will undergo a simulation to demonstrate the presentation of the proposed required information in connection with best practices and to determine whether the greater emphasis on quality assurance and support can enable the SMEs to achieve high levels of customer satisfaction and reduced costs, and therefore compete more effectively, both locally and globally.

6. DEVELOPMENT OF THE LEAN MULTI-AGENT SYSTEM

6.1 Introduction

The LMAS conceptual model framework proposed in Chapter 5 is intended to improve the operating practices of SMEs and help them to both overcome limitations in resources and to address issues with quality, followed by issues with stock availability, and thus lower the costs that result from high levels of waste, errors, delays, and defective and damaged goods, as identified by 39 SMEs in the food distribution industry. The results of the survey showed that small and large firms all operate the same value stream, from initiation of the process with the salesperson, procurement, goods receiving, warehouse, goods dispatch and transport to the end customer. They measure the same critical factors of performance in their SC operations and share the same opinion on what they consider the most significant obstacles. This chapter explains the development of a conceptual framework as an application to demonstrate LMAS as an operating platform and test the recommendations to address the critical issues associated with quality, time and cost that have been determined to hinder the operational effectiveness of SMEs. This conceptual model proposes to design and integrate key principles from Lean, Kanban, 5S and 7 Wastes with quality assurance and to develop these into a MAS within the value stream flow of goods and information, to promote and maintain quality assurance.

6.2 Conceptual Lean Multi-Agent System Model

This study proposes applying the conceptual model in MAS. The design proposes reproducing the full value stream and SC processes required to manage the flow of goods and information, from customer order to delivery and fulfilment, within the set functions of sales, procurement, inventory, warehouse, dispatch, goods receiving and delivery, incorporating Lean techniques.

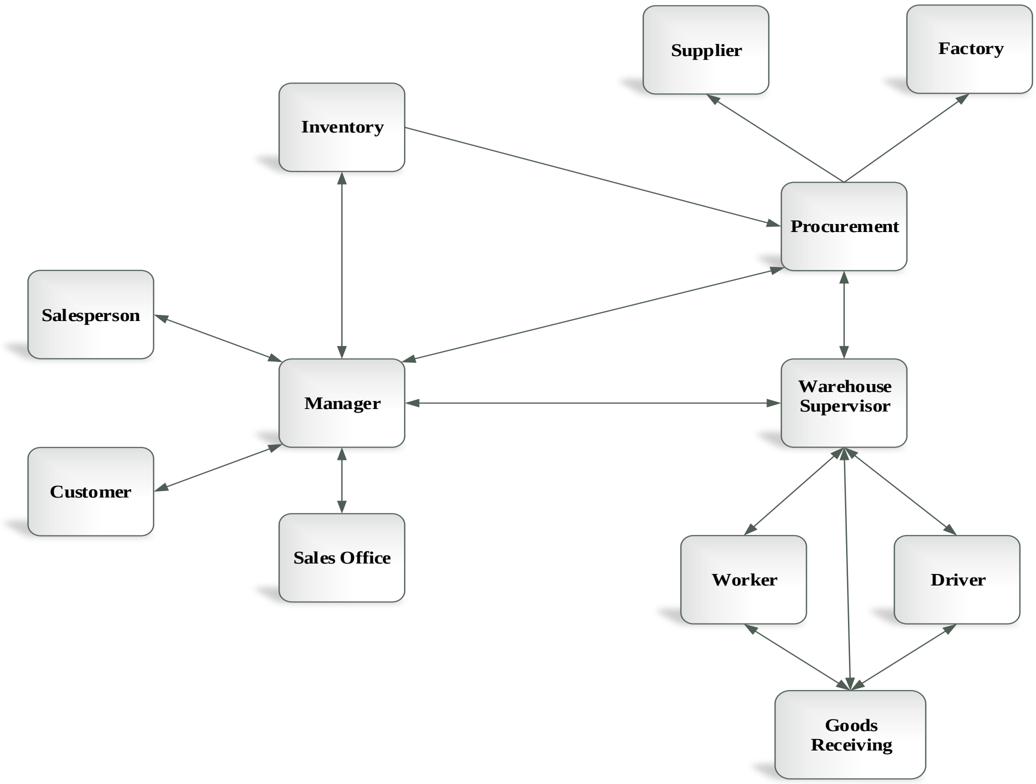


Figure 6.1: Depicts the flow and connectivity between the functions of the SME supply chain

A key advantage of MAS is that the agent is delegated responsibility for physical participants (roles) within the business process. The complex distributed environment, even within the SC of SMEs, consists of multiple internal and external players, even when considering one organisation. In this system, agent behaviours can be modelled to represent the coordination and complex interplay of the functional players. At the same time, it is possible to introduce the expected standards, sequencing and priority of goods flow. Furthermore, the agent can map the physical flow whilst also providing a messaging and information trail through asynchronous communication.

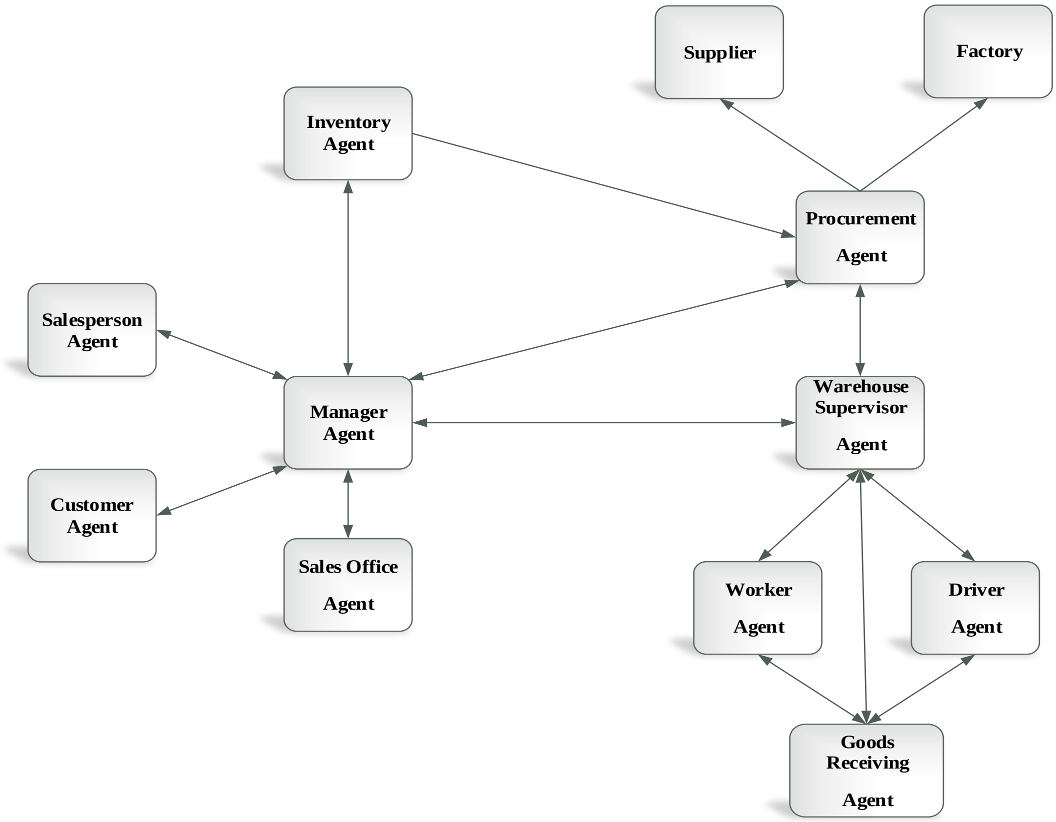


Figure 6.2: Intelligent agents map the physical functions flow and decision points in the SME SC

The intelligent agents in MAS are enabled to autonomously prioritise tasks and activities through prioritised and integrated sequences of business rules and procedures that help the system to problem solve within the system as described in the reengineered processes of Appendix F. In MAS, these agents are able to cooperate and compete, just as would be the case in real-world operations. Multiple agents with these capabilities can therefore promote flexibility in the system and provide essential information visibility.

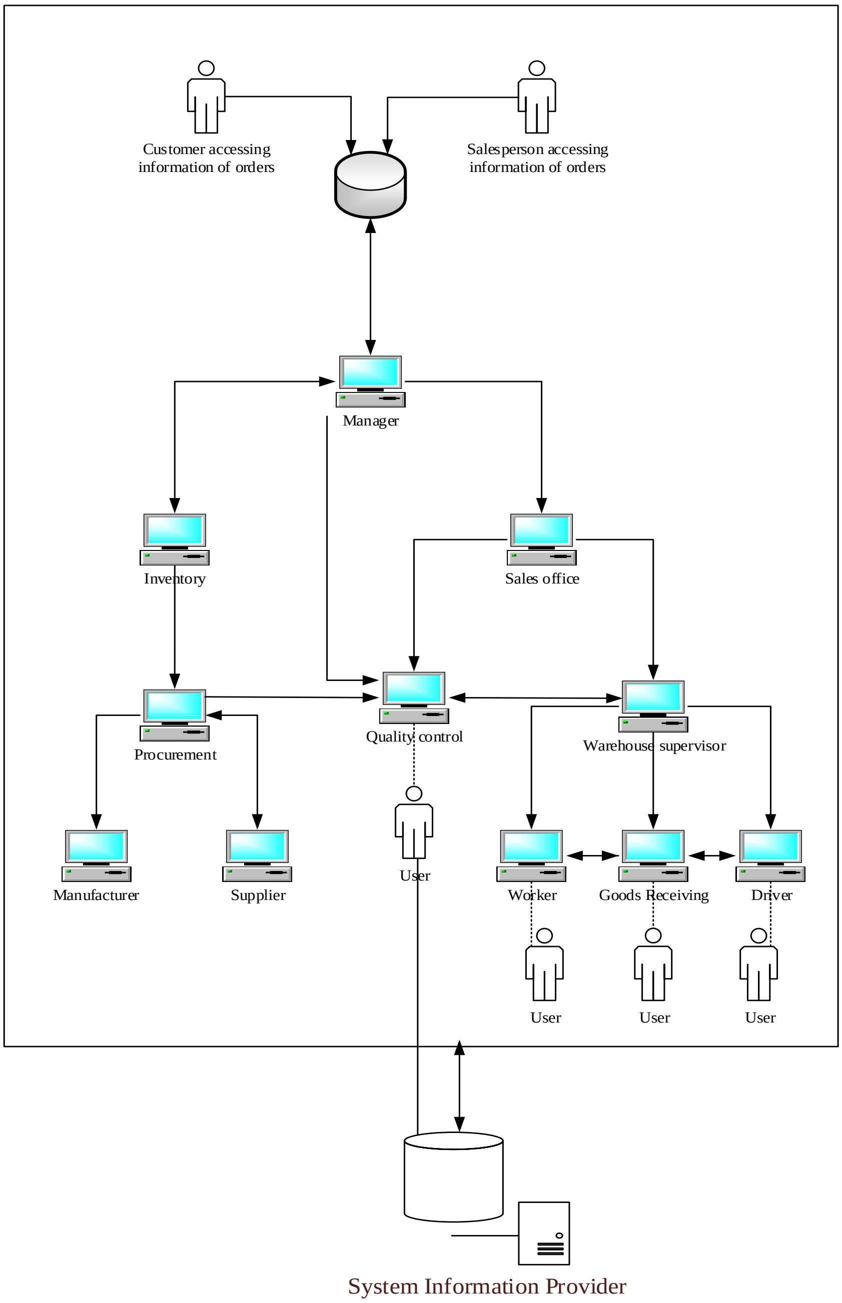


Figure 6.3: Indicates the communication and connectivity integration of the users, intelligent agents and the control centre and system information provider

This section indicates how the proposed programming of the Lean techniques of 5S using Kanban and 7 Wastes as business rules and procedures within MAS can provides the enhanced quality assurance system needed to overcome the quality issues identified in the survey. The application of these proposed Lean rules and procedures is summarised in Fig 6.4 below.

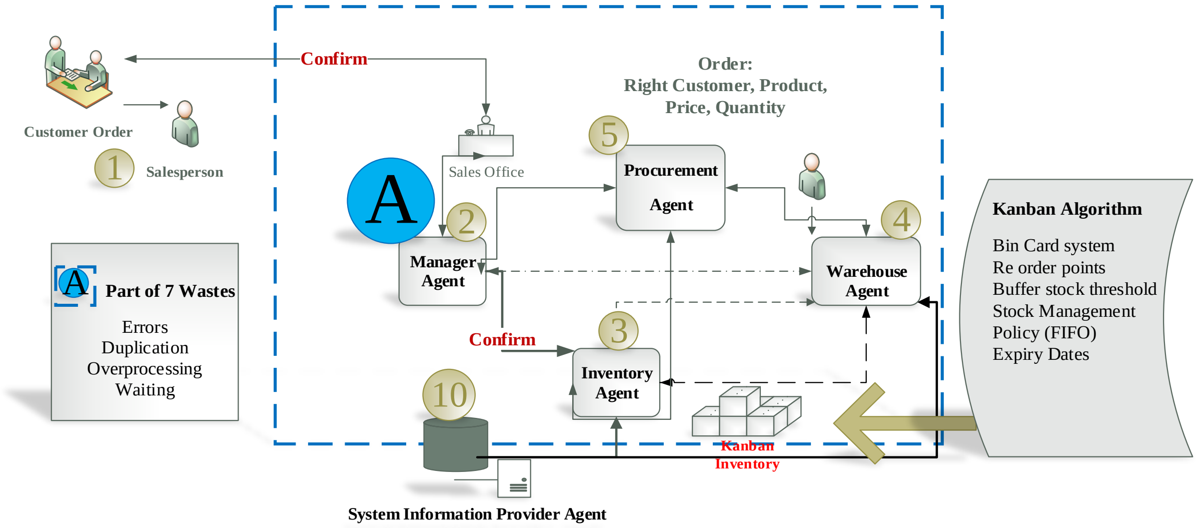


Figure 6.4: Part 1 – Indicates the integration of 7W and Kanban-related rules in agents' responsibilities from the order to inventory part of supply chain.

In Fig 6.4, Part 1 of the supply chain, from orders (customer and suppliers) to inventory, indicates the role of the intelligent agents as proxy representatives. These representative agents administer and coordinate the information received and stored as dictated by the procedures and business rules programmed into the application and stored in the Information Systems Provider (10). The Manager Agent (2) coordinates and supervises the order of communication and instructions between all the agents, based on the sequence of rules. It connects the shared information between all the individual agents so that they can perform the processing, communication and computations necessary to instruct the warehouse to fulfil the delivery. The scope of Part 1, referenced as A, proposes this integration to overcome the administrative wastes of the 7W approach.

In this figure the Sales Agent (1) places an order with the Inventory Agent (3) who checks availability. The Inventory Agent manages stock levels using the Kanban Algorithm and will initiate a query to order supplies from the Procurement Agent (5) if necessary, before the Warehouse Agent (4) is instructed to fulfil the order or receive new stock. The automated autonomous processing, computation and decision-making of the Intelligent Agents facilitate an increase in capacity and capability. The virtual agents become expert resources that consistently and repeatedly adopt a standardised approach that promotes and maintains the sustainability of the integrated Lean techniques in the SME.

The inclusion of the Kanban Cycle as depicted in Fig 2.10 within the MAS, as indicated by Fig 6.4 above, introduces best practices for efficient and effective stock management. MAS represents the physical stores area and movement of goods as a virtual representation controlled by an Inventory Agent. It augments the JIT approach by controlling the direction and flow of goods between the departmental functions using set visual cues and message triggers to escalate action. It includes visual bin codes allocated to each stock item.

The Kanban system introduces a standard approach to all stock inventory and is the method chosen to manage the allocation of stock to specific warehouse bins. The algorithm computes the reorder point, the stock buffer and the FIFO stock movement policy which should be adopted to control expiry dates. The computations also include the maximum threshold capacity of bins and packing areas to prevent packing that exceeds the desirable storage.

This method makes it possible to conduct quality compliance checks and direct the stack and store policies such as FIFO which are needed to manage expiry dates. It can also manage the thresholds between maximum and minimum stock levels that trigger the reorder process only when required. The reorder point takes into account the average lead time for orders to be received and includes variation.

Part 2 (see Figure 6.5) which is referenced as B, covers the scope of the supply chain from warehouse to delivery; it proposes the integration of the 5S techniques of Lean. These techniques are programmed as business rules for each of the agents, Picker (6), Packer (7), Driver (8) and Goods Receiving (9), within the warehouse helps to protect and promote effective and optimal management of the scarce resources and assets. Adopting an adapted form of 5S (‘Sort, Set, Safe, Skill and Standardise’) as a sequence of checks requiring confirmation by each agent can sustain a quality focus which is managed during the picking and packing process and supervised at the warehouse level by these respective warehouse agents (4).

The MAS system is therefore configured with a set of Lean-related instructions (business procedural and system rules) such as confirmation checks, notifications and escalations of variations within set thresholds or specifications to encourage compliance by the staff in their daily activities which will maintain the workplace.

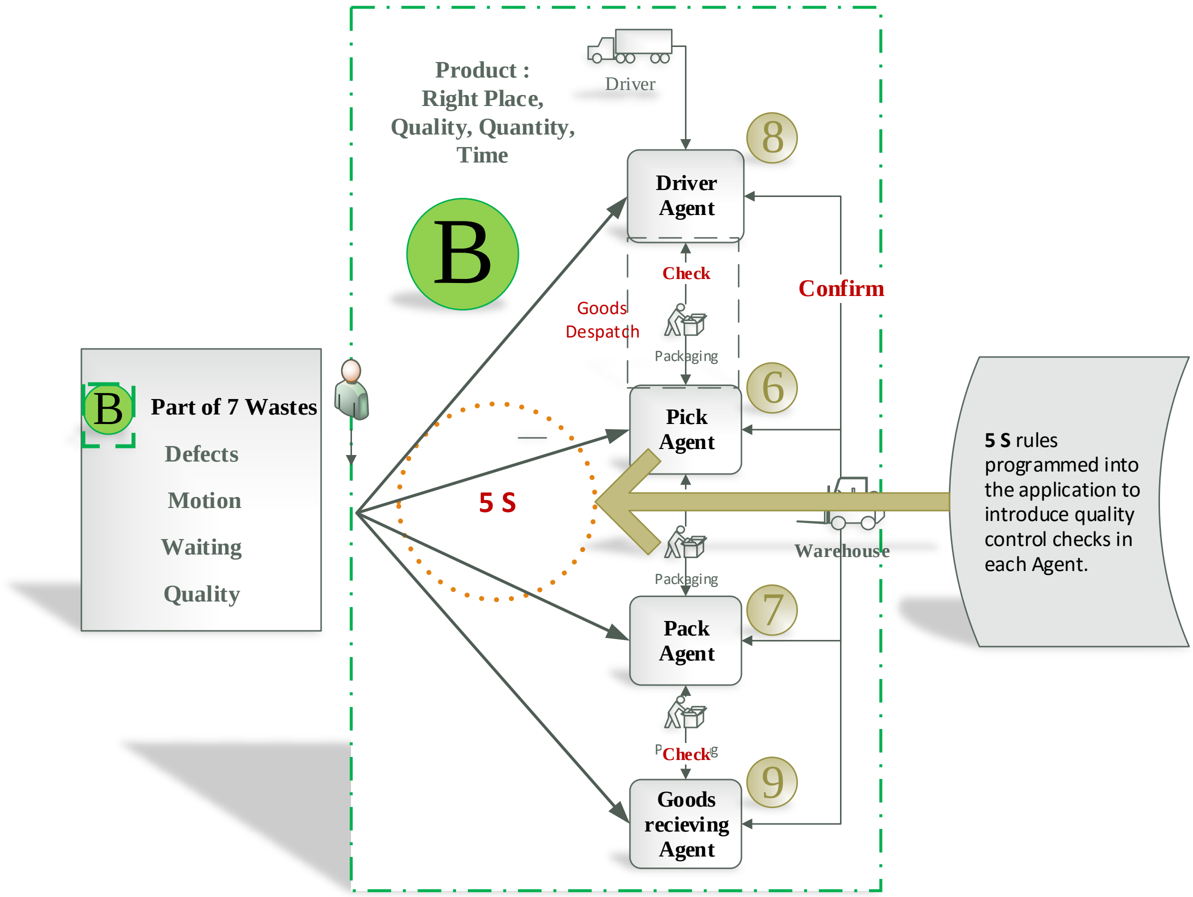


Figure 6.5: Part 2 – Indicates the integration of the rest of 7W- / 5S-related rules into the application of the agents' responsibilities from inventory to delivery part of supply chain

Instructions and confirmations will introduce a level of knowledge to the workers that enhances their skills, while the notifications and escalations improve communication within the workplace as a whole and ensure that motion within the supply chain is optimised. Furthermore, compliance and confirmation will promote safe work habits within defined parameters and conditions; these include instructions on what tools are required, and packing and loading instructions, etc. The agents therefore initiate the concept of doing it right the first time throughout the process and this increases the number of quality control inspections and therefore reduces the likelihood of defects. This enhanced quality assurance system improves productivity and reduces avoidable waiting times due to delays and downtime. The agents check confirmations, manage standards, and increase staff skills in each of the respective flow areas to ensure consistent ongoing application across the warehouses and depots.

In summary, Part 1 and Part 2 presents the conceptual model using intelligent agent behaviour programmed with Kanban and 5S-embedded techniques that can address the first four of the 7

Wastes: defects, errors in processing of orders due to inventory, waiting times, and overstocking and production, as well as optimising motion in the flow of goods, people and information. The quality assurance checks at the goods reception, goods dispatch and driver agents stages also reduce unnecessary motion and waiting times in transportation and reduce associated costs by ensuring that correct stock is available and only the expected quantity of goods is transported. The warehouse supervisor monitors overall quality assurance through system escalations. Therefore, it is suggested that the inclusion of automated Lean techniques in a supply chain designed within the MAS model will enable the SME to operate a systemised workplace and maintain a higher level of productivity and flexibility.

The researcher next proposes the development of the LMASs according to the requirements indicated above and configures this model using a JADE site, adopting the TILAB software development life cycle approach proposed by Nikraz et al. (2006). This methodology consists of four phases in the software development lifecycle: planning, analysis, design, and implementation.

6.3 Planning

In order to meet the specific needs of the SME, detailed planning is required as an essential step in properly modelling and simulating the system. The relationships between customers, salespersons, sales, inventory and warehouse needed to be thoroughly mapped (See Figure 6.1). The mapping of the coordination of relationships between the functions and key roles needs to be configured as a set of processes and detailed procedures. These procedures include the best practice approaches indicated in the conceptual model. The researcher designed and mapped a set of processes and procedures as the functional specification from which the rules in LMAS can be configured; these are presented in Appendix F, while Figure 6.6 represents the outline of the engineering process.

The initial design and coordination protocols were developed from the case study findings and analysis. In this study, the decision was made to set up the application for analysis in JADE using Java programming, based on the recommendation of TILAB, as indicated in Chapter 2. The JADE system consists of ten distinct agents as shown in Figure 6.6 which represent the proposed overall system structure. These agents will exist in different locations and are thus programmed in different containers. For this simulation only, the system will be simulated on one computer and all the agents located in the same platforms. If the system is applied in a real-world application, all the agents must be modelled in different platforms to simulate the actual situation. Agents communicate among themselves by sending each other JADE messages in an ACL language which includes Java objects.

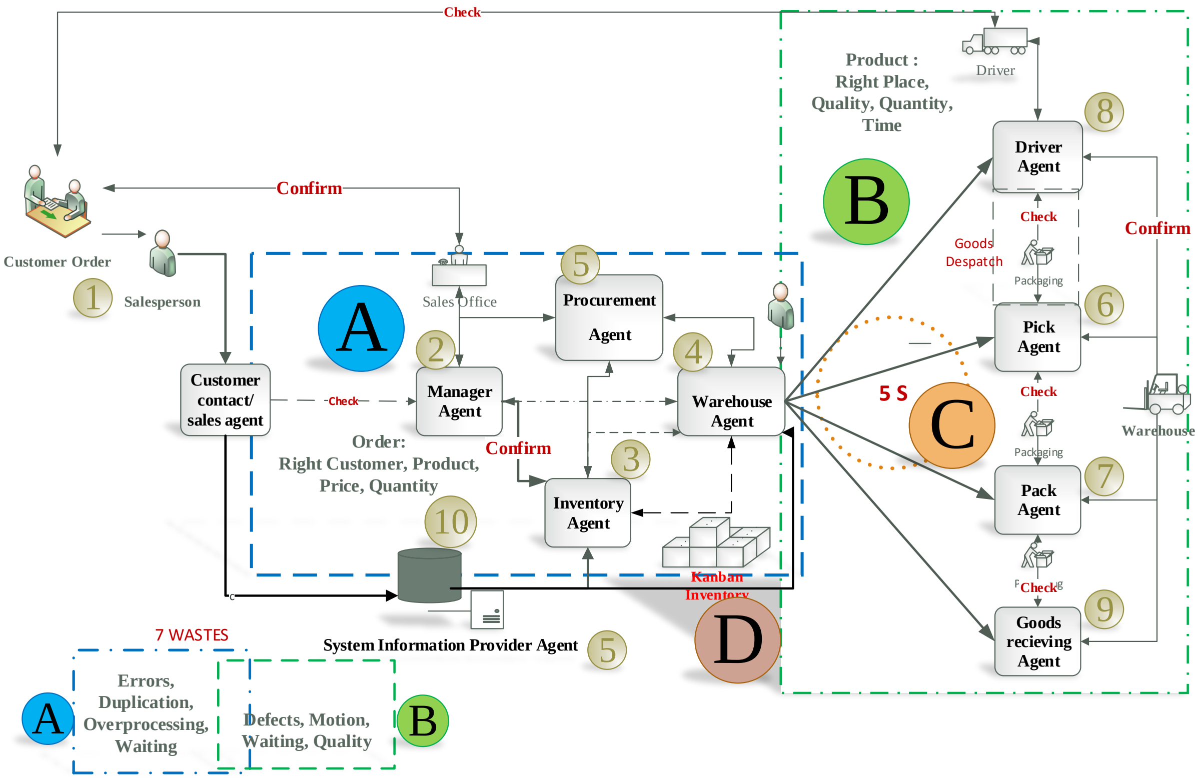


Figure 6.6: The procedural design of the integrated LMAS conceptual model with 7W, 5S and Kanban

6.4 Analysis

The analysis phase aims to clarify the problem without any or with only minimal concern for the solution. Nikraz et al. (2006) used the proposed methodology in their work on TILAB; with it, the analysis phase took place using a number of systems called use cases; this is one of the best ways to describe the functional requirements of a new system. Use case diagrams were employed to describe the interaction of operational participants known as agents and a step-by-step sequence of their actions (Helming et al., 2010) for each separate business process, such as ordering, warehousing, etc. Based on the description of the food distribution case study and after identifying the potential system users, it is possible to build up the current scenario of processes and highlight some of the steps that need to be reconsidered as described in Section 6.3 and highlighted in Figure 6.6. Accordingly, the use cases for the current scenario can be defined and a use case diagram proposed, as shown in Figure 6.7.

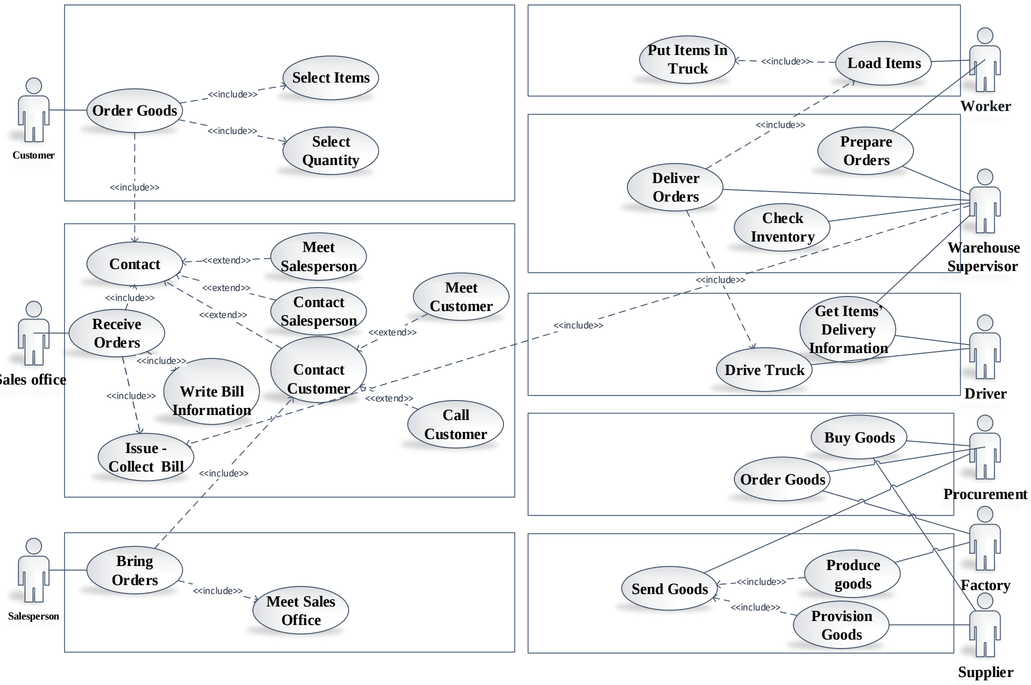


Figure 6.7: Use case diagram for food distribution case study (current scenario).

In the next step, an initial list of the main responsibilities for each identified agent is modelled to produce the responsibility table or diagram as it exists in the current situation before improvement. Figure 6.8 shows a use case with the proposed improvements as highlighted in Figure 6.6. Only two groups are highlighted in Figure 6.8 to reduce visual complexity but the same approach is applied to all user groups. The first group consists of the salesperson agent, customer agent and sales office agent and the second group consists of the warehouse supervisor agent, worker agent and driver agent.

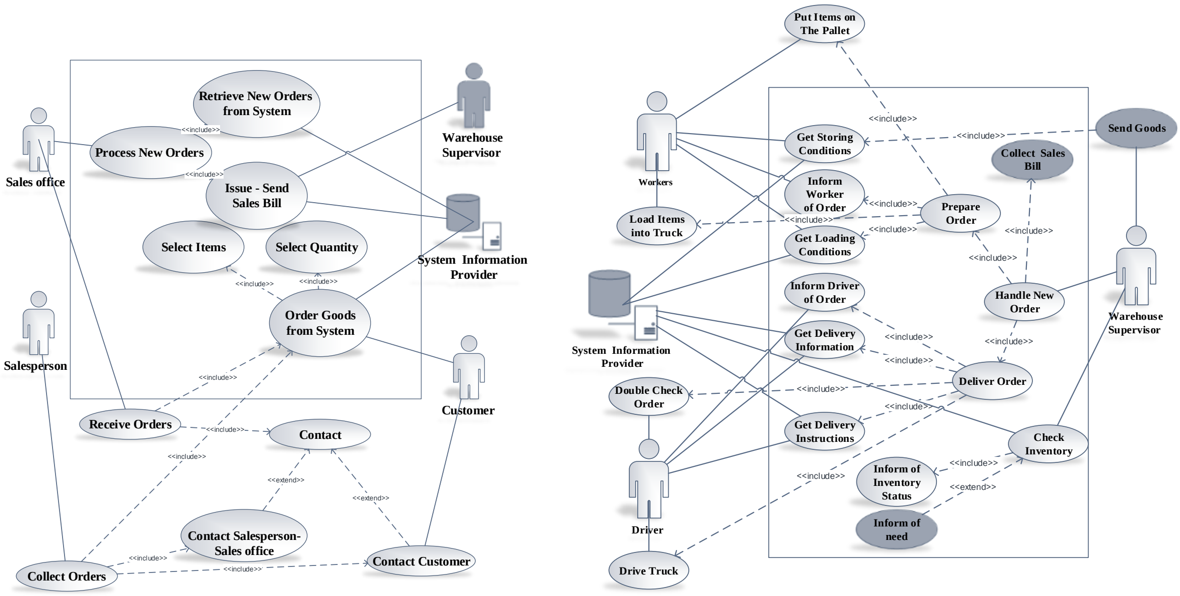


Figure 6.8: The two groups in the proposed improved scenario

Each identified agent type, known as ‘acquaintances’, demonstrates the communication links and interactions that exist (Figure 6.9) and how the agents are connected by one interaction or several interactions. These links and responsibilities produce the final agent deployment diagram in the proposed solution as shown in Figure 6.9.

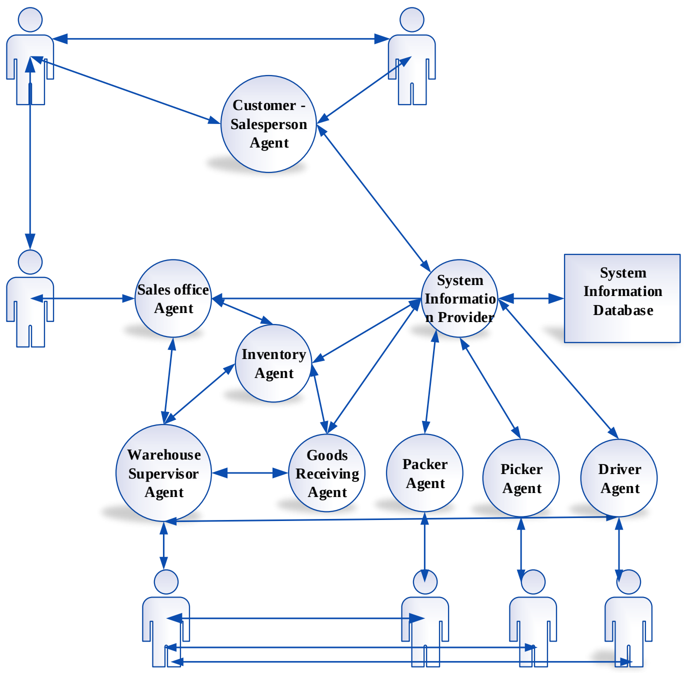


Figure 6.9: A refined and updated agent diagram

The sequence diagram given provides a visual demonstration of the designed coordination protocol. A sequence diagram shows the coordination process in a single group. Figure 6.10 shows the sequence diagram of the one group.

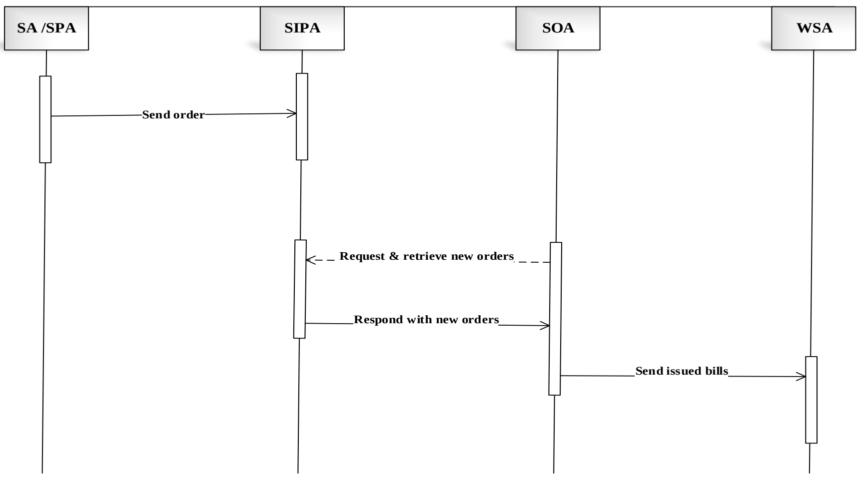


Figure 6.10: The sequence diagram of the first group

6.5 Design

The agent deployment diagram provides the map for the design phase, but further detail is needed before the generation of code can proceed. Decisions here have a direct impact on implementation (Xu and Shatz, 2003); to avoid the duplication of tasks among agents that must use the same information or need access to the same resources to complete their tasks, an essential step is to merge or split the tasks. Splitting the activities of agents can reduce system complexity and improve system efficiency, as each agent is deployed on a single computer. This next step produced the interaction table for each agent type with the relevant trigger conditions that indicate the coding instructions from the message template required to express the behaviours needed to receive incoming messages. The agents' behaviour then needs to be modelled from the responsibilities identified in the analysis phase, along with their key objectives; this determines how the agent will act and react based on the sequence of orders in the process algorithm (Nikraz et al., 2006). This produces the final diagram which shows the interactions and behaviours of the agents.

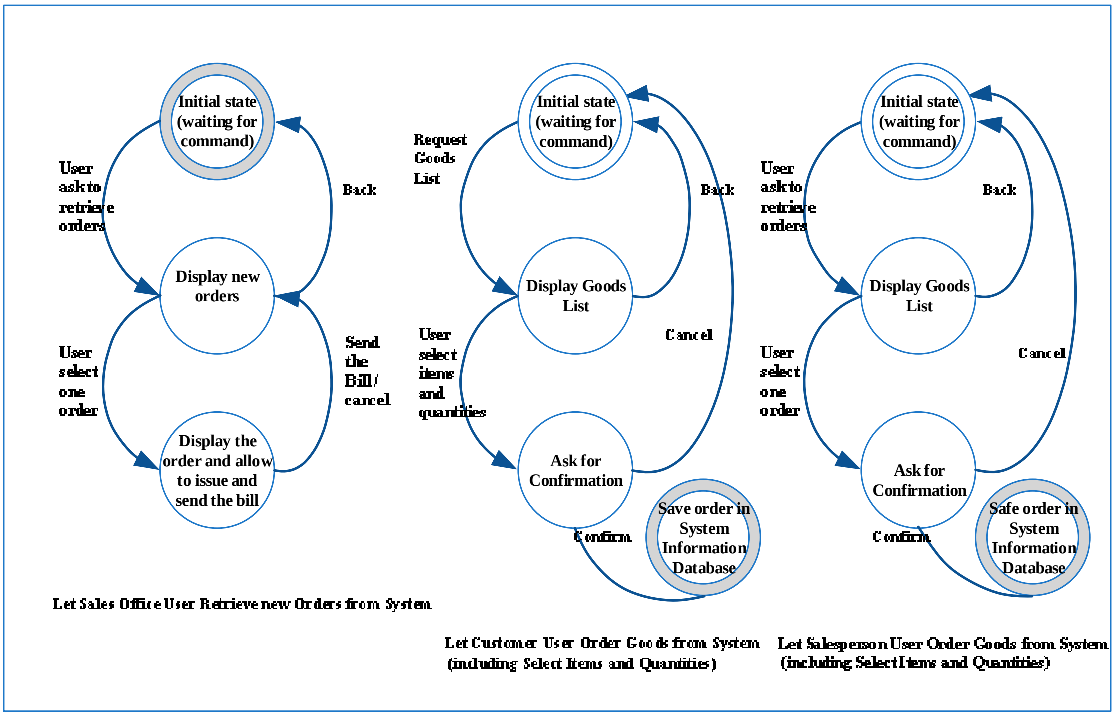


Figure 6.11: State transition diagrams

6.6 Implementation

The final stage is the implementation of the developed model adapted for application in the case study. The food distribution value chain of the SME was software-engineered to eliminate the identified problems and improve the system. It is not possible in the implementation to replicate the constraints that relate to the finite capacity of human and machine resources available. Additionally, it is not possible to replicate the scheduling required for specific machines as these have other software and functions within the firm relating to job routings, daily demands and due dates. Furthermore, in practice, the development of the agents would need to exist separately and to be programmed in different containers on different platforms to represent the actual situation. However, in this study, the system was only simulated on one computer with all the agents located on the same platform. In addition, each transaction was manually entered into the system by the researcher to replicate the real-world process in the MAS system. A full inventory database was populated to represent the exact state at the time of the study. Naturally, the inherent conflicts and delays that may occur between applications installed on desktops in real-world systems were not replicated. However, time buffers were introduced at each stage of the process to compensate for these limitations. Figure 6.12 indicates constraints within the application and simulation.

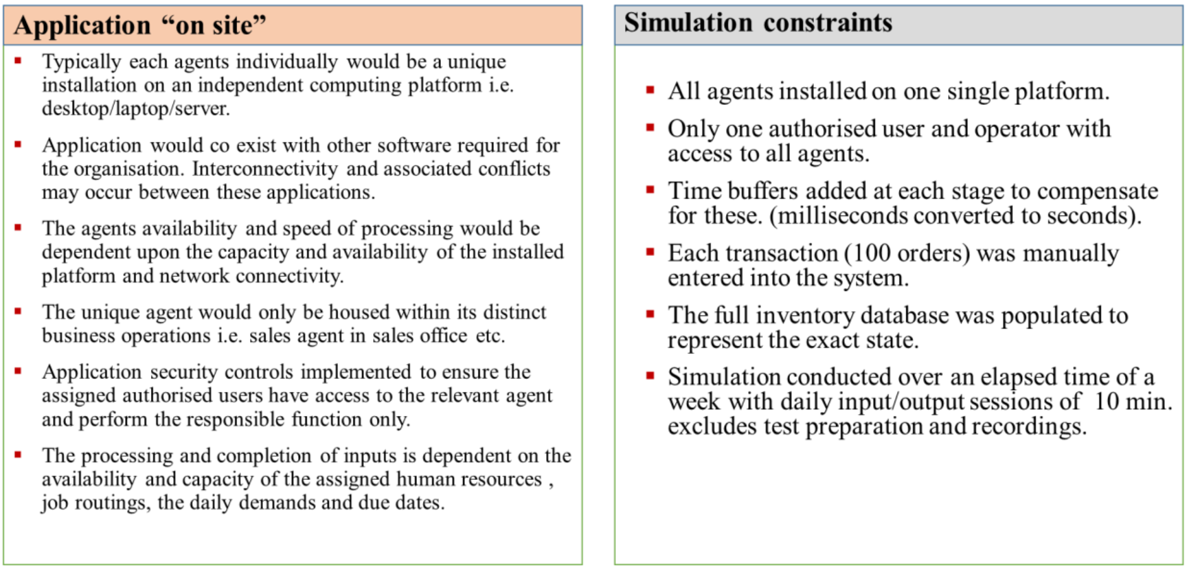


Figure 6.12: Constraints within the application and simulation

6.6.1 Definition of agent responsibilities

In this section, the role and functionality of each agent is summarised; only the core transactions within the system process are presented rather than the final detailed tailored dialogue behaviour specified for each agent. Ten distinct agent types are used in this LMAS scenario. The agents are identified below:

6.6.1.1 Customer and Sales Agent

In Figure 6.6 the customer and sales agents are referenced as (1). The objective of these two agents is to place the initial sales order; this can either be placed by the salesperson directly or by the customer using an online or web facility. An illustrative extract of the procedures in Appendix F for configuration is shown below:

By Phone to Salesman or Direct Face-to-Face*

1- *Customer will specify goods and quantity*
2- *Sales representative will select from online drop down menu*
3- *Sales representative will be advised of option delivery choices*
4- *Sales representative orders and receives confirmation order numbers*
5- *Sales representative provides a verification email with order reference and detail*
6- *Automatic email sent to the sales inbox*
7- *Automated update of main database*

**See Appendix F for the colour code key*

The agent requests specific information regarding the customer status to identify whether this is a new or repeat customer. A repeat customer needs to have their customer ID inputted; each ID is unique to a current or approved customer. The systems information provider will verify the ID code and validate the current operating status of the customer ID and whether the status is active, or inactive, and whether any warnings have been flagged on the account. If the ID is not verified, the system will generate a message to advise the customer that a salesperson will be in contact to resolve the issue. Simultaneously, a message will be generated by the manager agent directly to the sales agent to contact the customer. If the ID is verified by the system, the agents will be presented with the order placement screen and a pre-population screen with the customer's standard or specified product choice list. The customer will need to specify the quantity for each item selected, then the agent will present the updated request with confirmed stock item, quantity and sales price. The agent will request information about the status of the customer to confirm this as a repeat order or a one-time order. When the order is completed the confirmation message will present the final order number, list items ordered and the expected delivery date, and confirm the date and time of order for this customer ID. The system will generate an automated notice to the warehouse agent.

If the quantity ordered is not available or there is a shortage, the agent will immediately be presented with information about this and advise the customer and warehouse agent that the items have been assigned pending status. When the stock items are processed by the warehouse, the agent will send a message to the customer to advise that the order is in progress and on track for the anticipated delivery date. If this is a new customer, the agent will present all the fields to be completed: name, address, contact details, etc. Once all fields are complete the agent will confirm completion and send a message to the customer that they should await contact from a salesperson. These fields and the process for checking whether the customer is blacklisted or a legitimate customer are demonstrated in Figure 6.13.

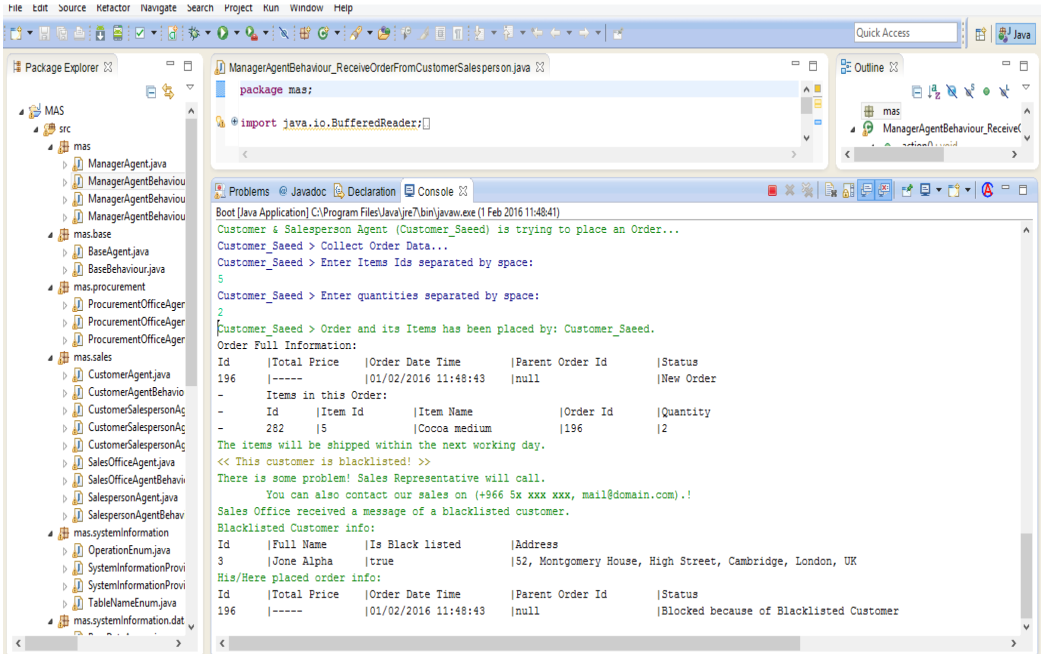


Figure 6.13: Customer/sales agent places the initial sales order

6.6.1.2 Manager Agent

In Figure 6.6, the manager agent is referenced as (2). The responsibilities of this agent are to supervise the flow of the processes and manage the sequence and routing of messages to the respective individual agents so as to initiate the next process in the sequence. The manager agent receives notifications of new orders approved by the system with all the detailed information, and routes this to the inventory agent for confirmation of availability. An illustrative extract of the procedures in Appendix F for configuration follows:

```
Manager-Operations Controller/Main Database*

   1- Receives automatic transaction update to ERP or main database
   2- Message Request to inventory - quantity, goods reference, status as
      stock requisition order

   *See Appendix F for the colour code key
```

The manager agent also receives confirmation at each stage of the flow of goods; this includes notifications from the picker and packer agents. Then a goods delivery note (GDN) and goods receiving note (GRN) are generated; these are then routed to the dispatch and receiving depots. The manager agent will also receive confirmation of the GDN from the driver agent and generate an updated customer sales invoice with all the relevant customer, order and stock details, which is routed to both the driver and sales agents. In Figure 6.14 the manager agent has received the order and submitted a request to the inventory agent to check the availability of the item.

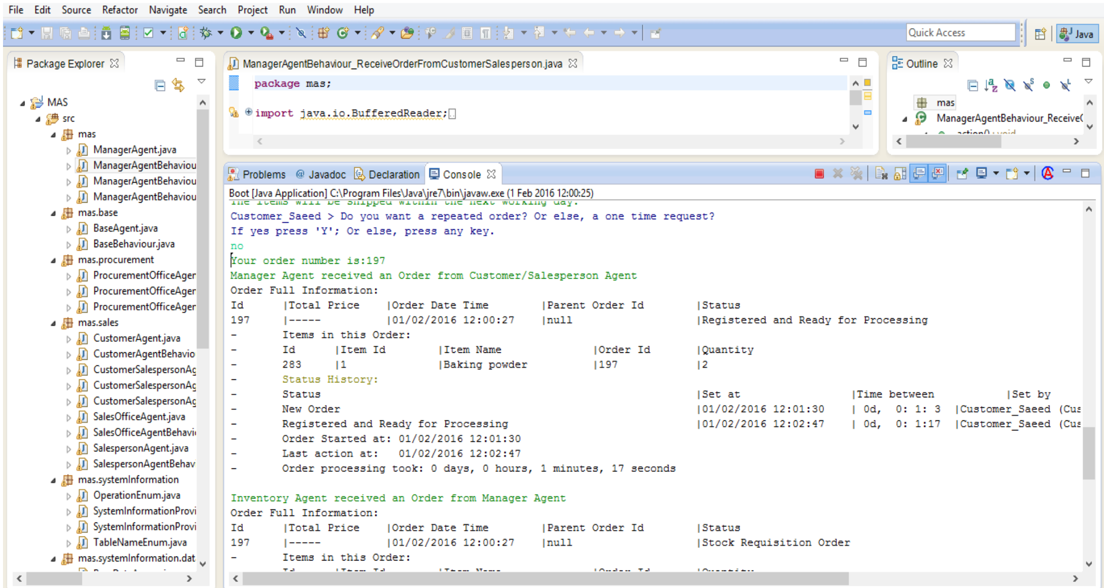


Figure 6.14: Manager agent receives notifications of the approved order

6.6.1.3 Inventory Agent

In Fig 6.6, the inventory agent is referenced to as (3). This agent receives notifications from the manager agent as a request to check stock availability to fulfil the placed order. If the stock is available and confirmed, the agent will generate a stores pick list and issue this to the warehouse supervisor agent with all the relevant instructions related to loading and handling. If the quantity is short of the requirement, the agent will immediately escalate to the warehouse agent and generate a pending list. Following is an example of the procedures developed in Appendix F with the key to the colour coding.

Stores/ Inventory

1- Receives stock requisition order
2- Checks stock availability

IF YES

- From available stock it will produce a stores pick list
- Include specific load or pack instructions if applicable
- Automatic message to confirm the issue of picking status to warehouse and procurement

IF NO

- From available stock it will produce a stores pick list
- Automatic generation of backorder quantity and a purchase request to warehouse

- Purchase request will be flagged for escalation, alert email to warehouse supervisor and stores supervisor (if applicable) for approval
- Automatically Produces a pending pick list

Automatic updates of the stock kanban status with approved backorder

The agent will update the Kanban status. Next the agent receives notifications from goods receiving to match the received goods to the detailed stock criteria and the pending list. The agent will generate a packing list for the packer who will pack and stack the goods according to the bin allocation and handling specifications. Figure 6.15 depicts the process where the inventory agent has checked availability of the stock and generated a stores pick list or a notification of a pending item for sales for the warehouse supervisor agent.

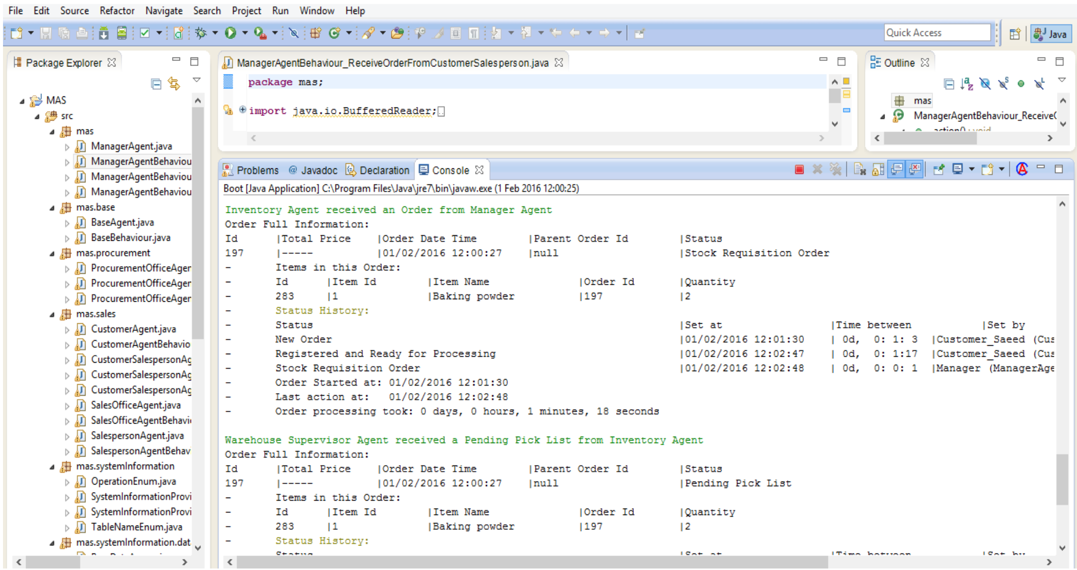


Figure 6.15: Inventory agent receives notifications to check stock availability and generates a stores pick list

Kanban algorithm

In Figure 6.6 the Kanban algorithm is referenced as C. The inventory agent maintains a set of algorithms that control and manage the level of stock for each stock item in each bin and location. Once the notification for a stock request is received by the inventory agent, it triggers a set of Kanban algorithms to determine whether sufficient stock is available. If the balance of stock calculations triggers the minimum threshold quantity, the inventory agent triggers the reorder point and sends a notification to procurement and the warehouse supervisor. The reorder point takes into account the average value for the two orders and the average lead time for orders to be received, within a tolerance of variation. The reorder point forecasts the quantity of stock to be purchase based on set parameters for that stock item, lead time, maximum thresholds, current demand levels and frequency of orders. The reorder point will also take into account the maximum threshold points, the maximum quantity of stock to be stored and stacked at any one time to ensure that bin and warehouse capacity are not exceeded. The algorithms include the following calculations:

- ***Calculated Average Daily Demand*** *= Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items =*
- ***Best Case Delivery Time*** *=(from Database)*
- ***Worse Case Delivery Time*** *=(from Database)*
- ***Average Delivery Time*** *=(Best Case Delivery Time + Worse Case Delivery Time) / 2*
- ***Minimum Order Quantity*** *= Average Daily Demand * Average Delivery Time*
- *Safety Stock Days =(from Database)*
- *Safety Stock =(from Database)*
- ***Kanban Card Position*** *= Minimum Order Quantity + Safety Stock*
- ***Quantity in Stock or Requested*** *= Quantity Available + Calculated Total Quantity Requested by Inventory*
- *Minimum Threshold (fetched from Database)*
- *Maximum Threshold (fetched from Database)*
- *Minimum Order Time (fetched from Database)*
- ***Quantities in Pending Pick Lists*** *= Sum(Quantity)for all occurrences of this item in the Pending Pick Lists*
- ***Kanban Card Position*** *= Minimum Order Quantity + Safety Stock + Quantities in Pending Pick Lists*
- ***Quantity in Stock or Requested*** *= Quantity Available + Calculated Total Quantity Requested by Inventory*
- ***Quantity in Stock or Requested*** *<=* ***Kanban Card Position*** *(There will be an Inventory Order and Kanban will be used and applied!)*
- ***Minimum Order Time*** *=*
- ***Window between Every 2 Orders*** *= Minimum Order Time * Average Daily Demand =*
- ***Actual Order Quantity*** *= Safety Stock + Window between Every 2 Orders – Quantity in Stock or Requested =*
- ***Actual Order Quantity*** *= Ceiling of Actual Order Quantity =*

Figure 6.16 demonstrates the query used to run the Kanban algorithm that determines the reorder point.

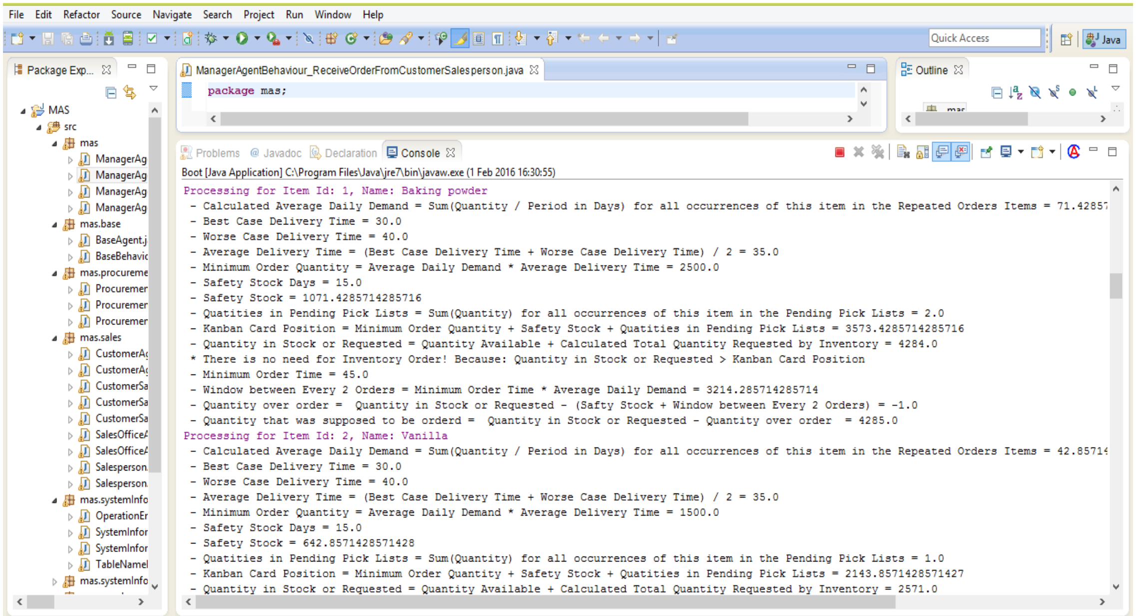


Figure 6.16: Running the Kanban algorithm

6.6.1.4 Warehouse Supervisor

In Figure 6.6 the warehouse agent is referenced as (4). This agent fulfils several responsibilities, starting with the generation of a stock pick list to fulfil a customer order. The pick list is generated after the agent receives confirmation from the inventory agent that all stock items are available as requested. The agent will generate a message to the customer and to sales that the order has been received in the warehouse and that the order is in progress. The agent will advise the picker of the detailed pick list containing stock code items, quantities, bin locations and loading instructions. The agent will request confirmation for each item picked regarding quantity and quality and whether there are any variances. If no variances are reported, the agent will receive a completion confirmation. If there are any variances, the agent will request a prioritised action for resolution on the floor. If there is a shortage of stock, the agent is notified and a pending list is generated. An illustrative example of the procedures with the key to the colour code is in Appendix F.

```
Warehouse Supervisor

    1- Receives confirmation of  store pick list
    2- Message update to sales/customer to confirm order delivery
    3- Receives automatic escalation alert of stock shortfall and backorder
    4- Approves the  replenish stock  request (re- order point) - purchase order
       requisition

If standard reorder

    -   Standard reorder purchase requisition request message to procurement to
        place order
```

- Message update to Inventory to update status (awaiting delivery) with order PLACED
- Message to goods Receiving to await expected delivery of quantity, supplier and date

If new request or variation (additional quantity or a new supplier)
If on-off

- Approve message purchase order requisition – quantity, goods reference, status to warehouse manager
- Validate and approve the status – on-off or repeatable order
- Approved requisition sent to procurement to place order
- Message update to inventory to update status with order placed and lead times
- Message update to salesman/customer to advise of status and confirm delivery

If repeatable

- Recalculate re order point and buffer zone with escalated (alert) approval reference by warehouse supervisor
- Purchase order requisition sent to procurement

Second, the agent receives escalation alerts from dispatch and driver agents in the event of variances in specified numbers or quality. The agent will escalate and prioritise actions for resolution to management. Once confirmed, the warehouse agent will notify the relevant agents of the intended action required to resume, complete or exclude goods. The warehouse agent will also receive confirmation of customer acceptance and rejection of orders and will confirm and accept the requested pending list or goods receiving request.

Third, the warehouse agent receives detailed requests from inventory to request purchase of stock when the Kanban reorder point is reached. Once the stock request is approved, the warehouse agent will generate a message with a purchase requisition to procurement to order stock; when confirmation is received from procurement, the agent will message the inventory agent to change the status to update the pending list to order placed. The agent will then notify goods receiving to expect receipt of goods with detailed information on stock items’ packing, loading and stacking. Finally, the warehouse agent will receive all notices of pending lists and automated alerts of goods nearing their expiry dates with specific dates and locations. Figure 6.17 demonstrates the escalation notification to the warehouse supervisor agent from the dispatch agent when there is a variance. The second query requests the warehouse supervisor agent to approve or reject the order.

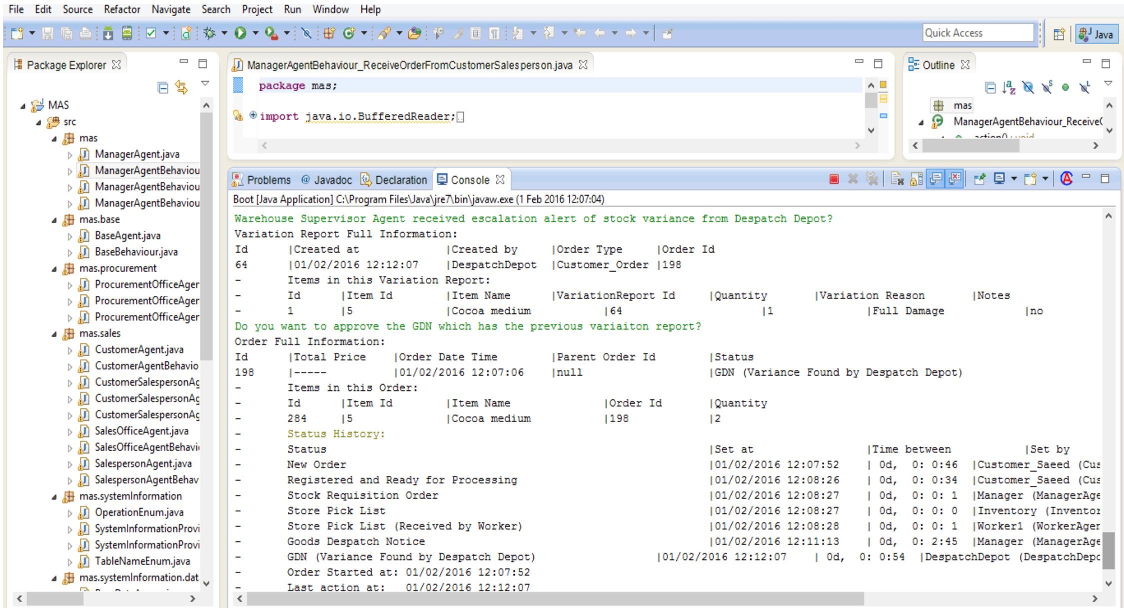


Figure 6.17: Warehouse agent receives escalation alerts from dispatch agent in the event of variances

6.6.1.5 Procurement Agent

In Figure 6.6 agent (5) receives confirmed instructions from the inventory system to reorder goods. In this simulation, the design of the system includes only known and purchased stock. The agent receives approved pending lists from inventory, picker, packer, driver and customer and sales agents. The procurement agent escalates to a specified resource to action the request. The procurement agent will confirm the order placed, the quantity, stock reference and expected delivery date to inventory and warehouse supervisor agents. Figure 6.18 is an example of the way queries are run when the warehouse supervisor agent is advised by Kanban to replenish stock levels. The warehouse supervisor agent will inform the procurement agent to place the orders approved. The warehouse supervisor agent will also notify goods receiving to await the order and inventory to confirm the pending order placed.

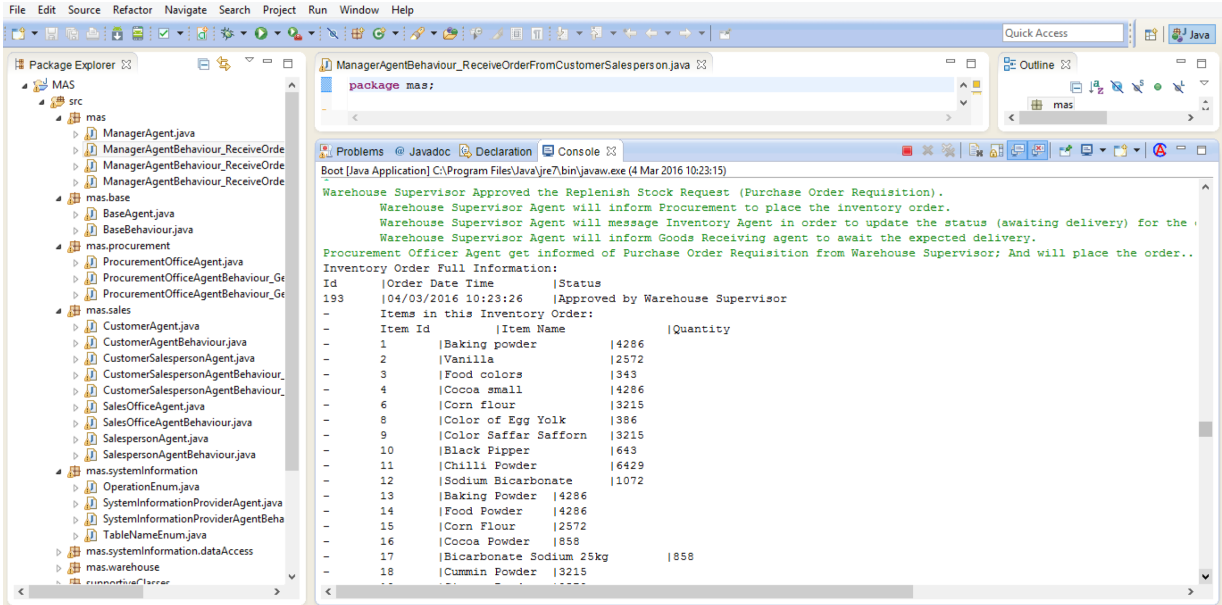


Figure 6.18: Procurement agent

6.6.1.6 Picker Agent

In Figure 6.6, the objective of the picker agent (6) is to action the request to pick stock items from system-generated, approved sales orders. The agent is initiated from a system-generated instruction from the warehouse supervisor which generates a picklist with all the stock items, stock unit codes, quantities and the order date. The list will include specific instructions related to the handling and carrying for each specific stock item. The agent will request confirmation for each item; if, however, there is a variance confirmation, the system will present an option to detail the variance that includes expected picking quantity, quality status of stock item picked and a comment field for additional notes. An illustrative extract from Appendix F of the procedures follows:

```
    1- Picker (worker) receives stores pick list with specific instructions
If no issues with picking (all stock available, no issues of quality or incidents)

    -   Picker confirms quantity and items on system to message picking completion
    -   System requests an update if there has been a variance/issues - yes /no
        (series of questions)
    -   Picker confirms that the stock was all in the correct location and correct
        bin
    -   Picker confirms that the area is clean, has removed any waste, all stock is
        straightened up (5S)
    -   Picking completes message auto-updates with NIL variance
    -   System deducts the goods picked from stock levels quantity and updates new
        stock levels
```

The agent will generate an immediate alert to the warehouse supervisor. In the event that the variance is caused by a shortage of available stock and the order cannot be fulfilled, the system will generate a request for stock purchase, initiate a pending list and alert the warehouse supervisor. If there is no variance, the agent will request completion and the completed action will initiate a completed message to the manager agent. In Figure 6.6, the 5S is introduced referenced as (D) with a set of following checking and confirmation rules. The agent will also request the user to confirm that the stock location has all the stock allocated to the bins, request information about the cleanliness status of the designated work floor area and confirm that the final stock quantity in the allocated bins is packed according to the instructions specified. The agent will submit the final confirmation status of the completed pick list to the manager agent. Figure 6.19 demonstrates the course of events when the sales agent receives confirmation of an order and the picker agent receives notification of a stores pick list, both from the warehouse supervisor agent.

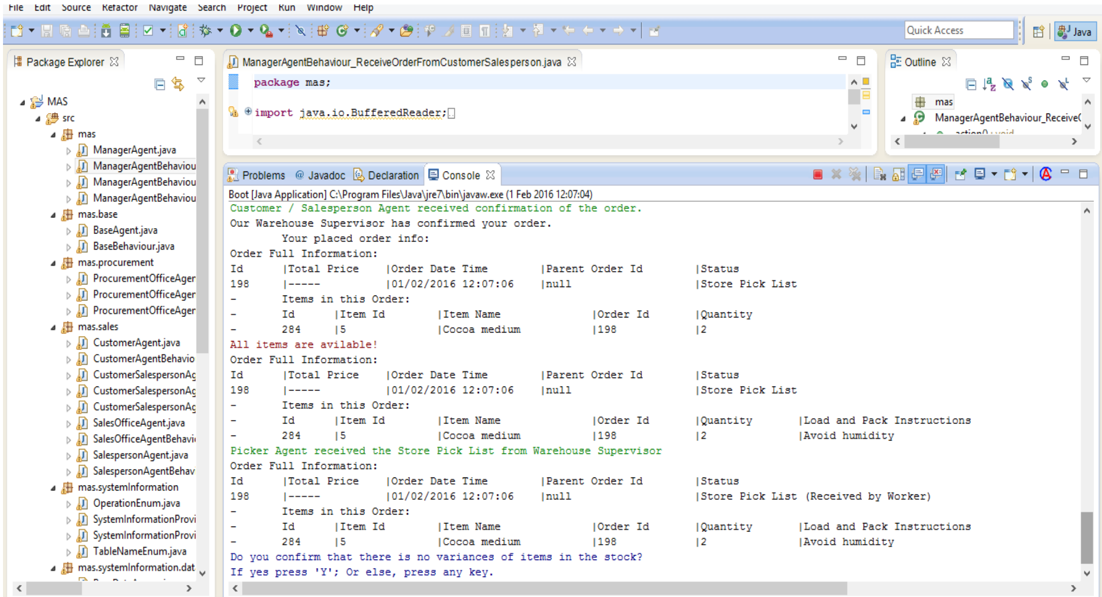


Figure 6.19: Picker agent receives store pick list from warehouse

6.6.1.7 Dispatch (Packer) Agent

In Figure 6.6, the packer/dispatch agent (7) facilitates the dispatch of outgoing goods from the warehouse and receives incoming goods into the inventory. The dispatch agent receives the GDN from the manager agent; this presents the completed list of stock picked and to be prepared for dispatch and delivery. The stock items will include reference instructions for lading, packing and temperature control. As indicated in Figure 6.6, the 5S is introduced referenced as (D) with a set of checking and confirmation rules to be followed. Each stock item needs to be individually confirmed for quantity, quality and packing check. If all the checks are confirmed and no variance identified between the physical stock and the GDN, the agent will update the status to an accepted GDN, which will submit the approved GDN to the driver agent, including packing and loading instructions. However, if the physical check identifies a variance, the GDN to the agent will request details of the variance and update the system as to quantity, stock item and reason, and alert the warehouse supervisor, before waiting for an accepted action that will either request that the driver exclude the items from the load or wait for replacement. Once the action is completed, the GDN will alter the status to an accepted GDN which will submit the approved GDN to the driver agent, including packing and loading instructions. Figure 6.20 demonstrates the confirmation by goods dispatch of goods received from the pick list; the dispatch agent receives the packing instruction list and forwards this to the driver agent.

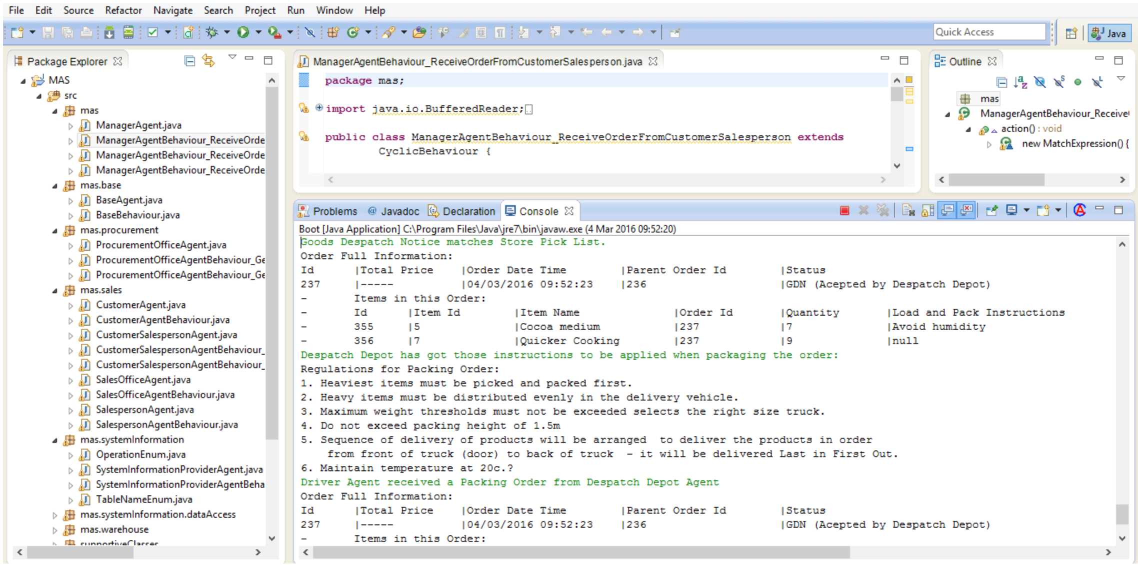


Figure 6.20: Packer agent checks and confirms variance

6.6.1.8 Driver agent

In Figure 6.6, the driver agent's (8) role is to receive the approved GDN and confirm that the correct quantity and quality of the specified stock units have been loaded using the appropriate packing method without any variances. The detailed procedures are presented in Appendix F. If there are no variances, the driver agent will request confirmation of an approved order; confirmation will alert the manager agent that the delivery is scheduled. If there is a variance in any criteria specified on the GDN, the manager agent will request variance details, with an additional notes field available to supplement the basic message. The agent will then alert the warehouse supervisor of the variances and the required and supplementary notes and await an action from the warehouse agent. That action will be either an instruction to complete the loading and exclude this item, complete the load and include the stock, or to wait for replacement stock or until the issue is otherwise resolved. As per Figure 6.6 (reference D), the

5S is also applied with a set of following checking and confirmation rules. Once all the actions are resolved, the driver agent will request confirmation of an approved order, which will message the manager agent that the delivery is scheduled. The manager agent will then issue the completed customer invoice with relevant address, contact details and the confirmed scheduled order.

The driver agent will carry out delivery to the customer site and will request the customer confirm receipt and acceptance of each stock item. The agent will present three options—accept, reject or accept with variance—for each stock item. If the item is rejected or accepted with variance, the driver agent will request specific information related to the issue and use supplementary fields for further information if needed. Once the customer order is completed and confirmed, the agent will generate a message to the warehouse supervisor that the delivery is either fully or partially completed. Any variances will initiate an action to generate a pending list, a new pick list or a purchase order request. If any of the goods have been rejected, the agent will generate a goods receiving note to prepare goods receiving to accept the incoming goods into the warehouse. Figure 6.21 demonstrates the driver agent receiving a customer invoice from the manager agent. The driver agent receives the travel route guide. At the customer site, the driver agent notifies the warehouse supervisor agent of customer order acceptance with no variances. The warehouse supervisor agent updates the goods delivery note as completed.

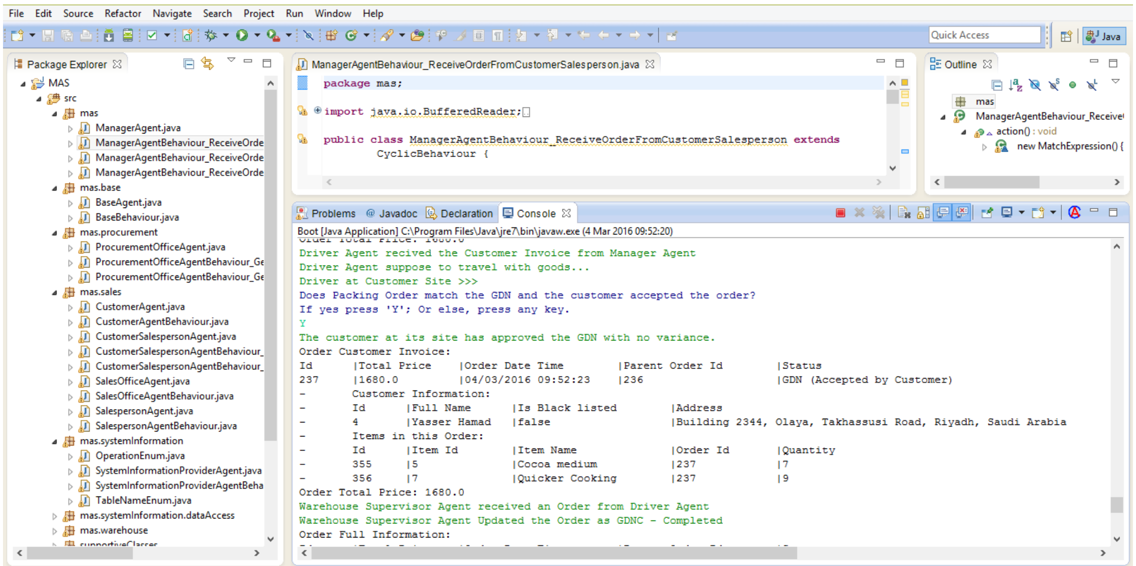


Figure 6.21: Driver agent receives instruction

6.6.1.9 Goods Receiving Agent

In Figure 6.6 the goods receiving agent's (9) role is to manage the receipt of goods into the inventory system. The agent will receive a goods receiving note from the warehouse supervisor agent with full details of stock to be delivered with quantity, stock item, bin location number, expected arrival date and supplier name. The agent matches the goods to the procurement order. The agent notifies the procurement agent of all confirmations and exceptions with full details and supplementary comments fields. The same process of matching will apply and any variances will operate the same way. When a particular incoming delivery is completed, the agent will generate a message to the inventory agent to expect the confirmed goods. If the scheduled goods do not arrive within a specified time frame, the goods receiving agent will escalate matters and alert the warehouse, purchasing and inventory. Figure 6.22 demonstrates notification receipt to the goods receiving agent of a purchase requisition from the warehouse supervisor agent to await the order. When the order is received the goods receiving agent will need to confirm quantity and quality of stock items and as per Figure 6.5; the 5S is also applied (referenced as D) with a set of checking and confirmation rules to be followed.

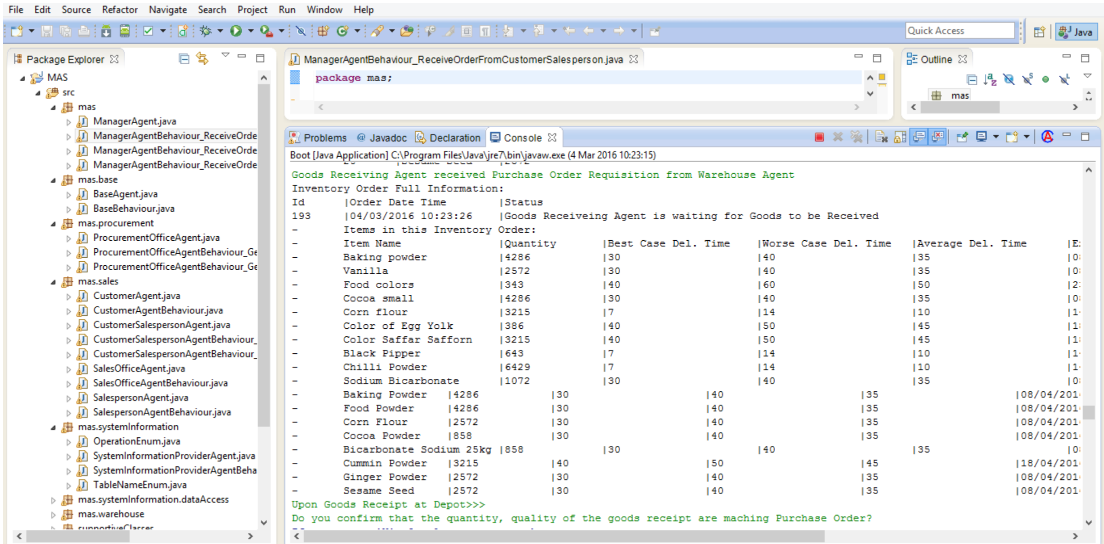
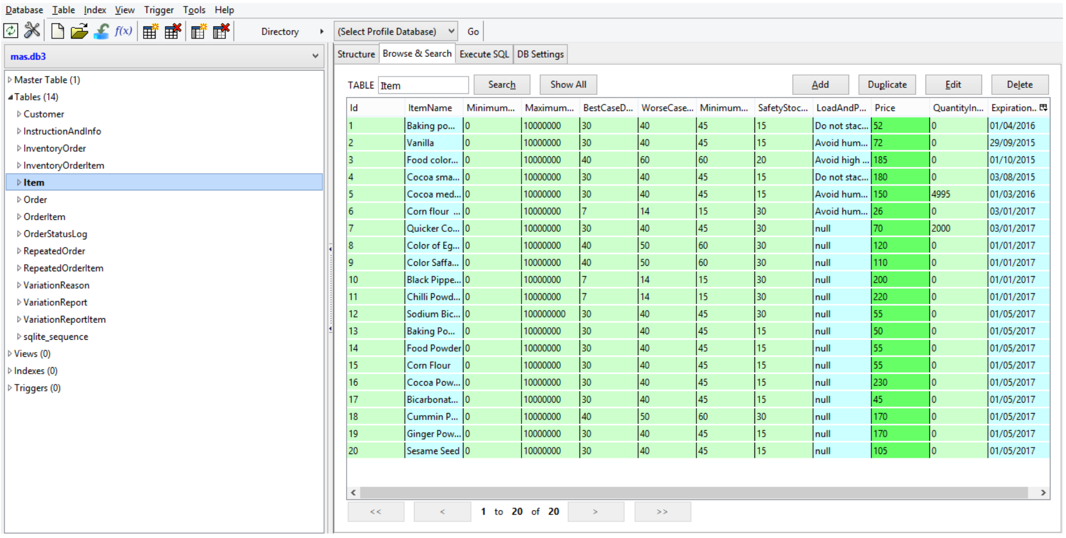


Figure 6.22: Goods receiving agent receives instruction to await and confirm receipt of order

6.6.1.10 Systems Information Provider Agents

In Figure 6.6 the systems information provider agent's (10) responsibility is to store and supply the entire database. This contains all the requisite data for customers, suppliers, salespersons, machines, tools, vehicles and all staff members, with their allocated responsibilities and security levels. The database has all the related data needed for each function and enables the various agents to collect, supplement, verify inputs and generate outputs that initiate the next process or transaction. The database also provides all the rules, regulations and policies related to the sales, stock, customer, warehouses, inventory locations, allocation measurements and criteria. It stores a history of prior transactions and prompts agents once the different Kanban algorithm calculations have been triggered in areas such as expiry dates, reorder dates, etc.

Finally, the database flags suppliers, customers, warehouse locations, vehicles or tools and stock items where variances have been recorded. Figure 6.23 presents a snapshot of the stock item details recorded by the systems information provider agent database.



Id	ItemName	Minimum...	Maximum...	BestCaseD...	WorseCase...	Minimum...	SafetyStoc...	LoadAndP...	Price	QuantityIn...	Expiration...
1	Baking po...	0	10000000	30	40	45	15	Do not stac...	52	0	01/04/2016
2	Vanilla	0	10000000	30	40	45	15	Avoid hum...	72	0	29/09/2015
3	Food color...	0	10000000	40	60	60	20	Avoid high ...	185	0	01/10/2015
4	Cocoa sma...	0	10000000	30	40	45	15	Do not stac...	180	0	03/08/2015
5	Cocoa med...	0	10000000	30	40	45	15	Avoid hum...	150	4995	01/03/2016
6	Corn flour ...	0	10000000	7	14	15	30	Avoid hum...	26	0	03/01/2017
7	Quicker Co...	0	10000000	30	40	45	30	null	70	2000	03/01/2017
8	Color of Eg...	0	10000000	40	50	60	30	null	120	0	01/01/2017
9	Color Saffa...	0	10000000	40	50	60	30	null	110	0	01/01/2017
10	Black Pippe...	0	10000000	7	14	15	30	null	200	0	01/01/2017
11	Chilli Powd...	0	10000000	7	14	15	30	null	220	0	01/01/2017
12	Sodium Bic...	0	100000000	30	40	45	30	null	55	0	01/05/2017
13	Baking Po...	0	10000000	30	40	45	15	null	50	0	01/05/2017
14	Food Powder	0	10000000	30	40	45	15	null	55	0	01/05/2017
15	Corn Flour	0	10000000	30	40	45	15	null	55	0	01/05/2017
16	Cocoa Pow...	0	10000000	30	40	45	15	null	230	0	01/05/2017
17	Bicarbonat...	0	10000000	30	40	45	15	null	45	0	01/05/2017
18	Cummin P...	0	10000000	40	50	60	30	null	170	0	01/05/2017
19	Ginger Pow...	0	10000000	30	40	45	15	null	170	0	01/05/2017
20	Sesame Seed	0	10000000	30	40	45	15	null	105	0	01/05/2017

Figure 6.23: Systems information provider agent database

6.7 Lean Multi-Agent System Verification

In order to test the relevance and functionality of the system, real data was introduced and validated with interviews, after which the proposed model itself needed to be verified and validated. Verification is the process of determining whether the behaviour of the simulation model is consistent with what is outlined in the model's specifications. In this case the described procedures, rules configuration and processes (in Appendix F) were submitted to the manager of the SME being examined in the case study to verify that they were relevant and to check if they were a true representation of the firm's current operational processes and also that the lean practices and techniques were highlighted (in colour) to check for validity, relevance and applicability. The manager confirmed that the procedures were accurate and relevant with a few minor changes.

The second verification process presented the simulation programme to the managers to establish whether it produced a good representation of their current operations as well as ensuring the programming reflects the behaviour expected from the conceptual model. It included a sense check which was used to debug a simulation programme(s) using a set of test cases to determine if the results can be easily predicted (Ramanath and Gilbert, 2003).

Following Kelton et al. (2007), the researcher elected to test the system by using a specialist to overview the programming code and a comparison of a sample of test results matched to the real-world output taking place on the warehouse floor. Wainer (2009) views this manual simulation approach as an informal technique. A test case was conducted and a sample of customer order requests were processed through the programme. Appendix E offers three detailed examples of configurations for salesperson order, customer agent order and Kanban algorithm. The agents' behaviour was compared to the real-world workflow sequence. The system presented precisely the same results as with the actual warehouse and the inventory staff conducting the check and picking activities in relation to the sampled stock items on the warehouse floor. Figure 6.24 presents the configuration of the customer, sales office, manager, warehouse, worker and inventory agents embedded in this programme. They are the virtual equivalents of the onsite functions and staff. This confirmed that the simulated programme was a complete virtual replication of the onsite situation.

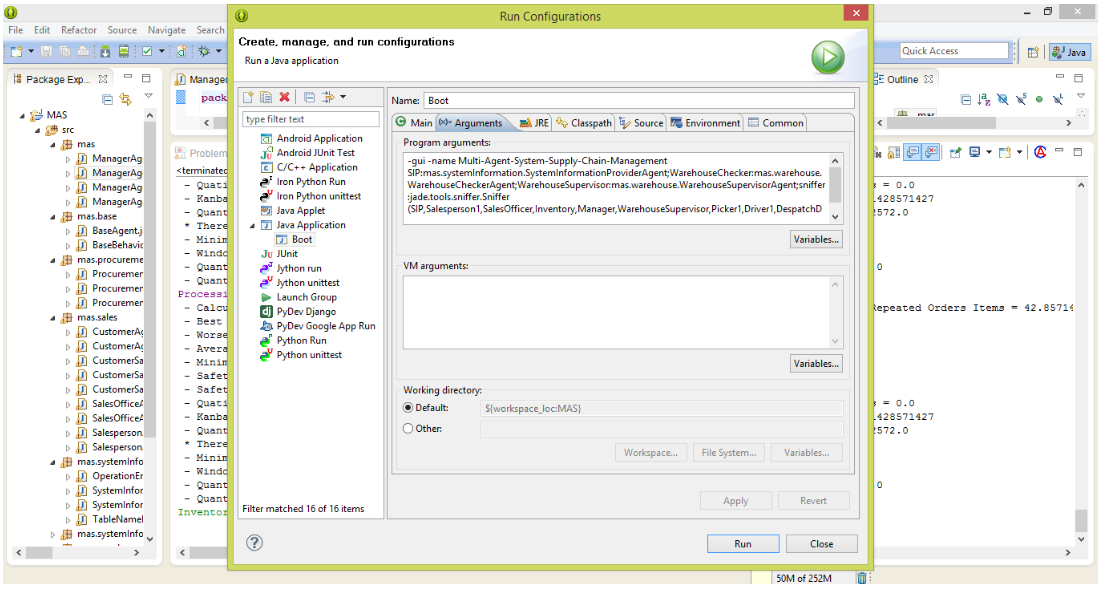


Figure 6.24: The configuration of agents

Figure 6.25 presents a snapshot of the autonomous sequence of agent behaviours and the inter-relationships between the agents when the customer places the order. The sequence of steps includes request 0, where the system checks the customer data (name, account status) with the SIP (System Information Provider); requests 1, 2, 3, and 4 are requests from the customer agent of the SIP as the agent places the respective product order. Request 1 also shows the order of request from the customer to the manager. The manager serves a request (8, 9) on SIP to check for the regulations and limits of the customers and confirm the order fits within the customers' specified parameters.

The manager informs inventory of the product request (1,2,3,4) and inventory sends a requests to SIP for the status confirmation that there is sufficient stock for each requested unique stock items. Request 4 informs the warehouse agent that there is not sufficient stock of this product, so the original request 4 from the customer cannot be satisfied. The warehouse agent informs the customer of the confirmed stock items and the one item that is now pending. The warehouse agent informs the worker that they should pick the requested stock items, and the worker agent requests the location status of the products and regulations regarding the appropriate packing tools or related instructions. The worker agent requests the quantity of the stock withdrawn from stock (request 0) and this is updated in Kanban by the SIP. Once all the stock is picked the worker agent informs the manager that all confirmation request have been satisfied.

This sequence of behaviour was confirmed as being consistent with the current onsite practices with the addition of the enhanced confirmations and checks shown by requests 8 and 9.

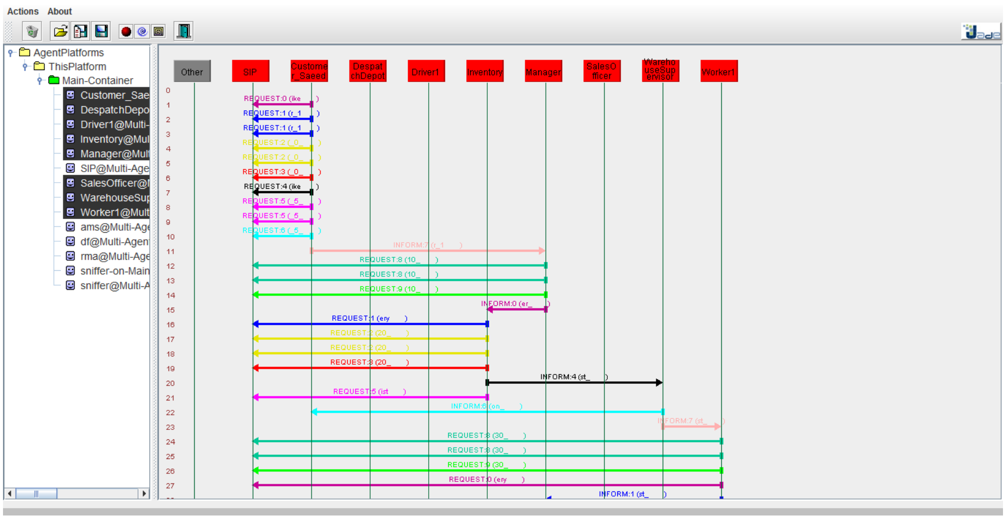


Figure 6.25: The sequence of agent behaviours and the relationships between agents

Figure 6.26 demonstrates the completed run, showing the complete sequence and the JADE completion screen. The system results for the time it takes to complete each sequence is compared with the actual timing for the current in-house manual warehouse and inventory systems in use by the organisation. This demonstrates that the Jade programme which includes the enhanced checks and confirmations introduced compares favourably with the in-house applications.

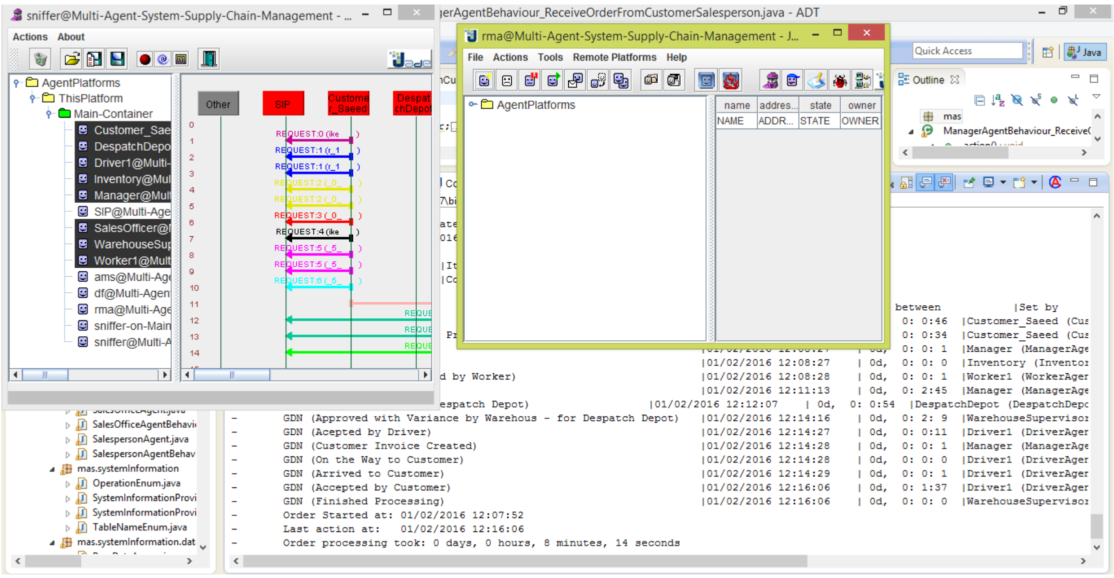


Figure 6.26: the completed rum showing the complete sequence and JADE completion screen

If a model can be relied on to reflect the behaviour of the target model, a simulation can be considered to correspond to the real world (Ramanath and Gilbert, 2003) and thus to be externally validated. Given the results outlined above, the developed LMAS model can be considered to be a verified virtual representation of the real-world workflow of this SME SC operations. The LMAS can now be used to demonstrate how the integration of the Lean system techniques of Kanban, 5S and 7 Wastes in a real-time MAS will influence the quality, time and cost factors within an operational workflow, through the application of real-world data.

6.8 Summary

This chapter proposed the design of a conceptual framework LMAS which, when developed and simulated with real-world data from a case study of a SME, demonstrated that the integration of the Lean system techniques of Kanban, 5S and 7 Wastes within a real-time MAS will positively influence the quality, time and cost factors within an operation. The virtual intelligent agents become additional resources that increase skill and capability within the SME and increase the capacity for decision-making in the SME.

7. RESULTS AND DISCUSSION

7.1 Introduction

The level of project success in LSS can be measured in terms of quality in general, efficiency, cost and responsiveness (Shah et al., 2008), which are in keeping with the measures of delivery, flexibility, quality and cost which are often seen in previous operations management literature (Ward and Duray, 2000). This means that it will be useful to measure how successful LSS has been by comparing process efficiency, responsiveness, quality and cost in projects to overall levels, along with observing the project's stage of maturity (Hilton and Sohal, 2012). In this chapter, the researcher presents an industrial case study to gain further insight and understanding of the integration LSS with MAS, and then applied the principles begins building the MAS model to test and demonstrate the proposed benefits of MAS. Experiments are the essence of research because they discover something about a particular process or system. Montgomery (2008) has defined experimentation as "*a test or series of tests in which purposeful changes are made to the input variables of a process or system so that we may observe and identify the reasons for changes that may be observed in the output response*". The researcher begins by introducing the industrial case and explaining the data collection approach, followed by a discussion of the results obtained and the validation process used.

7.2 Industrial Case

The case study is of an SME food distribution company in Saudi Arabia. This application will extend the work previously undertaken at the same SME. The company's activities are detailed in Chapter 4. This study aims to improve upon the original findings of the earlier investigation in which LSS was initially applied in Chapter 4. This case study intends to determine what further improvements can be obtained with the application of LSS principles, Kanban, 7Wastes and the 5S model integrated into the implementation of MAS within the SC.

7.3 Late Delivery Improvement

The first snapshot of data was initially collected in Chapter 4 from warehouse manager and driver delivery reports and included the investigated of a sample of 36 customers. Examination of the complaints database indicated that problems related to delivery were incorrect billing, late delivery, supply of a reduced quantity, substandard items delivered and incorrect products or quantities delivered. Late delivery to the shops was used as the critical-to-quality variable (CTQ-Y), with the defect being late delivery. This initial sample was followed by a more comprehensive, random study of 100 transactions. A random sample of 100 orders were collected daily during a four-week period. The cycle time measured for each activity in the SIPOC diagram was recorded in hours and shown below in the truncated Table 7.1.

Table 7.1: Current situation before improvement of delivery times of 100 transactions

	Delivery Time of 100 transactions – before improvement in hours									
Order Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	24.73	21.01	25.51	20.95	22.23	20.98	25.05	25.06	25.98	21.01
2	21.68	23.13	25.08	22.1	25.55	21.05	22.60	25.65	20.28	21.01
3	21.03	20.2	20.41	25.18	20.35	20.06	22.36	24.60	25.68	21.06
4	22.01	21.15	25.33	21.43	20.53	20.43	21.33	25.45	24.96	24.91
5	22.33	20.35	21.06	21.35	22.5	26.05	25.13	26.16	25.18	21.31
6	23.38	22.39	21.01	21.2	21.51	22.48	25.05	26.01	25.06	25.08
7	22.15	21.36	21.21	20.58	20.53	21.96	20.31	21.91	25.05	22.18
8	24.98	25.03	25.28	21.46	25.05	26.03	24.91	23.51	20.36	24.95
9	25.91	24.93	21.01	22.2	25.33	25.12	24.96	24.9,	23.11	25.16
10	21.21	25.05	21.33	25.25	20.95	20.91	20.21	25.18	24.98	19.96

The Total Cycle Time initially calculated in Chapter 4 for these 100 transactions was 1,380 minutes (23 hours) before improvement as indicated in Figure 7.2; therefore 23 hours has elapsed between receipt of the order from the customer through submission to sales administration and delivery to the customer, so effectively a whole working day was lost just here alone. Figure 7.2, indicates that, from the time that the order had been received by the administration, the time taken to fulfil it was 213 minutes (1380 minutes -1162-5 minutes). The sales office then processed the bill of sale, which was then collected by the warehouse supervisor; the stock was extracted, packed, loaded and delivered to the customer. The data collected from Table 7.1 is represented in the distributions graphs are shown in Figure 7.1 originally represented in Chapter 4 and indicate that the number of defects in a four week period was 42 late delivery times and the level of Six Sigma calculated was 1.7.

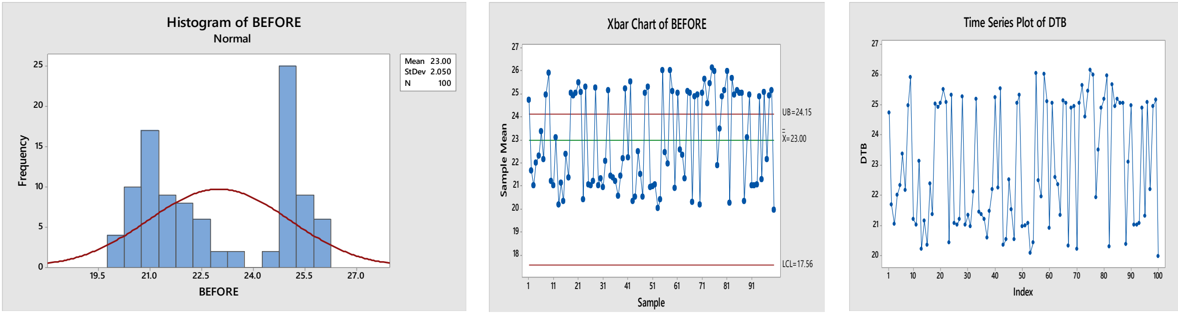


Figure 7.1: Distribution graphs before improvement

From this table, the average cycle times for the critical observations of these 100 operational processes (SIPOC) are presented in Figure 7.2. The most significant delay was the average of 1,162.32 minutes from the receipt of the order by the salesperson to its submission for processing. This delay was due to the salesperson's having to wait until the following morning to submit the order.

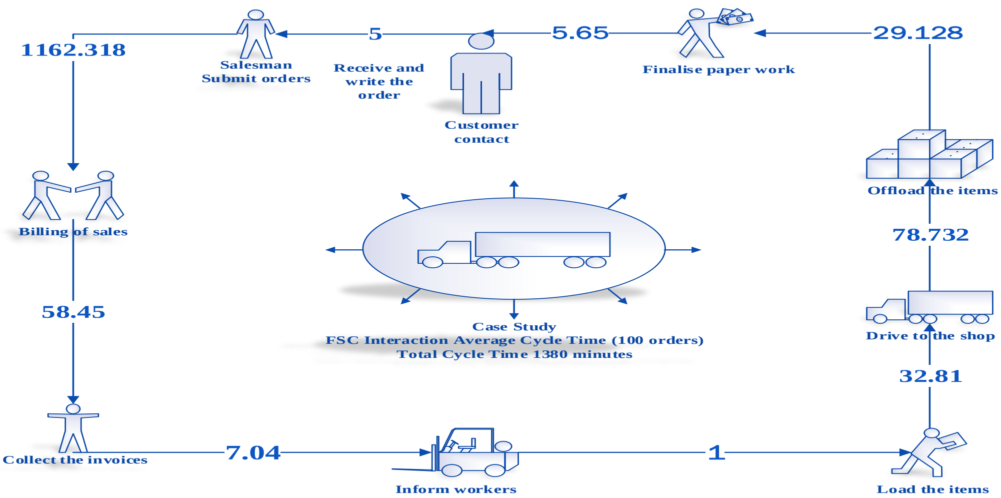


Figure 7.2: The case study FSC interaction average cycle time totalling 1380 minutes

Using LSS to obtain a root cause analysis of the poor quality of service identified in Figure 4.3 as the most significant issues to be addressed. Applying a number of operational improvements to the entire operation reduced defects by 95 percent and average delivery time by 27.8%, with a subsequent 40% fall in the number of customer complaints. Furthermore, the cost per defect was reduced by 48%, although this required changing the official office working hours as a temporary fix (during the DMAIC stage), producing a 29% improvement in this period, which was, however, not sustainable.

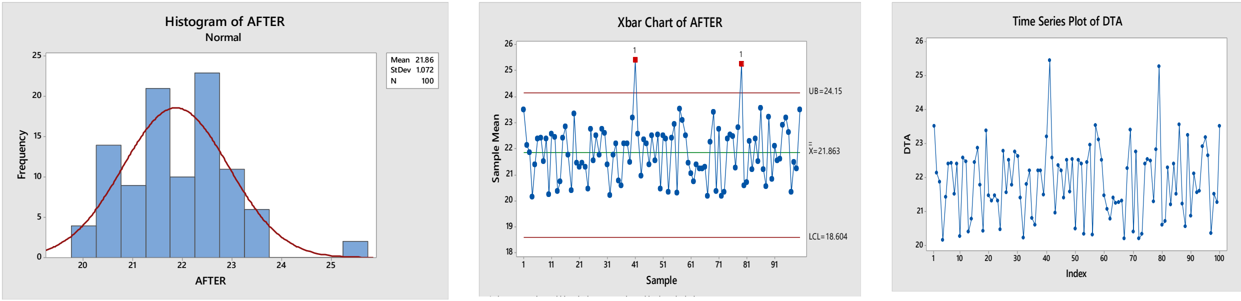


Figure 7.3: Distribution graphs after LSS improvement

Table 7.2: After improvement using LSS delivery time of 100 transactions

	Delivery Time of 100 transactions – after improvement									
Order Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	23.5	22.58	21.3	21.4	25.43	22.51	21.05	22.75	20.7	22.1
2	22.13	22.45	21.46	20.22	22.56	22.38	20.76	20.2	22.28	21.55
3	21.85	20.38	21.31	21.78	20.95	20.33	21.4	20.33	21.2	21.6
4	20.15	20.76	20.46	22.2	22.35	22.43	21.23	22.4	22.38	22.9
5	21.41	22.43	22.76	20.78	22.2	22.95	21.25	22.53	21.51	23.18
6	22.38	22.85	21.55	20.6	21.4	20.3	21.31	22.48	23.55	22.63
7	22.41	21.76	22.51	22.2	22.51	23.53	20.2	21.28	21.21	20.35
8	21.51	20.41	21.76	22.2	21.56	23.1	22.25	22.81	20.55	21.5
9	22.4	23.36	22.75	21.48	22.53	22.51	23.4	25.26	23.23	21.25
10	20.26	21.45	22.61	23.2	20.48	21.46	20.38	20.6	20.85	23.51

A permanent solution was therefore required to overcome the operational inefficiencies that resulted from the elapsed cycle time that included processing errors, defective stock and delivering partial stock to customers. In summary of the analysis of the results in chapter 4, the application of LSS based on late delivery produced an initial improvement from 1.7 to 3.55. However, as a more permanent solution was required to reduce the operational cycle time further, application of MAS was applied using a simulation approach of the 100 transactions to identify a potential permanent solution. Using this proposed MAS model integrated with the LSS principles of Kanban, 7 Wastes and 5S, over 100 simulations of orders were performed using LMAS; the results were obtained and compared with the original times as presented in Table 7.4 and Figure 7.5.

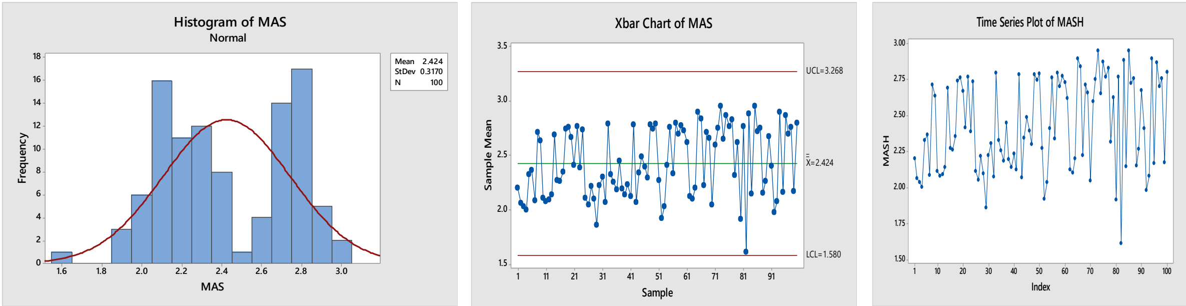


Figure 7.4: Distribution graphs after MAS improvement

Table 7.3: Matrix of delivery time of 100 transactions (after improvement using MAS).

	Delivery Time of 100 transactions– after MAS improvement									
Order Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	131.98	124.73	144.82	138.15	127.54	136.23	157.07	155.89	166.1	144.4
2	123.78	125.41	165.98	124.31	166.99	115.3	127.28	165.08	96.66	118.85
3	122.01	128.49	143.39	167.53	124.15	122.07	126.06	177.07	172.96	124.59
4	120.23	161.55	164.14,	139.52	140.7	144.52	131.88	159.14	128.85	173.74
5	139.59	136.46	126.63	135.26	149.26	165.77	173.73	172.2	177.05	129.91
6	141.9	135.8	122.96	131.14	143.54	140.16	170.25	166.13	163.45	171.98
7	125.2	141.17	133.07	146.92	137.89	167.66	133.3	169.56	165.28	161.92
8	162.77	164.52	125.84	131.51	166.98	162.01	162.71	139.06	129.11	165.37
9	158.05	165.73	111.54	128.5	164.82	166.46	159.41	157.35	135.87	130.29
10	126.73	160.03	133.32	133.93	167.3	163.82	122.87	114.72	160.43	168.03

The results in Table 7.4 demonstrate a significant reduction in the cycle time required to deliver orders to customers during official working hours from a total of 1,380 minutes to 145.36 minutes.

Table 7.4: Reduction in cycle time in FSC with MAS simulation (minutes)

Process	**Receive and write the order**	**Submit orders**	**Billing of sales**	**Collect the invoices**	**Inform workers**	**Processing time**	**Load the items**	**Drive to the shop**	**Offload the items**	**Finalise paper work**	**Total**
MAS Simulation	*	*	*	*	*	*				*	
Before improvement	5	1162.318	58.45	7.04	1	-	32.81	78.732	29.128	5.65	**1380**
After improvement	1.39	0.1	0.1	0.1	0.1	2.7	32.81	78.732	29.128	0.2	**145.36**

In principle, this demonstrates a nine-fold improvement in total time. There was a reduction in elapsed time from approximately 23 hours to 2 hours for the entire cycle, which is 10.31% of the time initially taken. Such a considerable improvement in delivery time would result in a direct measurable improvement in customer satisfaction and cost. This is summarised in Table 7.5 and the distribution graphs in Figure 7.5. The histogram clearly demonstrates that the "After" status now falls within the normal distribution range and that the fluctuation range spread is reduced.

Table 7.5: Demonstrable improvement in time for all stages

	Mean / hour	Standard deviation	Varianc e	USL	Capability process index	Sigma level
Current situation	23.002	2.050	4.201	24.15	0.187	1.7
Using LSS	21.863	1.072	1.149	24.15	0.713	3.55
Using MAS model	2.423	0.317	0.1005	24.15	2.125	5.99

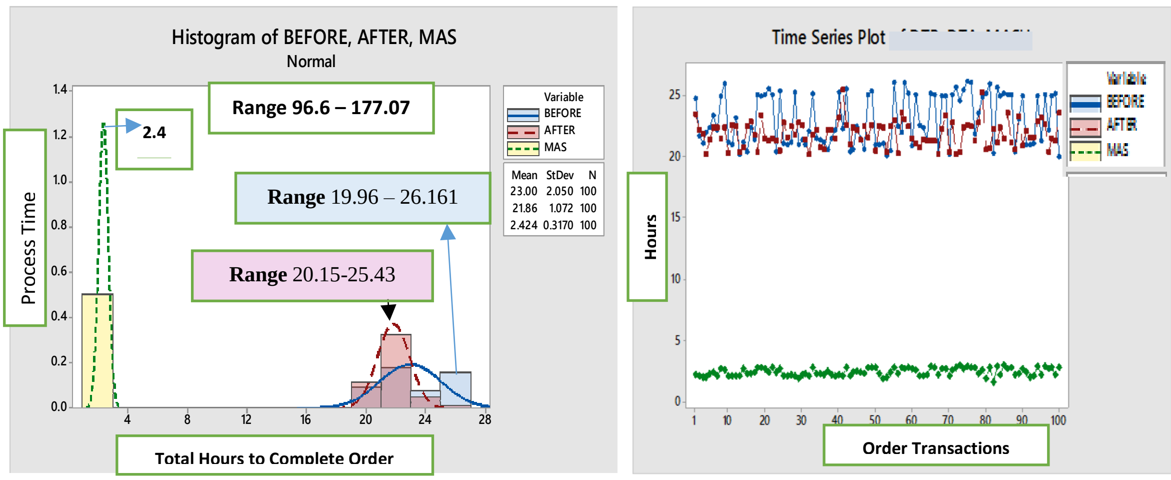


Figure 7.5: Summarised distribution graphs for all improvement stages

7.4 Quality Improvement

The second most significant issue experienced was quality concerns. An interview with the warehouse manager indicated that they believed the average the warehouse experienced 5% to 10% quality issues on the product and orders respectively. Table 7.6 shows a sample of 19 identified defects and errors from a sample of 100 orders.

Table 7.6: Quality defects and errors in sample in 1 Month period

Period	Defects/Errors	Reason	Time to fix	Source of Error
Week 1	Error in invoice	Sales office	1d	Admin
	Error in item number	Officer	1h	Admin
	Error in invoice	Salesperson	1d	Admin
	Incorrect items	Workers	1d	Admin
Week 2	Incomplete delivery	Workers	1d	Inventory
	Incorrect quantity	Workers	1d	Admin
	Error in prices	Salesperson	1d	Admin
	Incorrect quantity	Customer	1d	Admin
	Box Damaged	Picker	1d	Warehouse
	Food Expiration	Supplier	1d	Supplier
Week 3	Food Expiration	Expiration	1d	Inventory
	Box Damaged	Picker	1d	Warehouse
	Incomplete delivery	Workers	1d	Inventory
	Incomplete delivery	Workers	1d	Inventory
	Incomplete delivery	Workers	1d	Inventory
Week 4	Error in invoice	Sales office	1d	Admin
	Incorrect items	Workers	1d	Admin
	Incorrect quantity	Workers	1d	Admin
	Error in item No	Officer	1h	Admin

The defects, errors and full processing time were analysed. The results of the 100 orders represents an 81% yield with 19% defects, which calculates as a Six Sigma level of 2.38. Additionally, the defects per million opportunities (DPMO) calculated was 190,800 with only one opportunity in the current system to check for defects, and that check performed only by the customer. Using the Six Sigma conversion table, this presents the capability process index as 0.792 over the short term. This indicates there is significant room for improvement.

Table 7.7: Cumulative Time taken to initially process and then to repair the errors

	Sample (100 orders)			
Department	**Errors**	**Time to Process (Hrs)**	**Time to Repair (Hrs)**	**Total Cumulative Hours**
Admin	11	243	218	461
Warehouse	2	49	48	97
Inventory	5	117	5	122
Supplier	1	25	1	26
Total	**19**	**434**	**272**	**706**

Table 7.7 summarises the hours lost to the business according to the function where the error originated. LMAS was applied to reduce the incidence of these problems and improve operations to be more competitive. Using the developed integrated LMAS, a simulation of the orders was performed. Results were compared with the original result, indicating that 11% of the 19% were administration pricing and invoicing errors, which were eliminated in the LMAS simulation, as setting the price of stock in the system and calculating cost at each purchase would prevent such pricing errors. Furthermore, once a salesperson completed a sale, a copy of the order was generated by email and sent to the customer, displaying the correct item, price and total before the order was processed internally. Additionally, incorrect items were less likely to be picked, as the picking list was auto-generated by the system based on confirmed and approved orders. Each item picked required a check and confirmation at the picking stage and subsequently by the warehouse supervisor and at goods dispatch. These checks are very likely to spot and correct picking errors and reduce these error types. Eliminating the 11% admin errors reduced the total defect rate to 8%, a significant improvement in and of itself. The next error type was in the inventory function. Four of the errors were partially picked stock items from within inventory; this was a result of inaccurate picking by pickers. It is unlikely that this would occur under LMAS, although it will also auto-generate a pick list, because the products picked will need to be confirmed at three levels prior to actually being shipped, which would reduce errors by 4%.

There were two incidents of food decay in the warehouse function that resulted from missed expiry dates. One was the fault of the supplier, which is an external factor that cannot be remediated by the system, although it can be identified earlier at the Goods Receiving stage and prevented from being stored or delivered to the customer. The second was the result of poor stocking and picking policy. As the system would be managing the expiry dates using a FIFO, the system would alert the warehouse of such issues, reducing the likelihood of goods lost in this manner. Thus, the defect rate was reduced by another 2% from 4% to 2%. There were two incidents of boxes damaged when they arrived at the customer. These boxes were damaged within the warehouse and were not corrected at goods dispatch. It is unlikely that this error would occur in the LMAS because the new procedures require the state of the packaging is to be confirmed by the picker and at goods dispatch, and the driver must confirm receipt of undamaged packages. Furthermore, if the package were damaged in route to the customer, the driver must also confirm the state upon delivery to the customer, so the customer would not receive damaged goods. These checks would reduce the number of these errors to zero.

Applying these new defect rates, the new DPMO is calculated at 10 defects per million opportunities, taking into account the three checks for defects (sales, inventory and driver). The Six Sigma level is now recalculated from 2.38 to 5.76, which presents a capability process index of 1.958. This demonstrates a significant improvement towards the world-class level of Six Sigma. Based on the 272 hours lost in the sample of 100 order, when this is extrapolated to the full 250 orders expected per month this would translate into 1762 hours. On a 8 hour working day this would approximate 220 man days. Eliminating the administration, warehouse and inventory errors led to an estimated annualised minimum savings of 220 person-days. The cost of errors associated with administration, warehouse and inventory will lead to an annualised minimum saving of SR 208,820 of the 272 man-hours using the table of costs above. If the sample is extrapolated to 250 orders the full annualised saving of the error SR 445466 for the 220 man days.

Table 7.8: Results of current situation and LMAS model

	Capability Process Index	**Sigma level**
Current situation	0.792	2.38
Using LMAS model	1.958	5.76

7.5 Inventory Improvement

As the company had demonstrated significant issues related to stock management and warehousing in the sample, 20 stock items were selected out of 35 to gain specific details about the management of stock within the warehouse. Table 7.9 provides the details regarding the stock inventory system. An interview with the warehouse manager indicated that the warehouse experienced 5–10% quality issues on average; since they did not use Kanban techniques, stock was allowed to drop to zero, resulting in partial deliveries, pending orders and customer complaints. Purchase order quantities were based on annual average forecasts of the previous year with no accounting for new customers or changes in ordering trends. Furthermore, purchases were set to maximise purchasing power by bulk buying at lowest rates and discounts and to reduce shipping costs by having full containers.

Detailed analysis of the stock inventory indicated that the company frequently had depleted stock levels and items were damaged in the warehouse. This damage was associated with constant movement, storage of high levels of stock and the expiration of goods. In this sample, the cost of damaged inventory was calculated at SR 170,000, using the cost of stock and time lost in processing damaged goods. This produces a ratio of 1:2.6. Therefore, for each SR 1 of defective product, there is SR 2.6 of organisational cost to process and repair.

Table 7.9: Current stock levels for 20 products

Product number	Repeat orders	Best-case delivery time	Worst-case delivery time	Minimum order time	Safety stock	Current quantity	Standard quantity ordered	Maximum quantity in stock	Quality issues
1	500	30	40	90	30	0	6000	7000	5-10%
2	300	30	40	90	30	0	3600	4000	5-10%
3	30	40	60	180	30	0	720	750	5-10%
4	500	30	40	90	30	0	4500	5500	5-10%
5	500	30	40	90	30	5000	4500	5500	5-10%
6	500	7	14	30	30	0	3000	4000	5-10%
7	160	30	40	90	30	2000	3000	4000	5-10%
8	30	40	50	180	30	0	800	850	5-10%
9	250	40	50	180	30	35	3000	3500	5-10%
10	100	7	14	180	30	0	1200	1400	5-10%
11	100	7	14	180	30	5	1200	1400	5-10%
12	100	30	40	90	30	0	1000	1200	5-10%
13	500	30	40	90	30	0	6000	7000	5-10%
14	500	30	40	90	30	0	6000	7000	5-10%
15	300	30	40	90	30	0	3600	4000	5-10%
16	100	30	40	90	30	300	1000	1200	5-10%
17	100	30	40	90	30	0	1000	1200	5-10%
18	250	40	50	180	30	50	3000	3500	5-10%
19	300	30	40	90	30	0	3600	4000	5-10%
20	300	30	40	90	30	0	3600	4000	5-10%

The MAS enables a more responsive approach to forecasting stock levels that can significantly improve the issue of depleted and damaged stock. Using Kanban techniques, stock levels can be more dynamic and respond to current and predicted forecasts. The technique also encourages that minimum stock threshold levels be adopted to avoid situations where there is no stock available or excess stock is ordered although stock is still on hand. Therefore, the ordering quantity will change according to current stock levels and agreed-upon maximum stock levels. More advanced calculations can factor product expiry dates into the order thresholds. Two scenarios were simulated in LMAS. Scenario 1 was based on this sample and used the actual levels of stock present on the selection day. Additionally, this scenario assumed that the SME had not yet placed an order and that there were no standard pending orders. Kanban calculated the minimum threshold position (safety stock level + forecasted level of stock between two orders + pending orders) and the proposed Kanban order that the system would present for approval. The proposed Kanban order was compared to the current standard order quantity to determine the extent of over- or under-ordering.

Table 7.10: Scenario 1 no pending orders

SU	Repeat orders	Minimum order time	Safety stock	Safety stock quantity	Current stock position	Quantity when ordering	Minimum Kanban threshold	Kanban order	Surplus/ shortfall stock order	% Surplus/ shortfall of stock order	Cost of surplus/ shortfall (SR)
1	500	45	15	1071	0	6000	2500	4286	1714	40%	66846
2	300	45	15	643	0	3600	1500	2572	1028	40%	57568
3	30	60	20	86	0	720	214	343	377	110%	45805.5
4	500	45	15	1071	0	4500	2500	4286	214	5%	19474
5	500	45	15	1071	5000	4500	2500	0	4500	0%	301500
6	500	15	30	2143	0	3000	714	3215	-215	-7%	-3547.5
7	160	45	30	686	2000	3000	800	0	3000	0%	177000
8	30	60	30	129	0	800	193	386	414	107%	26082
9	250	60	30	1071	35	3000	1607	3180	-180	-6%	-11520
10	100	15	30	429	0	1200	143	643	557	87%	79651
11	100	15	30	429	5	1200	143	638	562	9%	76432
12	100	45	30	429	0	1000	500	1072	-72	-7%	-2952
13	500	45	15	1071	0	6000	2500	4286	1714	40%	59990
14	500	45	15	1071	0	6000	2500	4286	1714	40%	59990
15	300	45	15	643	0	3600	1500	2572	1028	40%	43176
16	100	45	15	214	300	1000	500	558	442	79%	64974
17	100	45	15	214	0	1000	500	858	142	17%	4118
18	250	60	30	1071	50	3000	1607	3165	-165	-5%	-14685
19	300	45	15	643	0	3600	1500	2572	1028	40%	89436
20	300	45	15	643	0	3600	1500	2572	1028	40%	52428
											1,191,766

Table 7.10 presents the comparison between the current standard order and the Kanban order. This table indicates the cost of the surplus and shortfall using the cost price. Figure 7.6 presents the comparison between the current standard order and the Kanban actual order, the level of surplus and shortfall of stock in ordering. The results show that the standard order significantly exceeds the Kanban level: stock unit 17 by17%, stock units 1, 2, 13 to 15, 19 and 20 exceed Kanban by 40% and stock unit 3 by 110%. The total value of the excess stock purchased is SR 1,191,766.

As the firm places large orders on a quarterly basis, this is an indication of the value of cash unnecessarily locked in the warehouse that would have a significant effect on cash flow. In the case of units 6, 9, 12 and 18, the order placed represented a shortfall of between 5–7%, which could result in a shortage of stock to match customer requests, increasing the likelihood of lost revenue, late delivery and reduced customer satisfaction. It could also lead to emergency purchases that are often accompanied by a higher overall cost per unit.

Although maximum capacity had not been reached in the warehouse, sample stock levels that were higher than necessary impacted space availability and increased the difficulty of managing expiry dates. Limited space means that stock is likely to be over-stacked, which leads to damaged containers and possibly to stock. When there is no space in the allocated bin, stock is then packed elsewhere, often in thoroughfares where the likelihood of damage goes up. This also increases the likelihood of accidents in the workplace. When stock is allocated to an alternate location or mixed with other stock bins holding less stock, stock goes ‘missing’, resulting in partial and late deliveries to customers. Although purchasing attempts to negotiate maximum buying discounts with bulk buys, the cost of the surplus calculated thus results in a substantial cash investment and reduced cash flow, while the cost of damaged and destroyed stock due to overstocking exceeds the discount savings.

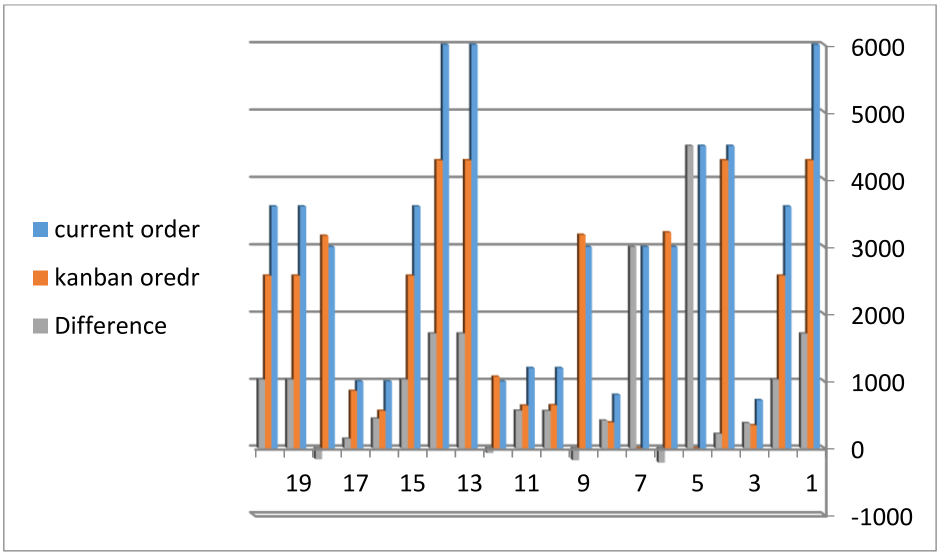


Figure 7.6: Chart demonstrating improvement by use of Kanban in Scenario 1

In scenario 2, the simulation assumed that the SME has in fact placed their order using the standard monthly order quantity determined from their annual planning forecast. The SME places this set quantity and does not consider the stock availability or the quantity of any pending stock items from partial deliveries. The SME standard order is used instead of letting the system calculate the Kanban order. The developed system then generated the final Kanban status. A comparison of the results is shown in Figure 7.7, with the difference between the standard set order and the Kanban order (Scenario 1) firs, followed by the results of the final

Kanban status compared to the established maximum stock capacity thresholds set by the SME in Table 7.11. This demonstrates how the results exceed warehouse space availability. The costs of the stock units that exceed the maximum threshold were then calculated.

Table 7.11: Scenario 2 Assumes Pending Orders at Levels Set by Organisation

Product number	Repeat orders	Minimum threshold Kanban	Minimum order time	Safety stock	Safety stock quantity Kanban	Kanban stock position	Quantity in pending (before Kanban)	Actual order Kanban	Maximum capacity excess/ availability	% Maximum capacity excess/ availability	Cost of excess capacity calculated (stock unit x cost price) (SR)
1	500	2500	45	15	1071	3572	6000	0	2572	137%	100308
2	300	1500	45	15	643	2143	3600	0	1742	144%	97552
3	30	214	60	20	86	300	720	0	270	136%	32805
4	500	2500	45	15	1071	3572	4500	0	2572	147%	234052
5	500	2500	45	15	1071	3572	4500	0	2572	147%	172324
6	500	714	15	30	2143	2857	3000	0	1857	146%	30640.5
7	160	800	45	30	686	1486	3000	0	486	112%	28674
8	30	193	60	30	129	321	800	0	271	132%	17073
9	250	1607	60	30	1071	2679	3000	0	2179	162%	139456
10	100	143	15	30	429	571	1200	0	371	127%	53053
11	100	143	15	30	429	571	1200	0	371	127%	50456
12	100	500	45	30	429	929	1000	0	-1129	6%	0
13	500	2500	45	15	1071	3571	6000	0	-4571	35%	0
14	500	2500	45	15	1071	3571	6000	0	-4571	35%	0
15	300	1500	45	15	643	2143	3600	0	-2543	36%	0
16	100	500	45	15	214	714	1000	0	-914	24%	0
17	100	500	45	15	214	714	1000	0	-914	24%	0
18	250	1607	60	30	1071	2679	3000	0	-3179	9%	0
19	300	1500	45	15	643	2143	3600	0	-2543	36%	0
20	300	1500	45	15	643	2143	3600	0	-2543	36%	0
											956,393.50

The analysis of the comparison between the actual existing order and the actual Kanban order in Figure 7.7 indicates the resulting surpluses and shortfalls. In this scenario, Kanban has indicated that not a single order should take place. All of these orders (with the exception of items 12–20) actually exceed the maximum capacity threshold, so the warehouse had to store the surplus stock in alternate areas and possibly mix stock units due to a lack of available space. Therefore, the ability to manage expiry dates decreased, whilst the likelihood of damaged stock increased. Additionally, the ability of the pickers to find stock in the warehouse is made more difficult and the likelihood of stock going “missing” is higher.

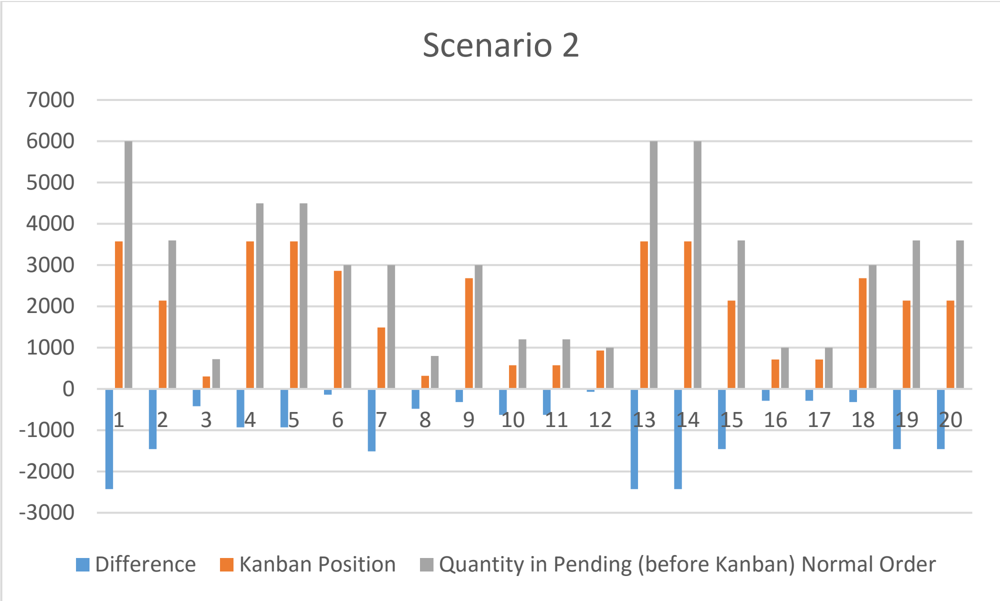


Figure 7.7: Chart demonstrating improvement by use of Kanban in Scenario 2

The cost of surplus stock exceeding maximum capacity from scenario 2 is SR 956,393. It is unlikely that the cost of any discount obtained from suppliers would make up for this excess spending. Table 7.12 below presents the overall savings; the financial calculations are representative of a sample size of 58% of the stock catalogue and 100 orders that represents 40% of monthly orders. The calculations from Scenario 1 demonstrate even higher savings.

Table 7.12: Financial savings in Saudi Riyal (SR) using Kanban and MAS

Scenario 1	Scenario 2
1,191,766	956,393

7.6 Cost Improvement

7.6.1 Cost of quality defects

The errors and problems from the 100 transactions allows the cost to the business to be extrapolated. Using the average costs supplied by management, it is possible to determine the costs of errors and defects to the business in this sample, which is then extrapolated for the month and the year, based on average orders per month. The costing methods was conducted using the average costs based on total operating costs. The average costs is obtained from a full burdened cost and unburdened cost respectively. The burdened cost includes the cost of the infrastructure and related operating costs, fuel and maintenance as well as the cost of personnel. The second method only used the average cost of salaries and wages with no burdened costs.

Therefore, if this was used the average hourly cost of the function that initiated the error would produce a lower cost. The average of these two costs have been used for calculations of cost. The total cost per month of the error extrapolated is SR37122 per month, annualised this is SR 445466. The actual lost time is calculated as approx 15.4 hours per week, 85 person-days per month.

7.6.2 Cost of damaged inventory

From the sample, one item had expired and therefore could not be sold and had to be discarded. According to the business, the actual annual cost of damaged and defective product is SR170,000. If this is added to the annualised average cost of defects and errors calculated SR 445466, this gives a total calculated annualised full cost of SR 615466 of errors and defects to the business. A correlation of waste can be calculated to provide an indicative relationship ratio: the ratio of annual defective product discarded can be linked to total organisational waste calculated annually associated with errors and defects in the operational SC. This indicative ratio produces a ratio of 1: 2.6, so for each SR1 of defective product an indicative ratio of SR 2.6 of total organisational cost has also been wasted in terms of cost to process and repair. This is the ratio used to demonstrate the quality relationship in the improvements. Any improvement in defective goods discarded will result in a 2.6 factor improvement in errors in the SC.

7.6.3 Cost of time wasted

Furthermore, there is a time aspect associated with quality defects, which is calculated in lost person-days. According to Table 7.7 the First the Cost to repair for the sample only is 272 hours lost per month However, as the original work required to process the item also has to be repeated, which is 434 hours, the total time lost therefore is 706 hours. Effectively 27.5 and 330 person-days annually are lost. If the level of waste were reduced by 272 hours in the sample then the cost of SR 14849 can be saved. However if this is extrapolated to the month then SR 37122 can be saved per month. A significant cost saving.

7.7 Case Study Evaluation

A meeting was held with the company manager, who is also a co-owner and had previously verified the procedural and system design, the sales manager, two employees and one long-term customer to discuss the results obtained from the system. After the presentation of the MAS system results for the respective scenario simulations the findings were discussed to highlight the differences between these scenarios and the current situation.

The first significant difference they observed was that their quality estimations of 5–10% errors were in fact low, as the MAS model showed it was actually more like 20%. The manager recognised that as they are not able to log all the quality issues, they recognised that the scale of errors indicated in the scenarios more accurately represented the nature and frequency of customer complaints. Therefore, in their opinion, the scale of improvements demonstrated by the use of Kanban inventory and procedural checks meant that they needed to consider this a priority and that it would significantly reduce incidents of late delivery and significantly improve customer satisfaction.

The second significant difference was the issue of time. As the MAS system integrated the ordering system and the warehouse, the manager realised this would save them considerable time currently lost in delays; they could also save the time spent correcting frequent human administration errors and avoid the frequent number of customer and stock orders that sometimes go missing because they are paper-based. The auto-generated picking and packing lists would also reduce time demands and avoid the current bottleneck of the warehouse supervisor having to check stock availability manually and then repeat the instructions to workers. This would simultaneously avoid many errors and potentially eliminate misallocation of stock to incorrect location bins. Any shortages or quality issues could be escalated immediately by the picker, packer or department and therefore prioritise the time of the supervisor appropriately. Furthermore, it would eliminate many quality control issues that arise from the over-and under-stock allocation problems experienced in the factory and depots, which wastes workers time because they have to search for stock. When the warehouses are full, this impedes the safe and timely movement of goods and people that currently results in quality deterioration and late delivery.

Furthermore, if these initial errors and quality issues were reduced, less time would need to be allocated to correcting errors, with more orders completed correctly the first time. The manager recognised that the firm would need to alter the layout of the warehouses and depots if the system were to be effective, but felt that was worth the investment, considering the potential time savings and the resulting reduction in unnecessary costs and delays. He noted that training would be needed to understand and use the system and how allocations work, but still felt that it would be much easier to use and understand than the current systems in place and was thus worthwhile. The final significant difference was cost. The company manager recognised the scale of the costs involved, indicating that this effectively explained the extent of loss and cost issues that they knew they were facing but could not actually calculate because of a lack of information. They could now understand why their actual profitability did not match their expectations. Their current financial systems could not capture information regarding quality, time lost or customer dissatisfaction, so they had no means of calculating that at present.

He indicated that the integration with sales, stock and warehousing would eliminate or reduce some of the most serious estimation issues associated with purchasing and production when they receive large, unexpected orders from customers and support their ability to manage factory production more effectively. The financial savings created by not making unnecessarily large orders compared to Kanban in Scenarios 1 and 2 were sufficient to restore the cash flow, improve profitability and justify the implementation of this type of system immediately. Furthermore, if physical stock-related quality issues and time delays in the warehouse and late delivery were reduced, the financial savings in labour productivity alone would translate into more time available to complete customer sales and directly increase profitability, as would less frequent occurrences of stock deterioration. The company manager stated that the financial results and the potential for cost improvement were very significant and that, with the quality improvement and time savings demonstrated, this system would deliver enhanced value added over the firm’s current isolated systems. Whilst the manager was not an expert in MAS and LSS technologies, he stated that all results obtained were sensible and logical given current realities within the firm.

7.7.1 Customer feedback

The customer advised that whilst low-level quality and invoicing errors were important, late delivery was the most important issue for them to service their own end customers. The customer indicated that they observed that if this system were in place, they could track their orders and avoid orders going missing and that they would be much more likely to receive correctly filled orders. The online system would be very beneficial, as it would formalise their relationship and orders and they would receive immediate confirmation. This was very important, as the system would indicate the expected delivery time do that the customer could ensure that their location and staff were ready to deal with the delivery. They would definitely value the ability to select the priority of their delivery if a situation developed that prevented a complete delivery at one time. The customer declared that he would prefer this system to the current one, as it would save them time, keep them better informed and allow them to plan their own business more effectively. It would also improve their own customer satisfaction.

7.7.2 Sales manager feedback

The sales manager believed that he would be the biggest beneficiary of the system, because it would reduce conflict and lack of cooperation he often experiences when he is forced to query errors and missing orders which result in delays and low customer satisfaction from late delivery and incorrect or incomplete deliveries. The sales manager currently wastes much of his time chasing down the sales team for their orders and correcting errors and mistakes that have occurred but where responsibility cannot be ascertained. This system would ensure that he allocated more of his time to supervision and enable the manager to engage proactively with customers, purchasing and the warehousing team to improve relations and meet more customer needs with a greater degree of satisfaction.

7.7.3 The employee's feedback

The system was discussed in general with the warehouse supervisor, then in more detail jointly with the two employee representatives, an administrator and an onsite warehouse employee. All the representatives agreed this would improve productivity, quality and working relationships. The representatives considered that the workflow was very important and that it clearly defined roles and allocated responsibilities, with clear separations of duties. As completed tasks were processed automatically, any problems or delays could be quickly identified, escalated and resolved. The representatives agreed that the system would improve communications and relations between their supervisors, the workers on the work floor and the different functions, thus significantly reducing interpersonal conflicts that often result when messages are lost, delayed or incorrectly interpreted.

The warehouse worker believe that the auto-generated tasks would be the most beneficial because they would avoid misallocating tasks to workers. The workers could inform supervisors immediately and save time lost searching the warehouse to locate the manager or supervisor. Additionally, as all escalations would be recorded and confirmed, the messages would be prioritised and actioned in the correct order, which would reduce delays in stock replacement orders, short deliveries, immediate identification of damaged or low levels of stock and the allocation of incoming stock to incorrect bins. The employee representatives reported that the system had considered all the key aspects of their work and the current problems that they faced. They did not suggest any improvements but recognised that all staff would need training to use the system effectively and that this would benefit them by increasing their skills.

7.8 Final Discussion and Summary

The purpose of this research was to understand the nature and scope of SMEs in the food industry, identify challenges and determine whether the application of LSS principles with MAS could support SMEs to overcome the challenges they faced in their SC operations. Whilst SMEs operations are similar to larger firms, because they lack the resources, systems and knowledge they lack the benefits of quality programmes. However, within the published literature there are gaps in how the integration of LSS and MAS can be applied to food distribution SMEs to support those operational improvement benefits.

The third chapter describes the application of the methodology adopted to collect data and analyse the nature of SMEs' operations and the challenges they face within their SCs. The study adopted a mixed quantitative-qualitative method, supported with an experimental approach. The data collection techniques included literature review, pilot study, questionnaire with semi-structured interviews and an empirical case study. The data collected helped to understand the nature of the scope and scale of the operations and practices within SMEs and to identify the challenges they face. The findings of the questionnaire survey and empirical case study were used to develop a conceptual framework of LSS and MAS. This conceptual framework was then developed within MAS and tested using a manual simulation that was verified. The results of the simulations were validated by interviews.

The case study of applying LSS to food distribution was undertaken in two phases, first to understand if the major challenges faced could be addressed using a Six Sigma DMAIC approach. The pilot study identified that late delivery and low customer satisfaction were considered the most significant problems, but when Six Sigma processes were applied, a significant improvement in late delivery issues was observed. Additionally, the process that contributed to the late delivery was developed within MAS, which also resulted in a significant improvement. The results indicated that the ease of use of MAS makes it a viable option for SMEs to integrate LSS more effectively and address the issues of delayed delivery and improving customer satisfaction. They would also gain indirect benefits that would improve quality and lower operational costs.

As the case study had indicated that the application of LSS principles with MAS could deliver improvements, the researcher sought to undertake the survey study. The methodology described the research design and approach of the main study, the research strategy and the methods used for data collection and analysis. The research aimed to create a greater understanding of existing practices in the Saudi Arabian food industry's SC by conducting a questionnaire and an empirical case study in SMEs in the food distribution sector. The findings were used to develop a framework for application in food distribution industry SMEs.

The analysis from the questionnaire made it evident that an SME in food distribution operates the same standard SC processes as a large firm, but in a predominantly manual environment. The SMEs' lack of sufficient resources and experience lead to several quality issues that are related to the way goods are stored, tracked and moved through the warehouse, resulting in high levels of defects, unsold goods disposal and stock shortages. Furthermore, the respondents indicated that have isolated and independent information systems and lack a seamless view of their operations. As a result, they suffer from loss of information, delays and frequent errors. The SME respondents had not taken advantage of modern operating practices and quality initiatives such as LSS and emergent RTI systems to support the growing dynamic complexity of their industry and manage their costs.

This research argues that, if these respondents introduce Lean Kanban inventory systems, 5S and 7Wastes techniques, this would reduce the cycle time for their processes as well as eliminate waste and defects such as the likelihood of late deliveries and not having sufficient stock to fulfil customer orders. Introducing standards to control optimal use of space by using 5S to sort out the warehouse and having a specific location and set quantity for stock would improve accessibility and address issues with communication in the warehouse. Effective stocking and storage will significantly reduce defects in, and damage and disposal of unsold stock. It will reduce wasted inspection times and overstocked warehouses and more optimally leverage available resources and personnel resources.

Adopting the Six Sigma approach to reduce process variation by embedding standardisation in the flow of goods processes and information flow leads to reduced levels of defects.

The combination of these two overcome many of the identified constraints in the warehouse but, with the addition of the MAS contribution, also allows limitations in skills to be addressed, costs to be reduced and quality to be improved. The introduction of intelligent agents extends the staffing virtually, increasing capacity and the capability to direct activities and assist decision-making. The intelligent real-time system therefore support firms in collaborating and coordinating functions and reducing waste; a complex decision-making capability promotes a more standardised SC feed-forward and feedback loop in a timely fashion. Management resources can then focus on exceptions and escalations instead of detailed daily transactional processes and delegate more of the detailed emphasis on quality into the system.

However, if they combined these standards with real-time system, this study suggests that they could improve collaboration and coordination between functions in a seamless way, clarify timely instructions, prompt relevant action by appropriate personnel across all departments and therefore better manage and maintain the feed-forward and feedback flow of requests and supplies within the enterprise. They could then leverage the benefits of the available resources more effectively, forecast seasonal variations in demand and manage the dynamic changes and quality issues within their SCs, leaving them able to accept new customers without compromising their level of service.

The emergence of alternate technologies such as MAS provides a more easy-to-use, affordable, real-time solution that can support compliance with LSS practices and facilitate collaboration and intelligent decision-making in a complex dynamic distribution environment by addressing the typical obstacles experienced by SMEs at manageable costs. Based on the recommendations, the study proposed a final framework that demonstrates how the critical factors reported by the respondents (quality, stock availability and lower cost) can be addressed by better managing the influencing variables of space, skill, storage through creating a more standardised and interconnected environment facilitated by an autonomous intelligent system. Developing this proposed LSS framework in MAS will further improve their operational efficiency. This research proposes that a simulation of real data within this LMAS will demonstrate how it can create additional capacity and therefore help SMEs utilise their limited personnel and support staff with lower skills to present the required information or undertake their work with greater emphasis on quality assurance and support. This would enable SMEs to overcome the lack of skills, interconnectivity and communication challenges and achieve higher levels of customer satisfaction and competitiveness at both local and global levels.

In the sixth chapter, the study presents the design of a conceptual framework LMAS which is then developed. LMAS uses the methodology guidelines published on the JADE site by TILAB. The system was developed on the JADE platform using Java programming. The roles of each agent are described within the operational procedures, which included Lean principles, the 5S, Kanban and the 7 Wastes. The relevance and functionality of the system's real data has been introduced and validated with interviews. The manager of the SME verified, with minor changes, that the procedures, functions and the agent behaviour when were a true representation of the operational processes in the real-world workflow sequence. Additionally, a second verification process confirmed that the results from the simulation program were a good representation of the conceptual model. A test case was conducted and a sample of customer order requests were processed through the program. The system presented precisely the same results as the warehouse and inventory staff conducting the checking and picking activities of the sampled stock items on the warehouse floor.

The seventh chapter presents the results and findings from a manual simulation of 100 random transactions from the SME where the LSS had been tested in the initial case study. The scale of the improvement achieved after the LSS was significant for late delivery with a Six Sigma level improving 1.7 to 3.55. However, after application of the LSS with MAS developed in this study, a further significant improvement to a Six Sigma level of 5.99 was observed. In quality improvement the level of Six Sigma showed similar improvement, from 2.38 to 5.76. Therefore, this study recommends that serious consideration should be given to this integrated implementation in SMEs in other service industries. It is important to note that this is only a demonstration, albeit one using real-world data, and that an agent-based system is not necessarily a universal solution within any SME in food distribution. Two scenarios were simulated to demonstrate the results that the integration of the Lean system techniques of Kanban, 5 S and 7W within a real-time MAS would positively influence the quality, time and cost factors within the operations.

8. CONCLUSION AND FURTHER WORK

8.1 Introduction

This chapter presents the conclusions drawn from this research, shares some of the model's strengths and advantages, offers suggestions regarding some areas for future work which will build on this research, and explains the originality of this research regarding the knowledge in this area.

8.2 Conclusion

The purpose of this research was to determine whether the application of LSS principles with MAS could support SMEs in overcoming the challenges they face in their SC operations.

The food distribution firm, irrespective of size, comprises a complex interplay of functional services that manage information and resources to control the flow of goods within their operations. The businesses that manage their information effectively are able to minimise the inefficiencies that cause bottlenecks, waste, variation in quality and service, increased costs, and customer dissatisfaction. Larger firms within the industry have been able to overcome many of their complex issues with advanced skills, techniques and technologies such as LSS, Total Quality Management (TQM) and Total Quality Control (TQC), Agile Manufacturing, Lean Manufacturing, Kanban and, more recently, in the field of artificial intelligence, with MAS.

Salah et al. (2011) have stated that LSS and SCM have several features in common in terms of how they concentrate on processes and on solving customer problems in order to achieve customer satisfaction; they also complement each other and can be integrated. This applies generally in business, including food distribution SMEs, regardless of their type and size. However, the literature review and the empirical case study of 39 firms confirmed that smaller firms within the food industry still have to address the same problems and complexity as larger firms, but lack the finances, knowledge and skills, resources and systems needed to take advantage of these advanced techniques.

The researcher identified a gap in the literature regarding the integration of LSS and MAS and that this integration could be beneficial to SMEs and help them compete more effectively despite their lack of resources. The evaluation of the results regarding the design and development of LMAS have clearly demonstrated that the integration of the LSS principles when established within the real-world MAS platform significantly improves the quality, cost and time factors which were identified as the critical factors by the respondents in the survey.

The manual introduction of Lean Six Sigma demonstrated an improvement in cycle time from 23 to 21.8 hours. The operational improvements reduced defects by 95% and improved delivery times by 27.8%. The implementation of the Kanban inventory system, quality assurance and 5S and 7 Wastes techniques within the Six Sigma approach can overcome the frequency of defects in the management of the stock, reducing the associated costs. Standardising and sorting the warehouse optimises space, and specified locations for stock which ensures that stock is more easily accessed and available results in effective stocking and storage which significantly reduces defects and damage in unsold stock and the need for its disposal. This would also reduce the likelihood of partial and late deliveries associated with a shortage of stock. This was demonstrated by the significantly improved level of Six Sigma which rose from 1.7 to 3.55.

The introduction of intelligent real-time agents with MAS facilitated the standardised SC feed-forward and feedback loop with a timely flow of information and instructions, enabled complex stock calculations and improved decision-making capability. This freed up management resources to deal with exceptions and escalations instead of detailed daily transactional processes and introduced a more detailed emphasis on quality into the system. This was demonstrated in the simulation by the improved level which rose from 3.55 to 5.99 – a significant improvement.

The adoption of the proposed conceptual framework for SMEs in general has considerable potential. The strengths and advantages are as follows:

- LMAS is relatively generic and is applicable in other sectors that use the same type of business processes;
- The proposed design and development of this framework is based on information and knowledge gained from SMEs in the chosen sector. The simulation applied LSS and the MAS system employed real data from an SME;
- The LMAS model presents known and proven benefits from service industry operations and literature that demonstrate both Lean's and Six Sigma's abilities to monitor and control variation;
- The SME can build LMAS gradually; the investment is comparatively low in relation to other enterprise real-time and independent systems. Most of the investment goes to

training staff on the application of tools and the use of simulation software. Therefore the investment is affordable for most SMEs;

- The visual aspects, workflow and the agent behaviour make LMAS easy to translate into the workplace; this trial proved that the two phase approach is feasible. The LSS framework can be implemented without technical complications, after which the introduction of MAS can improve operational performance.

8.3 Contribution to Knowledge

This research contributes to the knowledge of how the integration of Lean Six Sigma operating practices with MAS can assist SMEs overcome their many limitations in resources and skills and enable them to be more competitive through the improvement in their cost effectiveness, quality control and enhanced customer satisfaction. This research has made significant contributions to knowledge in the following aspects:

- A framework has been developed to integrate the LSS Principles with MAS to improve the operational efficiency for SMEs within the food distribution industry;
- In this framework a conceptual model was developed to improve SCM performance. This model incorporates Lean Methods (Kanban, and 5S and 7W) within the Multi-Agent System (LMAS) to improve quality, stock control, and training of the workers, which decreases exposure significantly to quality issues related to expired stock, over-stocking of warehouses, delayed deliveries, and customer dissatisfaction;
- This model demonstrates that an SME can introduce LSS with a flexible real time information system at lower cost and can support SMEs to help them become more globally competitive;
- The application of LSS within an SME’s current operational practices in the FSC has been examined and the impact and benefits of LSS in relation to operational performance in the FSC have been demonstrated to be quality improvement and cost savings;
- The operational practices and the difficulties that SMEs face in the food distribution sector in Saudi Arabia have been surveyed using an empirical study. This research provides insight into the scope and nature of operational practices, and difficulties and issues faced by SMEs within their SC operations that impinge on quality standards in the Saudi Arabian food distribution industry.

This new knowledge will be of significance to academics, practitioners and researchers in the fields of LSS, MAS and SC research. Furthermore, this study offers solutions to the obstacles and problems encountered by managers when attempting to implement LSS efficiently in SMEs in the food distribution industry. This research will benefit SMEs in many countries by helping reduce waste, increase efficiency in organisations and improve the manufacture and delivery of products.

8.4 Limitations and Recommendations for Further Work

However, there are some limitations and some proposals can be made for further work:

- There is a need to populate the entire stock inventory system; standards of space allocation have to be set up and included within the data tables;
- Consideration needs to be given to how workers will be able to access the system during their picking, packing and delivery duties. This will require an investment in sufficient tools for them to access the online system;
- There will be a need to maintain new suppliers and customers; testing and pilot trials will be required, which could affect operational productivity;
- The simulation to assess the effectiveness could be more effectively exploited using simulation techniques such as Monte Carlo to overcome some of the limitations addressed above;
- Finally, a real-time system needs to be backed up regularly and backup facilities must be tested; any issues that could cause downtime could have considerable impacts on the business;
- There is no universally appropriate system, so each business will need to customise the generic framework to meet its own needs. Further, if the 5S are incorporated, the warehouse must apply the design layout necessary to enable the 5S to operate correctly;
- The LMAS provides a means to manage operational performance but does not provide similar metrics to evaluate other aspects within business performance affected by operational performance.

The proposed model and development for the LMAS arose from information gained in the literature review, the survey and case study results, and also the author's own experience with and knowledge of Lean and Six Sigma. Therefore, this work may have a limited perspective and further research may be needed on how the integration of LSS and MAS can be used to support external SCs so that SMEs are able to benefit from being part of a global SC.

Furthermore, more detailed research is merited on how LMAS concepts could be applied to the manufacturing processes and inventories within the SMEs that operate these factories. This would enable even further improvements in cash flow and profitability through managing work in progress and raw materials to be made. Consideration could also be given to how such a framework can help these SMEs to obtain quality certifications that would enable them to operate further afield and export and attract a wider customer base.

Additionally, a more comprehensive simulation using simulation techniques such as Monte Carlo could improve the design and allow the model to be adapted so that it can be exploited more effectively.

References

AB RAHMAN, M., ISMAIL, A., DERO, B. M. & ROSLI, M. 2008. Barriers to SCM implementing. *Journal of Achievements in Materials and Manufacturing Engineering,* 31**,** 718-724.

AHN, H. J., LEE, H. & PARK, S. J. 2003. A flexible agent system for change adaptation in supply chains. *Expert Systems with Applications,* 25**,** 603-618.

AHUMADA, O. & VILLALOBOS, J. R. 2009. Application of planning models in the agri-food supply chain: A review. *European Journal of Operational Research,* 196**,** 1-20.

AL-HABIB, M. 2012. Identifying the traits of entrepreneurs in a university setting: An empirical examination of Saudi Arabian University students. *The International Business & Economics Research Journal (Online),* 11**,** 1019.

AL-MAHDI, H. Supporting SME's by Universities: An Empirical Study in Saudi Arabia towards Building a Conceptual Model for Best Practices. BBS Doctoral Symposium, 2009. 23-24.

ALSALEH, N. 2007. Application of quality tools by the Saudi food industry. *The TQM Magazine,* 19**,** 150-161.

ALSMADI, M., LEHANEY, B. & KHAN, Z. 2012. Implementing Six Sigma in Saudi Arabia: An empirical study on the fortune 100 firms. *Total Quality Management & Business Excellence,* 23**,** 263-276.

AMER, Y., LUONG, L., LEE, S.-H., WANG, W. Y., ASHRAF, M. A. & QURESHI, Z. Implementing design for six sigma to supply chain design. Industrial Engineering and Engineering Management, Paper presented at IEEE IEEM, 2–5 December 2007, Singapore, pp.1517–1521.

ANDERSEN, T. J. 2001. Information technology, strategic decision making approaches and organizational performance in different industrial settings. *The Journal of Strategic Information Systems,* 10**,** 101-119.

ANTONY, J. 2004. Six Sigma in the UK service organisations: results from a pilot survey. *Managerial Auditing Journal,* 19**,** 1006-1013.

ANTONY, J. 2011. Six Sigma vs Lean: Some perspectives from leading academics and practitioners. *International Journal of Productivity and Performance Management,* 60**,** 185-190.

ANTONY, J. & DESAI, D. A. 2009. Assessing the status of Six Sigma implementation in the Indian industry: results from an exploratory empirical study. *Management Research News,* 32**,** 413-423.

ANTONY, J., ESCAMILLA, J. L. & CAINE, P. 2003. Lean Sigma [production and supply chain management]. *Manufacturing Engineer,* 82**,** 40-42.

ANTONY, J., JIJU ANTONY, F., KUMAR, M. & RAE CHO, B. 2007. Six sigma in service organisations: Benefits, challenges and difficulties, common myths, empirical observations and success factors. *International journal of quality & reliability management,* 24**,** 294-311.

ANTONY, J., KUMAR, M. & MADU, C. N. 2005. Six sigma in small-and medium-sized UK manufacturing enterprises: Some empirical observations. *International Journal of Quality & Reliability Management,* 22**,** 860-874.

ANTONY, J., SWARNKAR, R., KUMAR, M. & TIWARI, M. K. 2006. Design of synchronised supply chain: a genetic algorithm based six sigma constrained approach. *International Journal of Logistics Systems and Management,* 2**,** 120-141.

ARNHEITER, E. D. & MALEYEFF, J. 2005. The integration of lean management and Six Sigma. *The TQM magazine,* 17**,** 5-18.

ARTHUR, J. 2007. *Six sigma simplified*, KnowWare International.

AYERS, J. B. 2001. Introduction to the supply chain. *Handbook of supply chain management. Boca Raton, FL: St. Lucie Press*.

BAHADDAD, A. A., ALGHAMDI, R. & HOUGHTON, L. 2012. To What Extent Would E-mall Enable SMEs to Adopt E-Commerce? *arXiv preprint arXiv:1211.2402*.

BALLOU, R. H., GILBERT, S. M. & MUKHERJEE, A. 2000. New managerial challenges from supply chain opportunities. *Industrial Marketing Management,* 29**,** 7-18.

BARBUCEANU, M., TEIGEN, R. & FOX, M. S. Agent based design and simulation of supply chain systems. Enabling Technologies: Infrastructure for Collaborative Enterprises, 1997. In Proceedings of WETICE 1997 (pp. 36–42). IEEE Computer Society Press.

BASU, R. 2004. Six-Sigma to operational excellence: role of tools and techniques. *International Journal of Six Sigma and Competitive Advantage,* 1**,** 44-64.

BELLIFEMINE, F., POGGI, A. & RIMASSA, G. JADE–A FIPA-compliant agent framework. Proceedings of PAAM, 1999. London, 33.

BELLIFEMINE, F., POGGI, A. & RIMASSA, G. 2001. Developing multi-agent systems with a FIPA-compliant agent framework. *Software-Practice and Experience,* 31**,** 103-128.

BEN MAHMOUD, H., KETATA, R., BEN ROMDHANE, T. & BEN AHMED, S. Modeling Quality Management System: A multi-agent approach. International Conference for Internet Technology and Secured Transactions, ICITST 2009. (pp. 1-6).

BEVAN, H. 2006. *Lean Six Sigma: some basic concepts*, NHS Institute for Innovation and Improvement.

BLAXTER, L. 2010. *How to research*, Open University Press, UK.

BRYMAN, A. & BELL, E. 2015. *Business research methods*, Oxford University Press, USA.

CARTER, S. & JONES-EVANS, D. 2006. *Enterprise and small business: Principles, practice and policy*, Pearson Education.

CARVALHO, R. & CUSTÓDIO, L. 2005. A multiagent systems approach for managing supply-chain problems: new tools and results. *Inteligencia Artificial,* 9**,** 79-88.

CAVINATO, J. L. 1992. A total cost/value model for supply chain competitiveness. *journal of Business Logistics,* 13**,** 285.

CHAN, F. T. & CHAN, H. K. 2006. A simulation study with quantity flexibility in a supply chain subjected to uncertainties. *International Journal of Computer Integrated Manufacturing,* 19**,** 148-160.

CHRISTOPHER, M. 1998. Logistics and supply chain management: Strategies for reducing cost and improving service. Pitman Publishing, London.

CINGIL, I. & DOGAC, A. 2001. An architecture for supply chain integration and automation on the internet. *Distributed and parallel databases,* 10**,** 59-102.

CLARK, T. H. & HAMMOND, J. H. 1997. Reengineering channel reordering processes to improve total supply-chain performance. *Production and Operations Management,* 6**,** 248-265.

CLEGG, B., PEPPER, M. & SPEDDING, T. 2010. The evolution of lean Six Sigma. *International Journal of Quality & Reliability Management,* 27**,** 138-155.

COLLINS, J. & HUSSEY, R. 2003. *Business Research,* Hampshire, UK, Palgrave Macmillan.

CORNFORD, T. & SMITHSON, S. 2006. *Project research in information systems: a student's guide*, Palgrave.

COUNCIL OF SAUDI CHAMBERS. 2006. *Statistical about the food factories* [Online]. Saudi Arabia: Council of Saudi Chambers. Available: http://www.csc.org.sa/arabic/Pages/ChambersResearch.aspx [Accessed 20/3/2015.

CRESWELL, J. W. 2003. *Research design : qualitative, quantitative and mixed methods approaches,* Thousand Oaks, Calif. ; London, SAGE.

CRESWELL, J. W. 2013. *Research design: Qualitative, quantitative, and mixed methods approaches*, Sage publications.

CROTTY, M. 1998. *The foundations of social research : meaning and perspective in the research process,* London ; Thousand Oaks, Calif., Sage Publications.

DASGUPTA, T. 2003. Using the six-sigma metric to measure and improve the performance of a supply chain. *Total Quality Management and Business Excellence,* 14**,** 355-366.

DEFRA. 2006. *Food industry sustainability strategy* [Online]. UK: Department for Environment, Food and Rural Affairs. Available: https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs [Accessed 15/3/2015].

EASTERBY-SMITH, M., THORPE, R. & LOWE, A. 2002. *Management research*, Management research: An introduction, Sage Publications Ltd.

EL YASMINE, A. S. L., GHANI, B. A., TRENTESAUX, D. & BOUZIANE, B. 2014. Supply Chain Management Using Multi-Agent Systems in the Agri-Food Industry. *Service Orientation in Holonic and Multi-Agent Manufacturing and Robotics.* Springer.

ELASRAG, H. 2012. The developmental role of SMEs in the Arab countries. *Available:* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2127954 [Accessed 15/3/2015].

ELLRAM, L. M. & COOPER, M. C. 1990. Supply chain management, partnership, and the shipper-third party relationship. *The International Journal of Logistics Management,* 1**,** 1-10.

FAWCETT, S. E. & MAGNAN, G. M. 2001. *Achieving world-class supply chain alignment: benefits, barriers, and bridges*, Center for Advanced Purchasing Studies Tempe, AZ.

FAWCETT, S. E., MAGNAN, G. M. & MCCARTER, M. W. 2008. Benefits, barriers, and bridges to effective supply chain management. *Supply Chain Management: An International Journal,* 13**,** 35-48.

FEARNE, A. & HUGHES, D. 2013. Success factors in the fresh produce supply chain. *British food journal*.

FERBER, J. & PERROT, J.-F. 1995. *Les systèmes multi-agents: vers une intelligence collective*, InterEditions.

FERRIN, D. M., MUTHLER, D. & MILLER, M. J. Simulation of customer-focused business processes: Six Sigma and simulation, so what's the correlation? Proceedings of the 34th conference on Winter simulation: exploring new frontiers, 2002. Winter Simulation Conference, 1439-1443.

FIELDING, N. & SCHREIER, M. Introduction: On the compatibility between qualitative and quantitative research methods. Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 2001. Qualitative Social Research, vol. 2, no. 1, art. 4.

FLYNN, B. B., SAKAKIBARA, S., SCHROEDER, R. G., BATES, K. A. & FLYNN, E. J. 1990. Empirical research methods in operations management. *Journal of operations management,* 9**,** 250-284.

FOLKERTS, H. & KOEHORST, H. 1998. Challenges in international food supply chains: vertical co-ordination in the European agribusiness and food industries. *British Food Journal,* 100**,** 385-388.

FOSTER, S. T. & GANGULY, K. K. 2007. *Managing quality: Integrating the supply chain*, Pearson Prentice Hall Upper Saddle River, New Jersey.

GANESHAN, R. & HARRISON, T. P. 1995. An introduction to supply chain management. *Department of management sciences and information systems,* 303.

GENESERETH, M. R. & KETCHPEL, S. P. 1994. Software agents. *Commun. ACM,* 37**,** 48-53.

GEORGE, M. 2002. Lean six sigma: combining six sigma quality with Lean production speed, combining six sigma quality with Lean production speed. McGraw Hill Professional.

GEORGE, M., ROWLANDS, D., PRICE, M. & MAXEY, J. 2005. The lean six sigma pocket toolbook.

GEORGE, M. L. & GEORGE, M. 2003. *Lean six sigma for service*, McGraw-Hill New York, NY.

GEORGE, M. L., ROWLANDS, D. & KASTLE, B. 2007. *Was ist Lean Six Sigma?*, Springer-Verlag.

GUNASEKARAN, A., PATEL, C. & TIRTIROGLU, E. 2001. Performance measures and metrics in a supply chain environment. *International journal of operations & production Management,* 21**,** 71-87.

HALGERI, P., MCHANEY, R. & PEI, Z. 2010. ERP systems supporting lean manufacturing in SMEs.

HANDFIELD, R. B. & NICHOLS, E. L. 1999. *Introduction to supply chain management*, prentice Hall Upper Saddle River, NJ.

HELMING, J., KOEGEL, M., SCHNEIDER, F., HAEGER, M., KAMINSKI, C., BRUEGGE, B. & BERENBACH, B. Towards a unified requirements modeling language. Requirements Engineering Visualization (REV), 2010 Fifth International Workshop on, 2010. IEEE, 53-57.

HIGGINS, A., MILLER, C., ARCHER, A., TON, T., FLETCHER, C. & MCALLISTER, R. 2010. Challenges of operations research practice in agricultural value chains. *Journal of the Operational Research Society,* 61**,** 964-973.

HILTON, R. J. & SOHAL, A. 2012. A conceptual model for the successful deployment of Lean Six Sigma. *International Journal of Quality & Reliability Management,* 29**,** 54-70.

HOERL, R. W. & GARDNER, M. M. 2010. Lean Six Sigma, creativity, and innovation. *International Journal of Lean Six Sigma,* 1**,** 30-38.

HOPP, W.J. & SPEARMAN, M.L., 2004. to pull or not to pull: what is the question?. *manufacturing & service operations management*, 6(2), pp.133-148.

JACOBSON, J. M. & JOHNSON, M. E. 2006. Lean and Six Sigma: not for amateurs. *Laboratory Medicine,* 37**,** 78-83.

JAIN, J., DANGAYACH, G., AGARWAL, G. & BANERJEE, S. 2010. Supply chain management: literature review and some issues. *Management,* 2**,** 0.

JANKOWICZ, A. D. 2005. *Business research projects,* Cengage Learning EMEA.

JENNINGS, N. R. 2001. An agent-based approach for building complex software systems. *Communications of the ACM,* 44**,** 35-41.

JING, G. 2009. A Lean Six Sigma breakthrough, quality progress. *American Society of Quality***,** 24-31.

JULKA, N., SRINIVASAN, R. & KARIMI, I. 2002. Agent-based supply chain management—1: framework. *Computers & Chemical Engineering,* 26**,** 1755-1769.

KANNAN, V. R. & TAN, K. C. 2005. Just in time, total quality management, and supply chain management: understanding their linkages and impact on business performance. *Omega,* 33**,** 153-162.

KARLSSON, C. 2002. Guest Editorial: Special issue on research methodology in operations. *International Journal of Operations and Production Management,* 22**,** 141-147.

KELTON, W. D., SADOWSKI, R. P. & SADOWSKI, D. A. 2007. *Simulation with ARENA (4th ed.)*, McGraw-Hill, Inc.

KILPATRICK, J. 2003. Lean principles. *Utah Manufacturing Extension Partnership***,** 1-5.

KIVELA, J. & KAGI, J. 2009. Applying Six Sigma in foodservice organizations. *Turizam: znanstveno-stručni časopis,* 56**,** 319-337.

KNOX, K. 2004. A researcher's dilemma-philosophical and methodological pluralism. *Electronic journal of business research methods,* 2**,** 119-128.

KREJCI, C. C. & BEAMON, B. M. Modeling food supply chains using multi-agent simulation. Proceedings of the Winter Simulation Conference, 2012. Winter Simulation Conference, 104.

KUMAR, S., PHILLIPS, A. & RUPP, J. 2009. Using Six Sigma DMAIC to design a high-quality summer lodge operation. *Journal of Retail & Leisure Property,* 8**,** 173-191.

KURESHI, N., MANN, R., KHAN, M. & QURESHI, M. 2009. Quality management practices of SME in developing countries: a survey of manufacturing SME in Pakistan. *Journal of Quality and Technology Management,* 5**,** 63-89.

KWAK, Y. H. & ANBARI, F. T. 2006. Benefits, obstacles, and future of six sigma approach. *Technovation,* 26**,** 708-715.

LA LONDE, B. J. & MASTERS, J. M. 1994. Emerging logistics strategies: blueprints for the next century. *International journal of physical distribution & logistics management,* 24**,** 35-47.

LABROU, Y. & FININ, T. Towards a standard for an Agent Communication Language. American Association for Artificial Intelligence fall symposium on "Communicative actions in humans and machines, 1997.

LAMBERT, D. & STOCK, J. 1993. Strategic Logistics Management, 3rd edn (Homewood, IL: Richard D. Irwin). Inc.

LAMBERT, D. M., COOPER, M. C. & PAGH, J. D. 1998. Supply chain management: implementation issues and research opportunities. *The international journal of logistics management,* 9**,** 1-20.

LAMBERT, D. M., GARCÍA-DASTUGUE, S. J. & CROXTON, K. L. 2005. An evaluation of process-oriented supply chain management frameworks. *Journal of business Logistics,* 26**,** 25-51.

LAURIE, H. & SULLIVAN, O. 1991. Combining qualitative and quantitative data in the longitudinal study of household allocations. *The Sociological Review,* 39**,** 113-130.

LEE, H. L. & BILLINGTON, C. 1995. The evolution of supply-chain-management models and practice at Hewlett-Packard. *Interfaces,* 25**,** 42-63.

LEE, K.-C. & CHOI, B. 2006. Six Sigma management activities and their influence on corporate competitiveness. *Total Quality Management & Business Excellence,* 17**,** 893-911.

LEE, S. M., OLSON, D. L., LEE, S.-H., HWANG, T. & SHIN, M. S. 2008. Entrepreneurial applications of the lean approach to service industries. *The Service Industries Journal,* 28**,** 973-987.

LIAU, C.-J. 2003. Belief, information acquisition, and trust in multi-agent systems—a modal logic formulation. *Artificial Intelligence,* 149**,** 31-60.

LINCOLN, Y. S. & DENZIN, N. K. 1994. *Handbook of qualitative research*, Sage Publications, Inc.

LUMMUS, R. R., KRUMWIEDE, D. W. & VOKURKA, R. J. 2001. The relationship of logistics to supply chain management: developing a common industry definition. *Industrial Management & Data Systems,* 101**,** 426-432.

MACINNES, R. L. 2002. *The lean enterprise memory jogger: create value and eliminate waste throughout your company*, Goal QPC Inc.

MADER, D. P. 2009. Lean Six Sigma's evolution: Integrated method uses different deployment models. *Quality control and applied statistics,* 54**,** 43-44.

MAHFOUZ, A. 2011. *An Integrated Framework to Assess' Leanness' Performance in Distribution Centres.* Ph. D. thesis, Dublin Institute of Technology, Dublin.

MANGINA, E. & VLACHOS, I. P. 2005. The changing role of information technology in food and beverage logistics management: beverage network optimisation using intelligent agent technology. *Journal of Food Engineering,* 70**,** 403-420.

MARSDEN, T., MURDOCH, J. & MORGAN, K. 1999. Sustainable agriculture, food supply chains and regional development: editorial introduction. *International Planning Studies,* 4**,** 295-301.

MATURANA, F. P., TICHÝ, P., ŠLECHTA, P., DISCENZO, F., STARON, R. J. & HALL, K. 2004. Distributed multi-agent architecture for automation systems. *Expert Systems with Applications,* 26**,** 49-56.

MAYER, R. C., DAVIS, J. H. & SCHOORMAN, F. D. 1995. An integrative model of organizational trust. *Academy of management review,* 20**,** 709-734.

MCADAM, R. & DONEGAN, S. 2003. A comparative analysis of trilateral and concurrent business improvement methodologies in the high technology sector. *International journal of manufacturing technology and management,* 5**,** 210-231.

MCMILLAN, J. H. A. S., S. 2001. *Research in education: A conceptual introduction. 5th edition,* Longman, New York.

MEEHAN, J. & MUIR, L. 2008. SCM in Merseyside SMEs: benefits and barriers. *The TQM Journal,* 20**,** 223-232.

MENTZER, J. T., DEWITT, W., KEEBLER, J. S., MIN, S., NIX, N. W., SMITH, C. D. & ZACHARIA, Z. G. 2001. Defining supply chain management. *Journal of Business logistics,* 22**,** 1-25.

MERDAH, W. O. A. & SADI, M. A. 2011. Technology Transfer in Context with Saudi Arabian Small-Medium Enterprises. *International Management Review,* 7**,** 30.

MEREDITH, J. 1998. Building operations management theory through case and field research. *Journal of operations management,* 16**,** 441-454.

MI DAHLGAARD-PARK, S., ANDERSSON, R., ERIKSSON, H. & TORSTENSSON, H. 2006. Similarities and differences between TQM, six sigma and lean. *The TQM magazine,* 18**,** 282-296.

MI DAHLGAARD-PARK, S. & BENDELL, T. 2006. A review and comparison of six sigma and the lean organisations. *The TQM magazine,* 18**,** 255-262.

MINISTRY OF COMMERCE AND INDUSTRY. 2015. *Food factories in Saudi* [Online]. Ministry of Commerce and Industry. Available: http://mci.gov.sa/en/Pages/default.aspx [Accessed 3/3/2015].

MO YANG, H., SEOK CHOI, B., JIN PARK, H., SOO SUH, M. & CHAE, B. 2007. Supply chain management six sigma: a management innovation methodology at the Samsung Group. *Supply Chain Management: An International Journal,* 12**,** 88-95.

MONCZKA, R. M. & MORGAN, J. 1997. What's wrong with supply chain management. *Purchasing,* 122**,** 69-73.

MONTGOMERY, D. C. 2008. *Design and analysis of experiments*, John Wiley & Sons.

MOOSA, K. & SAJID, A. 2010. Critical analysis of Six Sigma implementation. *Total Quality Management,* 21**,** 745-759.

MORGAN, G. & BURRELL, G. 1979. Sociological paradigms and organisational analysis: elements of the sociology of corporate life. *Aufl., London*.

MOWAT, A. & COLLINS, R. 2000. Consumer behaviour and fruit quality: supply chain management in an emerging industry. *Supply Chain Management: An International Journal,* 5**,** 45-54.

MOYAUX, T., CHAIB-DRAA, B. & D'AMOURS, S. 2006. Supply chain management and multiagent systems: An overview. *Multiagent based supply chain management.* Springer.

MYOUNG, K., PARK, S., YANG, K., KANG, D. & CHUNG, H. A supply chain management process modelling for agricultural marketing information system. EFITA, 3rd conference of the European Federation for Information Technology in Agriculture, Food and the Environment, Montpellier, France, June 18, 2001.

NABHANI, F. & SHOKRI, A. Application of Six Sigma in a Food Distribution SME to improve Supply Chain Management. World Congress on Engineering, 2007. 1162-1170.

NABHANI, F. & SHOKRI, A. 2009. Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology. *Journal of manufacturing technology Management,* 20**,** 957-974.

NAGENDRA, P. B. 1999. MRP/sfx: a Kanban-oriented shop floor extension to MRP. *Production Planning & Control,* 10**,** 207-218.

NÄSLUND, D. 2008. Lean, six sigma and lean sigma: fads or real process improvement methods? *Business Process Management Journal,* 14**,** 269-287.

NASLUND, D. & WILLIAMSON, S. 2010. What is management in supply chain management?-a critical review of definitions, frameworks and terminology. *Journal of Management Policy and Practice,* 11**,** 11-28.

NAU, D. S. 1995. Mixing methodologies: can bimodal research be a viable post-positivist tool? *The Qualitative Report,* 2**,** 1-6.

NEUMAN, W. L. A. K., L. 2003. *Social work research methods: Qualitative and quantitative approaches,* Boston, Allyn and Bacon.

NIKRAZ, M., CAIRE, G. & BAHRI, P. 2006. *A methodology for the analysis and design of multi-agent systems using JADE,* Rockingham, Western Australia, Center, Murdoch University.

NISSEN, M. E. 2001. Agent-based supply chain integration. *Information Technology and Management,* 2**,** 289-312.

NORTH, M. J. & MACAL, C. M. 2007. *Managing business complexity: discovering strategic solutions with agent-based modeling and simulation,* Oxford University Press.

NOVACK, R. A. & SIMCO, S. W. 1991. The industrial procurement process: a supply chain perspective. *Journal of Business Logistics,* 12**,** 145.

O'ROURKE, P. M. 2005. A multiple-case analysis of Lean Six Sigma deployment and implementation strategies. DTIC Document.

OPPENHEIM, A. N. 2000. *Questionnaire design, interviewing and attitude measurement*, Bloomsbury Publishing.

OTSUKI, M. 2002. SMEs supporting systems in Saudi Arabia. *Speech under the technical cooperation of SAGIA (Saudi Arabian General Investment Authority) and JICA (Japan International Cooperation Agency),* available *at:* http://www.planning.gov.sa/SME Development in Saudi Arabia.doc [Accessed 3/4/2013].

PANDE, P. S., HOLPP, L. & PANDE, P. 2002. *What is six sigma?,* McGraw-Hill New York, NY.

PAOLUCCI, M., REVETRIA, R. & TONELLI, F. 2008. An Agent-based system for sales and operations planning in manufacturing supply chains. *WSEAS TRANSACTIONS on Business and Economics,* 3**,** 103-112.

PAPADOPOULOU, T. C. 2013. *Application of lean scheduling and production control in non-repetitive manufacturing systems using intelligent agent decision support.* Brunel University School of Engineering and Design PhD Theses.

PARAST, M. M. 2011. The effect of Six Sigma projects on innovation and firm performance. *International Journal of Project Management,* 29**,** 45-55.

PARK, S. & SUGUMARAN, V. 2005. Designing multi-agent systems: a framework and application. *Expert Systems with Applications,* 28**,** 259-271.

PARVEEN, M. & RAO, T. 2009. An integrated approach to design and analysis of lean manufacturing system: a perspective of lean supply chain. *International Journal of Services and Operations Management,* 5**,** 175-208.

POLK, J. 2011. Lean six sigma, innovation, and the change acceleration process can work together. *Physician Exec,* 37**,** 38-42.

PORTER, A. M. 1997. One focus, one supply base. *Purchasing,* Vol. 6, p. 50–59.

RADY, H. A. 2011. Multi-agent system for negotiation in a collaborative supply chain management. *International Journal of Video & Image Processing and Network Security IJVIPNS-IJENS,* 11.

RAMANATH, A. M. & GILBERT, N. 2003. Towards a Methodology for Agent-based Social Simulation Research. *Agent-based Social simulation SIG, Barcelona*.

RAO, M. P. 2006. A performance measurement system using a profit-linked multi-factor measurement model. *Industrial Management & Data Systems,* 106**,** 362-379.

ROBSON, C. 2002. *Real world research: A resource for social scientists and practitioner researchers,* Wiley-Blackwell.

RONG, A., AKKERMAN, R. & GRUNOW, M. 2011. An optimization approach for managing fresh food quality throughout the supply chain. *International Journal of Production Economics,* 131**,** 421-429.

SABERI, S. & MAKATSORIS, C. 2008. Multi agent system for negotiation in supply chain management.

SALAH, S., RAHIM, A. & CARRETERO, J. A. 2010. The integration of Six Sigma and lean management. *International Journal of Lean Six Sigma,* 1**,** 249-274.

SALAH, S., RAHIM, A. & CARRETERO, J. A. 2011. Implementation of Lean Six Sigma (LSS) in supply chain management (SCM): an integrated management philosophy. *International Journal of Transitions and Innovation Systems,* 1**,** 138-162.

SAMSUNG 2007. Samsung does six sigma: A case study on supply chain management. *Strategic Direction,* 23.

SAUNDERS, M., LEWIS, P. & THORNHILL, A. 2009. *Research Methods for Business Students, 5th Edition*, Prentice Hall.

SAUNDERS, M. & THORNHILL, P. 2003. *Research Methods for Business Students,* London, Financial Times Prentice Hall Inc.

SCHROEDER, R. G., LINDERMAN, K., LIEDTKE, C. & CHOO, A. S. 2008. Six Sigma: Definition and underlying theory. *Journal of operations Management,* 26**,** 536-554.

SCHWANDT, T. A. 2000. Three epistemological stances for qualitative inquiry. *Handbook of qualitative research,* 2**,** 189-213.

SCOTT, C. & WESTBROOK, R. 1991. New strategic tools for supply chain management. *International Journal of Physical Distribution & Logistics Management,* 21**,** 23-33.

SEKARAN, U. 2006. *Research methods for business: A skill building approach*, John Wiley & Sons.

SERUGENDO, G. D. M., GLEIZES, M.-P. & KARAGEORGOS, A. 2011. *Self-organising software: From natural to artificial adaptation*, Springer Science & Business Media.

SHAH, R., CHANDRASEKARAN, A. & LINDERMAN, K. 2008. In pursuit of implementation patterns: the context of Lean and Six Sigma. *International Journal of Production Research,* 46**,** 6679-6699.

SHAMOU, M. & ARUNACHALAM, S. 2009. Integrating lean and six sigma for optimum manufacturing performance.

SHAMOU, M. E. I. 2011. *Development of an optimum framework for lean six sigma in small and medium manufacturing enterprises.* University of East London.

SHOKRI, A., NABHANI, F. & HODGSON, S. 2010. Supplier development practice: Arising the problems of upstream delivery for a food distribution SME in the UK. *Robotics and Computer-Integrated Manufacturing,* 26**,** 639-646.

SILVERMAN, D. 2013. *Doing qualitative research: A practical handbook*, SAGE Publications Limited.

SIMCHI-LEVI, D. 2005. *Designing and managing the supply chain*, Mcgraw-Hill College.

SINCLAIR, K., PHELPS, R. & SADLER, B. 2005. The Integration of Lean and Six Sigma–A powerful improvement strategy for Carbon Plants. *Light Metals***,** 641-646.

SNEE, R. D. 2010. Lean Six Sigma-getting better all the time. *International Journal of Lean Six Sigma,* 1**,** 9-29.

SONI, G. & KODALI, R. 2008. Evolution of supply chain management: development in academia and industry. *ICFAI Journal of Supply Chain Management,* 40**,** 7-40.

SPECTOR, R. E. 2006. How constraints management enhances lean and six sigma. *Supply chain management review, v. 10, no. 1 (Jan./Feb. 2006), p. 42-47: ill*.

STOCK, J. R. & BOYER, S. L. 2009. Developing a consensus definition of supply chain management: a qualitative study. *International Journal of Physical Distribution & Logistics Management,* 39**,** 690-711.

STRATOPOULOS, T. & DEHNING, B. 2000. Does successful investment in information technology solve the productivity paradox? *Information & management,* 38**,** 103-117.

SU, C.-T., CHIANG, T.-L. & CHANG, C.-M. 2006. Improving service quality by capitalising on an integrated Lean Six Sigma methodology. *International Journal of Six Sigma and Competitive Advantage,* 2**,** 1-22.

SWAMINATHAN, J. M., SMITH, S. F. & SADEH, N. M. 1998. Modeling supply chain dynamics: A multiagent approach*. *Decision sciences,* 29**,** 607-632.

TALIB, F. & RAHMAN, Z. 2010. Integrating total quality management and supply chain management: similarities and benefits. *Journal of Information Technology and Economic Development,* 1**,** 53.

TAN, K., LYMAN, S. B. & WISNER, J. D. 2002. Supply chain management: a strategic perspective. *International Journal of Operations & Production Management,* 22**,** 614-631.

TAN, K. C., KANNAN, V. R. & HANDFIELD, R. B. 1998. Supply chain management: supplier performance and firm performance. *Journal of Supply Chain Management,* 34**,** 2.

TARIQ, M. U. & KHAN, M. N. A. 2011. An Insight into Risk Identification, Quality and Productivity Enhancement using Six Sigma. *Journal of Education and Vocational Research,* 2**,** 24-33.

TASHAKKORI, A. & TEDDLIE, C. 2010. *Sage handbook of mixed methods in social & behavioral research*, Sage.

TAYLOR, G. M. 2008. *Lean six sigma service excellence: A guide to green belt certification and bottom line improvement,* J. Ross Publishing.

THABANE, L., MA, J., CHU, R., CHENG, J., ISMAILA, A., RIOS, L. P., ROBSON, R., THABANE, M., GIANGREGORIO, L. & GOLDSMITH, C. H. 2010. A tutorial on pilot studies: the what, why and how. *BMC medical research methodology,* 10**,** 1.

THOMAS, A., BARTON, R. & CHUKE-OKAFOR, C. 2008. Applying lean six sigma in a small engineering company-a model for change. *Journal of Manufacturing Technology Management,* 20**,** 113-129.

TICEHURST, G. W. & VEAL, A. J. 2000. *Business research methods.* , Frenchs Forest, Australia, Longman.

TJAHJONO, B., BALL, P., VITANOV, V. I., SCORZAFAVE, C., NOGUEIRA, J., CALLEJA, J., MINGUET, M., NARASIMHA, L., RIVAS, A. & SRIVASTAVA, A. 2010. Six Sigma: a literature review. *International Journal of Lean Six Sigma,* 1**,** 216-233.

TODORUŢ, A. V., CÎRNU, D. & NICULESCU, G. 2009. The relation among six sigma and other managerial techniques of improving the performances of the organizations. *OF THE UNIVERSITY OF PETROŞANI∼ ECONOMICS∼***,** 289.

TODORUŢ, A. V., RĂBONŢU, C. I. & CÎRNU, D. 2010. Lean management-The way to a performant enterprise. *OF THE UNIVERSITY OF PETROŞANI∼ ECONOMICS∼***,** 333.

TOLMIE, A., MUIJS, D. & MCATEER, E. 2011. *Quantitative methods in educational and social research using SPSS,* McGraw-Hill Education (UK).

TRYBUS, E. 2005. Six Sigma and Lean Manufacturing. *SME Technical Paper 2005*.

UM, W., LU, H. & HALL, T. J. 2010. A study of Multi-agent based supply chain modeling and management. *iBusiness,* 2**,** 333.

VAN DER VORST, J., BEULENS, A. & VAN BEEK, P. 2005. 10. Innovations in logistics and ICT in food supply chain networks. *Innovation in Agri-food Systems: Product Quality and Consumer Acceptance***,** 245.

VAN DER VORST, J. G. 2006. Performance measurement in agri-food supply-chain networks. *Quantifying the agri-food supply chain.* Springer.

VAN DER VORST, J. G., TROMP, S.-O. & ZEE, D.-J. V. D. 2009. Simulation modelling for food supply chain redesign; integrated decision making on product quality, sustainability and logistics. *International Journal of Production Research,* 47**,** 6611-6631.

VERHEES, F. J. & MEULENBERG, M. T. 2004. Market orientation, innovativeness, product innovation, and performance in small firms. *journal of small business management,* 42**,** 134-154.

VONDEREMBSE, M. A., UPPAL, M., HUANG, S. H. & DISMUKES, J. P. 2006. Designing supply chains: Towards theory development. *International Journal of Production Economics,* 100**,** 223-238.

VOSS, C., TSIKRIKTSIS, N. & FROHLICH, M. 2002. Case research in operations management. *International journal of operations & production management,* 22**,** 195-219.

WAINER, G. A. 2009. *Discrete-event modeling and simulation: a practitioner's approach,* CRC Press.

WARD, P. T. & DURAY, R. 2000. Manufacturing strategy in context: environment, competitive strategy and manufacturing strategy. *Journal of Operations Management,* 18**,** 123-138.

WARING, A. 1996. *Practical systems thinking,* Cengage Learning EMEA.

WELCH, J. & WELCH, S. 2005. *Winning,* New York, Harper Business.

WIDODO, K., NAGASAWA, H., MORIZAWA, K. & OTA, M. 2006. A periodical flowering–harvesting model for delivering agricultural fresh products. *European Journal of Operational Research,* 170**,** 24-43.

WOMACK, J. P. & JONES, D. T. 1996. Lean thinking: Banish waste and create wealth in your organisation. *Simon and Shuster, New York, NY,* 397.

WOOLDRIDGE, M. 2009. *An introduction to multiagent systems,* John Wiley & Sons.

WOOLDRIDGE, M. & JENNINGS, N. R. 1995. Intelligent agents: Theory and practice. *Knowledge engineering review,* 10**,** 115-152.

XU, H. & SHATZ, S. M. 2003. Adk: An agent development kit based on a formal design model for multi-agent systems. *Automated Software Engineering,* 10**,** 337-365.

YIN, R. K. 1994. *Case study research : design and methods,* London, Sage Publications.

YIN, R. K. 2013. *Case study research: Design and methods,* Sage publications.

YU, M. & NAGURNEY, A. 2013. Competitive food supply chain networks with application to fresh produce. *European Journal of Operational Research,* 224**,** 273-282.

YUAN, Y., LIANG, P. & ZHANG, J. J. 2001. Using agent technology to support supply chain management: potentials and challenges.

YUNG, S. K., YANG, C. C., LAU, A. S. & YEN, J. 2000. Applying Multi Agent Technology to Supply Chain Management. *J. Electron. Commerce Res.,* 1**,** 119-132.

ZAHEDIRAD, R. & SHIVARAJ, B. 2011. Supply chain: barriers and benefits Indian SMEs. *SCMS Journal of Indian Management,* 8**,** 11.

ZHANG, M. J. & LADO, A. A. 2001. Information systems and competitive advantage: a competency-based view. *Technovation,* 21**,** 147-156.

ZHANG, Q., IRFAN, M., KHATTAK, M. A. O., ZHU, X. & HASSAN, M. 2012. Lean Six Sigma: a literature review. *Interdiscip J Contemp Res Bus,* 3**,** 599-605.

Appendixes

Appendix A: Questionnaire Form in English

Appendix B: Questionnaire Form in Arabic

Appendix C: Ethics Approval

Appendix D: Results and Analysis Tables

Appendix E: Examples of Configurations

Appendix F: Procedure

Appendix A: Questionnaire Form in English

Questionnaire

Please read the questions carefully and answer them as appropriate (tick the answer of your choice or write the answer in the allocated space, choose one answer unless instructed otherwise).

Section 1 : Business Demographics (Influencing Variables)

1- How many workers does your company employ?

0-9 ☐ 10-49 ☐ 50-100 ☐ More than 100 ☐

2- Company Annual Turnover (optional)

Less than 2 million ☐ 2-10 million ☐ 11-20 million ☐ more than 20 million ☐

3- Your company role? (Select most appropriate option)

Owner/ CEO/Managing Director ☐ Head of Technical Operations ☐ Quality Manager ☐

Other (please specify):…………………………..

4-What is the ownership status of this company?

Locally owned ☐ Part of a Multinational Organisation ☐ A Joint Venture ☐

5- For how long has the company been in business? (Select most appropriate option)

Less than 12 months ☐ 1-2 years ☐ 2-5 years ☐ 5-10 years ☐ 10+ years ☐

6- In which Countries do you sell your products? (Tick all that apply)

Local ☐ Europe ☐ China ☐ India ☐ Africa ☐ **Other**………………

7- Where do you source your goods? (Tick all that apply)

Saudi ☐ Gulf Countries ☐ Africa, India, Asia ☐ ROW ☐

8- Generally, how far are most of your customers?

Same City ☐ Regional ☐ Countrywide ☐

9- Do you have the following? (Indicate the quantity)

Factory ☐ Depots ☐ Warehouses ☐ Distribution Centres ☐ **Other** ……………

10- What is the size of the fleet you operate (transportation/ delivery trucks) for deliveries?

Less than 5 ☐ 6- 20 ☐ More than 20 ☐

11- Do your drivers work according to a driver shift/rota system?

No ☐ Sometimes ☐ Yes ☐

12- Do you have standardised and documented procedures for all your operations?

No ☐ Some ☐ Yes ☐

13- Do you train your staff on these procedures?

Not at all ☐ Only once ☐ Fairly Often ☐ Regularly ☐

14- Do you think there are improvements needed in your operations?

No ☐ I don't know ☐ Yes ☐ (**Select all applicable options**)

Lead Times ○ Delivery Time ○ Quality ○ Lower Costs ○ Stock Availability ○ Flexibility ○

15- Which of the following measures of efficiency do you consider to be the most important?

Please rate the following measures of efficiency in your order of importance	**Very Important**				**Least Important**
	1	**2**	**3**	**4**	**5**
Lead Times					
Delivery Time					
Quality					
Lower Costs					
Stock Availability					
Flexibility					

16-Which functions do you think need the most improvement?

Please rate the functions in the order of improvement needed.	**Most Improvement**				**Least Improvement**
	1	**2**	**3**	**4**	**5**
Sales					
Purchasing					
Warehousing					
Transport					
Inventory					
Quality of Products					
Administration					

17 - What are the main obstacles/barriers you experience?

……………………………………………………………………………………..………………

Section 2 : Operations Value Stream (SCM Flow Paths)

Section 2.1 : Goods/Material Flow

1- How long are products held in stock by your company?

1-3 days ☐ 3-7 days ☐ 7-14 days ☐ 30 days or more ☐

2- How many products do you sell ?

1 - 10 ☐ 11- 20 ☐ 21 – 40 items ☐ more than 50 ☐

3- When do you reorder stocks and/or raw materials?

When no stock exists ☐ When stock reaches a set level ☐ To fill an order ☐ Other ☐

4- Where are stocks or raw materials stored?

Warehouse Bins ☐ Holding areas ☐

5- Do you hold buffer stock or maintain safety stock levels to prevent outages?

No ☐ Some ☐ Yes ☐

6- How many stock items have specific location (Bin) labelled with product details and stock quantity?

None ☐ Some ☐ All ☐

7- Do you maintain any of the specific stocking method policies?

NONE ☐ FIFO ☐ LIFO ☐ Other ☐

8- How frequently do you conduct Stock Counts?

None ☐ weekly ☐ Monthly ☐ Yearly ☐

9- Do you have to dispose of unsold goods and products?

Not at all ☐ Frequently ☐ Regularly ☐

Section 2.2 : Warehousing

1-How full is your warehouse in general?

Less than 30% ☐ 30- 50% ☐ 51- 75% ☐ Over 75% ☐

2- How frequently do goods/materials move before they reach their stores location?

I-2 times ☐ 3-6 times ☐ more ☐

3. Do you have a separate location for Goods Receiving?

No ☐ Yes in the warehouse ☐ Yes but located separately from warehouse ☐

4- How far are the warehouse bins or stores/holding areas from receiving area?

0-3m ☐ 4-7m ☐ 8-10m ☐ Over 15m ☐

5- How far is your manufacturing site from your distribution/warehouse centre?

Same City ☐ Regional ☐ Countrywide ☐ Not Applicable ☐

6- How frequently does your production/operation stall due to equipment failure breakdown?

Always ☐ Occasionally ☐ Never ☐

7- How long does your equipment, vehicles, tools stay working before it fails- Mean Time Between Failures (MTBF)?

Less than 30 days ☐ 30 – 180 days ☐ More than 180 days ☐ No Record ☐

8- If your equipment, vehicles or tools breakdown time – how long does it take to repair?

Less than 1 hour ☐ More than 1 hour ☐ More than 1 day ☐

Section 3 : Quality Control / Assurance

1- Where does most damaged or defective goods occur in your operations? (select all that apply)

Goods Receiving ☐ Warehousing ☐ Goods Despatch ☐ Transportation ☐ Customer Site ☐

2- We regularly inspect the following for compliance with regulation, food, environmental and hygiene standards?

Goods Receiving ☐ Warehousing ☐ Goods Despatch ☐ Transportation ☐ Customer Sit ☐

3- We spend too much time inspecting goods in (tick all that apply)?

Goods Receiving ☐ Warehousing ☐ Goods Despatch ☐ Transportation ☐

Customer Site ☐ No we don't spend too much time ☐ We do not inspect goods ☐

4- Which of the following errors/defects occur in your organisation? (tick all that apply)

Lost Invoices or orders ☐ Mistakes on invoices or requisitions ☐ Incorrect Orders to Suppliers ☐

Incorrect supplies to Customers ☐ Stock shortages ☐ Delays in receiving orders, goods or deliveries ☐

5. Which of the following causes you the most concern? (Tick the one that applies)

- Poor quality ☐ Incorrect order or price ☐ Partial Delivery ☐

6- Which of the following do you have or use in your organisation? (Select all applicable options).

Continuous flow ☐ ISO 9000 ☐ Lean ☐ Six Sigma ☐ Kanban ☐ TQM ☐

Food Certification Marks - Fair Trade ☐ Freedom Food ☐ Other ☐ None ☐

Section 4 : Information Sharing

1-How many new suppliers do you take on in one year on average?

Less than 5 ☐ 6- 10 ☐ More than 10 ☐

2- How many new customers do you engage in one year on average?

Less than 5 ☐ 6- 10 ☐ More than 10 ☐

3- How many suppliers do you order from regularly?

1-10 ☐ 10 -20 ☐ more than 20 ☐

4- How many customers order from you regularly?

Less than 10 ☐ 11-20 ☐ more than 20 ☐

5- Which method do you receive most of your customer orders? Tick all that apply

Salesperson ☐ Telephone ☐ Email ☐ Fax ☐ Other ☐

6- What method do you prefer to use with your suppliers? Tick all that apply

Salesperson ☐ Telephone ☐ Email ☐ Catalogue ☐ Fax ☐ Other ☐

7- Does your company use an electronic Real time Information Systems?

No ☐ **Then go to Question 10** Yes ☐ **How many years have you had this system** …………

8- What function do you use this system for?

Sales orders ☐ Procurement ☐ Inventory ☐ Warehouse ☐ Distribution ☐

9- How effective is this system?

Not effective ☐ Partially ☐ Just OK ☐ Very Effective ☐

10- How do you share information of customer orders to your functions (sales, procurement and warehousing etc.)?

Face-to-face ☐ Telephone ☐ Email ☐ Paper ☐ Fax ☐ Other ☐

11- What are the main issues that you experience with sharing information between the departments/ functions?

Delays ☐ Gets Lost ☐ Wrong person ☐ Inaccurate ☐ Not Completed ☐

Other……………… …………….

12- Which of the functions have the most issues in your organisation?

Please rate the following functions in the order of the frequency of issues that are experienced.	**Many Issues**				**No Issues**
	1	**2**	**3**	**4**	**5**
Sales					
Procurement					
Inventory					
Warehouse					
Distribution					

Section 5 : Managing Performance Indicators

1-Please rate these measures in order of importance	**Most Important**				**Not Important**
	1	**2**	**3**	**4**	**5**
Lower Cost					
Train staff					
Quicker Delivery times					
Better Quality					
Customer Satisfaction					

2- Please rate the benefits below in order of importance.	**Most Important**				**Not Important**
	1	**2**	**3**	**4**	**5**
Increased profitability					
Increased Flexibility					
Reduced waste					
Quality attitude					
Improved workflow					
Reduced customer complaints					
Reduced inventory					
Improved delivery times					
Improved productivity / efficiency					
Improved communication					
Improved product quality					

Appendix B: Questionnaire Form in Arabic

استبانة

يرجى قراءة الأسئلة بعناية والإجابة عليها بالشكل المناسب والصحيح (فضلا قم بوضع علامة على الإجابة التي تختارها أو اكتب الإجابة في المساحة المخصصة ويلزم اختيار إجابة واحدة ما لم يتم ذكر تعليمات بخلاف ذلك)

القسم (1) : الجوانب الديموغرافية للأعمال (المتغيرات المؤثرة)

1- كم عدد العمالة لدى شركتكم ؟

☐ 9- 0 ☐ 49-10 ☐ 100-50

2- ما مقدار العائد السنوي للشركة (اختياري) ؟

☐ أقل من مليونين ☐ من 2 إلى 10 ملايين ☐ من 11 إلى 20 مليون ☐ أكثر من 20 مليون

3- ما هو المنصب الذي تقوم به في الشركة ؟ (حدد الاختيار الأنسب)

☐ المالك / المدير التنفيذي / العضو المنتدب ☐ مدير العمليات ☐ مدير الجودة

أخرى (يرجى تحديدها) ....

4- ما هي حالة الملكية لهذه الشركة ؟

☐ ملكية محلية ☐ جزء من منشأة متعددة الجنسيات ☐ شركة تضامن

5- كم عمر الشركة ؟ (اختر الاجابة الأنسب)

☐ أقل من 12 شهر ☐ 1-2 سنة ☐ 2-5 سنوات ☐ 5-10 سنوات ☐ أكثر من 10 سنوات

6- ما هي الدول التي تقومون فيها بتسويق منتجاتكم ؟ (ضع علامة على كل ما ينطبق من الخيارات)

☐ محلياً ☐ أوروبا ☐ الصين ☐ الهند ☐ أفريقيا **آخرى** ....

7- من أين تحصلون على منتجاتكم ؟ (ضع علامة على كل ما ينطبق من الخيارات)

☐ المملكة العربية السعودية ☐ دول الخليج ☐ أفريقيا والهند وآسيا ☐ مختلف دول العالم

8- ما مدى اتساع نطاق عملائكم بشكل عام ؟

☐ في نفس المدينة ☐ على مستوى المحافظة ☐ على مستوى المملكة

9- هل لديكم أي مما يلي ؟ (يرجى تحديد العدد)

☐ مصنع ☐ مخزن ☐ مستودعات ☐ مراكز توزيع ☐ أخرى

10- ما هـو حجم أسطـول النقل (شاحنات وعربات النقل) لـديكم والمستخدم في عمليات التوزيع والتوريد؟

☐ أقل من 5 ☐ 6-20 ☐ أكثر من 20

11- هل يعمل السائقين لديكم وفقاً لنظام المناوبات أو المبادلات (shift/rota system) ؟

☐ لا ☐ أحيانا ☐ نعم

12- هل لديكم إجراءات قياسية أو لوائح موثقة لكل عمليات التشغيل التي تقومون بها ؟

☐ لا ☐ أحيانا ☐ نعم

13- هل تقومون بتدريب موظفيكم على هذه الإجراءات ؟

☐ لا على الإطلاق ☐ مرة واحدة فقط ☐ أحيانا الى حد ما ☐ بشكل دوري منتظم

14- هل تعتقدون أنه هناك حاجة الى تحسينات في العمليات التشغيلية التي تقومون بها ؟

☐ لا ☐ لا أعرف ☐ نعم **(يرجى اختيار كل الخيارات التي تحتاج تحسين فيما يلي):**

○ الوقت المستغرق منذ استلام الطلب من الزبون حتى التسليم (Lead Time) ○ وقت تسليم الطلبية (Delivery Time)
○ الجودة ○ تخفيض التكاليف (Lower Costs) ○ توفر المخزون (Stock Availability) ○ المرونة

15- أي من تدابير وإجراءات زيادة الكفاءة التي ترونها أكثر اهمية من بين الإجراءات التالية ؟

يرجى تصنيف الإجراءات التالية من حيث الفعالية حسب درجة الأهمية	**أكثر أهمية**				**أقل أهمية**
	1	2	3	4	5
الوقت المستغرق منذ استلام الطلب حتى التسليم للعميل					
وقت التوريد					
الجودة					
انخفاض التكاليف					
توفر المخزون					
المرونة					

16- ما هي الاقسام او المهام التي تحتاج إلى تحسينات أكثر حسب اعتقادكم ؟

يرجى تصنيف الوظائف التالية حسب درجة التحسين المطلوبة	**أكثر أهمية** 1	2	3	4	**أقل أهمية** 5
المبيعات					
المشتريات					
المستودعات					
النقل					
المخزون					
جودة المنتجات					
الإدارة					

17- ما هي العوائـق / العقبات الأسـاسية التي تواجهونها في الشركة ؟

....

القسم (2) : أنماط قيمة العمليات (مسارات التدفق لإدارة سلسلة الامدادات)

الجزء 2-1 : تدفق المنتجات / المواد

1- ما هي مدة تخزين المنتجات لدى شركتكم ؟

☐ 1-3 أيام ☐ 3-7 أيام ☐ 7-14 يوم ☐ 30 يوم أو أكثر

2- ما هو عدد المنتجات التي تقومون ببيعها ؟

☐ 1-10 اصناف ☐ 11-20 صنف ☐ 21-40 صنف ☐ أكثر من 50 صنف

3- متى تقومون بإعادة تقديم أوامر شراء المنتجات / أو المواد الخام ؟

☐ عند نفاذ المخزون ☐ عندما يصل المخزون إلى مستوى معين ☐ لتلبية طلبات الشراء من العميل ☐ أخرى

4- أين يتم تخزين وحفظ المواد الخام او المخزون ؟

☐ حاويات وصناديق مخصصة في المستودع (Warehouse Bins) ☐ مناطق وارضيات الحفظ (Holding areas)

5- هل تقومون عادة بتأمين مخزون احتياطي من أجل المحافظة على مستوى مخزون آمـن ولتجنب الانقطاع ونفاذ المخزون ؟

☐ نعم ☐ بعض الشيء ☐ لا

6- ما هو عدد أصناف المخزون التي لها حاويات (Bin) وعليها علامات الأسماء مع البيانات التفصيلية للمنتجات وبيان كمية المخزون ؟

☐ لا يوجد ☐ بعض الأصناف ☐ كل الأصناف

7- هل تنفذون أي سياسات لطرق وأساليب وأنماط التخزين ؟

☐ لا يوجد ☐ FIFO ☐ LIFO ☐ أخرى

8- ما هو معدل حصر أو جرد المخزون من طرفكم ؟

☐ لا يوجد ☐ أسبوعياً ☐ شهرياً ☐ سنوياً

9- هل تضطرون للتخلص من منتجات وبضائع غير مباعة ؟

☐ لا على الإطلاق ☐ في بعض الأحيان ☐ بشكل دوري ومنتظم

الجزء 2-2 التخزين

1- ما مدى درجة امتلاء وإشغال المستودع لديكم بشكل عام ؟

☐ أقل من 30 % ☐ 30-50 % ☐ 51-75 % ☐ أكثر من 75 %

2- ما معدل تنقل المنتجات / المواد قبل وصولها إلى مكان تخزينها ؟

☐ 1 -2 مرة ☐ 3-6 مرات ☐ أكثر من ذلك

3- هل يوجد لديكم مكان مخصص لاستلام المواد والمنتجات؟

☐ لا يوجد ☐ نعم يوجد مكان مخصص داخل المستودع ☐ نعم يوجد مكان مخصص منفصل عن المستودع

4- ما مدى بعد مقرات المستودعات أو المخازن عن منطقة الاستلام ؟

☐ 0-3 متر ☐ 4-7 متر ☐ 8-10 متر ☐ أكثر من 15 متر

5- ما مدى بعد موقع المصنع الخاص بكم عن مركز التوزيع/المستودعات التابعة لكم ؟

☐ في نفس المدينة ☐ في نفس المنطقة ☐ داخل الدولة ☐ لا ينطبق أي اختيار

6- ما هو معدل تكرار توقف الإنتاج / التشغيل بسبب تعطل المعدات ؟

☐ دائماً ☐ أحياناً ☐ أبداً

7- ما هي المدة التي تبقى خلالها المعدات والسيارات والأدوات بحالة تشغيلية قبل تعطلها MTBF (Mean Time Between Failures)

☐ أقل من 30 يوم ☐ 30-180 يوم ☐ أكثر من 180 يوم ☐ لا توجد بيانات مسجلة

8- في حالة تعطل المعدات أو السيارات أو الأدوات ما هي المدة التي تستغرق في الإصلاح؟

☐ أقل من ساعة واحدة ☐ أكثر من ساعة واحدة ☐ أكثر من يوم واحد

الجزء 3 : مراقبة / تأكيد الجودة

1- خلال قيامكم بعمليات التشغيل اليومية في أي المواقع تكثر تلفيات وعيوب المنتجات ؟ (اختر جميع الإجابات التي تنطبق بهذا الشأن)

☐ بمكان استلام البضائع ☐ المستودعات ☐ بموقع تحميل المنتجات ☐ أثناء النقل والتوصيل ☐ في موقع العميل

2- امتثالا للأنظمة والمعايير القياسية للأغذية والبيئة والصحة نقوم بالفحص والتفتيش بشكل منتظم في المواقع التالية ؟

☐ مكان استلام المنتجات ☐ المستودعات ☐ موقع تحميل المنتجات ☐ أثناء النقل ☐ في موقع العميل

3- نقضي وقت طويل جداً في فحص المنتجات والبضائع في.... (ضع علامة على كل الخيارات التي تنطبق بهذا الشأن) ؟

☐ مكان استلام المنتجات ☐ المستودعات ☐ موقع تحميل المنتجات ☐ أثناء النقل ☐ موقع العميل

☐ لا نحن لا نستغرق الكثير من الوقت ☐ نحن لا نقوم بفحص المنتجات

4- أي من الأخطاء والمشاكل التالية يحدث في منشأتكم؟ (ضع علامة على كل الخيارات التي تنطبق بهذا الشأن)

☐ فقدان الفواتير أو أوامر الشراء ☐ الأخطاء في الفواتير أو الطلبات ☐ استلام مواد غير صحيحة من الموردين

☐ توصيل مواد خاطئة إلى العملاء ☐ نقص المخزون ☐ لتأخيرات في استلام أوامر الشراء او البضائع أو توصيل المواد المطلوبة

5- أي من المشاكل التالية تقلقك وتثير اهتمامك أكبر من غيرها داخل الشركة ؟ (ضع علامة على كل الخيارات التي تنطبق بهذا الشأن)

☐ انخفاض مستوى الجودة ☐ الأخطاء في أوامر الشراء أو الأسعار ☐ تسليم فقط جزء من المواد المطلوبة للعميل

6- أي من الأدوات التالية تقومون بتطبيقها أو تتوفر لديكم في منشأتكم ؟ (ضع علامة على كل الخيارات التي تنطبق بهذا الشأن)

☐ Continuous flow ☐ ISO 9000 ☐ Lean ☐ Six Sigm ☐ Kanban ☐ TQM

☐ Food Certification Marks - Fair Trade ☐ Freedom Food ☐ أخرى ☐ لا يوجد

الجزء 4 : مشاركة وتبادل المعلومات

1- ما هو متوسط عدد الموردين الجدد الذين تتعامل معهم خلال السنة الواحدة ؟

☐ أقل مـن 5 ☐ 6 – 10 ☐ أكثر من 10

2- ما هو متوسط عدد العملاء الجدد الذين يتعاملون معكم خلال السنة الواحدة ؟

☐ أقل مـن 5 ☐ 6 – 10 ☐ أكثر من 10

4- كم عدد الموردين الذين تطلب منهم منتجات بشكل منتظم ؟

☐ 1-10 ☐ 10-20 ☐ أكثر من 20

5- كم عدد العملاء الذين يطلبون منكم منتجات بأوامر شراء منتظمة ؟

☐ أقل من 10 ☐ 11-20 ☐ أكثر من 20

6- ما هي طريقة استلام معظم أوامر الشراء من عملائكم ؟ (ضع علامة على كل ما ينطبق بهذا الشأن)

☐ مندوب المبيعات ☐ الهاتف ☐ البريد الالكتروني ☐ الفاكس ☐ أخرى

7- ما هي الطريقة التي تفضلون استخدامها في التعامل مع الموردين ؟ ضع علامة على كل ما ينطبق بهذا الشأن

☐ مندوب المبيعات ☐ الهاتف ☐ البريد الالكتروني ☐ الكتالوج ☐ الفاكس ☐ أخرى

8- هل تستخدم شركتكم نظام معلومات الكتروني يعتمد الوقت الفعلي في التعاملات ؟

☐ لا (**انتقل مباشرة إلى السؤال رقم 10**) ☐ نعم (**كم عدد سنوات استخدام هذا النظام**) ....

8- ما هي المهام التي من اجلها تستخدمون هذا النظام ؟

☐ أوامر المبيعات ☐ المشتريات ☐ المخزون ☐ المستودعات ☐ التوزيع

9- ما مدى فعالية هذا النظام ؟

☐ غير فعال ☐ فعال جزئياً ☐ جيد ☐ فعال للغاية

10- كيف تتم عملية مشاركة وتبادل المعلومات الخاصة بطلبات العملاء بين اقسام الشركة (المبيعات والمشتريات والمستودعات، الخ)

☐ وجهاً لوجه ☐ الهاتف ☐ البريد الالكتروني ☐ المستندات الورقية ☐ الفاكس ☐ أخرى

11- ما هي المشكلات الرئيسية التي تواجهونها عند مشاركة وتبادل المعلومات بين الأقسام ؟

☐ التأخيرات ☐ الفقدان ☐ الوصول للشخص الخطأ ☐ عدم دقة البيانات ☐ عدم اكتمال المعلومات

أخرى ....

12- أي من المهام التالية تمثل أكبر مصدر للمشكلات في المنشأة التي تعملون بها ؟

يرجى تصنيف الأقسام والمهام التالية	**الكثير من المشكلات**				**لا توجد مشكلات**
بحسب تكرر المشكلات داخلها أثناء العمل	1	2	3	4	5
المبيعات					
المشتريات					
المخزون					
المستودع					
التوزيع					

الجزء 5 : إدارة مـؤشـرات الأداء

1- يرجى ترتيب الإجراءات التالية بناء على درجة الأهمية	**أكثر أهمية** 1	2	3	4	**بدون أهمية** 5
تخفيض التكاليف					
تدريب الموظفين					
توصيل المواد المطلوبة بشكل أسرع					
جودة أفضل					
رضا العملاء					

2- يرجى ترتيب المزايا التالية بنـاء على درجـة الأهـمية	**أكثر أهمية** 1	2	3	4	**بـدون أهمية** 5
زيادة الارباح					
زيادة المرونة					
تقليص حجم الفاقد					
الاتجاه نحو الجودة					
تحسين سير العمل					
تقليل شكاوى العملاء					
خفض معدل المخزون					
تحسين وقت تسليم الطلب (التسليم في الوقت المطلوب)					
تحسين الانتاجية / الكفاءة					
تحسين التواصل					
تحسين جودة المنتجات					

Appendix C: Ethics Approval

Brunel University London

Brunel University London
Uxbridge UB8 3PH
United Kingdom

www.brunel.ac.uk

2 June 2015

STATEMENT OF ETHICS APPROVAL

Proposer: Fahed Algassem Student ID No: 0733150/1

Dear Fahed,

Project Title: Integration of Lean Six Sigma with Multi Agent Sytems into the Food Distribution

Under delegated authority from the College Research Ethics Committee, I have considered the application recently submitted by you. I am satisfied that there is no objection on ethical grounds to the proposed study.

Approval is given on the understanding that you will adhere to the terms agreed with participants and to inform me of any change of plans in relation to the information provided in the application form.

Yours sincerely,

John Park
College Research Mananger
T +44(0)1895 266057| E john.park@brunel.ac.uk

Appendix D: Results and Analysis Tables

1- Section 1: Business Demographics Influencing Variables

Table 1.1

Distribution of study sample according to

P1.Q1

	Frequency	Percent
0-9	3	7.7
10-49	16	41.0
50-100	16	41.0
More than 100	4	10.3
Total	39	100.0

Table 1.1.1

Distribution of study sample according to

P1.Q1

	Frequency	Percent
SME 2-100	35	89.7
Large More than 100	4	10.3
Total	39	100.0

Table 1.2

Distribution of study sample according to P1.Q2

	Frequency	Percent
Less than 2 million	7	17.9
2-10 million	13	33.3
11-20 million	13	33.3
More than 20 million	3	7.7
Missing	3	7.7
Total	39	100.0

Table 1.3

Distribution of study sample according to P1.Q3

	Frequency	Percent
Owner/ CEO/Managing Director	6	15.4
Head of Technical Operations	9	23.1
Quality Manager	8	20.5
Other	16	41.0
Total	39	100.0

Table 1-4

Distribution of study sample according to

P1.Q4

	Frequency	Percent
Locally owned	33	84.6
Part of a Multinational Organisation	4	10.3
A Joint Venture	2	5.1
Total	39	100.0

Table 1-5

Distribution of study sample according to

P1.Q5

	Frequency	Percent
Less than 12 months	----	----
1-2 years	----	----
2-5 years	----	----
5-10 years	6	15.4
10+ years	33	84.6
Total	39	100.0

Table 1-6

Distribution of where the firms sell their goods

P1.Q6

	Frequency	Percent*
Local	37	94.9
Europe	1	2.6
China	1	2.6
India	5	12.8
Africa	6	15.4
Other	5	12.8
No. of participants	39	

* Percent of No. of participants

Table 1.7

Distribution of study sample according to the Global Sourcing of Goods

P1.Q7

	Frequency	Percent*
Saudi	18	46.2
Gulf Countries	11	28.2
Africa, India, Asia	14	35.9
ROW	36	92.3
No. of participants	39	100.0

* Percent of No. of participants

Table 1.8

Distribution of study sample according to P1.Q8

	Frequency	Percent
Same City	11	28.2
Regional	4	10.3
Countrywide	24	61.5
Total	39	100.0

Table 1.9

Distribution of study sample according to Storage Facilities P1.Q9

	Frequency	Percent*
Factory	26	66.7
Depots	29	74.4
Warehouses	38	97.4
Distribution Centres	37	94.9
Missing	1	2.6
No. of participants	39	100.0

* Percent of No. of participants

Table 1.10

Distribution of study sample according to the size of your fleet

P1.Q10

	Frequency	Percent
Less than 5	7	17.9
6- 20	18	46.2
More than 20	14	35.9
Total	39	100.0

Table 1.11

Distribution of study sample according to whether drivers operate a shift/rota system

P1.Q11

	Frequency	Percent
No	18	46.2
Sometimes	10	25.6
Yes	11	28.2
Total	39	100.0

Table 1.12

Distribution of study sample according to

P1.Q12

	Frequency	Percent
No	11	28.2
Some	18	46.2
Yes	10	25.6
Total	39	100.0

Table 1.13

Distribution of study sample according to

P1.Q13

	Frequency	Percent
Not at all	16	41.0
Only once	7	17.9
Fairly Often	8	20.5
Regularly	7	17.9
Missing	1	2.6
Total	39	100.0

Table 1.14.1

Distribution of study sample according to

P1.Q14A

	Frequency	Percent
No	2	5.1
I don't know	2	5.1
Yes	35	89.7
Total	39	100.0

Table 1.14.2

Distribution of study sample according to

P1.Q14B

	Frequency	Percent*
Lead Times	6	17.1
Delivery Time	19	54.3
Quality	22	62.9
Lower Costs	25	71.4
Stock Availability	29	82.9
Flexibility	12	34.3
No. of participants	35	

* Percent of No. of participants

Table 1.15

Frequencies, Percentages, Means, and Standard Deviations for Sample responses related to P1.Q15

Statement		Least Important.---Very Important					Mean	Std. Deviation	Rank
Lead Times	Freq.	10	14	11		3	3.74	1.11	5
	%	26.3	36.8	28.9		7.9			
Delivery Time	Freq.	18	15	1	2	1	4.27	0.96	4
	%	48.6	40.5	2.7	5.4	2.7			
Quality	Freq.	28	8	2			4.68	0.57	1
	%	73.7	21.1	5.3					
Lower Costs	Freq.	26	9	2	2		4.51	0.82	3
	%	66.7	23.1	5.1	5.1				
Stock Availability	Freq.	27	4	6			4.57	0.77	2
	%	73.0	10.8	16.2					
Flexibility	Freq.	12	9	12	3	2	3.68	1.16	6
	%	31.6	23.7	31.6	7.9	5.3			
Mean for total							**4.26**		

Table 1.16

Frequencies, Percentages, Means, and Standard Deviations for Sample responses related to P1.Q16

Statement		Least Improvement----Most Improvement					Mean	Std. Deviation	Rank
Sales	Freq.	21	9	6	1	1	4.26	1.00	3
	%	55.3	23.7	15.8	2.6	2.6			
Purchasing	Freq.	8	11	12	2	1	3.68	1.01	6
	%	23.5	32.4	35.3	5.9	2.9			
Warehousing	Freq.	12	11	7	2		4.03	0.93	4
	%	37.5	34.4	21.9	6.3				
Transport	Freq.	7	15	9	3	1	3.69	0.99	5
	%	20.0	42.9	25.7	8.6	2.9			
Inventory	Freq.	19	11	3	1	1	4.31	0.96	2
	%	54.3	31.4	8.6	2.9	2.9			
Quality of Products	Freq.	21	10	4	1		4.42	0.81	1
	%	58.3	27.8	11.1	2.8				
Administration	Freq.	2	4	16	9	2	2.85	0.94	7
	%	6.1	12.1	48.5	27.3	6.1			
Mean for total							**4.00**		

2. Section 2: Operations Value Stream SCM Flow Paths:

Section 2.1 : Goods/Material Flow:

Table 2.1.1

Distribution of study sample according to

P2.1.Q1

	Frequency	Percent
1-3 days	4	10.3
3-7 days	2	5.1
7-14 days	8	20.5
30 days or more	25	64.1
Total	39	100.0

Table 2.1.2

Distribution of study sample according to

P2.1.Q2

	Frequency	Percent
1 – 10	4	10.3
11- 20	9	23.1
21 – 40 items	14	35.9
More than 40	12	30.8
Total	39	100.0

Table 2.1.3

Distribution of study sample according to

P2.1.Q3

	Frequency	Percent
When no stock exists	1	2.6
When stock reaches a set level	31	79.5
To fill an order	6	15.4
Other	1	2.6
Total	39	100.0

Table 2.1.4

Distribution of study sample according to

P2-1.Q4

	Frequency	Percent
Warehouse Bins	10	25.6
Holding areas	24	61.5
Both	5	12.8
Total	39	100.0

Table 2.1.5

Distribution of study sample according to

P2.1.Q5

	Frequency	Percent
No	5	12.8
Some	18	46.2
Yes	16	41.0
Total	39	100.0

Table 2.1.6

Distribution of study sample according to

P2.1.Q6

	Frequency	Percent
None	11	28.2
Some	19	48.7
All	9	23.1
Total	39	100.0

Table 2.1.7

Distribution of study sample according to

P2.1.Q7

	Frequency	Percent*
NONE	10	25.6
FIFO	23	59.0
LIFO	4	10.3
Other	10	25.6
No. of participants	39	

* Percent of No. of participants

Table 2.1.8

Distribution of study sample according to

P2.1.Q8

	Frequency	Percent
None	2	5.1
Weekly	.---	----
Monthly	3	7.7
Yearly	32	82.1
Monthly+ Yearly	2	5.1
Total	39	100.0

Table 2.1.9

Distribution of study sample according to

P2-1.Q9

	Frequency	Percent
Not at all	5	12.8
Frequently	28	71.8
Regularly	6	15.4
Total	39	100.0

2-2. Section 2.2 : Warehousing:

Table 2. 2.1

Distribution of study sample according to

P2.2.Q1

	Frequency	Percent
Less than 30%	----	----
30%- 50%	9	23.1
51%- 75%	16	41.0
Over 75%	14	35.9
Total	39	100.0

Table 2.2.2

Distribution of study sample according to

P2-2.Q2

	Frequency	Percent
I-2 times	25	64.1
3-6 times	10	25.6
More	4	10.3
Total	39	100.0

Table 2.2.3

Distribution of study sample according to

P2.2.Q3

	Frequency	Percent
No	5	12.8
Yes in the warehouse	25	64.1
Yes but located separately from warehouse	9	23.1
Total	39	100.0

Table 2.2.4

Distribution of study sample according to

P2.2.Q4

	Frequency	Percent
0-3m	13	33.3
4-7m	7	17.9
8-10m	9	23.1
Over 10m	10	25.6
Total	39	100.0

Table 2.2.5

Distribution of study sample according to

P2.2.Q5

	Frequency	Percent
Same City	22	56.4
Regional	4	10.3
Countrywide	5	12.8
Not Applicable	8	20.5
Total	39	100.0

Table 2.2.6

Distribution of study sample according to P2.2.Q6

	Frequency	Percent
Always	4	10.3
Occasionally	35	89.7
Total	39	100.0

Table 2.2.7

Distribution of study sample according to P2.2.Q7

	Frequency	Percent
Less than 30 days	5	12.8
30 – 180 days	21	53.8
More than 180 days	4	10.3
No Record	9	23.1
Total	39	100.0

Table 2.2.8

Distribution of study sample according to

P2.2.Q8

	Frequency	Percent
Less than 1 hour	2	5.1
More than 1 hour	20	51.3
More than 1 day	17	43.6
Total	39	100.0

3. Section 3: Quality Control / Assurance:

Table 3.1

Distribution of study sample according to

P3.Q1 Where does most damage /defective goods occur

	Frequency	Percent*
Goods Receiving	9	23.1
Warehousing	19	48.7
Goods Despatch	9	23.1
Transportation	20	51.3
Customer Site	17	43.6
Missing	1	2.6
No. of participants	39	

* Percent of No. of participants

Table 3.2

Distribution of study sample according to P3.Q2

	Frequency	Percent*
Goods Receiving	32	82.1
Warehousing	31	79.5
Goods Despatch	15	38.5
Transportation	11	28.2
Customer Sit	11	28.2
No. of participants	39	

* Percent of No. of participants

Table 3.3

Distribution of study sample according to P3.Q3

	Frequency	Percent*
Goods Receiving	30	76.9
Warehousing	24	61.5
Goods Despatch	11	28.2
Transportation	6	15.4
Customer Site	4	10.3
No we don't spend too much time	5	12.8
We do not inspect goods	3	7.7

No. of participants	39

* Percent of No. of participants

Table 3.4

Distribution of study sample according to

P3.Q4

	Frequency	Percent*
Lost Invoices or orders	9	23.1
Mistakes on invoices or requisitions	17	43.6
Incorrect Orders to Suppliers	1	2.6
Incorrect supplies to Customers	11	28.2
Stock shortages	33	84.6
Delays in receiving orders, goods or deliveries	22	56.4
No. of participants	39	

* Percent of No. of participants

Table 3.5

Distribution of study sample according to

P3.Q5

	Frequency	Percent*
Poor quality	17	43.6
Incorrect order or price	16	41.0

Partial Delivery	24	61.5
Missing	1	2.6
No. of participants	39	

* Percent of No. of participants

Table 3.6

Distribution of study sample according to

P3.Q6

	Frequency	Percent*
Continuous flow	----	----
ISO 9000	23	59.0
Lean	----	----
Six Sigma	----	----
Kanban	----	----
TQM	----	----
Food Certification Marks - Fair Trade	----	----
Freedom Food	----	----
Other	9	23.1
None	13	33.3
No. of participants	39	

* Percent of No. of participants

4- Section 4: Information Sharing:

Table 4.1

Distribution of study sample according to

P4.Q1

	Frequency	Percent
Less than 5	11	28.2
6- 10	10	25.6
More than 10	18	46.2
Total	39	100.0

Table 4.2

Distribution of study sample according to

P4.Q2

	Frequency	Percent
Less than 5	1	2.6
6- 10	5	12.8
More than 10	33	84.6
Total	39	100.0

Table 4.3

Distribution of study sample according to

P4.Q3

	Frequency	Percent
1-10	6	15.4
10 -20	13	33.3
more than 20	20	51.3
Total	39	100.0

Table 4.4

Distribution of study sample according to

P4.Q4

	Frequency	Percent
Less than 10	1	2.6
11-20	10	25.6
more than 20	28	71.8
Total	39	100.0

Table 4.5

Distribution of study sample according to

P4.Q5

	Frequency	Percent*
Salesperson	27	69.2
Telephone	21	53.8
Email	18	46.2
Fax	14	35.9
No. of participants	39	

* Percent of No. of participants

Table 4.6

Distribution of study sample according to

P4.Q6

	Frequency	Percent*
Salesperson	8	20.5
Telephone	22	56.4
Email	28	71.8
Catalogue	8	20.5
Fax	7	17.9
No. of participants	39	

* Percent of No. of participants

Table 4.7

Distribution of study sample according to

P4.Q7

	Frequency	Percent
No	3	7.7
Yes	36	92.3
Total	39	100.0

Table 4.8

Distribution of study sample according to

P4.Q8

	Frequency	Percent*
Sales orders	31	86.1
Procurement	28	77.8
Inventory	20	55.6
Warehouse	18	50.0
Distribution	9	25.0
No. of participants	36	

* Percent of No. of participants

Table 4.9

Distribution of study sample according to

P4.Q9

	Frequency	Percent
Not effective	----	----
Partially	14	38.9
Just OK	13	36.1
Very Effective	9	25.0
Total	36	100.0

Table 4.10

Distribution of study sample according to

P4.Q10

	Frequency	Percent*
Face-to-face	25	64.1
Telephone	11	28.2
Email	16	41.0
Paper	31	79.5
Fax	2	5.1
No. of participants	39	

* Percent of No. of participants

Table 4.11

Distribution of study sample according to P4.Q11

	Frequency	Percent*
Delays	29	74.4
Gets Lost	3	7.7
Wrong person	2	5.1
Inaccurate	19	48.7
Not Completed	11	28.2
No. of participants	39	

* Percent of No. of participants

Table 4.12

Frequencies, Percentages, Means, and Standard Deviations for Sample responses related to P4.Q12

Statement		No Issues---------------Many Issues					Mean	Std. Deviation	Rank
Sales	Freq.	15	12	5	4	2	3.89	1.20	2
	%	39.5	31.6	13.2	10.5	5.3			
Procurement	Freq.	1	14	5	9	6	2.86	1.22	5
	%	2.9	40.0	14.3	25.7	17.1			
Inventory	Freq.	17	10	6	2	1	4.11	1.06	1
	%	47.2	27.8	16.7	5.6	2.8			
Warehouse	Freq.	10	11	10	5	1	3.65	1.11	4

Statement		No Issues---------------Many Issues					Mean	Std. Deviation	Rank
	%	27.0	29.7	27.0	13.5	2.7			
Distribution	Freq.	13	9	8	6		3.81	1.12	3
	%	36.1	25.0	22.2	16.7				
Mean for total							**3.74**		

5- Section 5: Managing Performance Indicators:

Table 5.1

Frequencies, Percentages, Means, and Standard Deviations for Sample responses related to P5.Q1

Statement		Not Important------Most Important					Mean	Std. Deviation	Rank
Lower Cost	Freq.	27	6	4	1	1	4.46	0.97	3
	%	69.2	15.4	10.3	2.6	2.6			
Train staff	Freq.	9	10	12	3	3	3.51	1.19	5
	%	24.3	27.0	32.4	8.1	8.1			
Quicker Delivery times	Freq.	18	15	2	2		4.32	0.82	4
	%	48.6	40.5	5.4	5.4				
Better Quality	Freq.	28	8	1	1		4.66	0.67	2
	%	73.7	21.1	2.6	2.6				
Customer Satisfaction	Freq.	29	8	1	1		4.67	0.66	1
	%	74.4	20.5	2.6	2.6				
Mean for total							**4.34**		

Table 5.2

Frequencies, Percentages, Means, and Standard Deviations for Sample responses related to P5.Q2

Statement		Not Important------Most Important					Mean	Std. Deviation	Rank
Increased profitability	Freq.	30	7	2			4.72	0.56	2
	%	76.9	17.9	5.1					
Increased Flexibility	Freq.	8	16	8	4	2	3.63	1.10	11
	%	21.1	42.1	21.1	10.5	5.3			
Reduced waste	Freq.	19	15	4			4.39	0.68	3
	%	50.0	39.5	10.5					
Quality attitude	Freq.	13	13	11	1		4.00	0.87	8
	%	34.2	34.2	28.9	2.6				
Improved workflow	Freq.	10	14	9	3	2	3.71	1.11	10
	%	26.3	36.8	23.7	7.9	5.3			
Reduced customer complaints	Freq.	17	17	4	1		4.28	0.76	6
	%	43.6	43.6	10.3	2.6				
Reduced inventory	Freq.	18	14	7			4.28	0.76	6
	%	46.2	35.9	17.9					
Improved delivery times	Freq.	21	10	7			4.37	0.79	4
	%	55.3	26.3	18.4					
Improved productivity / efficiency	Freq.	17	17	4			4.34	0.67	5
	%	44.7	44.7	10.5					
Improved communication	Freq.	11	17	6	4		3.92	0.94	9
	%	28.9	44.7	15.8	10.5				

Statement		Not Important------Most Important					Mean	Std. Deviation	Rank
Improved product quality	Freq.	32	6	1			4.79	0.47	1
	%	82.1	15.4	2.6					
Mean for total							**4.23**		

Section 1 Table (C1-1)

Chi-square test to identify the difference in P1(Q6,Q7,Q10,Q12,Q14) depending to (P1.Q1)

Size and Scale of the business with the extent of the SCM Operations and the Areas requiring Improvement

Question		0-9		10-49		50-100		More than 100		Total		Chi-Square (Sig.)
		No.	%	No.	%	No.	%	No.	%	No.	%	
(P1.Q6)	Local	3	8.1	16	43.2	16	43.2	2	5.4	37	94.9	----
	Europe							1	100	1	2.6	
	China							1	100	1	2.6	
	India					4	80.0	1	20.0	5	12.8	
	Africa					4	66.7	2	33.3	6	15.4	
	Other					2	40.0	3	60.0	5	12.8	
(P1.Q7)	Saudi	3	16.7	8	44.4	6	33.3	1	5.6	18	46.2	----
	Gulf Countries			5	45.5	5	45.5	1	9.1	11	28.2	
	Africa, India, Asia			8	57.1	5	35.7	1	7.1	14	35.9	
	ROW			16	44.4	16	44.4	4	11.1	36	92.3	
(P1.Q10)	Less than 5	3	42.9	4	57.1					7	100	28.476

Question		0-9		10-49		50-100		More than 100		Total		Chi-Square (Sig.)
		No.	%	No.	%	No.	%	No.	%	No.	%	
	6-20			10	55.6	8	44.4			18	100	(0.01)
	More than 20			2	14.3	8	57.1	4	28.6	14	100	
(P1.Q12)	No	3	27.3	6	54.5	2	18.2			11	100	23.183 (0.01)
	Some			8	44.4	10	55.6			18	100	
	Yes			2	20.0	4	40.0	4	40.0	10	100	
(P1.Q14A)	No	1	50.0					1	50.0	2	100	16.471 (0.01)
	I don't know	1	50.0			1	50.0			2	100	
	Yes	1	2.9	16	45.7	15	42.9	3	8.6	35	100	
(P1.Q14B)	Lead Times			2	33.3	2	33.3	2	33.3	6	17.1	----
	Delivery Time	1	5.3	9	47.4	7	36.8	2	10.5	19	54.3	
	Quality			10	45.5	11	50.0	1	4.5	22	62.9	
	Lower Costs	1	4.0	11	44.0	10	40.0	3	12.0	25	71.4	
	Stock Availability			14	48.3	13	44.8	2	6.9	29	82.9	
	Flexibility			5	41.7	6	50.0	1	8.3	12	34.3	

Section 1 Table (C1-2)

Chi-square test to identify the difference in P1(Q6,Q7,Q10,Q12,Q14) depending to (P1.Q2

Size and Scale of the business with the extent of the SCM Operations and the Areas requiring Improvement)

Question		Less than 2 million		2-10 million		11-20 million		More than 20 million		Total		Chi-Square
		No.	%	No.	%	No.	%	No.	%	No.	%	(Sig.)
(P1.Q6)	Local	7	19.4	13	36.1	13	36.1	3	8.3	36	100	----
	Europe							1	100	1	2.8	
	China							1	100	1	2.8	
	India					3	60.0	2	40.0	5	13.9	
	Africa					3	60.0	2	40.0	5	13.9	
	Other					2	100			2	5.6	
(P1.Q7) In which country do you source your Goods	Saudi	5	29.4	6	35.3	6	35.3			17	47.2	----
	Gulf Countries	2	20.0	3	30.0	5	50.0			10	27.8	
	Africa, India, Asia	3	23.1	5	38.5	5	38.5			13	36.1	
	ROW	4	12.1	13	39.4	13	39.4	3	9.1	33	91.7	
(P1.Q10) What is the size if your fleet?	Less than 5	5	71.4	2	28.6					7	100	23.163 (0.01)
	6-20	2	11.1	8	44.4	8	44.4			18	100	
	More than 20			3	27.3	5	45.5	3	27.3	11	100	
(P1.Q12) Do you have standardised and documented procedures?	No	5	45.5	5	45.5	1	9.1			11	100	14.043 (0.05)
	Some	2	11.1	6	33.3	9	50.0	1	5.6	18	100	
	Yes			2	28.6	3	42.9	2	28.6	7	100	
(P1.Q14A)	No	1	100							1	100	6.533 (N. S.)
	I don't know	1	50.0	1	50.0					2	100	
	Yes	5	15.2	12	36.4	13	39.4	3	9.1	33	100	

Question		Less than 2 million		2-10 million		11-20 million		More than 20 million		Total		Chi-Square (Sig.)
		No.	%	No.	%	No.	%	No.	%	No.	%	
(P1.Q14B)	Lead Times			2	40.0	2	40.0	1	20.0	5	15.2	----
	Delivery Time	3	16.7	7	38.9	5	27.8	3	16.7	18	54.5	
	Quality	2	9.5	8	38.1	9	42.9	2	9.5	21	63.6	
	Lower Costs	3	13.0	9	39.1	9	39.1	2	8.7	23	69.7	
	Stock Availability	4	14.3	10	35.7	12	42.9	2	7.1	28	84.8	
	Flexibility			5	41.7	4	33.3	3	25.0	12	36.4	

Appendix E: Examples of Configurations

First configuration: Customer Order (By Cusomer Agent)

```
-gui -name Multi-Agent-System-Supply-Chain-Management
SIP:mas.systemInformation.SystemInformationProviderAgent;Customer_Saeed:mas
.sales.CustomerAgent;SalesOfficer:mas.sales.SalesOfficeAgent;Inventory:mas.
warehouse.InventoryAgent;Manager:mas.ManagerAgent;WarehouseSupervisor:mas.w
arehouse.WarehouseSupervisorAgent;Worker1:mas.warehouse.WorkerAgent;Driver1
:mas.warehouse.DriverAgent;DespatchDepot:mas.warehouse.DespatchDepotAgent;s
niffer:jade.tools.sniffer.Sniffer(SIP,Salesperson1,SalesOfficer,Inventory,M
anager,WarehouseSupervisor,Picker1,Driver1,DespatchDepot
```

…….

```
Mar 03, 2016 12:09:32 PM jade.core.Runtime beginContainer
INFO: ----------------------------------
    This is JADE 4.3.2 - revision 6708 of 2014/03/28 15:19:44
    downloaded in Open Source, under LGPL restrictions,
    at http://jade.tilab.com/
----------------------------------------
Mar 03, 2016 12:09:32 PM jade.imtp.leap.LEAPIMTPManager initialize
INFO: Listening for intra-platform commands on address:
- jicp://192.168.1.69:1099

Mar 03, 2016 12:09:32 PM jade.core.BaseService init
INFO: Service jade.core.management.AgentManagement initialized
Mar 03, 2016 12:09:32 PM jade.core.BaseService init
INFO: Service jade.core.messaging.Messaging initialized
Mar 03, 2016 12:09:32 PM jade.core.BaseService init
INFO: Service jade.core.resource.ResourceManagement initialized
Mar 03, 2016 12:09:32 PM jade.core.BaseService init
INFO: Service jade.core.mobility.AgentMobility initialized
Mar 03, 2016 12:09:32 PM jade.core.BaseService init
INFO: Service jade.core.event.Notification initialized
Mar 03, 2016 12:09:32 PM jade.mtp.http.HTTPServer <init>
INFO: HTTP-MTP Using XML parser
com.sun.org.apache.xerces.internal.jaxp.SAXParserImpl$JAXPSAXParser
Mar 03, 2016 12:09:33 PM jade.core.messaging.MessagingService boot
INFO: MTP addresses:
http://Acer.lan:7778/acc
Mar 03, 2016 12:09:33 PM jade.core.AgentContainerImpl joinPlatform
INFO: --------------------------------------
Agent container Main-Container@192.168.1.69 is ready.
--------------------------------------------
Agent Driver1 has started.
Agent Customer_Saeed has started.
Agent Manager has started.
Agent Inventory has started.
Agent SalesOfficer has started.
Agent WarehouseSupervisor has started.
Agent SIP has started.
Agent Worker1 has started.
Agent DespatchDepot has started.
Data in Database:
-- Start Printing from table Item --
Id     |Item Name        |Price     |QuantityInStock   |BestCaseDeliveryTime
       |WorseCaseDeliveryTime   |MinimumOrderTime |SafetyStockDays
       |ExpirationDate
1      |Baking powder          |52.0  |0                 |30                 |40
                   |45                |15                |01/04/2016
```

```
2      |Vanilla                |72.0 |0                  |30                 |40
             |45                 |15                  |29/09/2015
3      |Food colors            |185.0       |0                  |40
       |60                 |60                  |20                 |01/10/2015
4      |Cocoa small            |180.0       |0                  |30
       |40                 |45                  |15                 |03/08/2015
5      |Cocoa medium           |150.0       |4995               |30
       |40                 |45                  |15                 |01/03/2016
6      |Corn flour             |26.0 |0                  |7                  |14
             |15                 |30                  |03/01/2017
7      |Quicker Cooking        |70.0 |2000               |30                 |40
             |45                 |30                  |03/01/2017
8      |Color of Egg Yolk      |120.0       |0                  |40
       |50                 |60                  |30                 |01/01/2017
9      |Color Saffar Safforn   |110.0       |0                  |40
       |50                 |60                  |30                 |01/01/2017
10     |Black Pipper           |200.0       |0                  |7
       |14                 |15                  |30                 |01/01/2017
11     |Chilli Powder          |220.0       |0                  |7
       |14                 |15                  |30                 |01/01/2017
12     |Sodium Bicarbonate     |55.0 |0                  |30                 |40
             |45                 |30                  |01/05/2017
13     |Baking Powder        |50.0   |0                  |30                 |40
             |45                 |15                  |01/05/2017
14     |Food Powder              |55.0     |0                  |30
       |40                 |45                  |15                 |01/05/2017
15     |Corn Flour         |55.0     |0                  |30                 |40
             |45                 |15                  |01/05/2017
16     |Cocoa Powder             |230.0     |0                  |30
       |40                 |45                  |15                 |01/05/2017
17     |Bicarbonate Sodium 25kg|45.0 |0                  |30                 |40
             |45                 |15                  |01/05/2017
18     |Cummin Powder            |170.0     |0                  |40
       |50                 |60                  |30                 |01/05/2017
19     |Ginger Powder            |170.0     |0                  |30
       |40                 |45                  |15                 |01/05/2017
20     |Sesame Seed              |105.0     |0                  |30
       |40                 |45                  |15                 |01/05/2017
-- End Printing from table Item --
-- Start Printing from table Customer --
Id     |Full Name  |Is Black listed  |Address
0      |Com. Profile     |false                 |Company Address
1      |Doon B              |false                 |17, Montgomery House, UK
2      |Bakker T   |false                 |10, High Street, UK
3      |Jone A              |true                  |10, High Street, UK
4      |Yasser Hamad     |false                 |Building 2344, Olaya,
Takhassusi Road, Riyadh, Saudi Arabia
5      |Yasser S   |false                 |Bulding 11, Street 12, Central
Jonata, London, UK
6      |Saeed Saud |false                 |Riyadh, KSA
32     |Fahe S              |false                 |Riyadh - High street
33     |Fahed Suliman    |false                 |Riyadh - High street
34     |fahed              |false                 |138 high street
35     |fahed              |false                 |123 high street
36     |fahad      |false                 |123 high street
-- End Printing from table Customer --
Customer_Saeed > Is this an existing customer? Or else, a new one!
If yes press 'Y'; Or else, press any key.
Y
Please, enter the customer Id.
32
```

```
Customer Info (from Database):_[0m
Id      |Full Name   |Is Black listed  |Address
32      |Fahe S      |false                  |Riyadh - High street
Customer & Salesperson Agent (Customer_Saeed) is trying to place an
Order...
Customer_Saeed > Collect Order Data...
Customer_Saeed > Enter Items Ids separated by space:
1 2 3 4 5 6 7
Customer_Saeed > Enter quantities separated by space:
2 3 4 5 6 7 8
Customer_Saeed > Order and its Items has been placed by: Customer_Saeed.
Order Full Information:
Id      |Total Price       |Order Date Time   |Parent Order Id  |Status
232     |-----             |03/03/2016 12:09:34    |null              |New
Order
-       Items in this Order:
-       Id      |Item Id       |Item Name         |Order Id    |Quantity
-       333     |1             |Baking powder           |232          |2
-       334     |2             |Vanilla                 |232          |3
-       335     |3             |Food colors       |232          |4
-       336     |4             |Cocoa small       |232          |5
-       337     |5             |Cocoa medium            |232          |6
-       338     |6             |Corn flour        |232          |7
-       339     |7             |Quicker Cooking         |232          |8
The items will be shipped within the next working day.
Customer_Saeed > Do you want a repeated order? Or else, a one time request?
If yes press 'Y'; Or else, press any key.
Y
Enter Repeat Period In Days:
7
Repeated Order Full Information:
Id      |Customer Name     |Order Date Time   |Period in Days
40      |Fahe S      |03/03/2016 12:09:34    |7
-       Customer Information:
-       Id      |Full Name   |Is Black listed   |Address
-       32      |Fahe S      |false                  |Riyadh - High street
-       Repeated Items in this Repeated Order:
-       Id      |Item Id       |Item Name   |RepeatedOrder Id |Quantity
-       46      |1             |Baking powder           |40                 |2
-       47      |2             |Vanilla                 |40                 |3
-       48      |3             |Food colors       |40                 |4
-       49      |4             |Cocoa small       |40                 |5
-       50      |5             |Cocoa medium            |40                 |6
-       51      |6             |Corn flour        |40                 |7
-       52      |7             |Quicker Cooking         |40                 |8
Your order number is:232
Manager Agent received an Order from Customer/Salesperson Agent
Order Full Information:
Id      |Total Price       |Order Date Time   |Parent Order Id  |Status
232     |-----             |03/03/2016 12:09:34    |null
        |Registered and Ready for Processing
-       Items in this Order:
-       Id      |Item Id       |Item Name         |Order Id    |Quantity
-       333     |1             |Baking powder           |232          |2
-       334     |2             |Vanilla                 |232          |3
-       335     |3             |Food colors       |232          |4
-       336     |4             |Cocoa small       |232          |5
-       337     |5             |Cocoa medium            |232          |6
-       338     |6             |Corn flour        |232          |7
-       339     |7             |Quicker Cooking         |232          |8
Status History:
```

```
-     Status                                                |Set at
            |Time between           |Set by                       |Comment
-     New Order                                       |03/03/2016 12:10:47
      | 0d,   0: 1:13    |Customer_Saeed (CustomerAgent)          |
-     Registered and Ready for Processing                   |03/03/2016
12:11:19     | 0d,   0: 0:32    |Customer_Saeed (CustomerAgent)          |
-     Order Started at: 03/03/2016 12:10:47
-     Last action at:   03/03/2016 12:11:19
-     Order processing took: 0 days, 0 hours, 0 minutes, 32 seconds
```

Inventory Agent received an Order from Manager Agent

```
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
232    |-----            |03/03/2016 12:09:34    |null            |Stock
Requisition Order
-     Items in this Order:
-     Id     |Item Id     |Item Name         |Order Id   |Quantity
-     333    |1           |Baking powder          |232         |2
-     334    |2           |Vanilla                |232         |3
-     335    |3           |Food colors       |232         |4
-     336    |4           |Cocoa small       |232         |5
-     337    |5           |Cocoa medium           |232         |6
-     338    |6           |Corn flour        |232         |7
-     339    |7           |Quicker Cooking        |232         |8
```

Status History:

```
-     Status                                                |Set at
            |Time between           |Set by                       |Comment
-     New Order                                       |03/03/2016 12:10:47
      | 0d,   0: 1:13    |Customer_Saeed (CustomerAgent)          |
-     Registered and Ready for Processing                   |03/03/2016
12:11:19     | 0d,   0: 0:32    |Customer_Saeed (CustomerAgent)          |
-     Stock Requisition Order                               |03/03/2016
12:11:19     | 0d,   0: 0: 0    |Manager (ManagerAgent)       |
-     Order Started at: 03/03/2016 12:10:47
-     Last action at:   03/03/2016 12:11:19
-     Order processing took: 0 days, 0 hours, 0 minutes, 32 seconds
```

Warehouse Supervisor Agent received a Stores Pick List (of Available Stock) from Inventory Agent

This Stores Pick List is generated from parent order id: 232

```
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
233    |-----            |03/03/2016 12:09:34    |232             |Store
Pick List from Available Items
-     Items in this Order:
-     Id     |Item Id     |Item Name         |Order Id   |Quantity    |Load and
Pack Instructions
-     340    |5           |Cocoa medium           |233         |6
      |Avoid humidity
-     341    |7           |Quicker Cooking        |233         |8
      |null
```

Customer / Salesperson Agent received confirmation of the order.

```
Not all items that you have requested is avilable!
      Warehouse Supervisor has confirmed the avilable quantities of your
order.
      Your new placed order info:
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
233    |-----            |03/03/2016 12:09:34    |232             |Store
Pick List from Available Items
-     Items in this Order:
```

```
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      340    |5           |Cocoa medium            |233         |6
-      341    |7           |Quicker Cooking         |233         |8
Warehouse Supervisor Agent received a Pending Pick List from Inventory
Agent
Hint: This Pending Pick List is generated from parent order id: 232
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
234    |-----            |03/03/2016 12:09:34    |232              |Pending
Pick List
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      342    |1           |Baking powder           |234         |2
-      343    |2           |Vanilla                 |234         |3
-      344    |3           |Food colors       |234         |4
-      345    |4           |Cocoa small       |234         |5
-      346    |6           |Corn flour        |234         |7
Status History:
-      Status                                               |Set at
             |Time between           |Set by                      |Comment
Not all items are available!
      For that a sub-order of the available items will be created.
      And, a Pending Pickup List will be created for the unavailable
quantities.
Original Order >
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
232    |-----            |03/03/2016 12:09:34    |null             |Some
Items Avilable in Store Pick List (child order created)
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      333    |1           |Baking powder           |232         |2
-      334    |2           |Vanilla                 |232         |3
-      335    |3           |Food colors       |232         |4
-      336    |4           |Cocoa small       |232         |5
-      337    |5           |Cocoa medium            |232         |6
-      338    |6           |Corn flour        |232         |7
-      339    |7           |Quicker Cooking         |232         |8
Status History:
-      Status                                               |Set at
             |Time between           |Set by                      |Comment
Picker Agent received the Store Pick List from Warehouse Supervisor
Order Full Information:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
233    |-----            |03/03/2016 12:09:34    |232              |Store
Pick List (Received by Worker)
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity    |Load and
Pack Instructions
-      340    |5           |Cocoa medium            |233         |6
       |Avoid humidity
-      341    |7           |Quicker Cooking         |233         |8
       |null
Do you confirm that there is no variances of items in the stock?
If yes press 'Y'; Or else, press any key.
-      New Order                                        |03/03/2016 12:10:47
       | 0d,  0: 1:13    |Customer_Saeed (CustomerAgent)          |
-      Registered and Ready for Processing                    |03/03/2016
12:11:19     | 0d,  0: 0:32    |Customer_Saeed (CustomerAgent)          |
-      Stock Requisition Order                                |03/03/2016
12:11:19     | 0d,  0: 0: 0    |Manager (ManagerAgent)          |
```

```
-	Some Items Avilable in Store Pick List (child order created)
	|03/03/2016 12:11:21	| 0d,  0: 0: 2	|Inventory (InventoryAgent)
		|
-	Pending Pick List				|03/03/2016 12:11:24
	| 0d,  0: 0: 3	|Inventory (InventoryAgent)		|
-	Order Started at: 03/03/2016 12:10:47
-	Last action at:   03/03/2016 12:11:24
-	Order processing took: 0 days, 0 hours, 0 minutes, 37 seconds

-	New Order					|03/03/2016 12:10:47
	| 0d,  0: 1:13	|Customer_Saeed (CustomerAgent)		|
-	Registered and Ready for Processing			|03/03/2016
12:11:19	| 0d,  0: 0:32	|Customer_Saeed (CustomerAgent)		|
-	Stock Requisition Order				|03/03/2016
12:11:19	| 0d,  0: 0: 0	|Manager (ManagerAgent)		|
-	Some Items Avilable in Store Pick List (child order created)
	|03/03/2016 12:11:21	| 0d,  0: 0: 2	|Inventory (InventoryAgent)
		|
-	Order Started at: 03/03/2016 12:10:47
-	Last action at:   03/03/2016 12:11:21
-	Order processing took: 0 days, 0 hours, 0 minutes, 34 seconds

The 2 sub-orders of the previous original order
Order Full Information:
Id	|Total Price	|Order Date Time	|Parent Order Id	|Status
233	|-----	|03/03/2016 12:09:34	|232		|Store
Pick List from Available Items
-	Items in this Order:
-	Id	|Item Id	|Item Name	|Order Id	|Quantity
-	340	|5	|Cocoa medium	|233	|6
-	341	|7	|Quicker Cooking	|233	|8
Order Full Information:
Id	|Total Price	|Order Date Time	|Parent Order Id	|Status
234	|-----	|03/03/2016 12:09:34	|232		|Pending
Pick List
-	Items in this Order:
-	Id	|Item Id	|Item Name	|Order Id	|Quantity
-	342	|1	|Baking powder	|234	|2
-	343	|2	|Vanilla	|234	|3
-	344	|3	|Food colors	|234	|4
-	345	|4	|Cocoa small	|234	|5
-	346	|6	|Corn flour	|234	|7
NO
Is there a variation for the item (Cocoa medium)?
If yes press 'Y'; Or else, press any key.
Y
How much is the missed/defected quantities? Please, enter an integer
number.
1
What is the reason of variance? Please enter a number from below.
-- Start Printing from table VariationReason --
Id	|Info Name
1	|Shortage (Quantity does not exist)
2	|Full Damage
3	|Bad Quality
4	|Missed
-- End Printing from table VariationReason --
3
If you have any notes, please write it down. Or, just press Enter to pass.
NO NOTES
Is there a variation for the item (Quicker Cooking)?
```

```
If yes press 'Y'; Or else, press any key.
NO
Do you confirm that all stock is in the correct locaiton and correct bin?
If yes press 'Y'; Or else, press any key.
Y
Do you confirm that the area is clean, has removed any wast, all stock is
straightened?
If yes press 'Y'; Or else, press any key.
Y
Manager Agent received a Store Pick List from Picker.
Manager Agent produce GDN...
Order Full Information:
Id      |Total Price        |Order Date Time   |Parent Order Id  |Status
233     |-----              |03/03/2016 12:09:34    |232               |Goods
Despatch Notice
-       Customer Information:
-       Id      |Full Name    |Is Black listed   |Address
-       32      |Fahe S       |false                   |Riyadh - High street
-       Items in this Order:
-       Id      |Item Id      |Item Name         |Order Id     |Quantity
-       340     |5            |Cocoa medium            |233          |6
-       341     |7            |Quicker Cooking         |233          |8
Despatch Depot Agent received Goods Despatch Notice (GDN) from Manager.
Does Goods Despatch Notice match Store Pick List?
If yes press 'Y'; Or else, press any key.
NO
DespatchDepot has found a variance in the GDN!
Is there a variation for the item (Cocoa medium)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Quicker Cooking)?
If yes press 'Y'; Or else, press any key.
Y
How much is the missed/defected quantities? Please, enter an integer
number.
1
What is the reason of variance? Please enter a number from below.
-- Start Printing from table VariationReason --
Id      |Info Name
1       |Shortage (Quantity does not exist)
2       |Full Damage
3       |Bad Quality
4       |Missed
-- End Printing from table VariationReason --
4
If you have any notes, please write it down. Or, just press Enter to pass.
NO NOTES
Warehouse Supervisor Agent received escalation alert of stock variance from
Despatch Depot?
Variation Report Full Information:
Id      |Created at         |Created by |Order Type |Order Id
88      |03/03/2016 12:15:19     |DespatchDepot     |Customer_Order    |233
-       Items in this Variation Report:
-       Id      |Item Id      |Item Name    |VariationReport Id      |Quantity
        |Variation Reason |Notes
-       2       |7            |Quicker Cooking         |88                |1
        |Missed             |NO NOTES
Do you want to approve the GDN which has the previous variaiton report?
Order Full Information:
Id      |Total Price        |Order Date Time   |Parent Order Id  |Status
```

```
233    |-----              |03/03/2016 12:09:34    |232              |GDN
(Variance Found by Despatch Depot)
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      340    |5           |Cocoa medium            |233          |6
-      341    |7           |Quicker Cooking         |233          |8
-      _[33mStatus History:_[0m
-      Status                                                    |Set at
              |Time between            |Set by                         |Comment
-      New Order                                           |03/03/2016 12:10:47
       | 0d,   0: 1:13    |Customer_Saeed (CustomerAgent)                |
-      Registered and Ready for Processing                       |03/03/2016
12:11:19     | 0d,   0: 0:32    |Customer_Saeed (CustomerAgent)              |
-      Stock Requisition Order                                   |03/03/2016
12:11:19     | 0d,   0: 0: 0    |Manager (ManagerAgent)          |
-      Some Items Avilable in Store Pick List (child order created)
       |03/03/2016 12:11:21     | 0d,   0: 0: 2    |Inventory (InventoryAgent)
              |
-      Store Pick List from Available Items
       |03/03/2016 12:11:23     | 0d,   0: 0: 2    |Inventory (InventoryAgent)
              |
-      Store Pick List (Received by Worker)
       |03/03/2016 12:11:23     | 0d,   0: 0: 0    |Worker1 (WorkerAgent)
       |
-      Goods Despatch Notice                                     |03/03/2016
12:14:56     | 0d,   0: 3:33    |Manager (ManagerAgent)          |
-      GDN (Variance Found by Despatch Depot)                    |03/03/2016
12:15:19     | 0d,   0: 0:23    |DespatchDepot (DespatchDepotAgent)          |
-      Order Started at: 03/03/2016 12:10:47
-      Last action at:   03/03/2016 12:15:19
-      Order processing took: 0 days, 0 hours, 4 minutes, 32 seconds

If yes press 'Y'; Or else, press any key.
Y
The Warehouse Supervisor has approved the GDN (even with variance) for
DespatchDepot.
Driver Agent received a Packing Order from Despatch Depot Agent
Order Full Information:
Id     |Total Price        |Order Date Time   |Parent Order Id   |Status
233    |-----              |03/03/2016 12:09:34    |232              |GDN
(Approved with Variance by Warehous - for Despatch Depot)
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity    |Load and
Pack Instructions
-      340    |5           |Cocoa medium            |233          |6
       |Avoid humidity
-      341    |7           |Quicker Cooking         |233          |8
       |null
Driver Agent has to match the Packing Order with GDN
Does Packing Order match the GDN?
If yes press 'Y'; Or else, press any key.
NO
Driver (Driver1) has found a variance in the GDN!
Is there a variation for the item (Cocoa medium)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Quicker Cooking)
If yes press 'Y'; Or else, press any key.
Y
How much is the missed/defected quantities? Please, enter an integer
number.
```

```
1
What is the reason of variance? Please enter a number from below.
-- Start Printing from table VariationReason --
Id      |Info Name
1       |Shortage (Quantity does not exist)
2       |Full Damage
3       |Bad Quality
4       |Missed
-- End Printing from table VariationReason --
1
If you have any notes, please write it down. Or, just press Enter to pass.
NO NOTES
Warehouse Supervisor Agent received escalation alert of stock variance from
Driver (Driver1)!
Variation Report Full Information:
Id      |Created at         |Created by |Order Type |Order Id
89      |03/03/2016 12:16:29     |Driver1     |Customer_Order    |233
-       Items in this Variation Report:
-       Id      |Item Id      |Item Name   |VariationReport Id      |Quantity
        |Variation Reason |Notes
-       3       |7            |Quicker Cooking          |89                 |1
        |Shortage (Quantity does not exist)         |NO NOTES
Do you want to approve the GDN which has the previous variaiton report?
Order Full Information:
Id      |Total Price        |Order Date Time   |Parent Order Id   |Status
233     |-----              |03/03/2016 12:09:34     |232                 |GDN
(Variance Found by Driver)
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id    |Quantity
-       340     |5            |Cocoa medium             |233          |6
-       341     |7            |Quicker Cooking          |233          |8
Status History:
-       Status                                                  |Set at
              |Time between            |Set by                          |Comment
-       New Order                                          |03/03/2016 12:10:47
        | 0d,   0: 1:13     |Customer_Saeed (CustomerAgent)           |
-       Registered and Ready for Processing                     |03/03/2016
12:11:19     | 0d,   0: 0:32     |Customer_Saeed (CustomerAgent)           |
-       Stock Requisition Order                                 |03/03/2016
12:11:19     | 0d,   0: 0: 0     |Manager (ManagerAgent)         |
-       Some Items Avilable in Store Pick List (child order created)
        |03/03/2016 12:11:21     | 0d,   0: 0: 2     |Inventory (InventoryAgent)
              |
-       Store Pick List from Available Items
        |03/03/2016 12:11:23     | 0d,   0: 0: 2     |Inventory (InventoryAgent)
              |
-       Store Pick List (Received by Worker)
        |03/03/2016 12:11:23     | 0d,   0: 0: 0     |Worker1 (WorkerAgent)
        |
-       Goods Despatch Notice                                   |03/03/2016
12:14:56     | 0d,   0: 3:33     |Manager (ManagerAgent)         |
-       GDN (Variance Found by Despatch Depot)                  |03/03/2016
12:15:19     | 0d,   0: 0:23     |DespatchDepot (DespatchDepotAgent)        |
-       GDN (Approved with Variance by Warehous - for Despatch Depot)
        |03/03/2016 12:16:06     | 0d,   0: 0:47     |WarehouseSupervisor
(WarehouseSupervisorAgent)          |
-       GDN (Variance Found by Driver)
        |03/03/2016 12:16:28     | 0d,   0: 0:22     |Driver1 (DriverAgent)
        |
-       Order Started at: 03/03/2016 12:10:47
-       Last action at:   03/03/2016 12:16:28
```

```
-     Order processing took: 0 days, 0 hours, 5 minutes, 41 seconds

If yes press 'Y'; Or else, press any key.
Y
The Warehouse Supervisor has approved the GDN (even with variance) for
Driver (Driver1)._[0m
Manager Agent received a Packing Order (Approved to be matching GDN) from
Driver Agent_[0m
Manager Agent Generates Customer Invoice...
Order Customer Invoice:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
233    |1460.0           |03/03/2016 12:09:34    |232               |GDN
(Customer Invoice Created)
-     Customer Information:
-     Id     |Full Name   |Is Black listed   |Address
-     32     |Fahe S      |false                   |Riyadh - High street
-     Items in this Order:
-     Id     |Item Id     |Item Name         |Order Id    |Quantity
-     340    |5           |Cocoa medium            |233          |6
-     341    |7           |Quicker Cooking         |233          |8
Order Total Price: 1460.0
Driver Agent recived the Customer Invoice from Manager Agent
Driver Agent suppose to travel with goods...
Driver at Customer Site >>>
Does Packing Order match the GDN and the customer accepted the order?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Cocoa medium)?
If yes press 'Y'; Or else, press any key.
Y
How much is the missed/defected quantities? Please, enter an integer
number.
1
What is the reason of variance? Please enter a number from below.
-- Start Printing from table VariationReason --
Id     |Info Name
1      |Shortage (Quantity does not exist)
2      |Full Damage
3      |Bad Quality
4      |Missed
-- End Printing from table VariationReason --
2
If you have any notes, please write it down. Or, just press Enter to pass.
NO NOTES
Is there a variation for the item (Quicker Cooking)?
If yes press 'Y'; Or else, press any key.
NO
Does the customer fully reject to receive the order?
If yes press 'Y'; Or else, press any key.
NO
Order Customer Invoice:
Id     |Total Price      |Order Date Time   |Parent Order Id  |Status
233    |1310.0           |03/03/2016 12:09:34    |232               |GDN
(Partially Approved by Customer)
-     Customer Information:
-     Id     |Full Name   |Is Black listed   |Address
-     32     |Fahe S      |false                   |Riyadh - High street
-     Items in this Order:
-     Id     |Item Id     |Item Name         |Order Id    |Quantity
-     null   |5           |Cocoa medium            |233          |5
-     null   |7           |Quicker Cooking         |233          |8
```

```
Order Total Price: 1310.0
Warehouse Supervisor Agent received an Order from Driver Agent
The order was partially approved by customer. So, there is an associated
Pending Pick List with this order
Warehouse Supervisor Agent Updated the Order as GDNC - Completed
Order Full Information:
Id     |Total Price       |Order Date Time   |Parent Order Id  |Status
233    |1310.0            |03/03/2016 12:09:34    |232              |GDN
(Finished Processing)
-      Items in this Order:
-      Id     |Item Id     |Item Name        |Order Id   |Quantity
-      null   |5           |Cocoa medium           |233          |5
-      null   |7           |Quicker Cooking        |233          |8
Status History:
-      Status                                                  |Set at
             |Time between           |Set by                       |Comment
-      New Order                                         |03/03/2016 12:10:47
       | 0d,  0: 1:13     |Customer_Saeed (CustomerAgent)            |
-      Registered and Ready for Processing                     |03/03/2016
12:11:19     | 0d,  0: 0:32     |Customer_Saeed (CustomerAgent)            |
-      Stock Requisition Order                                 |03/03/2016
12:11:19     | 0d,  0: 0: 0     |Manager (ManagerAgent)          |
-      Some Items Avilable in Store Pick List (child order created)
       |03/03/2016 12:11:21     | 0d,  0: 0: 2     |Inventory (InventoryAgent)
             |
-      Store Pick List from Available Items
       |03/03/2016 12:11:23     | 0d,  0: 0: 2     |Inventory (InventoryAgent)
             |
-      Store Pick List (Received by Worker)
       |03/03/2016 12:11:23     | 0d,  0: 0: 0     |Worker1 (WorkerAgent)
       |
-      Goods Despatch Notice                                   |03/03/2016
12:14:56     | 0d,  0: 3:33     |Manager (ManagerAgent)          |
-      GDN (Variance Found by Despatch Depot)                  |03/03/2016
12:15:19     | 0d,  0: 0:23     |DespatchDepot (DespatchDepotAgent)        |
-      GDN (Approved with Variance by Warehous - for Despatch Depot)
       |03/03/2016 12:16:06     | 0d,  0: 0:47     |WarehouseSupervisor
(WarehouseSupervisorAgent)          |
-      GDN (Variance Found by Driver)
       |03/03/2016 12:16:28     | 0d,  0: 0:22     |Driver1 (DriverAgent)
       |
-      GDN (Approved with Variance by Warehous - for Driver)
       |03/03/2016 12:17:15     | 0d,  0: 0:47     |WarehouseSupervisor
(WarehouseSupervisorAgent)          |
-      GDN (Customer Invoice Created)
       |03/03/2016 12:17:16     | 0d,  0: 0: 1     |Manager (ManagerAgent)
       |
-      GDN (On the Way to Customer)                            |03/03/2016
12:17:17     | 0d,  0: 0: 1     |Driver1 (DriverAgent)           |
-      GDN (Arrived to Customer)                               |03/03/2016
12:17:17     | 0d,  0: 0: 0     |Driver1 (DriverAgent)           |
-      GDN (Partially Approved by Customer)
       |03/03/2016 12:18:05     | 0d,  0: 0:48     |Driver1 (DriverAgent)
       |Customer Signature: Fahe S
-      GDN (Finished Processing)                               |03/03/2016
12:18:06     | 0d,  0: 0: 1     |WarehouseSupervisor
(WarehouseSupervisorAgent)          |
-      Order Started at: 03/03/2016 12:10:47
-      Last action at:   03/03/2016 12:18:06
-      Order processing took: 0 days, 0 hours, 7 minutes, 19 seconds
```

```
Pending Pick List information:
Order Full Information:
Id     |Total Price      |Order Date Time  |Parent Order Id  |Status
235    |-----            |03/03/2016 12:09:34    |233              |Pending
Pick List
-      Items in this Order:
-      Id     |Item Id     |Item Name        |Order Id    |Quantity
-      347    |5           |Cocoa medium           |235         |1
```

Second configuration: Customer Order (By SalesPerson Agent):

-gui -name Multi-Agent-System-Supply-Chain-Management
SIP:mas.systemInformation.SystemInformationProviderAgent;Salesperson1:mas.sales.SalespersonAgent;SalesOfficer:mas.sales.SalesOfficeAgent;Inventory:mas.warehouse.InventoryAgent;Manager:mas.ManagerAgent;WarehouseSupervisor:mas.warehouse.WarehouseSupervisorAgent;Worker1:mas.warehouse.WorkerAgent;Driver1:mas.warehouse.DriverAgent;DespatchDepot:mas.warehouse.DespatchDepotAgent;sniffer:jade.tools.sniffer.Sniffer(SIP,Salesperson1,SalesOfficer,Inventory,Manager,WarehouseSupervisor,Picker1,Driver1,DespatchDepot)

………

```
Mar 04, 2016 9:52:20 AM jade.core.Runtime beginContainer
INFO: ----------------------------------
    This is JADE 4.3.2 - revision 6708 of 2014/03/28 15:19:44
    downloaded in Open Source, under LGPL restrictions,
    at http://jade.tilab.com/
----------------------------------------
Mar 04, 2016 9:52:21 AM jade.imtp.leap.LEAPIMTPManager initialize
INFO: Listening for intra-platform commands on address:
- jicp://192.168.1.69:1099

Mar 04, 2016 9:52:21 AM jade.core.BaseService init
INFO: Service jade.core.management.AgentManagement initialized
Mar 04, 2016 9:52:21 AM jade.core.BaseService init
INFO: Service jade.core.messaging.Messaging initialized
Mar 04, 2016 9:52:21 AM jade.core.BaseService init
INFO: Service jade.core.resource.ResourceManagement initialized
Mar 04, 2016 9:52:21 AM jade.core.BaseService init
INFO: Service jade.core.mobility.AgentMobility initialized
Mar 04, 2016 9:52:21 AM jade.core.BaseService init
INFO: Service jade.core.event.Notification initialized
Mar 04, 2016 9:52:21 AM jade.mtp.http.HTTPServer <init>
INFO: HTTP-MTP Using XML parser
com.sun.org.apache.xerces.internal.jaxp.SAXParserImpl$JAXPSAXParser
Mar 04, 2016 9:52:21 AM jade.core.messaging.MessagingService boot
INFO: MTP addresses:
http://Acer.lan:7778/acc
Mar 04, 2016 9:52:22 AM jade.core.AgentContainerImpl joinPlatform
INFO: --------------------------------------
Agent container Main-Container@192.168.1.69 is ready.
--------------------------------------------
Agent Driver1 has started.
Agent Manager has started.
Agent WarehouseSupervisor has started.
Agent Inventory has started.
Agent SIP has started.
Agent Salesperson1 has started.
Agent SalesOfficer has started.
Agent Worker1 has started.
Agent DespatchDepot has started.
Data in Database:
-- Start Printing from table Item --
Id     |Item Name        |Price      |QuantityInStock   |BestCaseDeliveryTime
       |WorseCaseDeliveryTime   |MinimumOrderTime  |SafetyStockDays
       |ExpirationDate
1      |Baking powder            |52.0  |0                 |30                |40
                  |45                |15                |01/04/2016
2      |Vanilla                  |72.0  |0                 |30                |40
                  |45                |15                |29/09/2015
```

```
3      |Food colors     |185.0      |0                 |40                |60
             |60                |20                |01/10/2015
4      |Cocoa small     |180.0      |0                 |30                |40
             |45                |15                |03/08/2015
5      |Cocoa medium          |150.0      |4988              |30
       |40                |45                |15                |01/03/2016
6      |Corn flour      |26.0 |0                 |7                 |14
             |15                |30                |03/01/2017
7      |Quicker Cooking       |70.0 |1992              |30                |40
             |45                |30                |03/01/2017
8      |Color of Egg Yolk     |120.0      |0                 |40
       |50                |60                |30                |01/01/2017
9      |Color Saffar Safforn  |110.0      |0                 |40
       |50                |60                |30                |01/01/2017
10     |Black Pipper          |200.0      |0                 |7
       |14                |15                |30                |01/01/2017
11     |Chilli Powder         |220.0      |0                 |7
       |14                |15                |30                |01/01/2017
12     |Sodium Bicarbonate    |55.0 |0                 |30                |40
             |45                |30                |01/05/2017
13     |Baking Powder   |50.0 |0                 |30                |40
             |45                |15                |01/05/2017
14     |Food Powder     |55.0 |0                 |30                |40
             |45                |15                |01/05/2017
15     |Corn Flour |55.0 |0                 |30                |40
       |45                |15                |01/05/2017
16     |Cocoa Powder    |230.0      |0                 |30                |40
             |45                |15                |01/05/2017
17     |Bicarbonate Sodium 25kg     |45.0 |0                 |30
       |40                |45                |15                |01/05/2017
18     |Cummin Powder   |170.0      |0                 |40                |50
             |60                |30                |01/05/2017
19     |Ginger Powder   |170.0      |0                 |30                |40
             |45                |15                |01/05/2017
20     |Sesame Seed     |105.0      |0                 |30                |40
             |45                |15                |01/05/2017
-- End Printing from table Item --
-- Start Printing from table Customer --
Id     |Full Name  |Is Black listed  |Address
0      |Com. Profile    |false                  |Company Address
1      |Doon B     |false                  |17, Montgomery House, UK
2      |Bakker T   |false                  |10, High Street, UK
3      |Jone A     |true             |10, High Street, UK
4      |Yasser Hamad    |false                  |Building 2344, Olaya,
Takhassusi Road, Riyadh, Saudi Arabia
5      |Yasser S   |false                  |Bulding 11, Street 12, Central
Jonata, London, UK
6      |Saeed Saud |false                  |Riyadh, KSA
32     |Fahe S     |false                  |Riyadh - High street
33     |Fahed Suliman   |false                  |Riyadh - High street
34     |fahed      |false                  |138 high street
35     |fahed      |false                  |123 high street
36     |fahad      |false                  |123 high street
-- End Printing from table Customer --
Salesperson1 > Is this an existing customer? Or else, a new one!
If yes press 'Y'; Or else, press any key.
Y
Please, enter the customer Id.
4
Customer Info (from Database):
Id     |Full Name  |Is Black listed  |Address
```

```
4      |Yasser Hamad     |false                  |Building 2344, Olaya,
Takhassusi Road, Riyadh, Saudi Arabia
Customer & Salesperson Agent (Salesperson1) is trying to place an Order...
Salesperson1 > Collect Order Data...
Salesperson1 > Enter Items Ids separated by space:
1 2 3 4 5 6 7
Salesperson1 > Enter quantities separated by space:
3 4 5 6 7 8 9
Salesperson1 > Order and its Items has been placed by: Salesperson1.
Order Full Information:
Id     |Total Price      |Order Date Time  |Parent Order Id  |Status
236    |-----            |04/03/2016 09:52:23    |null              |New
Order
-      Items in this Order:
-      Id     |Item Id     |Item Name        |Order Id    |Quantity
-      348    |1           |Baking powder          |236           |3
-      349    |2           |Vanilla                |236           |4
-      350    |3           |Food colors      |236         |5
-      351    |4           |Cocoa small      |236         |6
-      352    |5           |Cocoa medium           |236           |7
-      353    |6           |Corn flour       |236         |8
-      354    |7           |Quicker Cooking        |236           |9
The items will be shipped within the next working day.
Salesperson1 > Do you want a repeated order? Or else, a one time request?
If yes press 'Y'; Or else, press any key.
NO
Your order number is:236
Manager Agent received an Order from Customer/Salesperson Agent
Order Full Information:
Id     |Total Price      |Order Date Time  |Parent Order Id  |Status
236    |-----            |04/03/2016 09:52:23    |null
       |Registered and Ready for Processing
-      Items in this Order:
-      Id     |Item Id     |Item Name        |Order Id    |Quantity
-      348    |1           |Baking powder          |236           |3
-      349    |2           |Vanilla                |236           |4
-      350    |3           |Food colors      |236         |5
-      351    |4           |Cocoa small      |236         |6
-      352    |5           |Cocoa medium           |236           |7
-      353    |6           |Corn flour       |236         |8
-      354    |7           |Quicker Cooking        |236           |9
Status History:
-      Status                                               |Set at
             |Time between          |Set by                         |Comment
-      New Order                                      |04/03/2016 09:53:30
       | 0d,  0: 1: 7     |Salesperson1 (SalespersonAgent)          |
-      Registered and Ready for Processing                  |04/03/2016
09:53:56    | 0d,  0: 0:26     |Salesperson1 (SalespersonAgent)          |
-      Order Started at: 04/03/2016 09:53:30
-      Last action at:   04/03/2016 09:53:56
-      Order processing took: 0 days, 0 hours, 0 minutes, 26 seconds

Inventory Agent received an Order from Manager Agent
Order Full Information:
Id     |Total Price      |Order Date Time  |Parent Order Id  |Status
236    |-----            |04/03/2016 09:52:23    |null              |Stock
Requisition Order
-      Items in this Order:
-      Id     |Item Id     |Item Name        |Order Id    |Quantity
-      348    |1           |Baking powder          |236           |3
-      349    |2           |Vanilla                |236           |4
```

```
-	350	|3		|Food colors	|236		|5
-	351	|4		|Cocoa small	|236		|6
-	352	|5		|Cocoa medium		|236		|7
-	353	|6		|Corn flour	|236		|8
-	354	|7		|Quicker Cooking	|236		|9
```
Status History:
```
-	Status						|Set at
	|Time between		|Set by				|Comment
-	New Order					|04/03/2016 09:53:30
	| 0d,  0: 1: 7	|Salesperson1 (SalespersonAgent)		|
-	Registered and Ready for Processing		|04/03/2016
09:53:56	| 0d,  0: 0:26	|Salesperson1 (SalespersonAgent)		|
-	Stock Requisition Order				|04/03/2016
09:53:57	| 0d,  0: 0: 1	|Manager (ManagerAgent)		|
-	Order Started at: 04/03/2016 09:53:30
-	Last action at:   04/03/2016 09:53:57
-	Order processing took: 0 days, 0 hours, 0 minutes, 27 seconds
```

Warehouse Supervisor Agent received a Stores Pick List (of Available Stock) from Inventory Agent

This Stores Pick List is generated from parent order id: 236

```
Order Full Information:
Id	|Total Price	|Order Date Time	|Parent Order Id	|Status
237	|-----		|04/03/2016 09:52:23	|236		|Store
Pick List from Available Items
-	Items in this Order:
-	Id	|Item Id	|Item Name	|Order Id	|Quantity	|Load and
Pack Instructions
-	355	|5		|Cocoa medium		|237		|7
	|Avoid humidity
-	356	|7		|Quicker Cooking	|237		|9
	|null
```

Customer / Salesperson Agent received confirmation of the order.

```
Not all items that you have requested is avilable!
	However, our Warehouse Supervisor has confirmed the avilable
quantities of your order.
	Your new placed order info:
Order Full Information:
Id	|Total Price	|Order Date Time	|Parent Order Id	|Status
237	|-----		|04/03/2016 09:52:23	|236		|Store
Pick List from Available Items
-	Items in this Order:
-	Id	|Item Id	|Item Name	|Order Id	|Quantity
-	355	|5		|Cocoa medium		|237		|7
-	356	|7		|Quicker Cooking	|237		|9
```

Warehouse Supervisor Agent received a Pending Pick List from Inventory Agent

Hint: This Pending Pick List is generated from parent order id: 236

```
Order Full Information:
Id	|Total Price	|Order Date Time	|Parent Order Id	|Status
238	|-----		|04/03/2016 09:52:23	|236		|Pending
Pick List
-	Items in this Order:
-	Id	|Item Id	|Item Name	|Order Id	|Quantity
-	357	|1		|Baking powder		|238		|3
-	358	|2		|Vanilla		|238		|4
-	359	|3		|Food colors	|238		|5
-	360	|4		|Cocoa small	|238		|6
-	361	|6		|Corn flour	|238		|8
```

Status History:

```
-       Status                                                  |Set at
              |Time between            |Set by                        |Comment
Not all items are available! For that a sub-order of the available items
will be created. And, a Pending Pickup List will be created for the
unavailable quantities.
Original Order >
Order Full Information:
Id      |Total Price       |Order Date Time   |Parent Order Id  |Status
236     |-----             |04/03/2016 09:52:23    |null               |Some
Items Avilable in Store Pick List (child order created)
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id     |Quantity
-       348     |1            |Baking powder           |236          |3
-       349     |2            |Vanilla                 |236          |4
-       350     |3            |Food colors        |236          |5
-       351     |4            |Cocoa small        |236          |6
-       352     |5            |Cocoa medium            |236          |7
-       353     |6            |Corn flour         |236          |8
-       354     |7            |Quicker Cooking         |236          |9
Status History:
-       Status                                                  |Set at
              |Time between            |Set by                        |Comment
Picker Agent received the Store Pick List from Warehouse Supervisor
Order Full Information:
Id      |Total Price       |Order Date Time   |Parent Order Id  |Status
237     |-----             |04/03/2016 09:52:23    |236                |Store
Pick List (Received by Worker)
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id     |Quantity     |Load and
Pack Instructions
-       355     |5            |Cocoa medium            |237          |7
        |Avoid humidity
-       356     |7            |Quicker Cooking         |237          |9
        |null
Do you confirm that there is no variances of items in the stock?
If yes press 'Y'; Or else, press any key.
-       New Order                                            |04/03/2016 09:53:30
        | 0d,   0: 1: 7     |Salesperson1 (SalespersonAgent)          |
-       Registered and Ready for Processing                     |04/03/2016
09:53:56     | 0d,   0: 0:26     |Salesperson1 (SalespersonAgent)          |
-       Stock Requisition Order                                 |04/03/2016
09:53:57     | 0d,   0: 0: 1     |Manager (ManagerAgent)       |
-       Some Items Avilable in Store Pick List (child order created)
        |04/03/2016 09:53:59     | 0d,   0: 0: 2     |Inventory (InventoryAgent)
              |
-       Order Started at: 04/03/2016 09:53:30
-       Last action at:   04/03/2016 09:53:59
-       Order processing took: 0 days, 0 hours, 0 minutes, 29 seconds

The 2 sub-orders of the previous original order >
Order Full Information:
Id      |Total Price       |Order Date Time   |Parent Order Id  |Status
237     |-----             |04/03/2016 09:52:23    |236                |Store
Pick List from Available Items
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id     |Quantity
-       New Order                                            |04/03/2016 09:53:30
        | 0d,   0: 1: 7     |Salesperson1 (SalespersonAgent)          |
-       Registered and Ready for Processing                     |04/03/2016
09:53:56     | 0d,   0: 0:26     |Salesperson1 (SalespersonAgent)          |
```

```
-     Stock Requisition Order                                    |04/03/2016
09:53:57    | 0d,  0: 0: 1    |Manager (ManagerAgent)            |
-     Some Items Avilable in Store Pick List (child order created)
      |04/03/2016 09:53:59    | 0d,  0: 0: 2    |Inventory (InventoryAgent)
            |
-     Pending Pick List                                   |04/03/2016 09:54:01
      | 0d,  0: 0: 2    |Inventory (InventoryAgent)          |
-     Order Started at: 04/03/2016 09:53:30
-     Last action at:   04/03/2016 09:54:01
-     Order processing took: 0 days, 0 hours, 0 minutes, 31 seconds

-     355   |5          |Cocoa medium           |237        |7
-     356   |7          |Quicker Cooking        |237        |9
Order Full Information:
Id    |Total Price      |Order Date Time  |Parent Order Id  |Status
238   |-----            |04/03/2016 09:52:23    |236              |Pending
Pick List
-     Items in this Order:
-     Id    |Item Id    |Item Name        |Order Id   |Quantity
-     357   |1          |Baking powder          |238        |3
-     358   |2          |Vanilla                |238        |4
-     359   |3          |Food colors      |238        |5
-     360   |4          |Cocoa small      |238        |6
-     361   |6          |Corn flour       |238        |8
NO
Is there a variation for the item (Cocoa medium     )?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Quicker Cooking     )?
If yes press 'Y'; Or else, press any key.
NO
Do you confirm that all stock is in the correct location and correct bin?
If yes press 'Y'; Or else, press any key.
Y
Do you confirm that the area is clean, has removed any west, all stock is
straightened?
If yes press 'Y'; Or else, press any key.
Y
Manager Agent received a Store Pick List from Picker.
Manager Agent produce GDN...
Order Full Information:
Id    |Total Price      |Order Date Time  |Parent Order Id  |Status
237   |-----            |04/03/2016 09:52:23    |236              |Goods
Despatch Notice
-     Customer Information:
-     Id    |Full Name  |Is Black listed  |Address
-     4     |Yasser Hamad     |false                      |Building 2344,
Olaya, Takhassusi Road, Riyadh, Saudi Arabia
-     Items in this Order:
-     Id    |Item Id    |Item Name        |Order Id   |Quantity
-     355   |5          |Cocoa medium           |237        |7
-     356   |7          |Quicker Cooking        |237        |9
Despatch Depot Agent received Goods Despatch Notice (GDN) from Manager.
Does Goods Despatch Notice match Store Pick List?
If yes press 'Y'; Or else, press any key.
Y
Goods Despatch Notice matches Store Pick List.
Order Full Information:
Id    |Total Price      |Order Date Time  |Parent Order Id  |Status
237   |-----            |04/03/2016 09:52:23    |236              |GDN
(Acepted by Despatch Depot)
```

```
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id    |Quantity     |Load and
Pack Instructions
-       355     |5            |Cocoa medium             |237           |7
        |Avoid humidity
-       356     |7            |Quicker Cooking          |237           |9
        |null
Despatch Depot has got those instructions to be applied when packaging the
order:
Regulations for Packing Order:
1. Heaviest items must be picked and packed first.
2. Heavy items must be distributed evenly in the delivery vehicle.
3. Maximum weight thresholds must not be exceeded selects the right size
truck.
4. Do not exceed packing height of 1.5m
5. Sequence of delivery of products will be arranged  to deliver the
products in order
    from front of truck (door) to back of truck  - it will be delivered
Last in First Out.
6. Maintain temperature at 20c.?_[0m
Driver Agent received a Packing Order from Despatch Depot Agent
Order Full Information:
Id      |Total Price       |Order Date Time    |Parent Order Id  |Status
237     |-----             |04/03/2016 09:52:23     |236               |GDN
(Acepted by Despatch Depot)
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id    |Quantity     |Load and
Pack Instructions
-       355     |5            |Cocoa medium             |237           |7
        |Avoid humidity
-       356     |7            |Quicker Cooking          |237           |9
        |null
Driver Agent has to match the Packing Order with GDN
Does Packing Order match the GDN?
If yes press 'Y'; Or else, press any key.
Y
The driver has approved the GDN with no variance.
Order Full Information:
Id      |Total Price       |Order Date Time    |Parent Order Id  |Status
237     |-----             |04/03/2016 09:52:23     |236               |GDN
(Acepted by Driver)
-       Items in this Order:
-       Id      |Item Id      |Item Name          |Order Id    |Quantity
-       355     |5            |Cocoa medium             |237           |7
-       356     |7            |Quicker Cooking          |237           |9
The driver has got those instructions to be applied when packaging the
order:
Regulations for Packing Order:
1. Heaviest items must be picked and packed first.
2. Heavy items must be distributed evenly in the delivery vehicle.
3. Maximum weight thresholds must not be exceeded selects the right size
truck.
4. Do not exceed packing height of 1.5m
5. Sequence of delivery of products will be arranged  to deliver the
products in order
    from front of truck (door) to back of truck  - it will be delivered
Last in First Out.
6. Maintain temperature at 20c.?_[0m
Manager Agent received a Packing Order (Approved to be matching GDN) from
Driver Agent
Manager Agent Generates Customer Invoice...
```

```
Order Customer Invoice:
Id     |Total Price       |Order Date Time    |Parent Order Id  |Status
237    |1680.0            |04/03/2016 09:52:23    |236              |GDN
(Customer Invoice Created)
-      Customer Information:
-      Id     |Full Name   |Is Black listed   |Address
-      4      |Yasser Hamad     |false                  |Building 2344,
Olaya, Takhassusi Road, Riyadh, Saudi Arabia
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      355    |5           |Cocoa medium            |237         |7
-      356    |7           |Quicker Cooking         |237         |9
Order Total Price: 1680.0
Driver Agent recived the Customer Invoice from Manager Agent
Driver Agent suppose to travel with goods...
Driver at Customer Site >>>
Does Packing Order match the GDN and the customer accepted the order?
If yes press 'Y'; Or else, press any key.
Y
The customer at its site has approved the GDN with no variance.
Order Customer Invoice:
Id     |Total Price       |Order Date Time    |Parent Order Id  |Status
237    |1680.0            |04/03/2016 09:52:23    |236              |GDN
(Accepted by Customer)
-      Customer Information:
-      Id     |Full Name   |Is Black listed   |Address
-      4      |Yasser Hamad     |false                  |Building 2344,
Olaya, Takhassusi Road, Riyadh, Saudi Arabia
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      355    |5           |Cocoa medium            |237         |7
-      356    |7           |Quicker Cooking         |237         |9
Order Total Price: 1680.0
Warehouse Supervisor Agent received an Order from Driver Agent
Warehouse Supervisor Agent Updated the Order as GDNC - Completed
Order Full Information:
Id     |Total Price       |Order Date Time    |Parent Order Id  |Status
237    |1680.0            |04/03/2016 09:52:23    |236              |GDN
(Finished Processing)
-      Items in this Order:
-      Id     |Item Id     |Item Name         |Order Id    |Quantity
-      355    |5           |Cocoa medium            |237         |7
-      356    |7           |Quicker Cooking         |237         |9
Status History:
-      Status                                                |Set at
             |Time between             |Set by                           |Comment
-      New Order                                       |04/03/2016 09:53:30
       | 0d,  0: 1: 7     |Salesperson1 (SalespersonAgent)           |
-      Registered and Ready for Processing                   |04/03/2016
09:53:56     | 0d,  0: 0:26     |Salesperson1 (SalespersonAgent)           |
-      Stock Requisition Order                               |04/03/2016
09:53:57     | 0d,  0: 0: 1     |Manager (ManagerAgent)        |
-      Some Items Avilable in Store Pick List (child order created)
       |04/03/2016 09:53:59     | 0d,  0: 0: 2     |Inventory (InventoryAgent)
             |
-      Store Pick List from Available Items
       |04/03/2016 09:54:00     | 0d,  0: 0: 1     |Inventory (InventoryAgent)
             |
-      Store Pick List (Received by Worker)
       |04/03/2016 09:54:01     | 0d,  0: 0: 1     |Worker1 (WorkerAgent)
       |
```

```
-     Goods Despatch Notice                                 |04/03/2016
09:55:33    | 0d,  0: 1:32    |Manager (ManagerAgent)       |
-     GDN (Acepted by Despatch Depot)
      |04/03/2016 09:59:28    | 0d,  0: 3:55    |DespatchDepot
(DespatchDepotAgent)        |
-     GDN (Acepted by Driver)                               |04/03/2016
10:03:52    | 0d,  0: 4:24    |Driver1 (DriverAgent)        |
-     GDN (Customer Invoice Created)
      |04/03/2016 10:03:53    | 0d,  0: 0: 1    |Manager (ManagerAgent)
      |
-     GDN (On the Way to Customer)                          |04/03/2016
10:03:54    | 0d,  0: 0: 1    |Driver1 (DriverAgent)        |
-     GDN (Arrived to Customer)                             |04/03/2016
10:03:54    | 0d,  0: 0: 0    |Driver1 (DriverAgent)        |
-     GDN (Accepted by Customer)                            |04/03/2016
10:05:09    | 0d,  0: 1:15    |Driver1 (DriverAgent)        |Driver:
Driver1; On behalf of Customer: Yasser Hamad
-     GDN (Finished Processing)                             |04/03/2016
10:05:10    | 0d,  0: 0: 1    |WarehouseSupervisor
(WarehouseSupervisorAgent)          |
-     Order Started at: 04/03/2016 09:53:30
-     Last action at:   04/03/2016 10:05:10
-     Order processing took: 0 days, 0 hours, 11 minutes, 40 seconds
```

Third configuration: Kanban:

-gui -name Multi-Agent-System-Supply-Chain-Management

SIP:mas.systemInformation.SystemInformationProviderAgent;InventoryChecker:mas.warehouse.InventoryCheckerAgent;Inventory:mas.warehouse.InventoryAgent;WarehouseSupervisor:mas.warehouse.WarehouseSupervisorAgent;GoodsReceiving:mas.warehouse.GoodsReceivingAgent;Worker1:mas.warehouse.WorkerAgent;ProcurementOfficer:mas.procurement.ProcurementOfficeAgent;sniffer:jade.tools.sniffer.Sniffer(SIP,InventoryChecker,Inventory,Inventory,WarehouseSupervisor,Worker1,GoodsReceiving,ProcurementOfficer)

……

```
Mar 04, 2016 10:23:15 AM jade.core.Runtime beginContainer
INFO: ----------------------------------
    This is JADE 4.3.2 - revision 6708 of 2014/03/28 15:19:44
    downloaded in Open Source, under LGPL restrictions,
    at http://jade.tilab.com/
----------------------------------------
Mar 04, 2016 10:23:15 AM jade.imtp.leap.LEAPIMTPManager initialize
INFO: Listening for intra-platform commands on address:
- jicp://192.168.1.69:1099

Mar 04, 2016 10:23:16 AM jade.core.BaseService init
INFO: Service jade.core.management.AgentManagement initialized
Mar 04, 2016 10:23:16 AM jade.core.BaseService init
INFO: Service jade.core.messaging.Messaging initialized
Mar 04, 2016 10:23:16 AM jade.core.BaseService init
INFO: Service jade.core.resource.ResourceManagement initialized
Mar 04, 2016 10:23:16 AM jade.core.BaseService init
INFO: Service jade.core.mobility.AgentMobility initialized
Mar 04, 2016 10:23:16 AM jade.core.BaseService init
INFO: Service jade.core.event.Notification initialized
Mar 04, 2016 10:23:16 AM jade.mtp.http.HTTPServer <init>
INFO: HTTP-MTP Using XML parser
com.sun.org.apache.xerces.internal.jaxp.SAXParserImpl$JAXPSAXParser
Mar 04, 2016 10:23:16 AM jade.core.messaging.MessagingService boot
INFO: MTP addresses:
http://Acer.lan:7778/acc
Mar 04, 2016 10:23:16 AM jade.core.AgentContainerImpl joinPlatform
INFO: --------------------------------------
Agent container Main-Container@192.168.1.69 is ready.
--------------------------------------------
Agent GoodsReceiving has started.
Agent InventoryChecker has started.
Agent SIP has started.
Agent WarehouseSupervisor has started.
Agent ProcurementOfficer has started.
Agent Worker1 has started.
Agent Inventory has started.
Data in Database:
-- Start Printing from table Item --
Id     |Item Name         |Price      |QuantityInStock   |BestCaseDeliveryTime
       |WorseCaseDeliveryTime   |MinimumOrderTime |SafetyStockDays
       |ExpirationDate
1      |Baking powder           |52.0  |0                 |30                |40
                   |45                |15                |01/04/2016
2      |Vanilla                 |72.0  |0                 |30                |40
                   |45                |15                |29/09/2015
3      |Food colors       |185.0      |0                 |40                |60
                   |60                |20                |01/10/2015
```

```
4      |Cocoa small      |180.0      |0                 |30                |40
                   |45               |15                |03/08/2015
5      |Cocoa medium           |150.0      |4995              |30
       |40               |45               |15                |01/03/2016
6      |Corn flour       |26.0 |0                 |7                 |14
             |15               |30                |03/01/2017
7      |Quicker Cooking        |70.0 |2000              |30                |40
                   |45               |30                |03/01/2017
8      |Color of Egg Yolk      |120.0      |0                 |40
       |50               |60                     |30                |01/01/2017
9      |Color Saffar Safforn   |110.0      |0                 |40
       |50               |60                     |30                |01/01/2017
10     |Black Pipper           |200.0      |0                 |7
       |14               |15                     |30                |01/01/2017
11     |Chilli Powder          |220.0      |0                 |7
       |14               |15                     |30                |01/01/2017
12     |Sodium Bicarbonate     |55.0 |0                 |30                |40
                   |45               |30                |01/05/2017
13     |Baking Powder    |50.0 |0                 |30                |40
             |45               |15                |01/05/2017
14     |Food Powder      |55.0 |0                 |30                |40
             |45               |15                |01/05/2017
15     |Corn Flour |55.0 |0                 |30                |40
       |45               |15                |01/05/2017
16     |Cocoa Powder     |230.0      |0                 |30                |40
                   |45               |15                |01/05/2017
17     |Bicarbonate Sodium 25kg      |45.0 |0                 |30
       |40               |45               |15                |01/05/2017
18     |Cummin Powder    |170.0      |0                 |40                |50
                   |60               |30                |01/05/2017
19     |Ginger Powder    |170.0      |0                 |30                |40
                   |45               |15                |01/05/2017
20     |Sesame Seed      |105.0      |0                 |30                |40
                   |45               |15                |01/05/2017
-- End Printing from table Item --
-- Start Printing from table Customer --
Id     |Full Name  |Is Black listed  |Address
0      |Com. Profile     |false                   |Company Address
1      |Doon B     |false                   |17, Montgomery House, UK
2      |Bakker T   |false                   |10, High Street, UK
3      |Jone A     |true              |10, High Street, UK
4      |Yasser Hamad     |false                   |Building 2344, Olaya,
Takhassusi Road, Riyadh, Saudi Arabia
5      |Yasser S   |false                   |Bulding 11, Street 12, Central
Jonata, London, UK
6      |Saeed Saud |false                   |Riyadh, KSA
32     |Fahe S     |false                   |Riyadh - High street
33     |Fahed Suliman    |false                   |Riyadh - High street
34     |fahed      |false                   |138 high street
35     |fahed      |false                   |123 high street
36     |fahad      |false                   |123 high street
-- End Printing from table Customer --
Inventory Checker Agent will Check the Inventory...
-- Start Printing from table RepeatedOrder --
Id     |Customer Name    |Order Date Time   |Period in Days
0      |Doon B     |27/07/2015 20:39:55    |7
-- End Printing from table RepeatedOrder --
Processing for Item Id: 1, Name: Baking powder
 - Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all
occurrences of this item in the Repeated Orders Items = 71.42857142857143
 - Best Case Delivery Time = 30.0
```

- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 2500.0
- Safety Stock Days = 15.0
- Safety Stock = 1071.4285714285716
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 3571.4285714285716
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 3214.285714285714
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 4285.714285714286
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 4286.0

Processing for Item Id: 2, Name: Vanilla
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 42.857142857142854
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1500.0
- Safety Stock Days = 15.0
- Safety Stock = 642.8571428571428
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2142.8571428571427
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 1928.5714285714284
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 2571.428571428571
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 2572.0

Processing for Item Id: 3, Name: Food colors
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 4.285714285714286
- Best Case Delivery Time = 40.0
- Worse Case Delivery Time = 60.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 50.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 214.28571428571428
- Safety Stock Days = 20.0
- Safety Stock = 85.71428571428571
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 300.0

 - Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
 * Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
 - Minimum Order Time = 60.0
 - Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 257.1428571428571
 - Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 342.85714285714283
 - Actual Order Quantity = Ceiling of ActualOrderQuantity = 343.0
Processing for Item Id: 4, Name: Cocoa small
 - Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 71.42857142857143
 - Best Case Delivery Time = 30.0
 - Worse Case Delivery Time = 40.0
 - Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
 - Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 2500.0
 - Safety Stock Days = 15.0
 - Safety Stock = 1071.4285714285716
 - Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
 - Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 3571.4285714285716
 - Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
 * Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
 - Minimum Order Time = 45.0
 - Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 3214.285714285714
 - Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 4285.714285714286
 - Actual Order Quantity = Ceiling of ActualOrderQuantity = 4286.0
Processing for Item Id: 5, Name: Cocoa medium
 - Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 71.42857142857143
 - Best Case Delivery Time = 30.0
 - Worse Case Delivery Time = 40.0
 - Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
 - Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 2500.0
 - Safety Stock Days = 15.0
 - Safety Stock = 1071.4285714285716
 - Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
 - Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 3571.4285714285716
 - Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 4995.0
 * There is no need for Inventory Order! Because: Quantity in Stock or Requested > Kanban Card Position
 - Minimum Order Time = 45.0
 - Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 3214.285714285714
 - Quantity over order = Quantity in Stock or Requested - (Safty Stock + Window between Every 2 Orders) = 710.0
 - Quantity that was supposed to be orderd = Quantity in Stock or Requested - Quantity over order = 4285.0

Processing for Item Id: 6, Name: Corn flour
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 71.42857142857143
- Best Case Delivery Time = 7.0
- Worse Case Delivery Time = 14.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 10.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 714.2857142857143
- Safety Stock Days = 30.0
- Safety Stock = 2142.857142857143
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2857.1428571428573
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0

 * Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)

- Minimum Order Time = 15.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 1071.4285714285716
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 3214.2857142857147
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 3215.0

Processing for Item Id: 7, Name: Quicker Cooking
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 22.857142857142858
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 800.0
- Safety Stock Days = 30.0
- Safety Stock = 685.7142857142858
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 1485.7142857142858
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 2000.0

 * There is no need for Inventory Order! Because: Quantity in Stock or Requested > Kanban Card Position

- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 1028.5714285714287
- Quantity over order = Quantity in Stock or Requested - (Safty Stock + Window between Every 2 Orders) = 286.0
- Quantity that was supposed to be orderd = Quantity in Stock or Requested - Quantity over order = 1714.0

Processing for Item Id: 8, Name: Color of Egg Yolk
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 4.285714285714286
- Best Case Delivery Time = 40.0
- Worse Case Delivery Time = 50.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 45.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 192.85714285714286
- Safety Stock Days = 30.0

- Safety Stock = 128.57142857142856
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 321.42857142857144
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 60.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 257.1428571428571
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 385.71428571428567
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 386.0

Processing for Item Id: 9, Name: Color Saffar Safforn
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 35.714285714285715
- Best Case Delivery Time = 40.0
- Worse Case Delivery Time = 50.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 45.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1607.142857142857
- Safety Stock Days = 30.0
- Safety Stock = 1071.4285714285716
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2678.5714285714284
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 60.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 2142.857142857143
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 3214.2857142857147
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 3215.0

Processing for Item Id: 10, Name: Black Pipper
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 14.285714285714286
- Best Case Delivery Time = 7.0
- Worse Case Delivery Time = 14.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 10.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 142.85714285714286
- Safety Stock Days = 30.0
- Safety Stock = 428.5714285714286
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 571.4285714285714
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 15.0

- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 214.2857142857143
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 642.8571428571429
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 643.0

Processing for Item Id: 11, Name: Chilli Powder

- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 142.85714285714286
- Best Case Delivery Time = 7.0
- Worse Case Delivery Time = 14.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 10.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1428.5714285714287
- Safety Stock Days = 30.0
- Safety Stock = 4285.714285714286
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 5714.285714285715
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 15.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 2142.857142857143
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 6428.571428571429
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 6429.0

Processing for Item Id: 12, Name: Sodium Bicarbonate

- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 14.285714285714286
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 500.0
- Safety Stock Days = 30.0
- Safety Stock = 428.5714285714286
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 928.5714285714287
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 642.8571428571429
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 1071.4285714285716
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 1072.0

Processing for Item Id: 13, Name: Baking Powder

- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 71.42857142857143
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0

- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 2500.0
- Safety Stock Days = 15.0
- Safety Stock = 1071.4285714285716
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 3571.4285714285716
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 3214.285714285714
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 4285.714285714286
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 4286.0

Processing for Item Id: 14, Name: Food Powder
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 71.42857142857143
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 2500.0
- Safety Stock Days = 15.0
- Safety Stock = 1071.4285714285716
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 3571.4285714285716
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 3214.285714285714
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 4285.714285714286
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 4286.0

Processing for Item Id: 15, Name: Corn Flour
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 42.857142857142854
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1500.0
- Safety Stock Days = 15.0
- Safety Stock = 642.8571428571428
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2142.8571428571427

- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 1928.5714285714284
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 2571.428571428571
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 2572.0

Processing for Item Id: 16, Name: Cocoa Powder
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 14.285714285714286
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 500.0
- Safety Stock Days = 15.0
- Safety Stock = 214.2857142857143
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 714.2857142857143
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 642.8571428571429
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 857.1428571428572
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 858.0

Processing for Item Id: 17, Name: Bicarbonate Sodium 25kg
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 14.285714285714286
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 500.0
- Safety Stock Days = 15.0
- Safety Stock = 214.2857142857143
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 714.2857142857143
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 642.8571428571429
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 857.1428571428572
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 858.0

Processing for Item Id: 18, Name: Cummin Powder

- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 35.714285714285715
- Best Case Delivery Time = 40.0
- Worse Case Delivery Time = 50.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 45.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1607.142857142857
- Safety Stock Days = 30.0
- Safety Stock = 1071.4285714285716
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2678.5714285714284
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 60.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 2142.857142857143
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 3214.2857142857147
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 3215.0

Processing for Item Id: 19, Name: Ginger Powder
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 42.857142857142854
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1500.0
- Safety Stock Days = 15.0
- Safety Stock = 642.8571428571428
- Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of this item in the Pending Pick Lists = 0.0
- Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities in Pending Pick Lists = 2142.8571428571427
- Quantity in Stock or Requested = Quantity Available + Calculated Total Quantity Requested by Inventory = 0.0
* Quantity in Stock or Requested <= Kanban Card Position (There will be an Inventory Order and Kanban will be used and applied!)
- Minimum Order Time = 45.0
- Window between Every 2 Orders = Minimum Order Time * Average Daily Demand = 1928.5714285714284
- Actual Order Quantity = Safty Stock + Window between Every 2 Orders - Quantity in Stock or Requested = 2571.428571428571
- Actual Order Quantity = Ceiling of ActualOrderQuantity = 2572.0

Processing for Item Id: 20, Name: Sesame Seed
- Calculated Average Daily Demand = Sum(Quantity / Period in Days) for all occurrences of this item in the Repeated Orders Items = 42.857142857142854
- Best Case Delivery Time = 30.0
- Worse Case Delivery Time = 40.0
- Average Delivery Time = (Best Case Delivery Time + Worse Case Delivery Time) / 2 = 35.0
- Minimum Order Quantity = Average Daily Demand * Average Delivery Time = 1500.0
- Safety Stock Days = 15.0
- Safety Stock = 642.8571428571428

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 - Quatities in Pending Pick Lists = Sum(Quantity) for all occurrences of
this item in the Pending Pick Lists = 0.0
 - Kanban Card Position = Minimum Order Quantity + Safety Stock + Quatities
in Pending Pick Lists = 2142.8571428571427
 - Quantity in Stock or Requested = Quantity Available + Calculated Total
Quantity Requested by Inventory = 0.0
 * Quantity in Stock or Requested <= Kanban Card Position (There will be an
Inventory Order and Kanban will be used and applied!)
 - Minimum Order Time = 45.0
 - Window between Every 2 Orders = Minimum Order Time * Average Daily
Demand = 1928.5714285714284
 - Actual Order Quantity =  Safty Stock + Window between Every 2 Orders -
Quantity in Stock or Requested = 2571.428571428571
 - Actual Order Quantity = Ceiling of ActualOrderQuantity = 2572.0
Inventory Checker Agent has Checked the Inventory... (Kanban Algorithm)
There is/are item(s) at the store that their quantities have reatched
Kanban Card possition.
Number of items: 18
Inventory Order Full Information:
Id     |Order Date Time  |Status
193    |04/03/2016 10:23:26    |Replenish Stock Request (ReOrderPoint)
-      Items in this Inventory Order:
-      Item Id           |Item Name        |Quantity
-      1      |Baking powder          |4286
-      2      |Vanilla                |2572
-      3      |Food colors      |343
-      4      |Cocoa small      |4286
-      6      |Corn flour       |3215
-      8      |Color of Egg Yolk      |386
-      9      |Color Saffar Saffron   |3215
-      10     |Black Pipper           |643
-      11     |Chilli Powder          |6429
-      12     |Sodium Bicarbonate     |1072
-      13     |Baking Powder    |4286
-      14     |Food Powder      |4286
-      15     |Corn Flour |2572
-      16     |Cocoa Powder     |858
-      17     |Bicarbonate Sodium 25kg      |858
-      18     |Cummin Powder    |3215
-      19     |Ginger Powder    |2572
-      20     |Sesame Seed      |2572
Inventory Checker Agent will notify Warehouse Supervisor Agent...
Warehouse Supervisor Agent received a Replenish Stock Request (Purchase
Order Requisition) from Inventory Checker Agent
Inventory Order Full Information:
Id     |Order Date Time  |Status
193    |04/03/2016 10:23:26    |Replenish Stock Request (ReOrderPoint)
-      Items in this Inventory Order:
-      Item Id           |Item Name        |Quantity
-      1      |Baking powder          |4286
-      2      |Vanilla                |2572
-      3      |Food colors      |343
-      4      |Cocoa small      |4286
-      6      |Corn flour       |3215
-      8      |Color of Egg Yolk      |386
-      9      |Color Saffar Saffron   |3215
-      10     |Black Pipper           |643
-      11     |Chilli Powder          |6429
-      12     |Sodium Bicarbonate     |1072
-      13     |Baking Powder    |4286
-      14     |Food Powder      |4286
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-	15	|Corn Flour |2572
-	16	|Cocoa Powder	|858
-	17	|Bicarbonate Sodium 25kg	|858
-	18	|Cummin Powder	|3215
-	19	|Ginger Powder	|2572
-	20	|Sesame Seed	|2572
Do you confirm the Replenish Stock Request?
If yes press 'Y'; Or else, press any key.
Y
Warehouse Supervisor Approved the Replenish Stock Request (Purchase Order Requisition).
Warehouse Supervisor Agent will inform Procurement to place the inventory order.
Warehouse Supervisor Agent will message Inventory Agent in order to update the status (awaiting delivery) for the order placed.
Warehouse Supervisor Agent will inform Goods Receiving agent to await the expected delivery.
Procurement Officer Agent get informed of Purchase Order Requisition from Warehouse Supervisor; And will place the order...
Inventory Order Full Information:
Id	|Order Date Time	|Status
193	|04/03/2016 10:23:26	|Approved by Warehouse Supervisor
-	Items in this Inventory Order:
-	Item Id		|Item Name	|Quantity
-	1	|Baking powder		|4286
-	2	|Vanilla		|2572
-	3	|Food colors	|343
-	4	|Cocoa small	|4286
-	6	|Corn flour	|3215
-	8	|Color of Egg Yolk	|386
-	9	|Color Saffar Safforn	|3215
-	10	|Black Pipper		|643
-	11	|Chilli Powder		|6429
-	12	|Sodium Bicarbonate	|1072
-	13	|Baking Powder	|4286
-	14	|Food Powder	|4286
-	15	|Corn Flour |2572
-	16	|Cocoa Powder	|858
-	17	|Bicarbonate Sodium 25kg	|858
-	18	|Cummin Powder	|3215
-	19	|Ginger Powder	|2572
-	20	|Sesame Seed	|2572
Inventory Agent received Purchase Order Requisition from Warehouse Supervisor Agent
Inventory Order Full Information:
Id	|Order Date Time	|Status
193	|04/03/2016 10:23:26	|Approved by Warehouse Supervisor
-	Items in this Inventory Order:
-	Item Id		|Item Name	|Quantity
-	1	|Baking powder		|4286
-	2	|Vanilla		|2572
-	3	|Food colors	|343
-	4	|Cocoa small	|4286
-	6	|Corn flour	|3215
-	8	|Color of Egg Yolk	|386
-	9	|Color Saffar Safforn	|3215
-	10	|Black Pipper		|643
-	11	|Chilli Powder		|6429
-	12	|Sodium Bicarbonate	|1072
-	13	|Baking Powder	|4286
-	14	|Food Powder	|4286
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-	15	|Corn Flour	|2572
-	16	|Cocoa Powder	|858
-	17	|Bicarbonate Sodium 25kg	|858
-	18	|Cummin Powder	|3215
-	19	|Ginger Powder	|2572
-	20	|Sesame Seed	|2572
Goods Receiving Agent received Purchase Order Requisition from Warehouse
Agent
Inventory Order Full Information:
Id	|Order Date Time	|Status
193	|04/03/2016 10:23:26	|Goods Receiveing Agent is waiting for Goods
to be Received
-	Items in this Inventory Order:
-	Item Name	|Quantity	|Best Case Del. Time	|Worse Case
Del. Time	|Average Del. Time	|Expected Del. Date
-	Baking powder	|4286	|30	|40
	|35	|08/04/2016
-	Vanilla	|2572	|30	|40	|35
	|08/04/2016
-	Food colors	|343	|40	|60	|50
	|23/04/2016
-	Cocoa small	|4286	|30	|40	|35
	|08/04/2016
-	Corn flour	|3215	|7	|14	|10
	|14/03/2016
-	Color of Egg Yolk	|386	|40	|50	|45
	|18/04/2016
-	Color Saffar Safforn	|3215	|40	|50
	|45	|18/04/2016
-	Black Pipper	|643	|7	|14	|10
	|14/03/2016
-	Chilli Powder	|6429	|7	|14
	|10	|14/03/2016
-	Sodium Bicarbonate	|1072	|30	|40
	|35	|08/04/2016
-	Baking Powder	|4286	|30	|40	|35
	|08/04/2016
-	Food Powder	|4286	|30	|40	|35
	|08/04/2016
-	Corn Flour	|2572	|30	|40	|35
	|08/04/2016
-	Cocoa Powder	|858	|30	|40	|35
	|08/04/2016
-	Bicarbonate Sodium 25kg	|858	|30	|40
	|35	|08/04/2016
-	Cummin Powder	|3215	|40	|50	|45
	|18/04/2016
-	Ginger Powder	|2572	|30	|40	|35
	|08/04/2016
-	Sesame Seed	|2572	|30	|40	|35
	|08/04/2016
Upon Goods Receipt at Depot>>>
Do you confirm that the quantity, quality of the goods receipt are maching
Purchase Order?
If yes press 'Y'; Or else, press any key.
NO
Goods Receiving Agemt did not confirm that the quantity, quality of the
goods receipt are maching Purchase Order!
Is there a variation for the item (Baking powder)?
If yes press 'Y'; Or else, press any key.
Y
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How much is the missed/defected quantities? Please, enter an integer
number.
2
What is the reason of variance? Please enter a number from below.
-- Start Printing from table VariationReason --
Id     |Info Name
1      |Shortage (Quantity does not exist)
2      |Full Damage
3      |Bad Quality
4      |Missed
-- End Printing from table VariationReason --
3
If you have any notes, please write it down. Or, just press Enter to pass.
NO NOTES
Is there a variation for the item (Vanilla)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Food colors)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Cocoa small)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Corn flour)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Color of Egg Yolk)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Color Saffar Safforn)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Black Pipper)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Chilli Powder)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Sodium Bicarbonate)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Baking Powder)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Food Powder)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Corn Flour)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Cocoa Powder)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Bicarbonate Sodium 25kg)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Cummin Powder)?
If yes press 'Y'; Or else, press any key.
NO
Is there a variation for the item (Ginger Powder)?
If yes press 'Y'; Or else, press any key.
```

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NO
Is there a variation for the item (Sesame Seed)?
If yes press 'Y'; Or else, press any key.
NO
Goods Receiving Agent will send Approved Purchase Order message to
Procurement to update Suppliers records.
Goods Receiving Agent will request from Inventory to receive the quantity
for goods.
Procurement Officer Agent get informed of Receiving an Inventory Order from
Good Receiving Agent
Inventory Agent received Good Receiving Note from Goods Receiving Agent
Inventory Agent matches the Purchase Order Requisition to the Goods
Received Note
Inventory Order Full Information:
Id      |Order Date Time   |Status
193     |04/03/2016 10:23:26     |Goods Received Note
-       Items in this Inventory Order:
-       Item Id            |Item Name         |Quantity
-       1       |Baking powder          |4284
-       2       |Vanilla                |2572
-       3       |Food colors      |343
-       4       |Cocoa small      |4286
-       6       |Corn flour       |3215
-       8       |Color of Egg Yolk      |386
-       9       |Color Saffar Safforn   |3215
-       10      |Black Pipper           |643
-       11      |Chilli Powder          |6429
-       12      |Sodium Bicarbonate     |1072
-       13      |Baking Powder    |4286
-       14      |Food Powder      |4286
-       15      |Corn Flour |2572
-       16      |Cocoa Powder     |858
-       17      |Bicarbonate Sodium 25kg      |858
-       18      |Cummin Powder    |3215
-       19      |Ginger Powder    |2572
-       20      |Sesame Seed      |2572
Message to Worker to pack goods in stores bin with regulations!
Worker (Worker1) is notified to receive the inventory order:
Inventory Order Full Information:
Id      |Order Date Time   |Status
193     |04/03/2016 10:23:26     |Goods Received Note
-       Items in this Inventory Order:
-       Item Id            |Item Name         |Quantity
-       1       |Baking powder          |4284
-       2       |Vanilla                |2572
-       3       |Food colors      |343
-       4       |Cocoa small      |4286
-       6       |Corn flour       |3215
-       8       |Color of Egg Yolk      |386
-       9       |Color Saffar Safforn   |3215
-       10      |Black Pipper           |643
-       11      |Chilli Powder          |6429
-       12      |Sodium Bicarbonate     |1072
-       13      |Baking Powder    |4286
-       14      |Food Powder      |4286
-       15      |Corn Flour |2572
-       16      |Cocoa Powder     |858
-       17      |Bicarbonate Sodium 25kg      |858
-       18      |Cummin Powder    |3215
-       19      |Ginger Powder    |2572
-       20      |Sesame Seed      |2572
```

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Do you confirm that there is no variances of items in the stock?
If yes press 'Y'; Or else, press any key.
Y
You should collects the goods and pack them in the allocated bin...
Please, follow the mentioned pack and load instructions for each item when
loading the items into the stock.
Inventory Order Full Information:
Id	|Order Date Time	|Status
193	|04/03/2016 10:23:26	|Goods Received Note
-	Items in this Order:
-	Item Name		|Quantity	|Load and Pack Instructions
-	Baking powder		|4284		|Do not stack more than 6 items
on top of each other
-	Vanilla		|2572		|Avoid humidity and direct sunlight
-	Food colors		|343		|Avoid high temperature (more than 30
C)
-	Cocoa small		|4286		|Do not stack more than 8 items on top
of each other. And avoid high temperature (more than 28 C)
-	Corn flour		|3215		|Avoid humidity, Do not stack more than
6 items on top of each other, And avoid high temperature (more than 33 C)
-	Color of Egg Yolk |386		|null
-	Color Saffar Safforn	|3215		|null
-	Black Pipper		|643		|null
-	Chilli Powder		|6429		|null
-	Sodium Bicarbonate	|1072		|null
-	Baking Powder		|4286		|null
-	Food Powder |4286		|null
-	Corn Flour	|2572		|null
-	Cocoa Powder		|858		|null
-	Bicarbonate Sodium 25kg |858		|null
-	Cummin Powder		|3215		|null
-	Ginger Powder		|2572		|null
-	Sesame Seed |2572		|null
Additionally, follow those general instructions:
General Regulations for Storing Conditions:
1.	Temperature
	Be sure that each item is sotred in a place with the recommended
temprature.
2.	Humidity
	Avoid humidity for each item as descripted in the items pack and load
instrucion.
3.	Load
	Do not exceed the maximum packing load for each item.
	Do not exceed the maximum stacking height for each item.

The inventory Order will be registered as completed.
Inventory Order Full Information:
Id	|Order Date Time	|Status
193	|04/03/2016 10:23:26	|Goods Received (Completed)
-	Items in this Inventory Order:
-	Item Id		|Item Name		|Quantity
-	1	|Baking powder		|4284
-	2	|Vanilla		|2572
-	3	|Food colors		|343
-	4	|Cocoa small		|4286
-	6	|Corn flour		|3215
-	8	|Color of Egg Yolk	|386
-	9	|Color Saffar Safforn	|3215
-	10	|Black Pipper		|643
-	11	|Chilli Powder		|6429
-	12	|Sodium Bicarbonate	|1072
```

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-	13	|Baking Powder	|4286
-	14	|Food Powder	|4286
-	15	|Corn Flour |2572
-	16	|Cocoa Powder	|858
-	17	|Bicarbonate Sodium 25kg	|858
-	18	|Cummin Powder	|3215
-	19	|Ginger Powder	|2572
-	20	|Sesame Seed	|2572
Quantities will be added to Items' Available Quantitiy.
Bellow is the items after the quantities has been added.
-- Start Printing from table Item --
Id	|Item Name	|Price	|QuantityInStock	|BestCaseDeliveryTime
	|WorseCaseDeliveryTime	|MinimumOrderTime |SafetyStockDays
	|ExpirationDate
1	|Baking powder	|52.0 |4284	|30	|40
	|45	|15	|01/04/2016
2	|Vanilla	|72.0 |2572	|30	|40
	|45	|15	|29/09/2015
3	|Food colors	|185.0	|343	|40	|60
	|60	|20	|01/10/2015
4	|Cocoa small	|180.0	|4286	|30	|40
	|45	|15	|03/08/2015
5	|Cocoa medium	|150.0	|4995	|30
	|40	|45	|15	|01/03/2016
6	|Corn flour	|26.0 |3215	|7	|14
	|15	|30	|03/01/2017
7	|Quicker Cooking	|70.0 |2000	|30	|40
	|45	|30	|03/01/2017
8	|Color of Egg Yolk	|120.0	|386	|40
	|50	|60	|30	|01/01/2017
9	|Color Saffar Safforn	|110.0	|3215	|40
	|50	|60	|30	|01/01/2017
10	|Black Pipper	|200.0	|643	|7
	|14	|15	|30	|01/01/2017
11	|Chilli Powder	|220.0	|6429	|7
	|14	|15	|30	|01/01/2017
12	|Sodium Bicarbonate	|55.0 |1072	|30	|40
	|45	|30	|01/05/2017
13	|Baking Powder	|50.0 |4286	|30	|40
	|45	|15	|01/05/2017
14	|Food Powder	|55.0 |4286	|30	|40
	|45	|15	|01/05/2017
15	|Corn Flour |55.0 |2572	|30	|40
	|45	|15	|01/05/2017
16	|Cocoa Powder	|230.0	|858	|30	|40
	|45	|15	|01/05/2017
17	|Bicarbonate Sodium 25kg	|45.0 |858	|30
	|40	|45	|15	|01/05/2017
18	|Cummin Powder	|170.0	|3215	|40	|50
	|60	|30	|01/05/2017
19	|Ginger Powder	|170.0	|2572	|30	|40
	|45	|15	|01/05/2017
20	|Sesame Seed	|105.0	|2572	|30	|40
	|45	|15	|01/05/2017
-- End Printing from table Item --
```

Appendix F: Procedure

Procedures

Assumption – which the MAS will integrate with current systems in place

Kanban

Database

Message/connectivity

Include 6 S (5S + Safety)

Order: Online Current Customers

1- Customer access online to place order, will present all the address and identity
2- Customer will select goods and quantity from drop down menu
3- Customer will be presented with a frequency selection – once off, repeat options
4- Customer will be advised of option delivery choices – provide a selected date
5- System check to ensure credit status and amount are within set limits

If System Check Accepts order:

- Customer places order, verifies and receives confirmation order number
- Automatic email sent to the Sales Inbox

If System Check Rejects order:

- Automatic request will be sent to Sales representative
- System Notice to Customer to advise if there is a problem and that a Sales Representative will call them

Order: Online New Customers:

1- Customer access online to place order, will present all the address and identity for registration
2- Customer will select goods and quantity from drop down menu
3- Customer will be presented with a frequency selection – once off, repeat options
4- Customer will be advised of option delivery choices
5- Customer places order, verifies and receives confirmation of contact by salesman representative

By Phone to Salesman or Direct Face-to-face

8- Customer will specify goods and quantity
9- Sales representative will select from online drop down menu.
10- Sales Representative will be advised of option delivery choices
11- Sales Representative order and receives confirmation order numbers
12- Sales representative provides a Verification email with order reference and detail
13- Automatic email sent to the Sales Inbox
14- Automated update of main database

Manager -Operations Controller/Main Database

3- Receives automatic transaction update to ERP or Main Database

4- Message Request to Inventory – quantity, goods reference, status as Stock Requisition Order

Stores/ Inventory

3- Receives Stock Requisition Order
4- Checks stock availability

IF YES

- From Available stock it will produce a Stores Pick List
- Include Specific load or pack instructions if applicable
- Automatic message to confirm the issue of picking status to warehouse and procurement

IF NOT

- From Available stock it will produce a Stores Pick List
- Automatic generation of Backorder Quantity and a Purchase Request to warehouse
- Purchase Request will be flagged for escalation, alert email to Warehouse Supervisor and Stores Supervisor (if applicable) for approval
- Automatically Produces a Pending Pick List
- Automatic updates of the Stock Kanban Status with approved backorder

Warehouse Supervisor

5- Receives confirmation of Store Pick list
6- Message update to Sales/Customer to confirm order delivery
7- Receives automatic escalation alert of stock shortfall and backorder
8- Approves the Replenish Stock Request (Re- Order Point) – Purchase Order Requisition

If Standard Reorder

- Standard reorder Purchase Requisition request message to procurement to place order
- Message update to Inventory to update status (awaiting delivery) with order placed
- Message to Goods Receiving to await expected delivery of quantity, supplier and date

If New Request or Variation (Additional Quantity or a New Supplier)
If Once-Off

- Approve Message Purchase Order Requisition – quantity, goods reference, status to Warehouse Manager
- Validate and Approve the status – once-off or repeatable order
- Approved Requisition sent to Procurement to place order
- Message update to Inventory to update status with order placed and lead times
- Message update to salesman/Customer to advice of status and confirm delivery dat

If Repeatable

- Recalculate Re Order Point and Buffer Zone with escalated (Alert) approval reference by warehouse supervisor
- Purchase Order Requisition sent to procurement

Goods Despatch:

2- Picker (Worker) receives Stores Pick List with specific instructions

If no issues with picking (all stock available, no issues of quality or incidents)

- Picker confirms quantity and items on system to message picking completion
- System requests an update if there has been a variance/issues – yes /no (series of questions)
- Picker confirms that the stock was all in the correct location and correct Bin
- Picker confirms that the area is clean, has removed any waste, all stock is straightened (5S)
- Picking complete message auto-updates with NIL variance
- System deducts the goods picked stock levels quantity and updates new stock levels

If issues with picking

- Picker confirms stock item with items picked and updates variances with quantity and notes – reason for the shortfall Variance Menu – Drop down menu – quality, shortage
- Picking complete message auto-updates with variance
- System deducts the goods picked stock levels quantity and updates new stock levels
- Picking Completion List updates Operations Controller
- Controller sends variance escalation alert to Warehouse Supervisor

- Operations Controller produces a goods despatch notice (GDN)

- Auto message of GDN message sent to Despatch depot to expect goods in depot

Despatch depot:

- Upon receipt of goods into despatch, depot matches GDN to Stores Pick List
- If stock is correct and goods are in order, Depot approves GDN on system
- Approved GDN issues a Packing Order with specific instructions and specifies Truck
- Auto- message to Delivery to Pack specified Truck with pack/load/route instructions
- If Goods Packed with no variances – approval updates GDN

If there is a Variances /Issue

- Variance Alert escalated to Warehouse Supervisor
- Warehouse Supervisor approves/rejects instruction to proceed, replace items or delay delivery

Manager:

- Approved GDN and Delivery auto-generates Customer Invoice
- with GDN with Customer Invoice travels with goods to Customer

Or

- send it separately to Customer by post

Customer site:

- Approves GDN with signature if no variances
- If Variances – rejects or partially rejects with reasons

Warehouse Supervisor:

- Receives accepted or rejected GDN
- Updates the GDN as completed

IF Variances

- Updates as Pending
- Auto message to sales office and stores

Goods Receiving

Receives Message to await expected delivery of quantity, supplier and date.
Upon Goods Receipt at Depot, match the quantity, quality to Purchase Order.

Approved Purchase Order message to Procurement to update Suppliers records

Message to Stores to receive quantity of goods

Stores /Inventory

Receive message and match to the goods received note

Message to worker to pack goods in stores bin with regulations

Regulations

1. Temperature
    a. Product x must be stored at a max of 10 degrees Celsius
    b. Product x must not be packed near dairy or refreshments
2. Expiry Date

    Input Expiry Date (Auto calc from date of delivery to expiry dte)

    Set an alarm 5 days prior to expiry date – instruct packer to move product to front of the picking queue.

    Alarm 2 – Calculate 3 days prior to expiry send alert to warehouse manager and sales office for sale offer or discount

    Alarm 3 – Date of expiry alert warehouse for destruction

3. Load
    a. Product x maximum packing load 10kg
    b. Product Stacking maximum stacking height is2metrew
4. The stock is labelled with the appropriate barcode sequence that specifies the nature of the stock – perishable, non perishable, indicated expiry length
    a. WL06C- GO TO THE BACK OF STOREROOM , MID LOCATION RACK

        W- Non perishable

        A – Persihable

        L – Liquid

        06 – expiry in months

        C – Above 1 kg

Collects goods and packs the goods in the allocated bin (depends on the stock labelling system

Worker updates system with new stock levels and any variances

Stores Picking List Instruction

Select the product in order of the most recent sell by date (FIFO)

Use this specified trolley ……………

Maximum packing weight is …………..

Packing Confirmation

Have you used the specified container trolley size Yes/ No

Which of these prevented you from using the specified trolley

- Not available y/N
- Not in working condition y/N
- Oher y/N

Did you exceed the maximum weight specified? Yes/No

Driver Goods Despatch/Delivery Notice = Customer

Customer	Special Notes	Goods Delivery	Details	Delivery instructions
Name ……………………………………. Address ……………………….. Order of delivery is based on below LIFO	Must get parking permit signed Do not park in visitor parking	Product …………………… ………………………….	500 x 10 kg boxes (Heavy first in last out)	Customer parking bay 6 Customer to pay on presentation of goods or Customer pays on account only

Despatch Packing / Ship to Sequence Algorithm

Regulations for Packing Order -By Product

1. Heaviest items must be picked and packed first
2. Heavy items must be distributed evenly in the delivery vehicle s
3. Maximum weight thresholds must not be exceeded selects the right size truck
4. Do not exceed packing height of 1.5m
5. Sequence of delivery of products will be arranged to deliver the products in order from front of truck (door) to back of truck - it will be delivered Last in First Out
6. Maintain temperature at 20c