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# DEVELOPMENT OF A MULTI-DIMENSIONAL MATRIX FOR SUPPLY CHAIN MANAGEMENT

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# DEVELOPMENT OF A MULTI-DIMENSIONAL MATRIX FOR SUPPLY CHAIN MANAGEMENT

by

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# Author's Signed Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Sub-Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment.

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Publications (or presentation of other forms of creative and performing work):

*** See section: *Publications and Conference Presentations***

Presentation and Conferences Attended:

*** See section: *Publications and Conference Presentations***

External Contacts:

**This research used a panel of academic and industry experts to obtain professional insight in to aspects of supply chain operations.**

*** For list of contacts, see Appendix G:**

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# Abstract


## DEVELOPMENT OF A MULTI-DIMENSIONAL MATRIX FOR SUPPLY CHAIN MANAGEMENT

With the rise of globalisation, more of the world's cargo depends on sea transportation, spanning countries and continents, increasing the complexity of Supply Chain (SC) operations. Multinational companies and SMEs have faced various challenges adapting to the changing environment. This research explores these complexities and aims to identify the most suitable SC and logistics strategy that companies can incorporate into their business framework. In achieving this, a Multi-Dimensional Matrix (MDM) is developed, firstly by analysing the development of SC and logistics strategies throughout time and dividing them into seven eras. The five earliest eras describe the emergence and development of SCs, while the last two eras (six and seven), establish the literature for the MDM, which is tested for its capability to diagnose and recommend suitable strategies for companies. A conceptual framework for an interactive web-based MDM is designed to illustrate the development of the model and its capability to allow companies to insert their own variables, creating a tailored MDM unique to their company. The MDM incorporates most characteristics of the SC, allocating them into a matrix which has four quarters (Agile, Lean, Leagile and Basic SC). The data collection consists of mixed-methods (quantitative and qualitative) approaches. The qualitative approach is Fuzzy Delphi, where statements are based on the literature, and the experts' responses are analysed using statistical quantitative methods. The consensus from the Fuzzy Delphi are translated into (If-Then) fuzzy rules, then written as JavaScript and HTML, providing the MDM's interactive capability. The testing is conducted through semi-structured interviews with a UK-based, global car manufacturer Jaguar Land Rover. The results indicate the usefulness of a diagnostic MDM tool able to recommend a suitable SC and logistics strategies, while allowing companies to choose, tailor and amend options according to their specific requirements; thus allowing companies to analyse and further understand their SC and logistics framework.

# Publications and Conference Presentations

**Sindi, S.H., and Roe, M.** (2016), "Development of an interactive Multidimensional matrix for logistics and supply chain strategies", Routledge Publishers. (In progress as a book chapter)

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**Sindi, S.H., and Roe, M**. (2014), "Development of an automated multidimensional model for supply chain management", *The International Scholarly and Scientific Research and Innovation*, Vol. 8, No. 10, pp.338-342.

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**Sindi, S.H., and Roe, M**. (2013), "Supply Chain Multidimensional Automated Model", *Journal of Automation and Control Engineering*, Vol.1, No.2, pp 91-94.

**Sindi, S.H., and Roe, M**. (2012), "Deepwater Horizon British Petroleum Offshore Oil Spill: *Contemplating the supply chain of information flow throughout the crises and the methods in which it can be mitigated in future*". *Journal of the Geological Society of London*, (Special online edition).

## Conferences

**October 2014 International Conference on Supply Chain Management (ICSCM)**

Organised and held by the World Academy of Science Engineering and Technology (WASET), Osaka, Japan.

**June 2014 International Conference on Logistics and Sustainable Transport (ICLST)**

Organised and held by University of Maribor, Faculty of Logistics, Celje, Slovenia.

**September 2013 Logistics Research Network (LRN) Conference**

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**June/July 2013 PhD Summer Academy in Maritime Logistics, Sustainability and Supply Chains**

MIT Sponsored Program - Organised and held in Zaragoza Logistics Centre, Spain.

**January 2013 5th International Conference on Computer and Automation Engineering (ICCAE)**

Sponsored by IACSIT. Held in Brussels, Belgium.

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# Glossary

| | |
|---|---|
| APS | Advanced Planning and Scheduling |
| ASC | Agile Supply Chain |
| BSC | Basic Supply Chain |
| CLM | Council of Logistics Management |
| ECR | Efficient Consumer Response |
| EDI | Electronic Data Interchange |
| ERA | Describes certain period of supply chain evolutions and denotes events before and after they change significantly. |
| ERP | Enterprise Resource Planning |
| JIT | Just In Time |
| LeSC | Legile Supply Chain |
| MDM | Multi-Dimensional Matrix |
| MRP | Material Requirement Planning |
| SME | Small and Medium size Enterprise |
| TPS | Toyota's Production System |
| TQM | Total Quality Management |

# Chapter 1

## Introduction

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*"Whosoever commands the sea commands the trade; whosoever commands the trade of the world commands the riches of the world and consequently the world itself."* – Sir Walter Raleigh[1]

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The concept of supply chains became crucial with the first industrial revolution in Britain in the late 18th. Century, through the mechanisation of the textile industry. Tasks previously done by hand in weavers' cottages were brought together in a single cotton mill and the factory was born (Handfield and Nichols, 1999). This resulted in the need for sophisticated coordination of raw materials, production and the delivery of finished products (Baldwin, 2012). This sophistication of material flow became apparent with the second industrial revolution in the early 20th century, when Henry Ford mastered the moving assembly line hence the age of mass production. The first two industrial revolutions made people richer and more urban (Lee and Bilington, 1995). According to early research on the creation of supply chains by Georgia Tech Supply Chain and Logistics Institute (2010), logistics was a term used almost exclusively to describe military movements. However, in the 1940s and 1950s, after the industrial revolution, the focus was on logistics research due to evolving machinery. The aim was to improve labour intensive processes such as material handling and to maximise the utilisation of space, by the use of efficient racking and warehouse design improvement. In the mid-1950s, the "unitised load" concept became popular in shipping, especially with regards to container ships. This concept was extended to transportation such as trains and trucks that deal with these containers (Georgia Tech Supply Chain and Logistics Institute, 2010). The third technological revolution has come with digital integration that revolutionised supply chains. For example, a number of technologies such as: clever web-based software services, novel materials, more dextrous robots, three-

[1] Judicious and Select Essays and Observations by the Renowned and Learned Knight Sir Walter Raleigh (1554 – 29 October 1618), upon the First Invention of Shipping.

dimensional printing and a range of services aiming to create a fast and responsive supply chain that can satisfy the increasingly volatile market (The Economist, 2012). This third technological revolution did not only affect how things are made, but where. Factories used to move to low-wage countries to cut labour costs. However, due to markets becoming highly fluctuating, companies prefer to set up additional manufacturing plants closer to their customers, in order to respond faster to changes in demand (Friedman, 2005). This can be seen with specialised and sophisticated products, as it helps designers and production to be close to their market, for example, high-end watches and jewellery. Although consumers prefer the new age of better products and swiftly delivered goods; governments however, may find it harder due to their obligation to protect home-industries and companies, hence subsidising old factories in an attempt to minimise the production from moving abroad (Friedman, *ibid*). Seeing that the old method of production has proven to be inefficient due to intensive labour activities, the factory of the future will focus on mass customisation, as a product can be designed on a computer and printed on a 3D printer to be sent to the manufacturer for mass production (Pearce *et al*., 2010). The 3D printing creates a solid object by building up successive layers of material, and can make many things which are too complex for a traditional factory to handle. Furthermore, 3D printing creates new horizons for supply chain sustainability, as with reduced logistic distribution comes a reduction in carbon emissions (Pearce *et al*., *ibid*). Digital design and 3D printing will further revolutionise the supply chain of the future, as "where" production is held will no longer matter, as it can take place from any location resulting in an increase in decentralisation (Jalwan and Israel, 2014). The factories of the future will be uncluttered, sophisticated and almost deserted, as jobs will not be on the factory floor, but in the management offices close to the market, which will be full of specialist workers such as designers, software engineers, logistics experts, marketing staff and other professionals (BBC News, 2012).

With the increase in competition and advances in technology, large companies as well as Small and Medium Enterprises (SMEs) face the challenging issue of selecting an optimal supply chain strategy. Never before has the distinction of which supply chain model to incorporate within the business strategy been of such importance to business success. The confusion of which strategy to implement is due to the many supply chain models and definitions developed over the years (Cagliano *et al*., 2004). This study's aim is to develop a Multi-Dimensional Matrix

(MDM) with interactive capability to help organisations diagnose the best logistics and supply chain strategy for their market. The objective however, is to establish a theoretical framework outlining the evolution of supply chains and logistics, creating a historical time-line, establishing a clear understanding of the definition and models created over time. This creates a MDM which helps organisations by recommending the best logistics and supply chain strategies, by diagnosing the position of the organisation's logistics and supply chain in their chosen market.

## 1.1 Outlining the Knowledge Gap

The evolution of the supply chain has developed from a logistical concept into a concept of its own and can be traced back to the 1940s; the "Creation Era". The problematic issue facing many SMEs as well as corporations, is the distinction of which supply chain model to incorporate within their business strategy (Cagliano *et al*., 2004). This study creates a literature review in the form of a theoretical framework to provide an overview of how supply chains developed through time. Therefore, it establishes the different evolutionary stages of supply chains with their relevant models and definitions. The literature/theoretical framework is divided into seven eras, each representing a period of evolution. The phrase "Era" is well suited to describing certain periods of evolution, as it denotes events before and after they change significantly. Due to the slow pace of change in some business aspects, and due to overlapping economic effects, the phrase "Era" is appropriate as it is not defined by a time constraint (Kumar *et al*., 2008). The models and strategies found from the literature/theoretical framework will be incorporated into a multi-dimensional model which is shaped into a matrix in order to help SMEs and organisations diagnose their position in the market and identify the best suited strategy for their business structure and speciality. The Multi-Dimensional Matrix (MDM) aims to generate recommendations and choices for businesses to select. Their preferred strategy can then be integrated into their business structure through supply chain re-engineering to maximise efficiency of the end-to-end distribution processes whereby customer value is prioritised.

### 1.1.1 Aim and Objective

The overview of this research is to investigate the hypothesis of the issues facing SMEs and organisations in diagnosing their position in the market and choosing a suitable supply chain strategy for the business structure. The research addresses the hypothesis by firstly mitigating the complexity of supply chains by identifying the prominent strategies developed and allocating them into "Eras". The strategies that are allocated to Eras have been selected according to the emerging definitions arising in each era. This helps achieve the aim of this research, which is incorporating the relevant strategies from each era into developing the Multi-Dimensional Matrix (MDM) to aid SMEs and organisations by diagnosing the suited logistics and supply chain strategies in accordance with their speciality and market. Furthermore, the MDM acts as a diagnostic tool that can generate recommendations as well as options for SMEs and organisations to choose from. To ensure the model has sufficient capabilities to survive in a digitalised era, the MDM will be enhanced with interactive capabilities that can be further improved and tailored by (Table. 1). Additionally, a sustainable decision tree will be established to help SMEs and organisations incorporate sustainable thinking in their decision making.

*Table 1: Aim and objective of study (Source: author)*

| Aims | Objective |
|---|---|
| ▪ Using the historical time-line to develop the MDM that serves as a diagnostic tool capable of recommending suitable supply chain and logistics strategies.<br>▪ The MDM becomes interactive to survive a digitalised era.<br>▪ Provide a sustainable decision making tree complementing the MDM to help establish sustainable thinking | ▪ Create a framework to outline the evolution of supply chain and logistics strategies to achieve a historical time-scale that can be divide into eras accordingly. |

### *Aims*

The aim of this research is to use the models and strategies from the historical time-scale (seven eras) to develop an interactive MDM that can help SMEs and organisations diagnose the best logistic and supply chain strategic position for their market by offering recommendations and options for them to choose.

Additionally, the MDM's interactive capability will enable SMEs and organisations create their own tailored strategy. Furthermore, a complementary sustainability decision making tree will be created to encourage users of the interactive MDM to reduce waste and carbon footprint whilst implementing the recommended strategies.

### *Objective*

To achieve the aim of this research; a combined literature and theoretical framework will be created, in order to devise a time-scale of supply chain models and strategies that can be divided into "Eras" accordingly. The purpose of identifying the models and strategies into seven eras in the theoretical framework, is to provide a basis for the interactive MDM to be developed (Table. 2).

*Table 2: Outline of the theoretical framework (Source: author)*

| Era name | Time period |
|---|---|
| **One**: Creation | 1940-1980 |
| **Two**: Integration | 1970-2000 |
| **Three**: Globalisation | 1980-2000 |
| **Four**: Specialisation | 1990-2008 |
| **Five**: Specialised globalisation | 2008-2011 |
| **Six**: Multi-dimensional strategies | 2012-present |
| **Seven**: Interactivity and automation | Future forecast |

## 1.2 Overview of the Thesis Structure

This research will commence by providing an overall background of supply chain development. This provides the basis of the literature review as it merges with the theoretical framework which examines in depth the details of each evolution period. This leads to the creation of a conceptual framework that highlights the process of this research, in addition to a preliminary conceptual framework of the MDM matrix. Next, a methodological perspective is examined and established in order to create a suitable data collection process. Once the method of data collection is chosen, it is designed in accordance with the issues being studied and set in motion. Once the data collection is completed, the analysis process will be undertaken to develop the interactive MDM. Additionally, a complementary sustainability decision making tree will be established. Finally, this research will test the capability and applicability of the interactive MDM with the help of an established authoritative organisation in the UK automobile industry. Furthermore, due the MDM's interactive capability, SME's and organisations can alter the MDM to give it unique capabilities that are relevant only to the specification of the organisation that has altered it. The research will add further approaches to enhance the MDM and improve upon its capabilities.

# Chapter 2

# Historic Evolution of Supply Chains and Logistics

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*"You have to look at history as an evolution of society."* – Jean Chrétien[2]

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An outline of the importance of supply chains in business and the process of its evolution through time is provided in this literature review. This is examined through a theoretical time-scale framework that explain the relationship between the problem statement and the known approaches to the supply chain. The literature review provides relative information to the theoretical and conceptual frameworks to enable this study to create a feasible solution that will help companies identify the optimal supply chain strategy for their market. This will achieve the aim and objective of the study, by establishing a basis for the development of the interactive Multi-Dimensional Matrix (MDM) that acts as a diagnostic tool, helping SMEs and organisations select and tailor the most suited strategy for their logistics and supply chain operations.

## 2.1 Introduction of Supply Chains and Logistics

In early years logistics was a term that had been used almost exclusively to describe the support of military movements. This shifted in the early 1940s and 1950s as the focus of logistics was on how to use machineries to improve the labour intensive processes of material handling and utilise warehousing design layout (Handfield and Nichols, 1999). Although the terms "warehousing" and "materials handling" were used to describe many of these activities, fundamentally it was viewed as part of industrial engineering rather than a discipline on its own (Cooper *et al.*, 1997).

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[2] Joseph Jacques Jean Chrétien is a Canadian politician and statesman who served as the 20th Prime Minister of Canada, from November 4, 1993 to December 12, 2003.

By the 1960s the term “Physical Distribution” formed as a result of freight transportation shifting to truck rather than rail (Tan, 2001). Hence the NCPDM was formed in 1963 focusing on satisfying the growing logistics’ industries’ needs. All transactions were recorded manually until the arrival of commercialised computers in the 1970s. This led to the creation of the Georgia Tech Production and Distribution Research Centre[3] and the Computational Optimisation Centre at Columbia University[4]. These centres focused on opening doors to the innovation of supply chains, logistics and distribution, such as optimising inventory and route tracing, all of which was made possible by the computerisation of data (Georgia Tech Supply Chain and Logistics Institute, 2010).

The emergence of personalised computers in the 1980s changed logistics in terms of graphical planning, flexible spreadsheets, mapping interfaces, and optimisation models for supply chain design and distribution planning (Garcı´a-Dastugue and Lambert, 2003). The Georgia Tech Production and Distribution Research Centre was the earliest innovation leader in combining map interfaces with optimisation models for supply chain design and distribution planning, while the Material Handling Research Centre (MHRC) provided leadership in developing new control technology for material handling automation. The Computational Optimisation Centre developed new large-scale optimisation algorithms that enabled solution of previously intractable airfreight scheduling problems. Much of the technological development in these centres began to find its way rapidly into commercial industry, giving logistics and supply chains increased recognition from business executives (Georgia Tech Supply Chain and Logistics Institute, 2010). Therefore, company executives invested resources in the development of logistics to significantly improve their supply chain and business strategy. Moreover, in the mid-1980s Material Requirement Planning (MRP) systems were developed in an attempt to integrate multiple company data bases that exist in companies and encourage them to communicate together (Lambert *et al.*, 1998). This resulted in 1985 in the technological revolution that led the National Council of Physical Distribution Management (NCPDM) to recognise this shift in logistics importance and change its name to the Council of Logistics Management (CLM). This name change was said to reflect the evolving discipline which included the integration of

[3] https://smartech.gatech.edu/handle/1853/36178

[4] http://www.corc.ieor.columbia.edu/

inbound, outbound and reverse flows of products, services, and related information (Harland and Lamming, 1999).

## 2.2 Technological Impact on Supply Chains and Logistics

Logistics and supply chains became even more accepted as a discipline and practice in industry and increased in 1990 through the emergence of Enterprise Resource Planning (ERP), which tremendously improved data availability and accuracy (Lummus and Vokurka, 1999). The ERP system was an expansion on the Material Requirements Planning (MRP) systems developed in the 1970s and 1980s, further increasing recognition of the need for better planning and integration among logistics databases and components. The aim of the MRP system was to integrate the multiple databases in almost all companies that seldom talked to each other (Lummus and Vokurka, *ibid*). MRP follows a top-down hierarchical approach (Fig.1). It begins with the Master Production Schedule (MPS) orders for the final products, by quantity and date; which is then translated into a specific planned start and due dates for all components based on the product structure, resulting in a detailed scheduling solution to meet these due dates. Unfortunately, MRP does not account for capacity constraints and assumes lead times are fixed, creating problems in production and increases in bottlenecks (Chen and Ji, 2007).

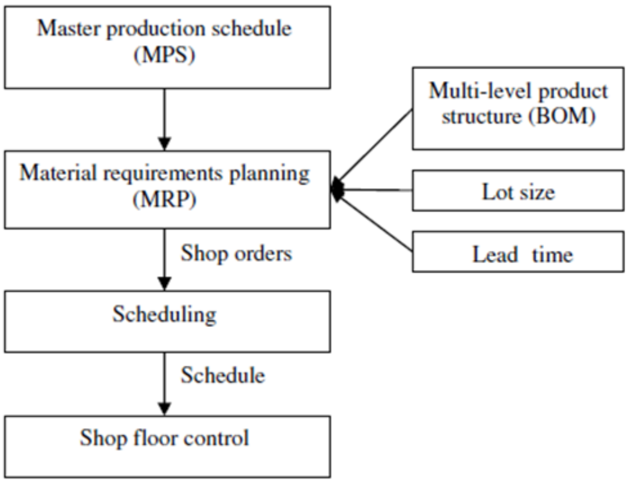


*Figure 1: The scheduling of MRP (Chen and Ji, 2007)*

These issues resulted in the creation of ERP. There was major concern that ERP systems would fail at the start of the new Millennium as they would not recognise the data. Nevertheless, Chen and Ji (2007) state that many companies overcame this issue and installed ERP systems into their database, resulting in tremendous improvements in data availability and accuracy. With globalisation, companies recognised the need for better planning and integration among logistics components, hence worked hard towards improving ERP, resulting in a new generation of Advanced Planning and Scheduling (APS) software (Kim and Kogut, 1996). The APS software contains a range of capabilities such as capacity scheduling, constraint-base planning, and allowing companies to optimise their supply chain resources and reduce costs. APS software aims to improve product margins, lower inventory and increase manufacturing throughout, by helping companies decide when to build each order, in what operation sequence, and with what equipment in order to meet the required due date (Lee *et al*., 2002).

## 2.3 Globalisation Influences on Supply Chains and Logistics

The increase of globalisation and development of technology are changing supply chains. Product designers, marketers and manufacturers that were previously housed in a single facility are now spread over several continents forcing businesses to integrate with different cultures, languages and business objectives (Johnson, 2006). The globalisation of manufacturing, particularly in China has increased the amount of outsourcing, off-shore suppliers, distribution and shipping capacity since the mid-1990s. This has increased the widespread use of the term "supply chain" as the result of globalisation increasing the need of logistics strategies to deal with complex networks spanning multiple continents (Cooper *et al*., 1997). The term "supply chain" arose to refer to strategic issues while the term "logistics" began to refer to tactical and operational issues (Tan, 2001). This resulted in the Council of Logistics Management changing its name again to Council of Supply Chain Management Professionals. This marked the distinction that logistics is part of a supply chain process that plans, implements and controls the efficient, effective forward and reverse flow of goods, storage, services, customer requirements and related information between the point of origin and point of consumption (Cooper *et al*., 1997). Globalisation has brought new risks and challenges, such as short product life cycles and uncertain demand. This has led companies to invest in technologies and approaches for enhancing supply chains in order to gain competitive advantage (Cavinato, 1992). With supply chain complexity leading to new risks, efficiency, price discrimination and low-cost resources, outsourcing jobs has become increasingly common, although it has created global winners and losers (Johnson, 2006).

There are now two distinctive supply chain strategies "Lean Supply Chain and Agile Supply Chain". "Lean Supply Chain" was initiated by the Japanese business method. The term "Lean supply" implies the use of lean production that aims to eliminate waste and enhance customer value with the continuous improvement of manufacturing system, practices, and techniques (Ugochukwu, 2012). This gained popularity in manufacturing companies. However, to create a successful Lean Supply Chain, companies must adopt "Leanness" through their entire business structure, resulting in the integration of lean concepts within every node, such as suppliers, focal organisations, distributors, and customers (Ugochukwu, *ibid*). A Lean supply chain was recognised by companies to have the following benefits as described by Li *et al*. (2006) and Gereffi, (1999b): improved quality reduced cost, improved delivery, high flexibility, reduced shortage, and so forth. It was further distinguished by having the following competitive advantage attributes: long-term relations with suppliers, effective communication and information sharing, integrated supply chain members, continuous improvements, predictability, etc. However, though Lean supply chains reduce inventory costs, they are susceptible to shocks such as natural disasters or global pandemics (Bullington, 2005).

The second distinctive strategy is known as "Agile Supply Chain". With globalisation giving birth to an era of a time-based competition, as customers insist on shorter delivery times, it became critical for supply chains to be flexible and synchronise to meet peaks and troughs of demand (Mansor *et al*., 2011). Agility requires a business-wide integration of flexibility in all nodes of the supply chain's organisational structures, information systems, logistics processes and manufacturing. Having an agile supply chain with flexible manufacturing systems has its disadvantages. For agile management to ensure flexibility and customer satisfaction, the customer must be clear about the expected project output, otherwise a risk arises in the output of manufacturing (Mansor *et al*., *ibid*). For agility to succeed requires adaptability to the changing market environment, both time consuming and expensive, contradicting the low cost and lead time requirements of customers (Macheridis, 2014). This has resulted in the creation of a Leagile concept that combines the strength of Lean and Agile as it improves on their weaknesses. Leagile supply chain strategy combines Lean and Agile with the use of the decoupling point[5], which uses Agile strategy for responding to a volatile demand downstream yet uses Lean strategy to provide high-level scheduling upstream from the marketplace (Jones *et al*., 2000). This makes Leagile the perfect system for supply chains to adopt in order to survive in any market. Globalisation has created some challenges for supply chains such as, de-centralised management, outsourcing of raw materials, manufacturing and jobs to countries such as China and India (Gereffi, 1999b). This has redirected companies' energy to research and development of new information technologies, such as radio frequency identification (RFID) and tools that enable enterprise integration and collaboration to enable them to gain an edge in competitive advantage (Hayes, 2001). Furthermore, globalisation has increased competition in consumer pricing, supplier contact and negotiations, adding further strain on the economic forces within and between companies' supply chains. Risk management has become key, as demand volatility makes supply chains more complex and leads companies to further explore product life-cycle management, planned obsolescence[6], post-sale service and reverse logistics in the case of product recovery, all of which contribute to the changing environment that awaits the future of supply chains (Chandak *et al*., 2014).

## 2.4 Future Forecast of Supply Chains and Logistics

Technology has and will be moving at a fast pace, with communication capabilities made extremely easy, as it has re-shaped the way information sharing is perceived. This technological advance provides tremendous value in addressing supply chain and logistics issues such as warehousing, distribution, transportation and manufacturing logistics (Lummus and Vokurka, 1999). Supply chains and logistics planning are based on distribution models simulated by software. This study will aim to create an interactive MDM model that is accessible on a website. Today interactive software tools have become crucial for systematic, strategic and tactical coordination of logistics functions within a company and across its suppliers for the purpose of improving the long term performance of the business and its supply chain as a whole (Tan *et al*., 1998). Moreover, the technology of 3D printing has

[5] The decoupling point is the point in the material flow streams to which the customer's order penetrates.

[6] Built-in obsolescence in industrial design is a policy of planning or designing a product with an artificially limited useful life, so it will become obsolete, that is, unfashionable or no longer functional after a certain period of time

challenged manufacturing systems as it is cost-effective, efficient and environmentally-friendly. The use of 3D printing for manufacturing in certain locations can be low-cost and very beneficial for a global logistics network (Kaltenbrunner, 2014). However, for 3D printing to be cost efficient, businesses need to station local manufacturing centres closer to strategic markets, in order to reduce the length of the supply chain and transportation costs hence helping towards a reduced carbon footprint (Pearce *et al*., 2010). In a world of 'next-day delivery' where consumers want products fast, 3D printing helps tackle inventory concerns, especially for industrial spare parts as regional manufacturing can easily implement leanness as 3D printing technology will enable manufacturers to easily produce goods to order, helping save money and minimise waste (Jalwan and Israel, 2014). It also helps the implementation of agile systems, as with the constant changes in consumer taste, 3D printing is a perfect tool for selling highly-customised products in the tightest lead-times (Jalwan and Israel, *ibid*).

However, there are many new branches of supply chain that are being addressed, such as agricultural supply chains, medical supply chains, and humanitarian logistics; all of which have become a focal point in expanding supply chains, logistics and their modelling systems beyond their traditional boundaries (Lummus and Vokurka, 1999). All this expansion brought by globalisation has in turn created confusion as to how a supply chain can actually be initiated within a company to incorporate a suitable business structure for its market and a commodity that can then expand in future (Johnson, 2006). With the volatility of the global integrated market, supply chains face several issues in future. These are, cost adaptation to the market, visibility as with the rapid increase in information, supply chain executives are struggling to identify and act on the right information. Additionally, there are issues in risk management as well as customer intimacy, as despite the drive in demand, companies prefer to create better connections with their suppliers than with their customers (IBM, 2009).

The next section identifies a gap in the process of initiating a supply chain particularly the struggle in choosing an optimal strategy with regards to small and medium sized enterprises (SMEs). This research aims to create a MDM that will help large companies as well as SMEs deal with these issues in future. The matrix model will ease the process of identifying the most suitable supply chain and logistic strategy a business needs to incorporate for their marketplace by illustrating the characteristics of each supply chain strategy and its usefulness in solving the issues of cost, visibility, risk and customer intimacy in the market. Meanwhile companies will additionally have options generated by the MDM that enables them to customise the best suited strategy for their supply chain that is tailored to their specific needs and requirements.

## 2.5 Issues in Initiating a Supply Chain

Supply chain management has emerged as one of the major areas for companies to gain a competitive edge. Managing supply chains effectively is a complex and challenging task, encompassing the end-to-end flow of information, products and money (La Londe and Masters, 1994). The effects of globalisation have resulted in trends of expanding product variety, short product life cycle, increasing outsourcing and continuous advances in information technology with the support of the internet. With it, companies in a supply chain can be connected in real time with information and knowledge shared continuously (Garcı´a-Dastugue and Lambert, 2003). New products and services can be designed to fit special market segments, increasing needs and opportunities to develop supply chain management to serve customers new-found requirements (Mentzer *et al*., 2001). The pressures a company's supply chain faces are excessive inventory, outsourced customer service, escalating costs and declining profits. Ability to cope with challenges and opportunities in new markets strongly affects an organisation's competitiveness in such areas as product cost, working capital requirements, speed to market, and service perception (Cavinato, 1992). For that reason, proper alignment of the supply chain with business strategy is essential to ensure a high level of business performance. In order to achieve a successful alignment, the right supply chain strategy to implement depends on a number of factors (Lee, 2002):

- The strategy needs to be tailored to meet specific needs of the customers.
- A product with a stable demand and a reliable source of supply should not be managed in the same way as one with a highly unpredictable demand and an unreliable source of supply.
- The Internet can be a powerful tool for supporting or enabling supply chain strategies for products with different demand and supply uncertainties. Software modelling is the new tool to support supply chain strategies

based on a “one-size-fits-all” as they can be programmed to be tailored to fit the needs of the company as it has all the options required for a firm to choose from.

According to Lee (2002), there are two key uncertainties, product demand and product supply. The "uncertainty framework” was further expanded by Fisher (1997), to introduce supply chain strategies to the right level of demand uncertainties of the product. This is achieved by linking the demand uncertainty to the predictability of the product demand. Fisher (*ibid*), divided product demand into three types. First, functional products that have long product life cycle and therefore stable demand, such as household consumable items, basic foods, oil and gas, and basic clothing. Secondly, innovative products as interpreted by Britoa *et al*. (2008) as having short life cycles resulting in highly unpredictable demand, such as the fashion industry. Other examples of high-end products are computers and specialised sports equipment. Lastly, innovative functional products, which are a combination of necessary daily products that require innovation, for example mass-customised goods such as the automobile industry (Fisher, 1997).

### 2.5.1 Supply Chain Characteristics

An organisation's supply chain strategy is shaped by four main elements (Fig. 2). Firstly, the industry framework (the marketplace); the organisation's unique value proposal (its competitive positioning); its internal processes (supply chain processes); and its managerial focus (the linkage among supply chain processes and business strategy) as indicated by Porter (1980).

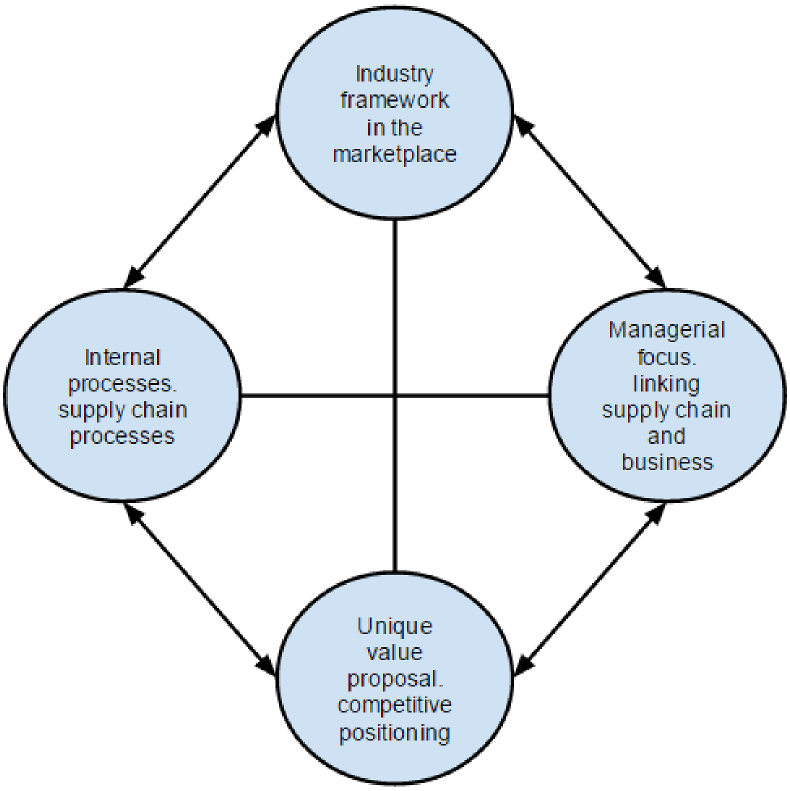


*Figure 2: Four elements of supply chain functions (adapted from Porter, 1980)*

With these product categories in mind, a company must consider the four elements of supply chain strategy before achieving a successful alignment. According to Michael Porter (1991), the reason why firms succeed or fail is perhaps the central question in strategy. Supply chain strategy defines the connection and combination of activities and functions throughout the value chain. In order to fulfil business value, operational efficacy is needed to achieve excellence in activities and functions to satisfy the customers across the marketplace.

**Industry framework**, refers to the interaction of suppliers, customers, technological developments and economic factors that affect competition in any marketplace (Porter, 1991). There are four main drivers affecting the industry's supply chain design: demand variation, market mediation costs associated with the imbalance of demand and supply, and product lifecycle, which is continually getting shorter in response to the speed of change in technology, fashion and obsolescence (Britoa *et at*., 2008). All of these push companies to increase the speed of product development and responsiveness to unexpected demand (Porter, 1991).

**Unique value proposal** requires the business to clearly understand its supply chain's competitive position (Li *et al*., 2006). For example, recognising the main product features and service will help a company determine if it is competing with a functional product, innovative product or innovative functional product (Porter, 1980).

**Managerial focus** links supply chain process and business strategy by ensuring coherence between supply chain execution and a business's unique value proposal. This approach encourages companies to focus on seeking local efficiencies such as identifying cost-effectiveness with in-house manufacturing, distribution and identifying the process that can be cost-effective by outsourcing (Ketchen and Hult, 2007).

**Internal processes** provides a connection and integration within the supply chain activities that fall under the categories of source, make and deliver. The most important element in the internal process according to Olhager (2011), is the location of the decoupling point that is linked to the material flow where the product is tied to a specific customer order; the basic choices being make-to-stock, assemble-to-order, make-to-order, and engineer-to order. Each material flow requires a different position for the decoupling point to be in (Fig. 3). The decoupling point divides the operations stages that are forecast-driven (upstream) from those that are customer order-driven (downstream) (Olhager, *ibid*). The decoupling point is also the last point at which inventory is held, and should be located at the end of the transformation process or, at least, at the output point for the most relevant manufacturing asset in terms of cost (Christopher and Gattorna, 2005). Prior to the decoupling point, is a "push" system, leading the production cycle to be long in order to increase production efficiency. After the decoupling point, is a "pull" system, where the chain is driven by demand and is therefore highly variable, and the production cycle tends to be shorter in order to reduce the order cycle time and increase customers' positive perception of service (Christopher *et al*., 2006). When the decoupling point is located farthest from the customer's end of the supply chain, product customisation increases, while when the decoupling point is located toward the customer's end, product customisation diminishes, such as the make-to-order and engineer-to-order (Olhager, 2011). Therefore, the demand buffering should be supported by excess capacity (Fig. 3).

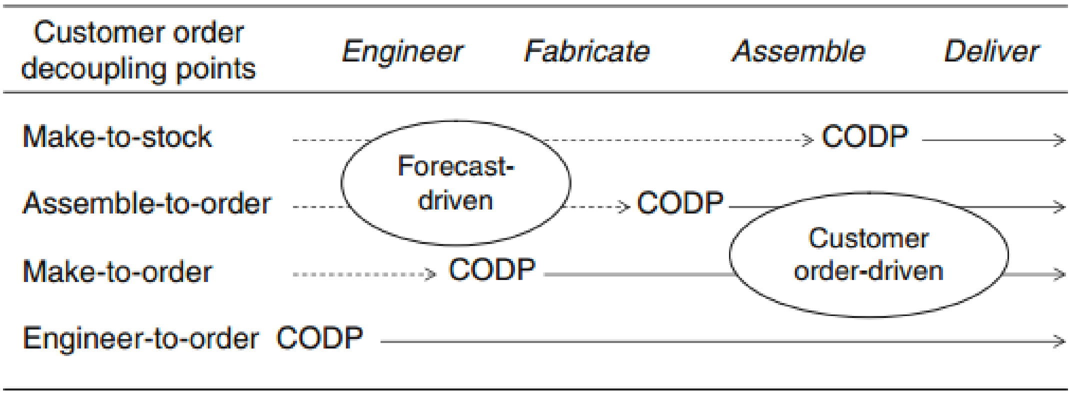


*Figure 3: Customer order decoupling points (Olhager, 2011)*

In addition, Novack and Simco (1991), state that collaborative relationships with customers become more useful as they help to reduce demand uncertainty. Consequently, the minimum size of the order does not depend on the size of the manufacturing batch, and minimum order size is governed by the relevance of transportation cost to the total cost. Identifying the decoupling point is of utmost importance to the selection of the best suited supply chain strategy. The location of the pull and push system will determine if a company will implement a Lean, Agile or Leagile strategy (Christopher and Gattorna, 2005).

Although each of these four elements includes multiple factors, some of those factors are relevant drivers for the formulation of a supply chain strategy model created by this research as a matrix to help SMEs and companies identify the best suited strategy for their marketplace. The matrix aim is to create a MDM that is able to account for the four main elements to help a company shape its own supply chain and tailor it to its specific needs with regards to uncertainty in the marketplace.  In addition, it aims to help companies mitigate the four issues of globalisation (Cost, Visibility, Risk and Customer Intimacy). Before embarking on the creation of the MDM, this study must first clarify the different definitions associated with supply chains and the most suitable interpretation for this research.

### 2.5.2 Definition of Supply Chains

Cagliano *et al*. (2004), expressed the need for a unified definition of supply chain strategy that extends to manufacturing and operations strategy in the upstream management. Supply strategies are generally defined on the basis of either supplier selection criteria or integration mechanisms. Although Cagliano *et al*. (2004), stated various studies consider supplier selection criteria as the link between competitive strategies and aligning the supply chain with the firm's objectives. Companies are increasingly attempting competitive success through integration of internal business processes and strategic alignment of internal functions but also through the integration and alignment of inter-company processes. According to Mentezr *et al*., (2001), the evolution of supply chain resulted in the creation of many definitions which complicated the selection of the most relevant strategy for companies. The difficulty firms faced in defining their supply chain resulted in misinterpretation of what their business requires in order to compete in the marketplace. The overlaps between each time frame of supply chain evolution created a diverse range of definitions. The lack of a single interpretation, created the need to adopt one unified definition which would add sophistication to research and practical implication.  Therefore for simplicity, a sample table has been drawn to highlight the definitions developed throughout the supply chain evolution that are most relevant to this study (Appendix B). This table has collected the most significant definition of supply chain and logistics and allocated them into "Eras". The use of the term "Era" is to allow flexibility of overlaps in time and to help identify each evolution period in which these definitions occurred. The definition table aims to provide a sample of relevant definitions to the creation of the eras, in order to simplify the selection process for companies as they seek to identify the best interpretation of their supply chain (Appendix B).

The literature gathered from the definition table shows how different institutes, centres and councils were created throughout the supply chain evolution. The National Council of Physical Distribution Management (NCPDM) was formed in 1963 while the Georgia Tech Production and Distribution Research Centre, and the Computational Optimisation Centre were initiated in the 1970s. The Council of Logistics Management (CLM) emerged in 1985 with the commercialisation of personalised computers, globalisation and technology, to cater for the fast development in supply chain and logistics management (Mentezr *et al*., 2001). Furthermore, the recognition of the importance of supply chains and its relation to business strategy is reflected by the CLM as it changed its name to the Council of Supply Chain Management Professionals (CSCMP) in 2005 (Georgia Tech Supply Chain and Logistics Institute, 2010). This resulted in a surge of exploration in the field by many esteemed researchers such as Marshall Fisher (1997) who introduced the revolutionary concept of supply chain segmentation in his article "What is the right supply chain for your product?" that caused several academics and consultants, including Lee (2002), Christopher and Gattorna (2005), Ketchen and Hult (2006), among many others to propose several models regarding the formulation of supply chain strategy.

Large organisations also developed a keen interest and took advantage of this emerging innovation in business strategy to develop their own unique supply chain systems. For example, Motorola's pursuit to achieve Six Sigma performance since 1986 has led to the company achieving its very own efficient performance metric to drive improvement, innovation and optimisation which later developed into a software "Digital Six Sigma" to cater for the technological development (Supply Chain Digital, 2011). Another example is the Toyota Production System (TPS) developing out of necessity in response to the market. Between the years of 1936-1956 the chief executives of TPS worked to formulate a sophisticated supply chain and logistics system by developing the Seven Wastes, Standardisation, kaizen-5S continuous improvement, quality control error proofing and Kanban system, to create a responsive chain that can tap into various markets (Sugimori *et al*., 1977).

During the 1990s, many third party suppliers such as manufacturers of spare parts and service providers realised the fierce competition facing them in wining projects from large organisations, and formed an alliance with their own suppliers to upgrade their management functions to share information in order to gain a competitive advantage over other supply chains (Lambert and Cooper, 2000). Meanwhile, rivalry in the market-place changed dramatically from completion of ''business versus business,'' to battles of ''supply chain versus supply chain.'' Within this context, value supply chains are emerging as a means to create competitive advantages and superior performance (Li *et al*., 2006). Traditional supply chains often focus primarily on one key outcome such as speed or cost, therefore an integration was required to merge the best attributes of both the traditional and value supply chains to cover an array of uniquely integrated priorities such as cost, quality, speed, customer intimacy and flexibility (Ketchen and Hult, 2007)

With increasing competition, companies that are unable to define supply chain strategy tend to be at a disadvantage, hence the use of the definition table

(Appendix B). Additionally, this study will aim to build a MDM that will diagnose the best suited strategy for a company's supply chain. However, this study must select a suitable definition that will reflect the research objective and adapt to the matrix model. This study will separate the logistic activities from supply chains as the term "supply chain" is used to refer to strategic issues, while the term "logistics" refers to tactical and operational issues; such as high due date reliability, short delivery times, low inventory level and high capacity utilisation, which in turn can be divided into two segments (Mangan *et al.*, 2008):

1) Inbound logistics which is one of the primary processes concentrating on purchasing and arranging inbound movement of materials, parts and/or finished inventory from suppliers to manufacturing or assembly plants, warehouses or retail stores.
2) Outbound logistics which is the process related to the storage and movement of the final product and the related information flows from the end of the production line to the end user.

This study found the definition by the CSCMP to be most relevant and adaptable as it states that "Logistics is part of the supply chain process that plans, implements and controls the efficient, effective forward and reverse flow, storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements", while "Supply Chain Management is the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (Georgia Tech Supply Chain and Logistics Institute, 2010).

### 2.5.3 Problem Statement

The issue facing many organisations especially SMEs, is the distinction of which supply chain model to incorporate within their business strategy. This is due to the many models and definitions developed over the years obscuring the key elements that companies need in order to identify what strategy best suits their supply chain to help it overcome the challenges it faces in the marketplace. This study aims to lessen the confusion by collecting a sample of definitions and allocating them into "Eras" (Appendix B). This assists the establishment of the MDM for business that aims to diagnose and tailor the strategies they need. The term MDM (Multi-dimensional Matrix) is chosen due to the variety of dimensions needed in creating the model, for example the supply chain's four elements (Industry framework, unique value proposal, managerial focus and internal processes). In addition, strategies Lean, Agile and Leagile, which form several dimensions that should be considered. This study will select the most relevant supply chain elements and strategy in order to build a MDM capable of mitigating the challenges of globalisation (Cost, visibility, risk and customer intimacy). The increase in technological progress will require the MDM to adapt to an automated Era. This study will further develop the MDM model to make it an interactive tool that can be accessed on a website and developed as software, enabling companies to upgrade it and use for continuous progress in diagnosing the alignment of their supply chain strategy with the market. This study will further establish a sustainability decision tree that will complement the MDM in mitigating the carbon footprint of their chosen strategy. With the development of 3D printing and movement towards sustainable solutions, companies will be forced to adapt to technological progress as well as develop a greener supply chain (Jalwan and Israel, 2014). The sustainability decision tree will help the thinking process of establishing a reduced carbon footprint strategy. In order to create the MDM this study will develop a theoretical framework where the evolution of supply chains will be divided into seven eras. Allocating each development into an era, will help examine the models of supply chain that were created and establish a conceptual framework of how this study will be conducted in order to build the MDM on the basis of the collective models develop through time, as each evolution of supply chain overlaps with its predecessor, hence the eras and historical time frames will follow suit. Furthermore, another conceptual framework will be created illustrating how this study will aim to structure the MDM.

According to Cagliano *et al*. (2004), supply chain research indicates a lack of multiple dimension supply strategies which could provide a more complete picture of the options available to managers for shaping the supply strategy in different contexts and help to align them with companies' goals. This study will aim to collect data by the use of expert opinion and combine statistical analysis with deductive reasoning to establish the various suitable strategies that can be incorporated into the MDM, in addition to providing options that companies can favour to create their tailored approach. This study will test the MDM and its interactive capability with an established organisation to investigate its applicability and suitability.

## 2.6 Theoretical Time-Scale Framework

This chapter will present a theoretical time-scale framework that forms a basis for the conceptual framework presented in the next chapter. The theoretical time-scale framework outlines the issues addressed in this study, where the conceptual framework in the next chapter will illustrate the possible solution to mitigate the issues. Both frameworks are based on the identification of key concepts and the relationships among these concepts. Both terms are sometimes used interchangeably though they have different meanings (Imenda, 2014). Theoretical framework is the researcher’s idea on how the research problem will be explored, which is a much broader scale of resolution. The theoretical framework dwells on developed theories tested through time that investigate the findings of how phenomena occurs, by providing a general representation of relationships between concepts (Imenda, *ibid*). This study’s theoretical framework will commence by creating a historical time-scale where supply chains are examined through time and their developments are allocated into “Eras” to mark the evolution of the concept. This will ease the categorisation of developed theories and aid the investigation of why supply chain models were created and how they can be integrated to form a conceptual framework that will mitigate the difficulty for organisations to diagnosing the most suitable strategy for their marketplace.

Meanwhile, the conceptual framework embodies the direction which the research will undertake, describing the relationship between specific variables identified in the study. It also outlines the input, process and output of the whole investigation, as it indicates the path the study will take in choosing a methodology to collect data, the analysis approach and testing; hence it plays a key role in mapping the research paradigm (Imenda, *ibid*). The theoretical and conceptual frameworks are both interlinked (Fig. 4), and play a key role in synthesizing existing views in the literature.

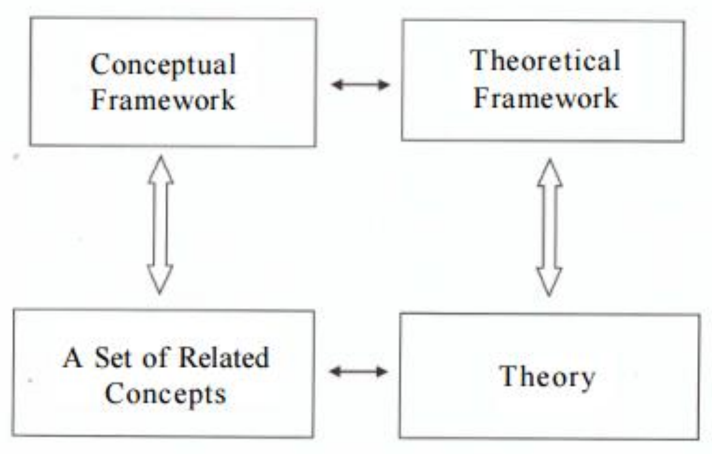


*Figure 4: Integration of frameworks (Imenda, 2014)*

This study will adopt this integrated approach to investigate the problem statement put forward, by using the literature gathered from the theoretical framework as an "input" of variables that will be researched, analysed and tested to create the "output" model. As both frameworks are interlinked, the theoretical framework will examine the developments of supply chains though the first five eras of evolution, then integrate the concepts and variables found with the conceptual framework in the last two eras in order to create a preliminary design of the model. The conceptual framework will map this research's path of selecting the most relevant methods in order for the final model to be put forward in the analysis and its applicability to be tested with a well-established organisation.

## 2.7 Era One: Creation (1940s – 1980s)

This section will look at the creation of the supply chain discipline and the breakthrough in understanding how industrial company success depends on the interactions between the flows of information, materials, money, manpower and capital equipment (Forrester, 1958). Theories were initiated for distribution management that integrated system dynamics with organisational relationships to maximise performance, product development, engineering, sales, promotion and marketing.

Since World War II, trade agreements have been established to bring countries together. In 1946 governments took measures to eliminate trade barriers to free the movement of finances through international agreements such as the General Agreement on Tariffs and Trade (GATT) (Crowley, 2003). In 1982 the International

Maritime Organisation (IMO), continued to produce new and updated procedures across a variety of maritime issues as well as focusing on sustainability such as emissions from ships and the Safety of Life at Sea (SOLAS) treaty, which covers maritime security (Crowley, ibid).

From the 1950s to 1960, manufacturing emphasised mass production in order to reduce the cost of unit production, as there was little flexibility in operations strategy. Manufacturing relied exclusively on in-house technology and capacity, which resulted in slow new product development (Shukla *et al.,* 2011). In the 1960s, the terms "warehousing" and "materials handling" were commonly used to describe many logistics efforts. However, the increasing shift to freight transportation by truck rather than rail, led to the development of the logistic term, "Physical Distribution" to join "warehousing", "material handling" and "freight transportation", which came under the NCPDM formed in 1963 (Lambert and Cooper, 2000). The start of mass customisation by manufacturers initiated Material Requirement Planning (MRP) in 1970, due to inventory management requiring large investments in crucial areas such as "Work In Process" (WIP), crucial for cost reduction, quality, product development and delivery lead-time. The MRP and WIP aided mass customisation by information sharing between companies, its consumers and suppliers in order to reduce inventory costs (Croom *et al*., 2000). However, sharing technology, information and expertise with customers or suppliers was considered risky, thus little emphasis was placed on cooperative and strategic buyer-supplier partnerships (Tan, 2001).

Academic research followed growing industry recognition, especially with regards to the computer revolution in the early 1970s. This in turn marked the beginning of supply chain globalisation to be discussed in Era three. In the 1980s Logistics was recognised as being very expensive, important and complex (Forrester, 1958). Company executives realised that opportunity came if they significantly improved logistics, investing in trained professionals and new technology. This was also noted in 1985 by the NCPDM when it integrated the various evolving aspects of supply chains, such as services, information flows, in-bound, outbound and reverse flows of products that led it to change its name to the Council of Logistics Management (CLM) (Georgia Tech Supply Chain and Logistics Institute, 2010).

### 2.7.1 Implementation and Coordination Mechanisms

The supply chain is not only a chain of business-to-business, but rather multiple networks of integrated relationships, such as marketing networks. This means it cannot be left to one department alone, but incorporated in each element of the business framework (Forrester, 1958). To reduce further complications in a business, CLM has divided and integrated logistic processes throughout the management of key business process within the supply chain. In 1982, the management of multiple relationships across the supply chain was referred to as SCM (Persson, 1997). The emergence of supply chains was due to the recession of the late 1980s and early 1990s; this gave industrial managers the opportunity to improve supply chain models and cost reduction processes at business strategic level (Chiu and Lin, 2004). The complexity of managing all the products and suppliers back to the point of origin requires SCM and Logistics to operate as independent yet interlinked sectors. Firms are required to establish a department designated to the coordination of suppliers and another logistics department that coordinates the intra and inter-logistic movement of goods (Forrester, 1958). This led in 1998 to CLM redefining logistics, categorising it as part of supply chain management: “Logistics is that part of supply chain process that plans, implements and controls the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption in order to meet customers’ requirements” (Lambert and Cooper, 2000). The rise of technological planning created a globalised market that changed the nature of competition from “business vs. business” to “supply chain vs. supply chain”. The survival of a supply chain rested upon its value and management which is reflected in how a firm can use its supply chains as a strategic weapon to gain advantages over its peers. This allowed the traditional supply chains concept to incorporate “value-added” into the traditional concept of “cost reduction” and integrate customer fulfilment throughout the organisational process (Harland and Lamming, 1999). This resulted in the traditional concept of supply chain, including warehousing, material handling and freight transportation, being expanded to include technological development such as MRP and WIP in addition to value added enabling it to cope with the marketplace. Hence the traditional supply chain gained a basic array of uniquely integrated priorities in addition to its cost reduction such as quality, speed, customer intimacy and flexibility (Ketchen and Hult, 2007).

In 1997, the popularity of this traditional basic supply chain concept was noted at the Annual Conference of the CLM as 22% of the sessions contained the term (Christopher, 1992). Due to its increasingly popularity until recent years, several other definitions and models have arisen. Christopher (*ibid*), summarises supply chains as multiple components, both upstream (i.e. supply) and downstream (i.e. distribution) and their integration of different processes and values in the form of products and services, that can be delivered efficiently to the end consumer. Meanwhile, other definitions were established, such as La Londe and Masters (1994) who defined supply chains as a set of firms that pass materials forward (i.e. upstream). Lambert *et al.* (1998), stated that supply chains include the alignment of firms that bring services or products to the market and finally to the consumer (i.e. downstream). From these definitions it is clear that technological progress is further leading the traditional basic supply chain to evolve into a new era of integration; in order to link different processes that meet the new demands of consumers, in addition to the need for an alignment between the business framework and the supply chain strategy to ensure optimal performance (Kim and Kogut, 1996). The need to align supply chain management strategies is to increase the competitive advantage of companies with a strategic plan of purchasing, providing benefits to the overall network performance of the company (Cagliano *et al*., 2004).

Era one establishes the development of the supply chain and logistics concept, its acceptance and use by companies. It also establishes the benefits of supply chain management in increasing business efficiency and re-structuring the market's concept from "business to business" into "supply chain to supply chains".

## 2.8 Era Two: Integration (1970 – 2000)

In the movement from era one to era two, successful supply chains required the management of cross-functional integration of key business processes within the organisation and across its network (Lambert, 2000). Supply chains have been defined by Lee and Billington (1995) as the integration of procurement, manufacturing and distribution. In order to optimise performance of the chain, Finch (2004), states that companies should add as much value as possible for the least cost possible. The challenge is to fully integrate external and internal processes in order to determine and achieve successful inter-network competition.

In the quest to fully integrate external and internal processes of the chain, Georgia Tech institute aimed to better understand the issues facing this challenge by better linking research, education and practice, hence the Georgia Tech research and Professional Education merged into The Logistics Institute in 1992 (Georgia Tech Supply Chain and Logistics Institute, 2010). This marked a historic event in which integration capabilities and development became a crucial area for strategic development. This led to the findings of the four base-line strategies which organisations adopted in order to take a detailed approach to integrating supply chains with their business framework (Stevens, 1989).

***Stage one "baseline":*** Companies designed a plan to be reactive for the very short term; to counter the company's vulnerability due to the effects of change on the supply chain's demand patterns (Jayaram *et al*., 2010b). The supply chain responsibility is divided across nodes to form the baseline. These nodes carry the inventory responsibility to integrate and synchronise activities across the control system to manage information of sales, manufacturing, material control (raw material flow through to finished goods), production control and purchasing (Frohlich and Westbrook, 2001).

***Stage two "Functional Integration":*** This involves functional integration which focuses on the inward flow of goods and combines time phased planing with materials and manufacturing management, using MRP with the distribution network, hence allowing the demand to be aggregated and avoiding poor visability of demand which leads to inadequate planing (Stevens, 1989). This increase in visibility aims to reduce risk and cost by implementing buffers in the inventory for demand fluctuation. Focused on improving performance, plant utilisation will increase efficiency as well as reduce costs (Frohlich and Westbrook, 2001). The Functunal integration between the nodes of the supply chain allows for a reactive approach towards customer service, that can be improved by acquiring internal integration of customer intimacy into its core culture (Jayaram *et al*., 2010b).

***Stage three "Internal Integration":*** Focuses on the management of goods to the customer, by integrating customer intimacy directly into the supply chain. Internal integration is characterised by a comprehensive integrated planning and control system (Das *et al*., 2006). Typically companies in the third stage will use Distribution Resource Planning (DRP) integrated with MRP for material management, as well as using Just in Time (JIT) for manufacturing to ensure full integration of systems such as, visibility from distribution through to purchasing, efficiency, synchronisation, and full utilisation focused on tactical rather than strategic approaches to achieve cost effectiveness (Sugimori *et al*., 1977). Additionally, extensive use of electronic data interchange (EDI) to integrate customers with faster response, leading to a faster reaction to customer demand rather than "managing" the customer (Kim and Kogut,1996).

***Stage four "External Integration":*** By applying these four steps, companies will attain full integration by extending their scope outside the company to embrace suppliers and customers, moving away from being product-orientated to being customer-orientated; hence understanding the products, culture, market and organisation (Das *et al*., 2006). This ensures a change in the company's attitude by adhering to the customer's needs and requirements, creating a foundation by which the company can mitigate the issues of cost, visibility, risk and customer intimacy brought by globalisation (Kim and Kogut,1996).

### 2.8.1 Call for Integration

The four baseline stages taken by firms to establish integration were made possible by the technological tools that aided the alignment of the various nodes of the chain with the business framework. In 1970s, MRP was a technological tool that integrated management with manufacturing in order to reduce the cost of new product development and reduce the lead-time of the Work In Process (WIP) (Kim and Kogut, 1996). The aim was to improve the outcome for customers by standardising transactions and transferring information in order to increase organisational efficiency based on integrating the marketing concept, the "4 P's" (Product, Price, Promotion and Place). Hence, integrating marketing with supply chain processes commenced, aiming to:

1) Identify the members of the marketing chain
2) Coordinate the marketing chain
3) Structure and illustrate the marketing chain process (Lambert, 2000)

However, the contribution of 3rd. party suppliers and manufacturers had not been accounted for; as it was assumed that everyone within the business knew who was a member of the supply chain, as little effort was spent on identifying significant supply chain members with the key processes. This resulted in managers not knowing how to establish a successful alignment due to issues of visibility within the supply chain (Jüttner *et al*., 2006). Therefore, the concept of relationship marketing was created to improve alignment. By allowing each node and member of the chain to focus on the business goal and establish communication with the customer side, this increases visibility and emphasises the downstream element in the supply chain (Webster, 1992).

Technological progress aided marketing as in the 1980s integration was about vertically aligning operations with strategy through a form of centralisation in order to organise the different product components produced by each node/member of the supply chain (Schoenherr and Swink, 2011). The aim of creating headquarter centres was to maximise consumer satisfaction by reducing the response time to demand. This according Frohlich and Westbrook (2001), required coordination of information technologies to manage the flow of data, hence the development of an Electronic Data Interchange (EDI) system, which helped busniesses integrates their suppliers and customers to improve performance. There are four dimensions or arcs that are improved with the EDI integration; quality, delivery, flexibility and cost performance (Frohlich and Westbrook, 2001).

In the 1990s the focus on alignment included horizontally integrating operations in order to sell products in a variety of markets as the world became more globalised. The proposed integration tactics aimed to coordinate the forward physical flow of activities that suppliers, manufacturers and customers have to undergo by the use of technological tools such as (ERP) systems (Chen and Ji, 2007). The emergence of ERP was developed by upgrading MRP developed in the 1970s and 1980s in order to integrate multiple databases, synchronise scheduling and lead-times as it became essential to a company’s survival (Hayes, 2001). In spite of problem installing the ERP systems due to fears of computer networks handling the change into the new millennium, most large companies had acquired it. This change from MRP to ERP systems improved data availability, and improved data capacity and accuracy as it increased the recognition for better planning and integration among logistics components, leading to a new generation of "Advanced Planning and Scheduling (APS)" software (Chen and Ji, 2007). Companies such as Toyota improved their own production system by the initiation of Just In Time (JIT) to enable delivery integration that aimed to maximise efficiency, fast product delivery and customisation in product development. The technological improvement of aligning their database to ensure their business operated with high responsiveness, leanness of delivering JIT, and reduced waste and cost, resulted in the development of the Toyota Production System (TPS), which became fully integrated into their business framework in the late 1990s (Sugimori *et al*., 1977). The TPS with JIT was created to stress the importance of delivery integration in terms of implementing fast product delivery and customisation in product development.

### 2.8.2 Integration Capabilities

The new era of inter-network competition depended on a business's management ability to successfully integrate the company's complex network. By categorising which processes are critical and beneficial to the business, these processes can be linked across firms and integrated within their internal network (Jayaram *et al*., 2010b). Management has the ability to accommodate the synergy of intra and inter-company integration by dealing with process excellence in an innovative way to strengthen relationships between nodes such as customer and supplier relationship (Lambert, 2000). For example, integration can further be increased if components of the supply chain are added to the operation level.

There are nine management components for a successful integration at the operation level: planning and control, work structure, organisation structure, product flow facility structure, information flow facility structure, management methods, power and leadership structure, risk and reward structure, culture and attitude (Lambert, *ibid*). Das *et al*. (2006), explores the different mechanisms that are put in place by companies to achieve integration between customers and suppliers, operational integration and technological integration. The former refers to the integration of operational activities such as planning, production, delivery and quality. The latter refers to collaboration techniques aimed at obtaining information sharing or joint decision-making, rather than on the redesign of internal operations (Das *et al*., 2006). Examples of these techniques are Just-in-Time (JIT) approach and Vendor-Managed Inventory (VMI), that help early supplier involvement and rapid prototyping in designing and developing new products (Cagliano *et al*., 2004). Furthermore, there is forward physical flow integrations requiring a closer relationship between the production systems, customer and the supplier. Additionally there is coordinate integration of backward information and data flows from customers to suppliers. This is a mechanism aimed at leveraging information from counterpart to improve internal activities and operations management (Cagliano, *ibid*). Identifying and integrating the key processes is a key element in achieving alignment between the busnies's supply chain and its business strategy. Lambert and Cooper (2000) as well as Ketchen and Hult (2007) stress that with integration, businesses compete as supply chains rather than individual entities, hence, busnieses ensure that every output is specifically tailored to add value to the chain. Therefore, facing a fundamental decision to select their best-suited suppliers, to ensure coherence and alignment between competitive strategy and functional strategies (Jüttner *et al*., 2006).

The adoption of supplier selection criteria has a positive impact on manufacturing performance. There are several categories of supplier selection criteria stated by Cagliano *et al*. (2004), which align manufacturing performance and competitive priorities, these are: cost, quality, delivery and flexibility. In establishing visibility and alignment across the processes, firms must ascertain their business structure by identifying the complexity of their product, availability of raw materials and the suppliers available (Das *et al*., 2006).  They must also identify their supplier members and categorise them into primary and supporting members. A busines can act as primary or as a supporting member to different companies, as a supply chain incorporates all nodes that are linked with an organisation directly or indirectly to establish a flow that connects suppliers and customers from point of origin to point of consumption (Lambert, 2000). Primary members are the strategic companies who conduct operational or managerial value adding activities in order to produce a specific design or product for a certain consumer or market. Supporting members provide resources, knowledge, utilities and assets. A busines must ascertain the dimension of its integration, whether it's horizontal or vertical (Lambert, *ibid*). Added value to the supply chain is achieved when a busines selects the relevant process. However, integrating all processes can be counterproductive if not impossible.

To help companies group their supply chain, Lambert and Cooper (2000), devised a framework with three categories (Fig.5). Firstly, the "Supply Chain Network Structure" consists of the key primary businesses which are external but are crucial to the company's product development.  At this level the company identifies its key supplier members, their ability to aquire raw materials and the complexity of designing the product. The management responsibility is to divide the supplier members and the task into primary and supporting teams. It is crucial at this stage to establish long-term relationships with supplier members as strong foundations add value to the chain as it mitigates any damage that may be caused by demand volatility (Lambert and Cooper, 2000). Secondly, the "Supply Chain Business Process" is referred to as the activities done by the primary members to produce specific outputs that add value to the consumer. Integrating customer value can come in the form of services such as warranties for the product or high customer service. Additionally, the company may also review its existing products and their potential in enhancing any features by adding value such as an additional complementary item to be included with the product (Ketchen and Hult, 2007). At the "Supply Chain Business Process" level a company identifies which process is relevant to their unique skills and that of their supplier members, as these processes will be added to the chain to increase its value to be used as a competitive advantage (Fig.5). This gains the product a Unique Selling Point (USP); for example in highly specialised technical organisation, their internal processers are integrated into their framework to be used as a competitive advantage as it is hard to replicate (Webster, 1992). Finally "Supply Chain Management Component" aims to integrate and manage the processes across the entire supply chain, thus managing both internal and external supply chain networks.

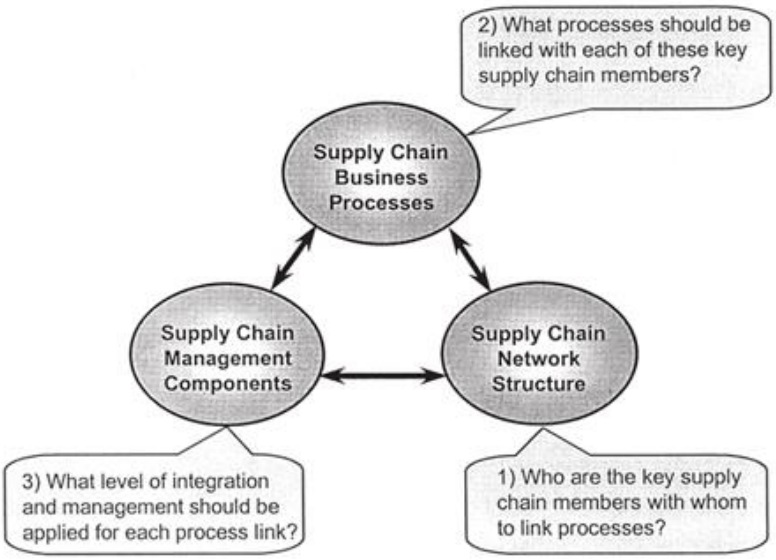


*Figure 5: Elements and keys decision framework (Lambert and Cooper, 2000)*

According to Lee and Billington (1995) businesses compete as supply chains rather than individual entities. The focus in integration has been on activities and information flows both within and across company boundaries in order to foster superior performance. By adapting Lambert and Cooper's frameworks (2000), the "Supply Chain Network Structure" is further examined to illustrate how each supplier member of the chain acquires their own supply chain in order to offer the best possible service with the lowest cost and highest value, hence illustrating how companies evolved to compete as supply chains. Finch (2004) states that optimising performance adds value to the chain as it ensures that process in every output is specifically tailored to add to the customer's value. To enable a competitive chain with integrated value, the "Supply Chain Network Structure" must be linked together via information flows that revolve around the requirements of the products produced.  Fig. 5 illustrates the levels of integration in the business process, whereby entities are divided into preliminary and supporting suppliers and are each linked via information flows. Each entity has the mutual aim to serve the customer's needs whilst feeding information feedback as it undergoes product development to the "Supply Chain Network Structure", where the responsibility for commercialising the product lies, to ensure that it reaches the end-user. The "Supply Chain Network Structure" duty is to unite the internal and external nodes of the chains, which is referred to as integrating and managing the supply chain components (Lambert and Cooper, 2000).

In Fig. 5 competitive advantage can be enhanced by increasing information flow and developing efficient communication, for example for a company to produce a product efficiently, it will have several entities: integration of business processes, e.g. purchasing of raw materials, production, logistic delivery and a finance department. However, effective communication with these entities and their relevant supply chains must be achieved in order to develop a competitive product. For instance the "Supply Chain business Process" divides the "Purchasing" into a preliminary member  while the "Production" will be the supporting member. The purchasing entity includes an outsourcing chain of materials that requires consistent communication to ascertain  inventory levels with the production entity which includes a chain of $2^{nd.}$ and $3^{rd.}$ party manufacturers. Similarly the logistics entity along with its chain of $2^{nd.}$ and $3^{rd.}$ party distribution centres maintains constant communication with the finance department to ensure the feasibility of the distribution strategy. The finance supply chain entity in some cases can outsource its audits, as firms seek cheaper labour. Fig. 6 illustrates that the flow of information is constantly communicated with the "Supply Chain Network Structure" by the help of the "supply chain management component" that ensures information which is managed and sent to the relevant supply members, in addition to ensure full integration of processes across the chain.

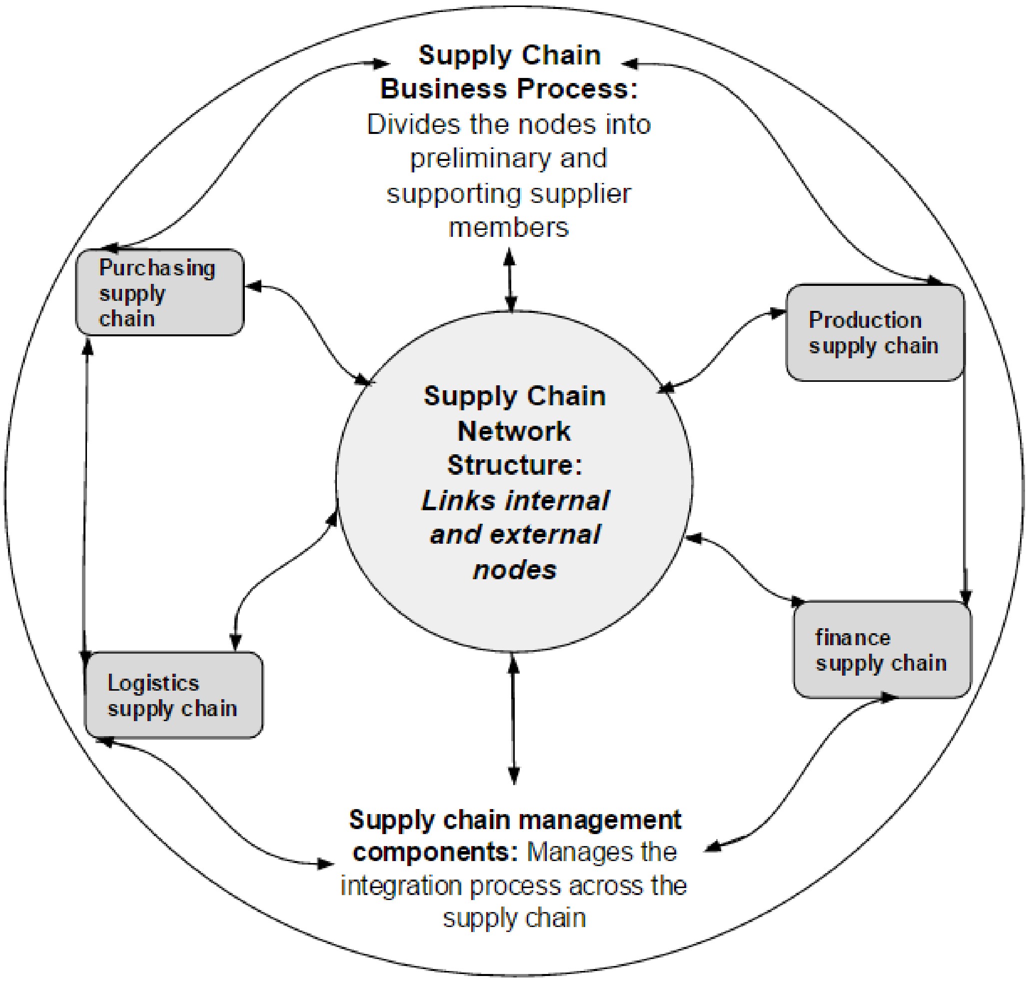


*Figure 6: Integrating key decision processes (adapted from Lambert and Cooper, 2000)*

To further illustrate the importance of sharing information between the nodes in a company, Lambert and Cooper (2000), devised a framwork for integrating and managing business processes across the supply chain (Fig. 7). The information flows between Tier one suppliers and Tier two, if applicable, through to manufacturing which includes (the logistics department, purchasing, research and development, finance, marketing and sales), to customers and finally to the end-user (Lambert and Cooper, 2000). The manufacturing node indicates that information of product flow is shared between its surround nodes. However, there is no indication of information being shared within the inter-nodes. It is clear that the forward movement of product flow shares information with all the key functions across the business supply chain. However, there is uncertainty on how information is distributed within the manufacturing processes from "customer relationship management" to "returns management". The integration between the top intra and bottom inter functions is only superficial, as there is insufficient indication of information flows traveling between the external and the internal functions. Moreover, there is insufficient indication on how the internal supply chain decision making is processed, as authority is not defined with respect to it being a hierarchy process or a bottom-up approach.

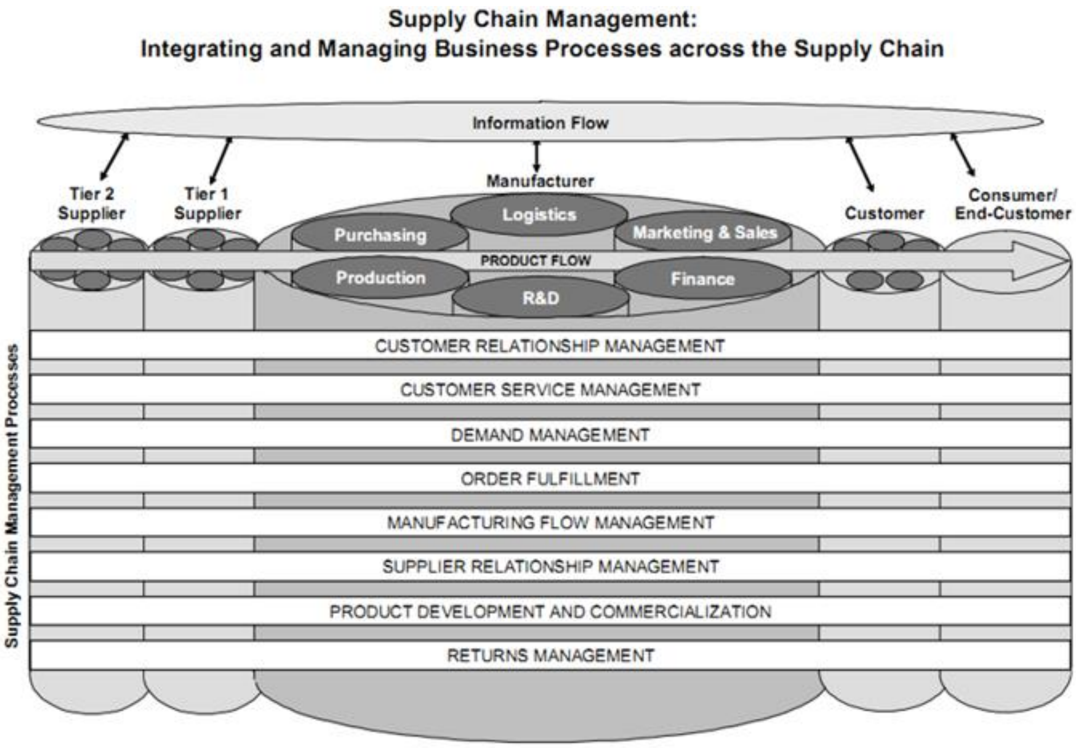


*Figure 7: Integrating business processes across (Lambert and Cooper, 2000)*

Adapting Lambert and Cooper's (2000) model (Fig. 8), the manufacturing department can establish efficient and effective communication with its sectors by establishing a circular information flow network. Once a product has been agreed on, it is given to the "Product Development and Commercialisation" sector, which analyses the feasibility of the product. Then to "Demand Management" which looks at the market needs and anticipates possible shifts in taste, while the "Manufacturing Flow Management", integrates the supply chain of raw materials with manufacturing whilst anticipating shifts in consumer taste from the feedback given by “Demand Management”. The product’s production quantity is then given to the “Order Fulfilment” department which will identify the stock level needed, then inform the “Manufacturing Flow Management” of the right quantity to be manufactured. Next is establishing a strong long term relationship with the supplier who helped produce the product. Creating strong foundations with suppliers adds value to the chain and increases its survival in a fluctuating market, as suppliers would likely help cost reduction in an economic downturn for long-term established partners. Creating a foundation with suppliers is achieved by sending information across the chain from manufacturing to Tier 1 and Tier 2 suppliers. Finally, “Customer Service Management” connects the business framework with customer needs to help further establish the product as a brand and to gain loyalty of consumers (Lambert and Cooper, 2000). During each department’s process, the flow of communication with manufacturing remains constant, once the final stage of “Customer Service Management” is complete, “Product Development and Commercialisation” continues with commercialising the product while maintaining links with manufacturing. In the case of faults, the “Returns management” becomes in charge of errors and reverse logistics. These steps can take place at different times, or altogether according to the company’s needs and the product’s requirements, and whether it is a new innovative product, or an upgrade to add value to a previous product (Fig. 8).

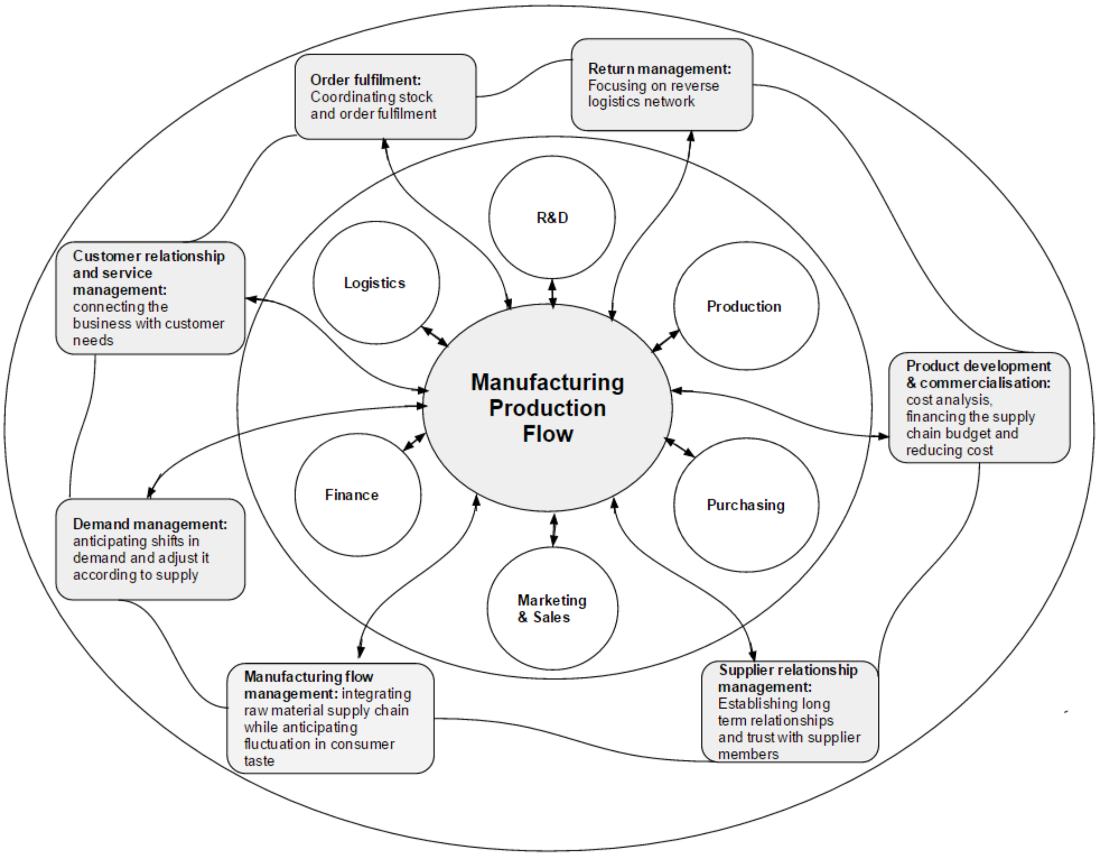


*Figure 8: Integrating business processes across the supply chain (adapted from Lambert and Cooper, 2000)*

Fig. 8 illustrates an inner circle where the supply chain main entities are located. The inner circle follows the same information flow structure as (Fig. 6), with "Manufacturing Production Flow" acting as a "Supply Chain Network Structure" as it coordinates and links the internal and external nodes of the chain. The outer circle hosts the different sectors that asses the creation of the product. They maintain a consistent flow of information "Manufacturing Production Flow" as the inner circle, whilst constantly circulating information amongst their neighbouring sectors.

#### *2.8.2.1 Integrating the Value Chain*

Identifying the supplier members is crucial for firms as it lessens network complexity. Establishing various marketing information flows eases product development and financial transactions. Information flows add value to the chain which in turn increases promotion of the product as it integrates the consumer and the stakeholder with the supply chain (Gibbon, 2001). The integration of process into the network structure can take two dimensions, horizontal structure integration and vertical structure integration. It is crucial for a company to integrate processes in both dimensions to ensure competitive advantage is achieved. In addition to it being essential when integrating the consumer and stake holder, to maintain investment of trusts in the company by analysing the competitive market, managing the supply chain by adding a value chain and ensure the various dimensions of information flows are organised into an efficient network (Webster, 1992).

The traditional basic chain initiated in the creation era was viewed predominantly as a process for moving materials and goods. However, as era one merged with era two, technology integrated with supply chains enabling information to integrate with nodes, such as supplier member and processes to form a coherent network. The traditional basic chain advanced through four base-line strategies to enable full integration with MRP, DRP, EDI and ASP information systems (Kim and Kogut, 1996). In addition to undergoing the four base-line integration strategies, the integration of process and information flows between supplier members, the traditional basic chain had to incorporate added value into its structure to increase its competitive advantage. This "added value" enhanced the traditional basic supply chain from merely a means to get products to where they need to be, to a means to strengthen key processes that drive a firm's strategic management and performance (Ketchen and Hult, 2007). The evolution to era two increased the scope of the traditional basic chain from focusing on either speed or cost, to integrating the best attributes of both information technology and added value to cover an array of capabilities such as cost reduction, information sharing, integration of processes to achieve a USP, network integration of supplier members, quality, speed, customer and stakeholder intimacy, prioritisation of long-term relationships and flexibility. This integrated and added value added enhanced traditional basic supply chain gained popularity as it became embedded in companies' framework as it became known to be a "basic supply chain" that every company primarily acquires (Ketchen and Hult, *ibid*). However as each company needs are different, and with the increase of globalisation, the basic supply chain has branched into six approaches throughout the next three eras to match the market's needs. These approaches were created to fit the product type, whether functional, innovative or innovative functional. These approaches can be categorised under four major strategies (Lean, Agile, Leagile and Basic) that businesses can choose to incorporate based on their specialisation and requirements. The next three eras will explain the increase in globalisation, the need for specialisation and the growth of the competitive specialised global environment for supply chains.

Era two marks the integration of supply chains and logistics process through several stages to increase the company's added value by the use of information technology. Era two also focuses on the alignment between the business framework and the supply chain strategy to ensure a company's competitive advantage. Additionally, it highlights the benefits of integrating 2nd and 3rd party logistics providers into the value chain to help accomplish the alignment between the company's processes.

## 2.9 Era Three: Globalisation (1980 – 2000)

The first successful mass market of the personal computer was incorporated by organisations for software programming to increase productivity in the 1970s. By the early 1980s, further commercialisation lead computers being developed for household entertainment, as well as for companies (Leiner *et al*., 2009). This marked the beginning of global access to new graphical planning and information sharing. Between 1984 and 1988 the installation of major internal computer systems, workstations and PCs at an accelerated rate began, marking the formation of the first Internet Service Provider (ISP) companies. Additionally, in the 1980s, the work of Tim Berners-Lee on the World Wide Web (WWW), theorised that protocols link hypertext documents into a working system, marking the beginning of the modern Internet (Leiner *et al*., *ibid*). Since the mid-1990s, the Internet has had a revolutionary impact on culture and commerce, including the rise of near-instant communication. This flood of new technology has made the markets globalised and integrated, highlighting the need for improvements in logistics' planning and execution (Hyder *et al*., 2009). Several research centres have emerged to examine the impact of the new technology on supply chains and to further improve optimisation solutions worldwide; for example, the Production and Distribution Research Centre part of the Georgia Tech institute[7], led research in combining computerised optimisation models for supply chain design with

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[7] SMARTech: is the Production and Distribution Research Centre part of the Georgia Tech institute, it contains over 40,000 scholarly works, including over 18,000 Georgia Tech theses and dissertations https://smartech.gatech.edu/

distribution planning, which led to the development of control technology for automated material handling. The Computational Optimisation Centre part of Columbia University [8], developed new optimisation algorithms enabling the solution of scheduling problems. Most of the methodology developed in these institutes rapidly became integrated with commercial technology and used in the area of logistics and supply chains (Georgia Tech Supply Chain and Logistics Institute, 2010).

Global-scale regulations affect the shape and direction of the value chain, due to geographical fragmentation and the continuing evolution of the global economy. Accessing the markets of the developing countries becomes a production network led by firms based in developed countries (Gereffi *et al*., 2005). Despite globalisation bringing opportunities to those organisations that outgrew their domestic market, there still remains a restriction on global trade. This is seen in the form of tariffs and subsidies. In some cases these barriers are caused by the different technical standards and regulations as countries accept products from other countries (Christopher *et al*., 2006). In 1946 governments took measures to eliminate trade barriers to free the movement of finance through international agreements such as the General Agreement on Tariffs and Trade which in 1995 then became the World Trade Organisation (WTO). Other barriers are cultural differences and geographical distance, as social norms and values regulate what is regarded as acceptable norms (Hummels *et al*., 2001). In some countries, the occurrence of corruption provides a barrier, hence firms generally prefer to operate in an environment where the microeconomics systems are stable. Meanwhile, geographical distance leads to transport problems, as the greater distance exists between countries, the less they are inclined to trade. However, as technology has advanced, transportation has become cheaper and techniques for carrying fragile products have improved (Hamilton and Webster, 2015)

### 2.9.1 Capitalist Economy and Global Competition

Since the mid-1990s, the term "supply chain" has been recognised worldwide as an important aspect of business strategy. This has resulted in the CLM changing its name for a second time to the Council of Supply Chain Management

[8] The Computational Optimisation Centre part of Columbia University, researchers advanced studies in optimisation problems, with special focus on implementation of algorithms. http://www.corc.ieor.columbia.edu/

Professionals (CSCMP) (Georgia Tech Supply Chain and Logistics Institute, 2010). Thus the relationship between the buyer and supplier has been recognised as important to the business strategy and as means to help businesses cooperate (Tan, 2001). The increasing trend to separate logistic activities to solve tactical and operational issues from supply chains to solve strategic issues, has led to raw material management integrating with physical distribution and transportation functions as a concept into the business logistics and supply chain strategy (Sheombar, 1995). This integration according to Giannoccaro and Pontrandolfo (2001), is accomplished by managing the information flows across geographic locations by the following methods:

1) Operational management: is the process of managing all the material and data flows across the supply chain.
2) Organisational management: is the process of decision making at different stages of the supply chain depending on the policy of governance which determines the relationship between the various supply chain actors.

The focus on globalisation emphasised the need for logistics strategies that are able to deal with complex networks including multiple entities spanning multiple countries with diverse control, as a result of manufacturing globalisation, particularly due to the growth of manufacturing in China (Georgia Tech Supply Chain and Logistics Institute, 2010). Thus many global organisations such as Toyota noted global market competition and planned to initiate a tactical/operational strategy to enable their logistics and supply chain network to improve manufacturing efficiency and product development cycle time in a crucial environment whereby little inventory is needed to mitigate production and scheduling problems with the aid of JIT systems (Sugimori *et al*., 1977).

#### *2.9.1.1 Capitalism influences on global competition*

The intense global competition of the 1980s forced multinational organisations to offer low cost yet high quality and reliable products with design flexibility to match consumer needs in any parts of the world (Tan, 2001). A global economy and a capitalist society are intertwined as the capitalist system provides constantly expanding wealth and the re-allocation of resources. Economic globalisation can be outlined as a cause for the re-allocation of resources from two different perspectives, as stated by Dicken *et al*. (2001):

1) Economic globalisation gives political purpose providing incentives for the allocation of different capitalism scales.

2) Macroeconomic incentives to extend the competition range for companies to compete at a global level to increase efficiency and to drive prices down.

According to Partridge (2011) there are risks involved in globalised manufacturing, as capitalism does not work without risk. Even though risk in the supply chain is outsourced to distant global mills, factories, dye houses, and farms, the social and environmental opportunities of wealth redistribution under this new regime is not divided fairly. The rapid change in tastes and fashion intensified with globalisation and with it the fierce competition, such as the textile industry (Bruce *et al*., 2004). This created ethical clothing production such as "Fair Trade" to implement either a Lean or Agile supply chain strategy to be able to survive in a highly competitive market (Porter and Kramer, 2006). Meanwhile, Partridge (2011) argues that supply chains have been used as a base for ethical intervention. However, if a company's supply chain is designed with a capitalist rationale or culture, then ethical claims cannot be trusted. Alternatively, to create an ethical supply chain, environmental issues, ethical outsourcing to developing countries as well as economic conditions such as externalities must be accounted for and mitigated. Organisations such as the "Fair Trade" movement, aim to have an in-built supply chain that seeks to tackle the exploitation of workers and ultimately help undeveloped countries by giving aid to the outsourced suppliers to build sufficient infrastructure, improve labour conditions, securing the rights of marginalised producers, and building long-term relationships and partnerships (Vieira et al., 2010). This helps the growth of socio-economic environmental certification worldwide in order to create an equitable world to some extent, rather than a division of helpers and helpees, as well as achieve better trading conditions and promote sustainability.

Since the late 1990's sustainability concerns have increased as institutions such as Global Reporting Initiatives have emphasised transparency and its concerns for risk from institutional investors as they play an important role in constituting standards due to their direct or indirect involvement in corporate governance through the International Corporate Network[9] (Hawley and Williams, 2004). With increased integration of capital markets and growing globalisation, businesses develop a co-operative capitalism structure, as suppliers have a deep interest in global corporate governance standards, resulting in institutions banding their principals together through the International Corporate Network, to formulate global standards. These standards focus on independence, structure, accountability, transparency, and articulating the rights of shareholders and the standards necessary to protect them. Sustainable projects include the reduction of carbon. By reinforcing corporate governance with issues of transparency, accountability and sustainability, this promises to expand a corporation's horizons to attempt a more ethical form of conducting business (Porter and Kramer, 2006). This trend also has an impact on public policy as major market actors place pressures on governmental regulators, as cooperate obligations move slowly away from the focused notion of profit maximisation to include market risk, social issues, and political influences and ethical regulation. Hawley and Williams (2004) conclude that this expansion resulted from the interaction of financial, market and political pressures to create a more responsible and responsive corporate behaviour. In particular, these trends have the potential to begin a long process of internalisation of negative externalities and a fostering of positive ones, as common standards cross market borders (Hawley and Williams, ibid).

This study will aim to create an additional sustainable framework complimentary to the interactive MDM. The sustainability framework acts as a decision tree that eases the thought process of identifying sustainable solutions to a company's supply chain. With the growing ethical and global social responsibility companies are facing increasing pressures to integrate a "green" framework into their business strategy. The sustainable decision tree provides a step by step guide to help incorporate sustainable thinking and implementation while using the interactive MDM. The aim for the interactive MDM is to help SMEs and organisations diagnose the supply chain they need for their market and mitigate the issues of choosing a strategy as well as provide options for them to create their own tailored model.

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[9] Founded in 1997, Global Reporting Initiatives is a non-profit organisation initiated in the USA with secretariat in Amsterdam and the Netherlands https://www.globalreporting.org/Pages/default.aspx

### 2.9.2 Benefits of Global Supply Chains

Globalisation creates interconnections between nations, allowing barriers (physical, political, economic and cultural) to be removed or reduced in order to liberalise the exchange of goods, services, money and people (Chandak *et al*., 2014). A global supply chain design model accounts for a variety of cost structures, outsourcing manufacturing, integration of supply chain departments, strategic alignment of the supply chain network, and complications of international logistics (Hamilton and Webster, 2015).

There are four dimensions according to Meixell and Gargeya (2005) that a supply chain will undergo to become global; decision variable, performance measurement, supply chain integration with globalisation consideration. Globalisation causes nations and firms to specialise in producing those goods and services at which they are most efficient. Although this allows benefits from economies of scale in production, it may create dependence upon a small variety of commodities, leaving the nation's economy, or the firm vulnerable to external events (Hamilton and Webster, 2015). There are on-going emerging issues regarding the global supply chain design. Firstly, businesses are increasingly outsourcing to domestic and global markets. Supply chain managers select the most suited suppliers based on their consumers' needs in terms of quality, quantity, delivery, price and services needed by the company. The supplier contracts influence the strategic structure such as geographical preferences which are strategically placed to reduce lead times and cost to a minimum, extend the build-to-order and increase direct sales around the world (Meijboom *et al*., 2007). Secondly, as businesses outsource their issues, they integrate decision processes across the supply chain. This influences the supply chain design as it incorporates the decisions of business processes across multiple organisational structures in different continents, such as integration of Vendor Managed Inventory (VMI) and Collaborative Planning Forecasting and Replenishment (CPFR). This integration gives the global supply chain the ability to coordinate decisions across multiple supply chain nodes (Meixell and Gargeya, 2005). Thirdly, the strategy of supply chain performance varies depending on the products offered to consumers. For example, a global supply chain's aim is to assemble large amounts of commodities in various locations, in order for the buyer-driven supply chain to gain the ability to establish close links with multiple leading organisations (Gereffi, 1999a). Sourcing globally can improve performance, resulting in benefits as stated by Meixell and Gargeya (2005), these are: improved quality, meeting schedule requirements, assessment of new technologies, and supply base broadening, leading businesses to find a quick response strategy for improving efficiency, gaining competitiveness, cost reduction and improving performance with the use of the Supply Chain Operations Reference (SCOR) model (Fig. 9). The SCOR model developed in 1996, enables users to address, improve, and communicate supply chain management practices within and between all interested nodes/supplier members (Supply Chain Council, 2003). According to Irfan (2008), it is a management tool, spanning from the supplier's supplier to the customer's customer and aims to describe the business activities associated with all phases of satisfying a customer's demand (Fig. 9). SCOR defines supply chains as the integrated process of Plan, Source, Make and Deliver; aligned with operational strategy, material, work and information flows (Irfan, *ibid*). These integrated processes are explained by Bauhof (2004) as: “Plan”, including mapping of demand and supply resources, material requirements, inventory, distribution, production capability and utilising capacity. “Source”, including acquisition of infrastructure and raw materials (in-house or outsourcing). “Make”, including the execution of production and the relevant elements. “Deliver”, is the management of order fulfilment, warehousing, transportation and installation of components. Finally, “Return” is the process to cater for circumstances where reverse-logistics is needed.

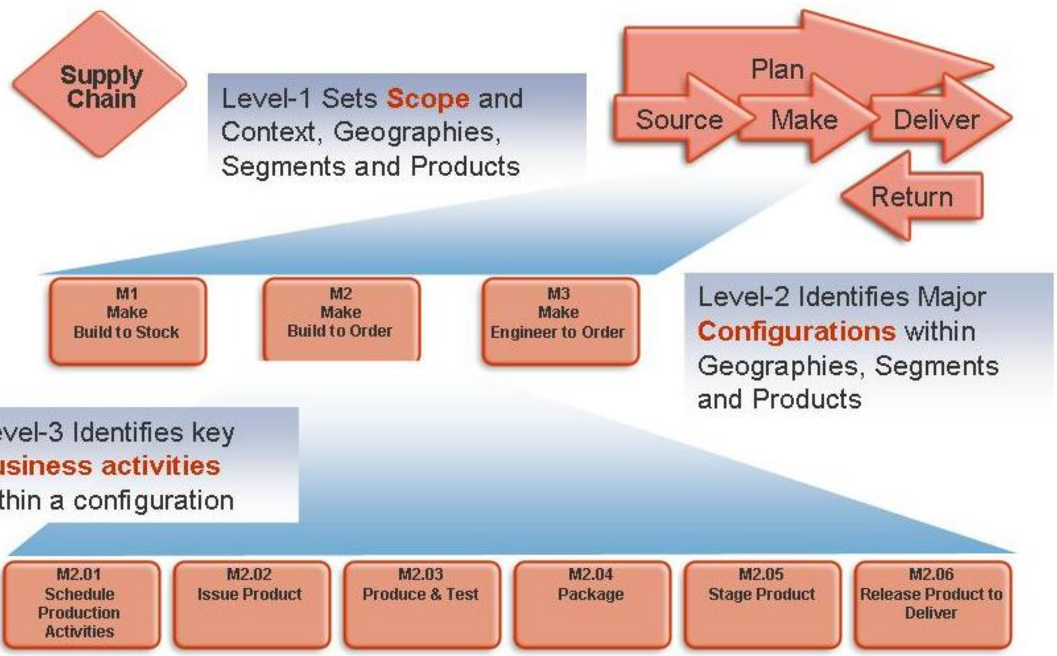


*Figure 9: Supply Chain Operations Reference (Supply Chain Council, 2003)*

There are three levels in the SCOR model. First, the "Scope" where the firm analyses the basis of competition, focusing on operation strategy to get products across geographic segments. The second level is "configuration" where the material flow is aligned with information work-flow and performance. The third level is "business activity" where the chain is designed in accordance with the other two levels and made flexible to account for changes in the marketplace (Bauhof, 2004). The development of SCOR model in addition to many others has conceptualised economic activities into the supply chain allowing the competition to cross borders and re-define the scopes of trade.

#### *2.9.2.1 Globalisation and Territorial Borders*

Supply chains expanded internationally across national borders, especially with regards to the automobile, computer and fashion industries (Britoa *et al*., 2008). This expansion imposed challenges upon the managers of the supply chain of new global products. Meixell and Gargeya (2005) reviewed global supply chain designs and their logistics, by identifying that global supply chain definition includes the facilities established at international locations. They pinpointed two forms of design decisions in globalised supply chains:

1) Decentralised - which provides more flexibility as managers are placed at each facility to make decisions based on the local circumstance; and
2) Centralised - decision making where decisions across the facilities are coordinated and reported back to headquarters for the final decision to be made.

Nevertheless, according to Galbraith (1974), information flow helps to reduce environmental uncertainty, especially in the case where a supply chain is clustered across the globe. Meixell and Gargeya (2005) highlighted the on-going issues in global supply chains, which are: geographical distance that increases transportation costs, complicated decisions due to inventory cost trade-offs, and increase lead-time. The cultural differences reduce the effectiveness of business processes due to difficulties in demand forecasting and material planning. What affects efficiency of business are infrastructure in developing countries, telecommunications, unskilled labour, technology, and quality and availability of supplies. Although global supply chains provide competitive advantage, they carry risks which can influence their performance such as uncertainty in currency exchange rates that affect the price paid for the goods purchased in the supplier's currency, which also influences the timing and volume of purchases and the financial performance of the chain (Meixell and Gargeya, *ibid*). Additionally, economic and political instability affects the value of goods and trade tariffs; as manufacturers' set-up foreign factories to avoid trade admission fees, hence benefiting from tapping into new markets, with low cost labour, capital subsidies, reduced logistics costs, and increased efficiency due to close proximity to their consumers.

A global supply chain allows ideas to cross borders as well as money, commodities and people, thus, challenging the territorial authority of states and their power to regulate what takes place within them, resulting in an imbalance in political economies of scale, whereby economic organisations and political institutions operate on different grounds (Shah, 2012). This, according to Hudson (1998), allows for order to be maintained by the use of two dimensions: regulating the scale of accumulated or economic activity and the management of the scale of political regulation. The modern classification of borders is to differentiate state domination in order to regulate the movement of citizens and commodities. Territories are being reconfigured because of the significant reduction in territorial borders due to the changes in organisations' supply chains and the process of globalisation (Cox, 2004).

### 2.9.3 Integrating Global Supply Chains with Value Chain

Conceptualising economic activities into a chain of interconnected elements has been explored in detail by a handful of authors, one of which is Michael Porter (1980) who exploited the notion of the value chain in individual firms. Moreover, incorporating the value chain concept within the global economic perspective has also been analysed by Gereffi (1999a) and Gibbon (2001) both stated that Global Commodity Chains (GCC) provide the means for organisations to study the impact of economic globalisation on their practices. Globalised industries have promoted GCC by establishing two distinct types of international economic networks, "producer-driven" and "buyer-driven" which refers to the whole range of activities involved in the GCC design, production, and marketing of a product (Gereffi, 1999a). According to Dicken *et al*. (2001), there are four dimensions to GCC which are:

1) An input-output structure: where the value-added chain consists of products, services and resources linked together across a variety of industries.
2) Territoriality: Geographical clusters of distribution that can either partly scatter or partly contract.
3) Governance structure: referring to authority and power relationships that assess how the financial and human aspects should be allocated and distributed within a chain.
4) Institutional framework: aims to identify how local national and international institutions influence the globalisation process at each stage of the chain.

During the process of making the traditional basic supply chain global, firms combine their basic chains with their value chains by linking complex information through computerisation and automated process technologies. This simplifies the inter-firm information linkage that reduces the misinterpretation of data (Gibbon, 2001). There are three benefits to linking the information:
Firstly, integrating information reduces complexity and helps companies to track outputs and services from their member supplier's base. Secondly, simplifying the allocation of resources, product development and innovation. Thirdly, keeping the member supplier's competence at a consistent level, enhancing the learning process of new technology, increasing capacity and utilisation to benefit from economies of scale (Chandak *et al*., 2014; Fine, 2000). Whilst companies learn new technologies they develop new means of organising and integrating their basic chain with the global value chain. They also establish a uniformed method by coding differentiation of products across the industry that are constantly evolving to enable accuracy, accommodate changes and bundle activities to account for market changes, policy rules and international regulations (Sturgeon, 2002). Fully integrating global value chains with the traditional basic chain requires unification of transactions, hence it's crucial to codify transactions, the member supplier's competences and capabilities (Gereffi, 1999b). These variables are determined by integrating the upstream end of the value chain that sets the parameters where customers adjust/customise the products; with the downstream end of the value chain, where the product design is determined by innovative research and development to satisfy changes in consumer demand and account for the volatile global market (Gereffi *et al.,* 2005).

In an extensive study of supply chains, IBM (2009), gathered 400 Supply Chain Executives, and found that most prominent issues facing companies are visibility, customer demands/intimacy, cost, risk and globalisation (Fig. 10). To enable companies to compete in a globalised market, companies must enhance the traditional basic value chain to be smarter.  IBM devised three characteristics. Firstly Instrumented chains require integration of automation capabilities, such as automate transactions, inventory location, shelf-level replenishment detection and transportation (Fig. 10). This enables real-time data collection and transparency that can sense and respond to demand/supply signals. Secondly, the chain must maintain interconnectivity by the use of technological software such as EDI and ERP, to maintain information flows, standardisation of data and processes across its network. Finally, by integrating intelligence into the basic value chain by the use of simulation models to evaluate trade-offs of cost, time, quality, service and carbon emissions, it will be able to mitigate the prominent issues of risk by probability-based risk assessment, mitigate the issue of customer demand/ intimacy by simulating predictive analysis and mitigate visibility issues by optimised forecasts, in addition to reducing cost by applying efficient networked planning (Fig. 10) (IBM, 2009).  With globalisation, the smart basic value supply chain can be a useful strategy amongst firms. However, businesses have realised that specialisation is key to gaining a competitive advantage, as consumers with increased access to information develop a taste for specialised brands and customised goods (Cavinato, 1992).

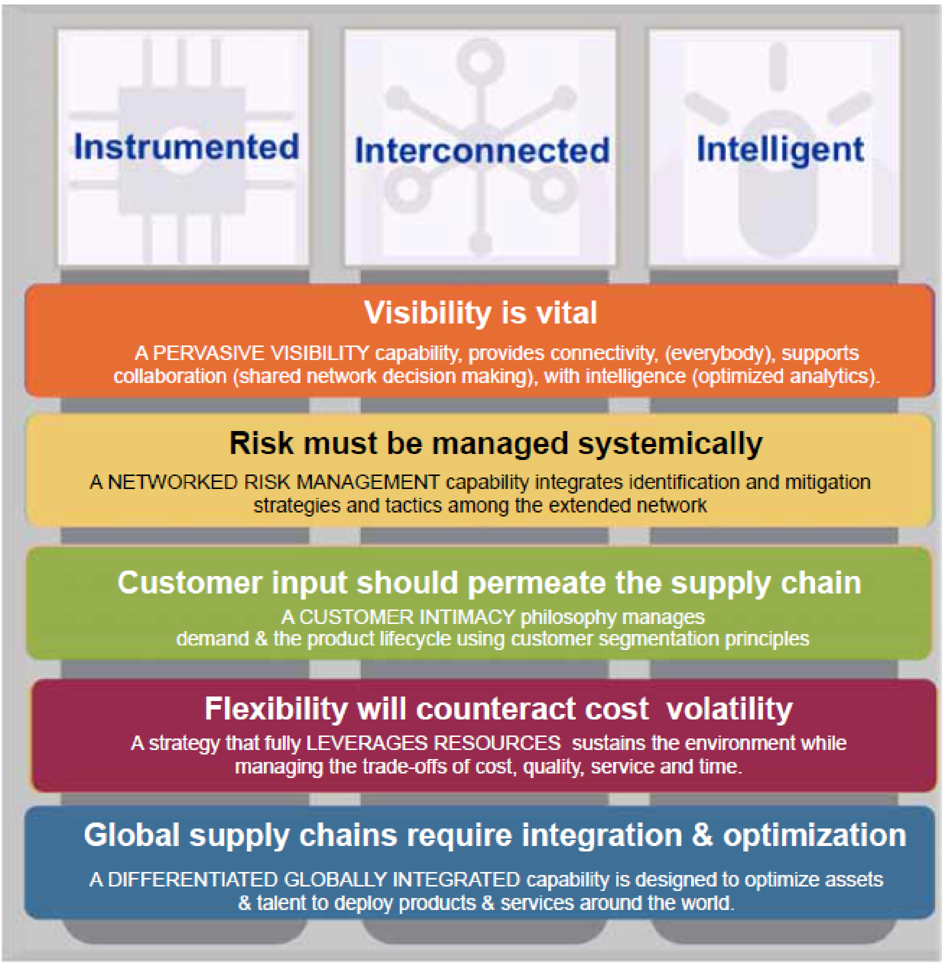


*Figure 10: Integration characteristics for global competition (IBM, 2009)*

Era three covers the rise in globalisation and how it has changed supply chain operations as they become more complex by crossing several borders and markets. Furth more, the increase in competition in the global economy resulted in a need for better supply chain management and integration of processes throughout the businesses' value chain, by ensuring the management of information flows across geographical locations. This gave a rise to global supply chains which in some cases are centralises while in other cases they are de-centralised. This focused on long lasting relationships with supplies and corporate responsibility due to the interlinked environmental issues.

## 2.10 Era Four: Specialisation (1990 – 2008)

Manufacturers and service providers during the 1990s collaborated with their suppliers to upgrade their management functions which became known as supply chain management (Lambert and Cooper, 2000). As seen from the previous eras, supply chains continued to evolve rapidly. In era two, integrating supply chain with logistics was taken into account during strategic decision making (Hale, 1999; Houlihan, 1988). Furthermore, era two divided the concept of logistics and supply chains, then integrated their processes in addition to outsourcing, manufacturing and distribution to cater for the emergence of era three and the influence of globalisation (Tan, 2001). Logistics expands further once the entire value chain from suppliers to customers is added. Therefore, it enables channel members to unify and compete as an entity rather than as a purchasing inventory along the value chain (Hale, 1999). Era two saw the need to use integration in order to optimise supply chains, hence manufacturers linked their internal processes to external suppliers and customers within the chains to add value to the product being supplied to the consumer across the global market. Wholesalers and retailers have integrated their physical distribution therefore offering a competitive advantage that is hard to imitate (Houlihan, 1988). In era three, globalisation occurred and expanded into era four as in the 1990's after the Global Commodity Chain (GCC) was introduced, organisations extended their businesses further to incorporate resources to include strategic suppliers and logistics in the value and supply chains (Gereffi, 1999a). Efficiency upgraded to include sophistication in managing processes and information, as well as cost and quality consideration. Moreover, to improve the value chain, businesses moved from using only traditional and certified suppliers who embrace the use of highly developed technologies and take risks at product development resulting in a customer focused supply chain whereby each entry in the business is solely focused on consumer marketing (Lambert and Cooper, 2000).

During era three, Lubbers and Koorevaar (1998) saw globalisation as a process in which geographical distance becomes less of a factor as a border crossing is no longer considered an obstacle. This resulted in supply chains becoming disordered as companies globalise to meet the global demand. They fail to match the desired production cost whilst achieving high customer services (Sturgeon, 2003). Hence during Era two and three, the traditional supply chain model developed added value and intelligent capability which labelled it as “Smart Basic Value Chain” (Lubbers and Koorevaar, *ibid*). The fundamental method of operating a supply chain is by using “Push” and “Pull” systems. The “Push” method is commonly used for the Smart Basic Value Chain as it aims to achieve the following: Forecast driven, high emphasis on customer service and inventory to buffer fluctuations in demand and lead times (Wright, 2010). The use of “Push” system in the Smart Basic Value Chain is due to its efficiency to cater for functional products which is normally the characteristic of the targeted market. Functional products are necessary goods that consumers require on a regular basis. Therefore, they have a stable forecasted demand with an established stable customer service, indicating controlled lead time as demand is predictable with additional buffer inventories in case of fluctuations (Fisher, 1997). The "Pull" method allows supply chains to plan effectively and put aside schedule resources to meet unpredictable demand. It is best suited for innovative and innovative functional products as they require sophisticated integration, efficiency and flexibility (Jüttner *et al*., 2007). The "Pull" method is characterised by the following: Upstream integration with suppliers, downstream integration with suppliers and high emphasis on efficiency/flexibility by reduced stock holding and efficient speed in reacting to unpredictable demand (Fisher, 1997). The "Pull" concept is most relevant in Agile and Lean supply chain strategies as they are demand-driven in contrast to the Smart Basic Value Chain which relies on specific long-term forecasting of products. The "Pull" system incorporates the elements needed for supply chains to be Lean or Agile, as it helps companies to organise their supply chains in accordance with functions that enables them to withstand the market-demand-pull (Wright, 2010).

In order to analyse the "Pull" method in Lean and Agile, this era will explain the need for specialisation in the global market that resulted in the six processes to be evolved from the Smart Basic Value Chain and divided into four strategies (Lean, Agile, Leagile and Basic supply chain (BSC)) to cater for this need. Supply chains aim in the short-term to increase productivity, and reduce inventory and cycle time. In the long term, supply chains aim to enhance strategic planning to increase customer satisfaction, market share and profit for the entire organisation (Lambert and Cooper, 2000). This is achieved by suppliers participating in the strategy choice from an early stage to ensure cost effectivity and competitively in the global market. If suppliers disagree with a specific design/strategy, manufacturers are able to develop other conceptual solutions (Cavinato, 1992). The chain's service focuses on manufacturing, mainly the distribution of raw materials, hence the enhancement of manufacturability is key for both the customer and supplier, requiring the crucial link between the supplier members and the organisation itself (Monczka *et al*., 1994). In era three the growth of globalisation and distortion of territorial borders resulted in firms taking either a centralised or decentralised approach. In order to have a distinguished and unique competitive advantage, firms must not only select their management position (centralised or decentralised), but also ensure their supplier's short-term and long-term goals aligning with their product type (functional, innovative and innovative functional) (Hale, 1999). Moreover, their suppliers must be specialised in the product type's market, as the input in designing the chain and choosing the relevant strategy is crucial to the business's competitiveness. Ensuring a coherent, specialised and integrated chain that is aligned with the firm's specialised product type as well as management approach is of crucial importance to survival in a global market, especially since competition is no longer between organisations, but among supply chains (Fisher, 1997).

According to Jüttner *et al*. (2006), due to specialisation and alignment, firms attempt to develop a unique edge for their competitive advantage. They select a suitable management approach, specialised suppliers to deliver their specialised product type and a suitable strategy with relevant characteristics to ensure alignment in their operation. Therefore, the Smart Basic Value Chain branched into six approaches which will be categorised into four specialised strategies (Lean, Agile, Leagile and Basic supply chain (BSC)).

### 2.10.1 Basic Supply Chain Strategy

The first branched approaches of the Smart Basic Value Chain will be categorised under the strategic category of "Basic Supply Chain (BSC)"; similarly to the characteristics of the Smart Basic Value Chain, these approaches have a "Push" method and commonly use a centralised management approach to coordinate the chain (Wu *et al*., 2013b). The approaches that fall under the BSC are most suitable for a company that specialises in functional products, and are as follows:

#### ***1. The progressive-flow approach***

The core feature in a progressive flow approach is that supply and demand are both stable, as it works well for businesses with essential functional products that consumers need daily and products with a short-shelf-life. Additionally, it is also suitable for manufacturers of parts or equipment (Alford et al., 2000). This approach typically is for a very mature supply chain with a customer demand profile that has little variation. Hence it fits the "added value" of long-term relationship with supplier members that is a key characteristic in the Smart Basic

Value (Ergen *et al*., 2007). Moreover, the scheduling needs to ensure a “Smart” steady continuous flow of information that is a key feature in the Smart Basic Value Chain. The production matches demand through a continuous-replenishment method of the “Push” system based on a "make to stock" decoupling point Chain (Garcı´a-Dastugue and Lambert, 2003). Therefore, the competitive edge is based on offering a continuous-replenishment system to customers in order to assure high service levels and low inventory levels, thus achieving optimisation of costs associated with inventory. Management is centralised and focused on promoting collaboration, by using information technology such as EDI and ERP, in order to reduce the order cycle, as well as sharing information on sales and inventory to improve visibility, reduce risk, increase customer intimacy by forecasting demand, hence reducing costs. In the most mature stage, collaborative planning with key customers helps to anticipate demand patterns (Garcı´a-Dastugue and Lambert, *ibid*).

### *2. The configuration approach*

The approach is characterised by a degree of configurations to the finished product. It allows companies with a functional product to have a competitive positioning to their “Push” system, by offering a unique configuration to the finished product according to the end consumer's needs (Alford *et al*., 2000). However, this flexibility is limited by technical constraints, as the product is configurable within a limited combination of product specifications, usually by combining parts into a component, usually during an assembly process, according to an individual customer's requirements. However, product configuration may be achieved in other types of processes, such as mixing items, packaging and printing (Mourtzis *et al*., 2008). The processes prior to product configuration are lengthier than the configuration itself and the downstream processes. Hence, limiting the number of possible finished products resulting from multiple combinations of parts or materials, aids forecasting demand and reduces inaccuracy. Consequently, product configuration and downstream processes are scheduled after receiving the customer's order and to ensure a short order cycle those processes are designed with extra capacity available (Ergen *et al*., 2007). Due to those factors, this approach employs a "configurable to order" decoupling point on the downstream side, where the processes occurring before configuration are managed under a “progressive-flow” method (Gunasekaran and Ngai, 2005). The downstream processes operate to some extent similarly to an agile strategy criteria. The customary product configuration decoupling point is at the finished-goods inventory, at the "progressive-flow" downstream side. This approach usually operates under centralised management to reduce complexity in coordinating order cycles and reduce lead times by ensuring the availability of materials and/or parts prior to the configuration process (Alford *et al*., 2000). Examples of where this approach is applicable is at the assembly of personalised products, such as computers and vehicles, in addition to the paper manufacturing industry, where the decoupling point occurs after the manufacture of the big paper rolls and the products are customised in the cutting and packaging process (Mourtzis *et al*., 2008).

### 2.10.2 Agile Supply Chain Strategy

The BSC approaches have similar characteristics to the Smart Basic Value Chain, however, as globalisation increases, companies move towards acquiring more flexibility, as observed from the "custom-configured" approach under BSC strategy (Wu *et al*., 2013b). Hence the development of a strategy specialising in being responsive, labelled Agile Supply Chain (ASC) strategy (Macheridis, 2014). The principle of being Agile is being market sensitive, as it requires capabilities of reading and responding to real demand, by applying three principles: Balance, strength and flexibility. However, most businesses are forecast driven rather than demand-driven. Due to having little direct data, they are forced to generate demand forecasts (Christopher, 2000). The Agile strategy is a template suited to products with a short life cycle but high demand uncertainty, as stated by Macheridis (2014), such as innovative products which require demand forecast. The most common problems faced by Agile strategy are delivery processes, faster responsiveness to the market and ensuring availability of stock in anticipation of consumers' changing taste (Jones *et al*., 2000).

To mitigate these issues, Agile strategy integrates information flow between buyers and suppliers, thus creating a "Virtual" supply chain that accounts for volatility and inventory levels (Fig. 11). This virtual chain is linked to "Market sensitivity" as it feeds the information through the agile chain to the relevant nodes. The configuration of patterns links the different nodes via "Process integration" and feeds the information into a "Network base" (Christopher, 2000).

Fig. 11 stresses the importance of the four process “virtual, market sensitive, process integration, network based” to be intra-linked to the Agile chain via information flows, as businesses do not compete alone as a single entity or as brand, but as supply chains. The expansion of globalisation created the need for a competitive edge, which gave birth to two distinct kinds of specialised competition, ‘network based’ established on market sensitivity and services, that is catered for the Agile strategy, and ‘speed/waste reduction’ usually catered for by a Lean strategy. Both strategies cater for cost reduction by utilising economies of scale when possible (Christopher, *ibid*).

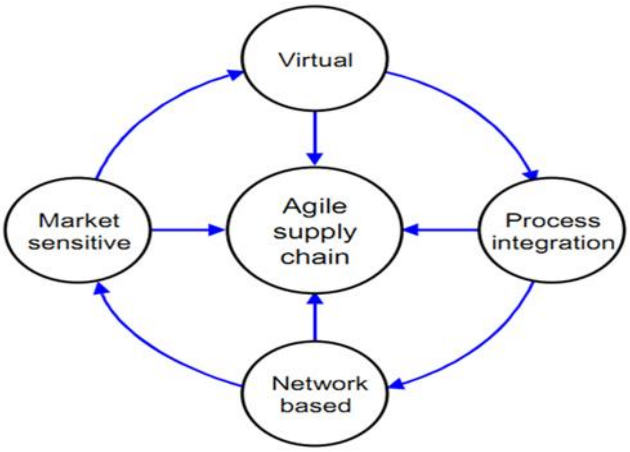


*Figure 11: Agile supply chains (Christopher, 2000)*

The birth of the two specialised competitions, led to the movement from the BSC strategy towards Agile strategy. Hence, the creation of the two approaches that branched from the Smart Basic Value Chain to be categorised under the Agile strategy. The two approaches created to cater for a ‘network based competition’ have the capability to integrate different structural systems, information flows, logistics process and assimilate a variety of processes (Juttner *et al*., 2006). The approaches are based on the Agile Flexible Manufacturing System (FMS) that allows organisations to respond rapidly to changes in demand, making it the perfect model for an unpredictable volatile demand where the requirement for variety and volume is high, making it suitable for companies specialising in innovative products (Christopher, 2000). Both approaches can have either a centralised or decentralised management, depending on the firm’s capabilities. Additionally, both approaches can use either “pull” or “push” systems. However, for an Agile strategy the “Pull” system is commonly applied in companies (Juttner *et al*., 2006). The two approaches categorised under Agile strategy are as follows:

***1. The Agile approach***

The classic agile approach is useful for companies that manufacture products under unique specifications for each customer. This is typically seen in industries that specialise in innovative products as they are characterised by unpredictable demand (Yusuf *et al*., 2004). They use a "make-to-order" decoupling point, producing the item after receiving the customer's order to ensure low inventory, reduce costs and avoid manufacturing products that have no certainty of future sales (Macheridis, 2014). Whether a centralised or decentralised management approach was chosen, the firm must ensure the chain is able to meet unpredictable demand in quantities exceeding the customer's forecast and/or within a shorter lead time than agreed. Management should focus on ensuring agility, which is supported by two main capabilities: excess capacity and integrating processes designed to produce the smallest possible batches (Gunasekaran and Ngai, 2005). For this approach to be successful, the following factors should be in place:

Reducing lead time, by designing materials on a common platform and ensuring the relevant components are constantly available in inventory (a platform with a group of products that share some key components) (Ergen *et al*., 2007). Additionally, low-variance designs are marketed with lower prices and lead time, while high variation designs have higher cost and relatively longer lead times (Tang and Tomlin, 2008). If extra capacity gradually decreases, the company should invest in additional assets so it can maintain its ability to be flexible. In order to do so, the company may need to switch between “Pull” system of flexibility, to a somewhat “Push” system of efficiency and adjust its value chain to increase visibility of stock levels (Yusuf *et al*., 2004). To ensure reliable adaptation to the market, collaboration with key customers and supplier members need to be secured, in order to enable accurate responsiveness to changes in capacity requirements, both in the short term for scheduling purposes and in the long term for asset-investment decisions (Tang and Tomlin, 2008).

This approach is commonly employed by manufacturers of intermediary goods that make products for industrial customers in accordance to their specific needs and place a high value on specialised configuration and short lead times. This approach’s added value is oriented toward offering products "on demand" and with a high service level, e.g. chemical specialties and machinery services (Garavelli, 2003).

### *2. The flexible approach*

This approach is suited to companies that have high demand peaks and long periods of low workload. It is characterised by flexible adaptability and use of a “Pull” system, as it aids the reconfiguration of internal processes in order to meet a customer's specific needs with a definitive “make to order” manufacturing method (Gunasekaran and Ngai, 2005). It is typically used by service companies that focus on handling unexpected situations or emergencies. Hence, the focus is not only the speed of a supplier's response, but also on the ability to tailor solutions to their needs. Consequently, the price becomes largely irrelevant to the customer (Garavelli, 2003). The management can be centralised or decentralised, with a focus on ensuring flexibility to support several capabilities: such as, extra capacity of critical resources, rapid-response capability, and technical strengths in process, product engineering and an efficient process of information flow that is designed to be quickly reconfigurable (Das and Abdel-Malek, 2003). For this approach to be successful, the following factors should be followed:

According to Sanchez and Nagi (2001), inventory for only critical resources should be maintained and available on stand-by (e.g. pumps for companies that provide flood recovery services, or metal machining equipment for spare-parts manufacturing). Additionally, establishing strong collaborative relationships with key suppliers are necessary for companies to maintain low to medium capacity, to ensure adaptability (Gong, 2008). However, having unlimited capacity or a few resources of high capacity is not economically feasible. A typical example of this approach being implemented is in specialised companies that provide metal working and machining services for the manufacturing of spare parts for industrial customers. This type of company may encounter emergency situations such as the need to immediately replace broken parts. Therefore, they must provide a fast response and sufficient capacity to develop unique parts by configuring and adapting consecutive processes, such as turning, reaming and welding tailored to a specific situation (Kesen *et al*., 2010).

### 2.10.3 Lean Supply Chain Strategy

While some companies move towards agile strategies, others find approaches related to Lean strategy more suitable to their needs. The concept of "Lean" was incorporated within the supply chains by Taiichi Ohno (1912-1990), the operations manager of Toyota, due to a supply shortage caused by a fluctuating demand resulting from World War II (Becker, 2001). Between the years 1936-1956 chief executives of Toyota developed the TPS which incorporated five core systems (5S) (Bullington, 2005). These are "Sort", a system to classify what is needed and reduce waste. "Straighten" which constitutes configuration and setting process in order, including clearly identifying the locations of all items so that anyone can find them and return them once the task is completed. "Shine", which includes checking that all process are set, tasks are completed in accordance to quality control protocols, defects are identified and standards are met. "Standardise" which conforms and stabilises the standardisation of processes, and finally "Sustain" which directs and improves the 5S operations (Jayaram *et al*., 2010a). The 5S are a tool for systematic organisation of the workplace and are applicable to every function with an organisation. For Lean production and systems to become successful requires unwavering commitment, not only from management, but also from the personnel within the organisation (Shah and Ward, 2003). Applying a Lean supply chain incorporates a decentralised management system that governs five key attributes. These are, "Value" defined from the perspective of the customer, "Flow" established by understanding the process and clearing any obstacles that do not add value, "Perfection" by continuously refining the process to improve efficiency, cycle time, costs, and quality, in addition to ensuring "Responsiveness" and applying a "Pull" system of make-to-order production (Hines, 1998). With globalisation, activities such as outsourcing manufacturing and distribution, this proved problematic with regards to the Lean system of waste reduction as it required a reduction in the numbers of supervisors and quality inspectors as workers are trained to know production standards and requirements; hence have the authority to take action (Sturgeon, 2003). This in turn gives the workers identity and loyalty to the firm as they are in charge of its operations and take part in the success of its products. Lean supply chains aim to reduce costs and speed deliveries in the best quality possible (Wright, 2010). The remaining branched approaches from the Smart Basic Value Chain are categorised under the Lean supply chain strategy and are as follows.

### *1. The efficient approach*

This is suitable for industries that are characterised by intense market competition, with several competitors fighting for the same group of customers who may not perceive major differences in their added value proposals, hence the competition is virtually based solely on offering the best price and speed of order fulfilment. As companies ensure they get the best price for each order, it results in recurrent peaks in demand (Juttner *et al*., 2007). Consequently, a continuous-replenishment model for inventory management is needed. Production requires a decentralised management in order to increase responsiveness and promote maximum end-to-end efficiency, as well as a “Pull” system based on “make to forecast” scheduling that relies on sales expectations of the product cycle (Heikkilä, 2002). This approach ensures high rates of asset utilisation by conducting high overall equipment efficiency in order to reduce cost. This is accomplished by ensuring high levels of forecast accuracy to guarantee product availability and consequently, perfect order fulfilment (Christopher and Gattorna, 2005). For this approach to be successful, the following factors should be in place:

The inventory management should accommodate extra capacity for outbound logistics, to absorb demand peaks without affecting the ability to meet customers' expected receiving dates. Additionally, reducing "high variation, low demand" will reduce costs, inventory levels, variation of configurations and hence complexity in production and service. The product cycle should be forecasted and scheduled to reduce lead time and order fulfilment (Jüttner *et al*., 2006). This can be achieved by reducing the amount of time that takes for changeovers and consequently the length of the production sequence, as it will be fixed and maintained for long periods of time. This, in turn, will increase the manufacturing line's experience for the next cycle (Gunasekaran *et al*., 2008). For example, when market demand follows seasonal trends, extra warehousing capacity should be available in anticipation of the need to store additional product during high-demand periods. To improve forecast accuracy, a business can initiate supplier and customer collaboration, where information is shared on demand variability and scheduling. The purpose is to generate higher levels of customer loyalty and use the information flow to build a continuous-replenishment model. This approach is well suited for businesses with commoditised functional products, such as cement and steel (Jüttner *et al*., 2007).

### *2. The fast-prompt approach*

This approach is best for companies that produce trendy products with a short lifecycle, such as innovative products. From the customer's perspective, the main difference among competitors' value proposals is how well they are able to update product portfolios in accordance with the latest trends, for example the fashion and technology industries (Jones and Towill, 1999). This focuses competition in the market on manufacturers' ability to continuously develop new products that can be sold at an affordable price. As a result, the main driver of competitiveness is the reduction of market mediation costs, hence understanding market trends and consumers' habits is crucial to maintaining production and distribution cost at an optimal level (Yusuf *et al*., 2004). Production should be scheduled by sales expectations for the season using a "make to forecast" decoupling point incorporated into a “Pull” system. As the product cycle shortens, production must schedule replenishment before the product goes out of fashion and consumers no longer want to buy it (Bruce *et al*., 2004). Therefore, having a decentralised management helps promoting continuous portfolio renewal, supported fast research and development, forecast accuracy to reduce market mediation cost and end-to-end efficiency to ensure affordable costs for customers (Yusuf *et al*., 2004). For this approach to be successful, the following factors should be in place:

The fast-prompt approach is the most demanding in terms of forecast accuracy, synchronised sales and operations planning, because it has to constantly anticipate market trends. Due to market volatility, it is crucial to develop the ability to produce small batches and purchase raw materials in small quantities (Gunasekaran et al., 2008). Therefore, businesses must aim to standardise raw materials by limiting their variety to reduce sourcing complexity. Additionally, establishing collaboration by sharing information and raw materials among several supplier members helps to ensure fast product development and manufacturability (Stratton and Warburton, 2003). For companies with high levels of seasonal demand, there must be a pool of suppliers that can provide additional capacity as needed. Although outsourced manufacturing could be more expensive than in-house manufacturing, in the long-term it would be less expensive than unused capacity (Ergen *et al*., 2007). Examples of companies that benefit from this approach are those that engage in catalogue sales of innovative products. It is, also, appropriate for retailers that sell trendy products and whose customers tend to visit stores regularly or seasonally. These retailers rely on the loyalty of their customers by ensuring they see a new product at each visit (Stratton and Warburton, 2003).

The Lean strategy can be applied to innovative functional products such as automobiles and is used largely by Toyota. To increase the speed and efficiency of their "Pull" system they developed the JIT technique into their production line at the "make to order" decoupling point (Alford *et al*., 2000). The JIT concept aims for materials to flow from the supplier to production. Finally, the partly finished goods arrive at the manufacturing stage to be personalised by the customer; leading to few raw materials and buffer stocks in warehouses, as no output stock of finished goods is released without being demanded, due to the "make to order" system (Womack and Jones, 1994). JIT aims to keep the scheduling of activities and resources aligned exactly within the requirements of no "safety stock", generating minimal waste and reducing error, allowing JIT the ability to identify potential problems of demand and waste (Melton, 2005). However, in order for this model to be fully effective, a company requires efficient communication with its suppliers and the relationship between the supply chain entities must be based on trust and reliability (Kilpatrick, 2003). Therefore, it aims to facilitate their elimination and drive the continuous improvement of the production system" (Naslund, 2008). To implement a full Lean strategy with a JIT concept, the following elements need to be applied by companies in order to fully utilise their Lean supply chain (James-Moore and Gibbons,1997).

***1. Elimination of waste***

Each stage of the Lean strategy aims at reducing excess inventory, this is achieved by EPR and JIT. The common processes taken to reduce waste are to identify the areas in which waste occurs, the cause of it and to eliminate it (Ketikidis, *et al*., 2008). Additionally, the reduction of lead time requires several stages to deliver a commodity that consists of many sub-processes such as: order entry, assembly, inspection, packaging and shipping. In order to reduce lead time, a business must reduce non-value-added activities, which include the time taken to change-over, set-up, inspect and waiting for approval (Fig. 12). This can be reduced by the use of Quick Response Manufacturing (QRM) (Ketikidis *et al*., ibid).

### *2. Process control*

Aims to create smooth operation flow with reduced bottlenecks, by limiting the number of components, to reduce production capacity particularly when resources are not utilised efficiently. The balance between the work stations and the process times require vigorous maintenance; hence the buffer of inventory will naturally be maintained (Fig. 12) (Kilpatrick, 2003).

### *3. Optimisation and People*

For the supply chain to gain a high level of efficiency and thorough attention to detail, maintenance is required in all aspects of manufacturing in order to maximise overall equipment effectiveness and utilisation (Li *et al*., 2006). The aim of quality assurance is to remove the cause of bad quality. To achieve the highest quality possible with minimum cost, is considered the essence of a lean supply chain. In order to acquire quality assurance, the supply chain must focus on the prevention of failures and sustain improvement of processes by documenting the standard operation procedures (Shah and Ward, 2003). This can be implemented by the use of Total Quality Management (TQM), by implementing the 5S of Total Product Maintenance (TPM), which allows operators to be trained to maintain their own charged products, therefore developing a self-help culture where workers are welcomed to improve the overall quality of machinery and operations (Bullington, 2005). This creates a people's culture that embeds loyalty to the company, team work, employee contribution, learning and respect (Fig. 12).

### *4. Flexibility*

Given the competition to retain customers is between supply chains rather than competing brands, flexibility has become ever more crucial. Businesses need to increase performance, apply flexible facilities, coordinate supplies with customer orders, establish fast process setups and reduce research and development lead times (Womack and Jones, 1994). Additionally, value adding activities should be maintained to allow the supply chain to progress as an innovative model. This is achieved by incorporating "Lean enterprise", which aims to group individuals, functions and operationally synchronise them into a coherent framework (Fig. 12) (James-Moore and Gibbons, 1997).

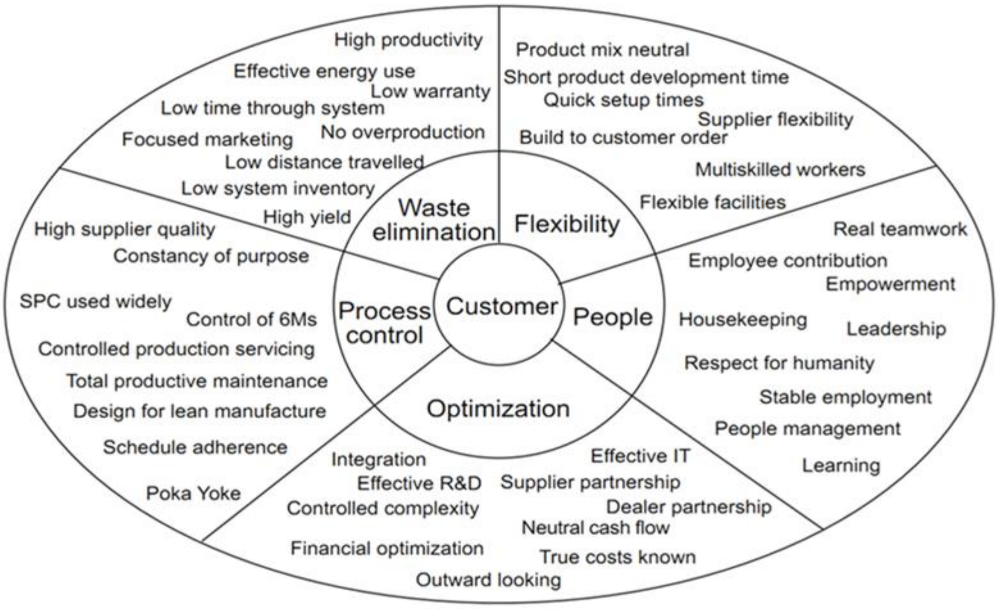


*Figure 12: Lean Automotive Model (James-Moore and Gibbons, 1997)*

Some businesses choose to specialise their supply chain by operating under either BSC, Agile or Lean strategies, others require a hybrid strategy that has both characteristics of Lean and Agile. This supply chain strategy is called Leagile. The six approaches branched from the Smart basic Value Chain were divided into four supply chain strategies (Agile, Lean, Leagile and BSC), with the first three acquiring two approaches and Leagile strategy combines an approach from Agile and Lean strategies. The Leagile strategy includes the “Flexible” approach from the Agile strategy and the “efficient” approach from the Lean strategy. The Leagile strategy along with its relevant approaches will be explored further in the next section of era five. Due to the term “Era” indicating continuous evolution, each era overlaps over the previous and the next eras, as supply chains continue to evolve building on past strategies to create new ones.

Era four is a continuation of era three where global supply chains become specialised by using different systems for their material flow such as “pull” and “push”. This lead to other strategies developing and be implemented as companies become increasingly specialised by having more customised products. Some of the developed strategies include agile supply chains to increase flexibility and lean supply chain to increase efficiency and eliminate waste.

## 2.11 Era Five: Specialised Globalisation (2008 – present 2016)

Era five marks the economic down turn yet it is an extension of era four as it continues to explore the rise of the global economy and the need for specialisation in order for businesses to gain a unique competitive advantage. Supply chains depend on coordinating the performance of others within the supply chain as the global economy increases the expectations of consumers with regards to cost and services resulting in supply chain re-engineering (Cagliano *et al*., 2004). Era five deals with the challenging economic climate and increasing competitive pressures, leading businesses to constantly change their operating methods, by breaking down their intra- and inter- organisational barriers to reduce uncertainty and increase the control over the supply chain (Jones and Towill, 1998). Thus, the cross-functional integration allows individual organisations to incorporate different channels of supply participants. Challenges exist in the integration of the customers and suppliers during the re-engineering processes (Changchien and Shen, 2002). These issues include, working with different engrained cultures based on past relationships, establishing trust in how benefits will be realised, coordinating resources across multiple companies, determining project leaders and resources, sharing funding and fearing loss of competitive information (Done, 2011). To help integrated measurement across supply chain strategies in relation to globalisation and sustainability Mollenkopf *et al*. (2010), puts forward a metrics which aims to examine the supply chain strategies in depth. The study revealed issues of barriers in trade which resulted in the need for a multi-functional approach, where the system that companies adopt takes the approach of adding strategic value and insight. Due to supply chain management becoming more strategic (rather than transactional) in nature as stated by Stavrulaki and Davis (2010), the need for a more integrated perspective of how products, and processes should be aligned with strategic decisions has become the turning point for enhancing competitive advantage. This resulted in various studies and business combining supply chain strategies in research and operations in order to archive a holistic approach. In this study the combination of Lean and Agile to improve supply chain efficiency and reliability is examined in order to be incorporated into the development of the Multi-Dimensional Matrix model (MDM).

### 2.11.1 Leagile Supply Chain Strategy

Era five explores the Leagile strategy, which is a hybrid model that combines "Lean" and "Agile" to optimise supply chain management. Hence, it combines the strength of both, and reduces all types of waste (inventory, unused capacity, poor quality, obsolete items, etc.) in order to minimise costs, and virtually integrate the supply chain components to create a better response system (Bruce *et al*., 2004).

There is a substantial difference between the performance of Lean and Agile supply chains. As mentioned previously, Lean supply chains are efficient for functional or innovative functional products, while the Agile supply chain shifts towards products and services that are innovative and volatile (Slack, 2005). According to Naylor *et al.* (1999), Agility is using marketing knowledge and virtual corporation to exploit profit opportunities in a volatile market. On the contrary, Lean uses strategies to eliminate losses, such as time and ensuring quality control. Christopher and Towill (2001) state that in order for a supply chain to qualify in the market and to win orders, it must identify specific aspects that act as indicators to determine the level of performance (e.g. quality, cost, response time and service). A Leagile supply chain is sensitive to the market and it is ready to respond to real demand and its logistics goal includes short response, feasible deadlines, ability to change the volume and the mix of production (Christiansen *et al.,* 2007). Leagile strategy utilises the unique characteristics of both “Agile” and “Lean” (e.g. Agile manufacturing) is considered an alternative to leanness, or as the second stage after leanness is achieved. Agility stands for using the market knowledge and virtual network of communication to exploit the profitable opportunities found in the volatile market environment (Naylor *et al.*, 1999). This can be considered the second stage after developing a Lean supply chain which aims to eliminate waste and create a value stream to ensure the accuracy of scheduling.

Both models of Lean and Agile can be combined in a single strategy by the use of the de-coupling point (Jones *et al*., 2000). Agility is different from Lean which focuses on doing more for less to obtain a ‘zero inventory’. However, Agile supply chains also focus on waste elimination which reduces buffer stock levels, though with a different strategic approach from Lean supply chains. Moreover, Agile supply chains focus on high responsiveness, high quality assurance and efficiency; all of which is shared with the lean supply chain within the smooth operation flow concept (Wright, 2010). Therefore a Leagile supply chain strategy has several key characteristics that combine an approach from each Lean and Agile strategy, as indicated by Wright (*ibid*). Leagile strategy combine the “Flexible” approach from the Agile strategy and the “Efficient” approach from the Lean strategy. Some of these combined key characteristic of both approaches are:

***1. Flexibility and Efficiency:*** Similar to the Lean/Agile strategy, it aims to fulfil quality and volume of various demands. This can be achieved by reducing product specification, thus reducing complexity by standardising the products to maximise mass customisation (Ergen *et al*., 2007).

***2. Postponement:*** As used by the Lean strategy it allows the supply chain to manufacture semi-finished goods that are not completely assembled until the final stage, where customisation takes place when the market requirements and the customer is known (Jayaram *et al*., 2010a). The stage where the semi-finished goods are stocked is referred to as the “de-coupling” point within the downstream lean supply chain (Pagh, 1998). The Postponement stage offers the supply chain operational, economic and market advantages, as it allows the lean supply chain to respond quickly to customise consumer demand with minimum waste as inventory levels are kept low (Wright, 2010).

***3. Virtual Network:*** As used by the Agile strategy it enables the supply chains to make use of the internet and allows technology to share data flows and information between customers, buyers, suppliers, manufacturers and distributors. This can be achieved through the use of Collaborative Planning Forecasting and Replenishment (CPFR) (Ketikidis *et al.*, 2008).

***4. Market Sensitivity:*** Similar to Agile strategy, the supply chain is capable of responding to demand with fast adaption to customer requirements. This can be achieved by the use of the Efficient Consumer Response (ECR) and the Customer Relationship Management (CRM) systems (Hayes, 2001) in addition to the use of information systems as stated by Ketikidis *et al*. (2008), for logistics and supply chain integration of ERP systems to improve visibility of resources and aggregation of data. The link is information flow co-ordination, which can be incorporated into the supply chain design in order to reduce uncertainty in a high “clock–speed” industry by applying product platforms (Fine, 2000). These platforms are a collection of assets that are shared by a set of products to increase product efficiency during manufacturing, development and reduce lead-time

(Meijboom *et al*., 2007). According to Robertson (1998) these product platform assets can be divided into five categories:

1) Components: consist of the relevant tools needed to designs a product, using fixtures, circuit designs and software programs,
2) Processes: The equipment used to make or assemble components,
3) Products: The final design and production process, including the equipment used to make and assemble components,
4) Knowledge: includes the design know-how, technology applications and limitations, production techniques, mathematical models and testing methods, and
5) People and relationships: consist of teams, building log-term relationships between the team and the larger organisation including building relations with a network of suppliers

Fig. 13 illustrates how the supply chain can excel by identifying the ways in which the “Market winners” can be highly competitive in the “Market Qualifiers” metrics (Jones *et al*., 2000). As each supply chain (Lean/Agile) responds to different markets, they require different strategies. However, to establish an optimum strategy the matrix helps businesses create a system-induced process which combines both Lean/Agile models to battle uncertainty and hence reduce the bullwhip effect depending on the commodity and market demand in question (Jones and Towill, 1998).

| | |
|---|---|
| • Quality<br>• Price<br>• Lead Time | • Service Level |
| • Quality<br>• Lead Time<br>• Service Level | • Price |
| Market Qualifiers | Market Winners |

*Figure 13: “Market Qualifiers” Matrix (Jones et al., 2000)*

The “Market Qualifiers” metrics by Jones et al (2000), is adapted in era six to create the multi-dimensional matrix (MDM) that is divided into four quarters, each designated to a supply chain strategy, its approaches and its characteristics (Agile, Lean, Leagile, BSC). In order to mitigate the issue of choosing the most suitable strategy, businesses will identify the two most significant factors to the MDM, the "Cost" of the supply chain and tolerated lead time "JIT Lean". Once these factors are identified among other variables, the business can initiate a premises to diagnose where its supply chain is located in the market and where it should be. However, to be able to effectively incorporate the MDM, the business must be able to undergo a re-engineering process, significantly changing their current business processes, job definitions, organisational structure, business policies and culture (Bevilacqua *et al*., 2009). In essence, after incorporating the MDM and diagnosing the best suited strategy, the business can create a new strategic model based on the MDM that increases the impact on performance, which according to Changchien and Shen (2002), will either be caused by a change in technological upgrade or an increase in profit margins. The sector that most businesses re-engineer is the organisational element (e.g. customer service, logistics and purchasing), with the process involving external customers and/or suppliers, otherwise it is just an internal project masquerading as supply chain re-engineering (Agarwal *et al*., 2006). Therefore, re-engineering decisions are generally based on either qualitative or simulation analysis, with detailed simulation on how their chosen diagnosed strategy by the MDM is considered the best option, as it customises and builds models that are tested in accordance with the simulation tools (Swaminathan *et al.*, 1998).

In Era five companies faced the challenge of a globalised market yet a desire for specialised products, this lead to the integration of several strategies in order to formulate a suitable model that companies could implement. However, due to supply chain managers spending approximately 40-60% of their time handling disruption as stated by Mulani and Lee (2002), which is increased with the disturbed economic climate that began in December 2007 then took a sharp downward turn in September 2008 marking the beginning of Era five. The unstable environment created by the great recession, caused a ripple effect in supply chains which according to Ivanov and Sokolov (2012), extended to cause imbalance many systems such as the financial, maritime and oil sectors with its domino effect remaining in Europe to the present date (Borok *et al*., 2008). This called for supply chains to be more responsive, adaptable and flexible with better integration of ERP systems, as examined in Era six. Furthermore to Era six being a continuation of era five, it also initiates the process of developing the interactive MDM model, as it forms the basis where the relevant supply chain strategies can be unifying in the next chapter in order to help SMEs and organisations establish a pathway most suited to their market and commodity.

## 2.12 Era Six (2012 – present 2016)

This uncertainty in Era five and six lead to developments in making supply chains more lean, agile and leaglie in terms of the different structures functional, organizational, informational and financial (Ivanov and Sokolov, 2012). To counter issues of market stability and risk, Ivanova *et al*. (2010), proposed methods to re-form supply chains in order to interrelate with each sector with the aim of changing the dynamics of the supply chain strategy that is to be implemented. To overcome uncertainty and mitigate risk, Ivanova *et al.* (*ibid*), introduces a conceptual framework for multi-structural planning and operations for a more adaptive supply chain that aims to help companies structure the dynamics of the strategy the wish to implement. The devised adaptive supply chain management model (A-SCM), is a tool for planning and control for structuring a supply chain strategy in times of uncertainty. However the A-SCM model requires flexibility in its implementation in order to counter the uncertainty created from Era five onwards (Ivanov and Sokolov, 2012). Looking at flexibility in the context of lean, agile and leagile supply chain networks in order to articulate a flexible framework for implementing a strategy, Purvis *et al*. (2014), put forward two key 'sources' of flexibility; vendor flexibility and sourcing flexibility.

The investigation conducted by Purvis *et al*. (*ibid*) introduces an extension of the 'Leagility' concept beyond the simple material flow decoupling point concept which was commonly applied in Era five. Two new types of leagility are put forward and were newly implemented in Era six: (1) leagile with vendor flexibility systems, which combine the use of agile vendors with lean sourcing practices and (2) leagile with sourcing flexibility systems, which combine the use of lean vendors with agile sourcing practices. Purvis *et al*. (*ibid*), implements this new concept on two cases of a UK based specialist retailers in the fashion industry in order to gain insight into the sourcing strategies used and the sources of flexibility employed by retailers at a supply network level. This resulted in a proposed guideline taxonomy linking vendor and sourcing flexibility with lean, agile and leagile strategies for managing parallel supply pipelines that match different operating environments.

Although having a responsive supply chain is an integral part for companies' survival in an uncertain environment, it has not been clear how firms build a responsive supply chain in global market. Roh *et al*. (2014), presented a model defining the drivers, strategy, and practices of a responsive supply chain and the performance outcomes. The objective is to identify key variables relevant to the implementation of a successful responsive supply chain. This includes careful definition of a responsive supply chain strategy in terms of the product range, and the frequency and innovativeness of the products being offered. According to Roh *et al.* (*ibid*), firms are required to provide key implementation practices such as sharing of information with customers, collaboration with suppliers and the use of advanced manufacturing technology to achieve effective responsiveness of pull production to the market.

To further investigate the effects of implementing a responsive supply chain, Huang and Handfield (2015), look at integration of ERP systems in the selection of ERP vendors on supply management performance. The study developed maturity ratings based on four key indicators, strategic sourcing, category management and supplier relationship management. The extensive analysis of how the deployment of ERP systems and the selection of ERP vendors can benefit a company's supply chain performance has provided valuable information for companies that are considering adapting an ERP system. However Huang and Handfield (2015), did not account for the differences between organizational scope of ERP deployment, global reach, or implementation duration.

The approaches in Era six aim to counter the ongoing issues of uncertainty from Era five by mitigating risk using effective and updated ERP systems to ensure the implementation of a responsive and flexible supply chain strategy that is equally adaptable to changes in the market. The objective of Era six is to unite all the previous supply chain models to create a basis for the MDM model adapted from the "Market Qualifiers" metrics by Jones *et al*. (2000). However, the MDM should also account for future technological development, which will be discussed in Era seven, as it may shape the mapping and planning of supply chains.

## 2.13 Era seven: Interactivity and Automation (Present to Future)

Era seven is a continuation of era six, where economic systems are increasingly prone to complexity and uncertainty. Therefore, making well-informed decisions requires risk analysis, control and mitigation. The increased frequency and severe consequences of past disruptions in supply chain have has resulted in an increasing interest in risk (Heckmann *et al*., 2015). This development has led to incorporating the advances in information technology to enable fast and reliable communication among different nodes as this creates a cyber-network that links the whole supply chain together as well as calculates or compares the firms' supply chain with its competitors. At present there are strong competitive conditions forcing companies to satisfy customer demands, which require the supplier's dependability with the lowest possible cost and minimal lead-times (Sarac and Absi, 2015). To ensure customer's demands are met, companies have developed new strategies and solutions to improve the quality of their supply chains and reduce their operational costs. These solutions involve enhanced information technologies such as the Radio Frequency Identification (RFID) which has drawn significant interests according to Sarac and Absi (*ibid*), as it has the ability to improve supply chain management by advancing their unique identification and real-time communication properties. The improved RFID resulted in enhancing the economical aspect of supply chains based on developing factors such as technology characteristics that integrate cost and product characteristics onto one database to be analysed.

However, a major constraint of integrating various nodes is their willingness of these nodes to communicate with each other in the chain, mostly because of data sensitivity issues (Min and Bjornsson, 2004). Communication is vaital in supply chains as it enables integrating knowledge that is spread across each of the nodes to facilitate smooth flow of materials from start to finish, as examined by Kumar *et al*. (2008), in a study of transition in the B2B e-Marketplace. To enable full integration of communication, standardisation of information technology must be facilitated across all sectors of the chain (Carlsson and Fuller, 2001). This requires automation of supply chain capabilities to ensure full alignment between processes. Once that is completed, the supply chain can accomplish full automation and integration of information (Alford *et al*., 2000). To ensure the success of automation, fast technological advances is essential to manage product life cycles, increase demand for variety and mitigate market uncertainty (Singh *et al*., 2016). However, there are several problems examined by Alford *et al*. (*ibid*) that require the supply chain process to be automated. This includes shortages, excessive finished goods inventories, under-utilised plant capacity, unnecessary warehousing costs and inefficient transportation. There are several pathways to automate a supply chain, one of which is explained by Kumar *et al*. (2008), which is to gather all the companies to into an e-marketplace, where negotiations on goods and services can take place. However, automating the business dealing processes into one e-marketplace will create a centralised domination which does not foster crucial aspects of the supply chain such as collaboration, alliance, and long-term relationships, but rather increases rivalry as companies aim to dominate one another in their pursuit of the best suppliers (Huhns *et al*., 2002;). This according to Singh *et al*. (2016), further enhances strategic alliance and supplier relationships which enables more flexibility in an automated system. Furth more, Huhns *et al.* (2002) proposed two properties that must be included when considering incorporating an automated system:

1) Disintermediation: creating direct association between users and their software without the use of intermediary body. This provides participants with the ability to interact and gather remote information on applications and human resources.

2) Error tolerance and exploitation: due to systems being extremely complex, errors occur, thus a system should have room to manoeuvre and anticipate such conduct if it occurs. Thus allowing its components to interact in time and mitigate these errors and prohibit them from reoccurring by following systematic protocols (Huhns *et al*., 2002).

For companies to establish a full automated system, these two above properties are combined in a new tool that develops and uses computer agent software. This software facilitates information and service by exchanging them with other programs, thus collaborating to solve complex problems (Huhns *et al*., 2002; Min and Bjornsson, 2004). By using the World Wide Web, an “agent” is an information gathering program that strategically forms and re-forms coalitions, creating dynamic business partnerships without the user’s immediate presence. The “agent“ helps increase sales through matching the end user’s needs with product offerings, as well as reduce transaction costs by using the automated business process (Fig. 14). Each agent communicates with other agents over the internet exchanging information dynamically such as inventory level, sales data, sales forecast and production or delivery schedule to mitigate the bullwhip effect (Sturgeon, 2003). An “Agent” gathers and shares schedule data, instead of sales data and sales forecast; this is sent to a supplier and the sub-supplier agent. On the basis of this information, the production schedule is updated and modified to meet the changes in demand (Min and Bjornsson, 2004).

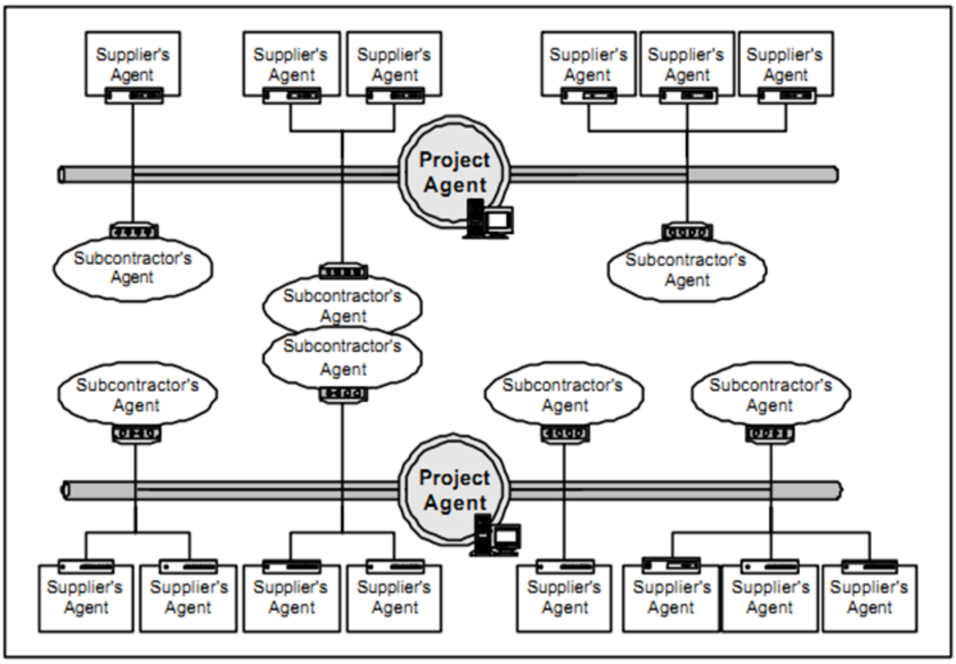


*Figure 14: Agent information flow system (Min and Bjornsson 2004)*

These information technologies are helpful in the coordination of process within the supply chain as they create platform for firms to develop and run a most effective and efficient material planning. Supply chain activities cover everything from product development, sourcing, production, and logistics, as well as the information systems needed to coordinate these activities (Soliman, 2015). Therefore, to achieve cost optimisation, many companies have begun selecting technological tools such as MRP, ERP and EDI systems as well as the Cloud system, as this maintains compatibility across various systems and provides simplified access to every part of the supply chain. This increases collaboration, visibility and coordination among supply chain partners and their logistics operations. Cloud-based systems help provide real time visibility shipments and inventory thus improving logistics tracking (Soliman, *ibid*). This helps companies control their system capacity more accurately, as they can adjust their capacities automatically based on their needs and the fluctuations in demand.

Era seven looks at updating the MDM to be interactive to accommodate the rise in technology and automation. However, incorporating an “agent” system within the interactive MDM is complex and is beyond the scope of this research. Nevertheless, the interactive MDM can be enhanced to include the “agent” system by the company if it wished to further develop the scope of this research. This study will focus on building the MDM to be an efficient interactive model that is web-based, hence incorporating elements of the cloud-based system. Therefore, to allow the MDM to be a flexible integral tool that can be incorporated in an automated business structure, two properties must be accounted for; “Disintermediation” which allows the staff in a company to use the interactive MDM without the need for any high skilled software engineer present to act as an intermediary; and “error tolerance” built into its system, as a company can update the database of the MDM by adding more variables and fuzzy rules into the MDM programing (Huhns *et. al.,* 2002). Each company has its own unique attributes, adding relevant variables into the MDM will make it exclusive to them. This can be a single procedure or a regular procedure to keep the MDM up to date and mitigate any errors (Roubens, 1997). The programming can be done by a qualified IT staff.

When a company decides to implement the MDM, it must first establish what type of market is it operating in (functional, innovative or innovative functional). It must then determine its level of Leanness and cost of its supply chain. Additionally, classifying its production strategy is important, whether it’s designed-to-order, make-to-order, or make-to-stock as these three categories cause problems associated with sudden change in product design, raw material inventory shortages, and lead-time, respectively (Li *et al.,* 2006). According to Min and Bjornsson (2004) the construction materials and categorisation of production strategy divides suppliers according to their production capacity into four categories; “stock supplier”, “build-to-order supplier”, “mass producer” and “capacitated supplier”. The “stock supplier” and the “Mass Producer” needs accurate demand forecast as they have a short lead-time to reduce inventory and transportation costs, the “build-to-order” and a “capacitated supplier” requires accurate data on the end-users’ actual construction progress and demand forecasting. Once these factors are established, the business can use the interactive MDM which will generate the most suitable strategy for a business as well as provide options to choose from (Min and Bjornsson, *ibid)*. The recommendation given by the MDM may cause the company to undergo a re-engineering process. However, supply chain strategy re-engineering has the potential to significantly impact performance in the future, hence it is essential for the company to perform a detailed risk analysis before adopting a new process (Swaminathan *et al.,*1998).

The "error tolerance" system can be further enhanced by the company based on the Automated Supply Chain Configurer (ASCC) model established by Piramuthu (2005). This model is linked to the "agent" system as it resides at every node in the supply chain. Each of the sectors shown in Fig. 15 represents an "agent" that makes decisions based on the information they have about the nodes in the next stage up-stream to them, and the prior information that comes from a stage downstream from them. For example, the "Sampler" agent in ASCC filters the information to extract necessary training examples that are used as input in the next "Learning" phase. The "Learning" agent learns the patterns that exist in the training examples, to formulate an algorithm to solve complex problems in the supply chain. These algorithms and patterns are then stored in a "knowledge base", where they are examined and tested. If an element is found to be incomplete, the problem is rectified through incremental learning using the "Performance Element" agent. The "Knowledge base" agent gathers and sorts the information, patterns and algorithms that pass the performance test and allows them to proceed to the "Dispatcher" agent. There the best choice is identified and given back to the (upstream) stage. This automated process repeats itself continually until all errors are identified, resolved and all orders are dispatched (Piramuthu, 2005).

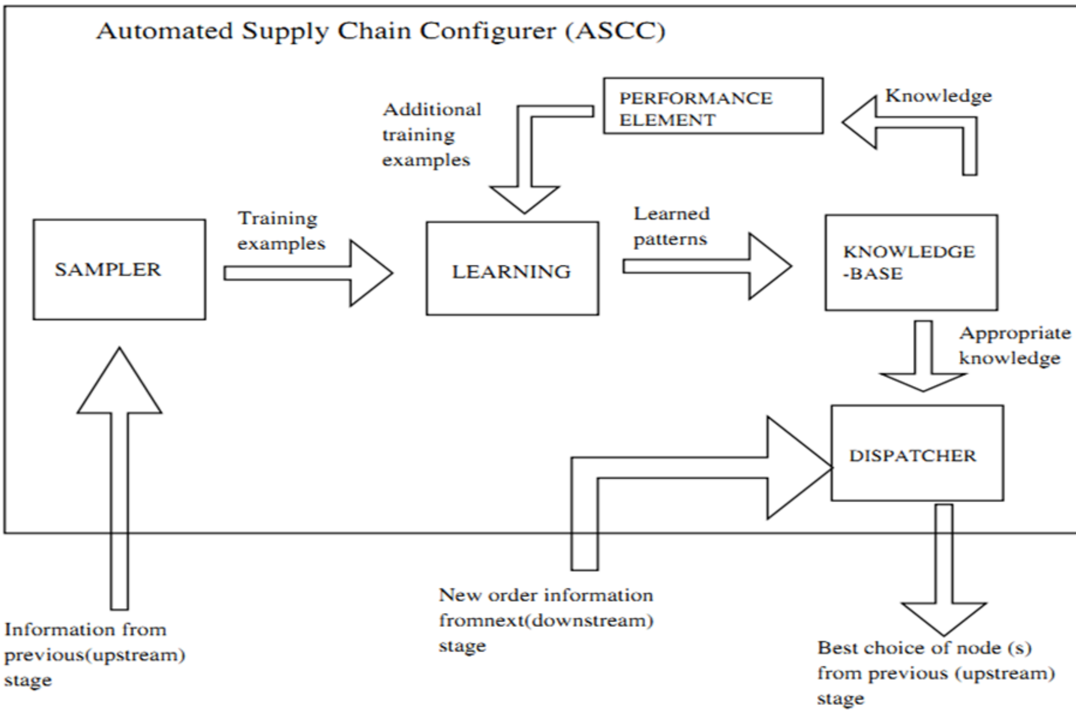


*Figure 15: Automated Supply Chain Configurer Model (Piramuthu, 2005)*

The ASCC software is difficult to implement within the scope of this study as an “error tolerance” system. It provides businesses with an outline to enhance and incorporate the interactive MDM within their automated structure. According to Piramuthu (2005), ASCC is ideal for specialised automated production, i.e. car, oil, aerospace and cloths. Their supply chain would benefit from the cyber software and gain production speed by incorporating a cyborg production chain for fast assembling of components. Although this is present in the current industries (car, oil and aerospace) it is not present as means to link the entire supply chain into a single unit (Alford *et al.,* 2000).

Era seven illustrates possible future development in supply chain and logistic planning by the adaption of technology and advanced integration of information and systems across the organisations’ framework. Furthermore Era seven builds on the basis of the MDM and puts forward the importance of incorporating an interactive capability to enable the model to adapt to future technological advances.

The literature review introduces the concept of supply chains, the technological advances and the issues that revolve around definition of the concept and the complexity of the market as it becomes more integrated and globalised. Furthermore, the literature review establishes a theoretical framework categorising each evolution of supply chain strategies and concepts into eras. These eras help academic research and companies understand the series of evolution, their purpose as well as the uses for the strategies developed in each era. Moreover, the theoretical framework in the literature review established a basis for the MDM's characteristics as well as devising various variables that can be incorporated into the development of the MDM. These variables will be extracted and discussed further in the next chapter where the modelling methods and tools for the development of the MDM will be established.

# Chapter 3

## Developing the Multi-Dimensional Matrix

*"Essentially, all models are wrong, but some are useful"* – *George E. P. Box*[10]

In developing the MDM a conceptual framework must first be designed in order to map the creation of the hybrid MDM supply chain model, which unifies all the previous approaches and strategies in past eras. This chapter will establish variables from the literature review in order to help build a framework for the MDM by selecting the most relevant variables to be examined by the data collection. This chapter will also create a preliminary model of the MDM to illustrate the strategy quarters and the process that will be conducted in the next chapters, in order to achieve this study's aim of developing an MDM that can help businesses establish the pathway most suited to their market, commodity, manufacturing and production. The MDM also attempts to incorporate adaptability as shown by Ivanova *et al.* (2010), in having dynamic multi-structural based variable functions that can be improved and amended according to the business's requirements. This will also allow the MDM to be responsive, however Roh *et al*. (2014), suggests that the key contextual factors that influence the extent of implementation of a responsive supply chain strategy are mostly the size of firms, industry characteristics and their supplier network. Therefore, this study aims to develop an MDM model that can be used as a tool for SMEs and larger organisation in order to create a flexible model that can be tailored to be unique to their business structure. The MDM can help establish effective implementation of a responsive supply chain network that enhances integration across the organisations global inter-processes.

[10] George Edward Pelham Box (18 October 1919 – 28 March 2013) was a statistician, who worked in the areas of quality control, time-series analysis, design of experiments, and Bayesian inference.

## 3.1 Theoretical variable functions

The process of identifying relevant variables to be used in the data collection involved gathering literature from suitable studies in order to select measurements. In addition to the literature review, various studies have contributed to the selection of variables such as, Kootanaee *et al*. (2013) who work on JIT manufacturing and implementation helped establish the type of performance variable function used to understand the panel's feedback. Additionally, Beamon (1999) presented an overview evaluation of performance measures used in supply chain models with a framework for the selection of flexibility measures of performance for manufacturing supply chains that contributed to creating several variable functions. Moreover, Stevens (1989), work examined supply chain integration and control of material flow from suppliers, through the value adding processes and distribution channels to customers which helped form several of the logistics variable functions. Meanwhile, Silveira et al. (2001) examined the various methods of mass customisation and their impact on the development of production systems, which was also examined by Alford *et al*. (2000), who studied mass customisation from an automotive perspective, all of which helped establish several variable functions such as the customisation variables, integration and push system variable. Additionally, Simeonovova and Simeonov (2012), examined the lead-time reduction methods, in addition to Elfving (2003), who explored the opportunities to reduce lead-times for engineered-to-order products that helped establish the manufacturing lead-time variable and shipping errors variables. Furthermore, Maycroft (2005), looked at consumption, planned obsolescence and waste, which helped develop the life cycle variable; while Fisher's (1997) study looked at what is the right supply chain for a product, by examining Functional, Innovative and Innovative functional products which helped establish several variable functions as well as the manufacturing cost variable. Moreover, Gunasekaran *et al*. (2001) and Monczka *et al*. (1994), looked at performance measures and metrics in a supply chain environment, which also helped establish several variables such as the delivery and distribution variables. Meanwhile Tan et al. (1998; 1999) carried out an empirical study on supplier performance and firm performance which helped establish several variable such as measuring output. The literature review, theoretical framework as well as the mentioned studies and various research such as Towill *et al*. (1992), whose work on designing industrial dynamic models for supply chains, helped establish the JIT Lean variable function parameters for the interactive MDM. However, due to the scope of the study, limitations must be placed on the variable functions incorporated into the interactive MDM. To summarise the gathered variables a table has been drawn to illustrate each variable and its definition (Table. 3)

*Table 3: Theoretical variable functions (Source: author)*

| Variable function | Definition |
|---|---|
| **Cost** | From the stages of manufacturing (cost of production) to customer. The cost includes the supply chain sector between producing a product, logistics distribution and delivery to the customer, including the cost of lead times during that process. |
| **JIT Lean** | This study considers time to be lean – the more time is lost the greater the waste as time is a resource. JIT Lean is defined as the development of a value stream that eliminates all waste, including time, to ensure a sophisticated level of scheduling. Therefore the assumption that time is lean is measured by JIT system, hence the term JIT Lean. |
| **Delivery strategies**<br>According to Gunasekaran *et al.* (2001), there are three types of deliveries:<br>Delivery to request, delivery to commit date and order fill lead time. | To classify the response time between order and corresponding delivery to develop the appropriate trade-offs for the delivery system so they can be applied as a basis for planning a supply chain and delivery from manufacturing to customer (Beamon, 1999). |
| **Manufacturing cost**<br>The total cost of direct material, labour, and manufacturing overheads | According to Fisher (1997), if a company produces an "*innovative*" product, its demand is very unpredictable and in need of a responsive supply chain. |

in the fabrication, assembly, and testing of an end item. This includes the utilisation of three inventory accounts for raw materials, inventory, work in process inventory, and finished goods inventory.

According to Fisher (1997), a "*functional*" product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in need of an efficient supply chain.

According to Fisher (1997), an "*innovative functional*" product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as toothpaste.

**Distribution strategies**

It integrates manufacturing in supply chains, as the material flow must be viewed from three aspects as a whole; strategic, tactical and operational (Stevens, 2007).

*Strategic distribution*: objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location of its key facilities. The competitive aspect is integrating its manufacturing and distribution with that strategy (Gunasekaran *et al*., 2001; Stevens, 2007)

*Tactical distribution*: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining the tools, approaches, resources necessary to manage and provide the information infrastructure for the supply chain by using (MRP, DRP, JIT) (Gunasekaran *et al*., 2001; Monczka *et al*. 1994).

*Operational distribution*: concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately in terms of supplier performance, inventory investment, service level, throughput efficiency and cost (Stevens, 2007).

| | |
|---|---|
| **Measuring Output**<br><br>Output is measured by the number of items produced, the time required to produce a particular item and/or set of items and customer satisfaction which is measured by the number of on time deliveries and less led-time between order and corresponding delivery (Tan *et al*., 1998). | *Customer satisfaction*: Good flexibility and response to customer needs, good customer service and response to customer queries as well as post transaction customer service, such as problems arising from warranty claims. Less customers complaining about product features or quality, delays or shipping errors (Beamon, 1999). In providing a higher service level will require higher costs (Stevens, 2007; Tan *et al*., 1999).<br><br>*Customer order path*: Is the path that orders travel by, where time is spent in non-value adding activities, such as paper work, checking, which can be eliminated by using JIT an EDI (Gunasekaran *et al.*, 2001).<br><br>*Manufacturing lead-time*: Total amount of time required to produce an item or batch (Beamon, 1999; Simeonovova and Simeonov, 2012).<br><br>*Shipping errors*: If a supply chain focuses on customer satisfaction in the retail industry number of incorrect shipments reflects on customer service as it is the combined effect of all functions along the supply chain (Beamon, 1999; Elfving, 2003). |
| **Measuring Product Demand**<br><br>By looking at the (1) End-user requirement, or (2) substitute product, or (3) competing product; then assessing the total volume of a product that can be bought by a | There are three product types:<br><br>“*Innovative products*” carry risk as the product has a short life cycle due to unpredictable demand, requiring a flexible supply chain with- Flexible Manufacturing System (FMS) and Computer Integrated Manufacturing (CIM) (Fisher, 1997). |

| | |
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| consumer group where the location, time period and marketing effort are defined. | "*Functional products*" have a longer life cycle of more than 2 years with an average margin forecast error of 10% (Fisher, 1997).<br><br>"*High-end products*" have a fluctuating demand, to counter this uncertainty Fisher (1997) suggested a blend of three strategies- reducing uncertainty by identifying and analysing new sources of data, avoiding uncertainty by cutting lead times and incorporating flexibility and hedging against uncertainty with buffers of inventory or excess capacity |
| **Product Life Cycle**<br><br>The product life cycle has 4 very clearly defined stages (Introduction Stage, Growth Stage, Maturity Stage and Decline Stage), each with its own characteristics that mean different things for business that are trying to manage the life cycle of their particular products (divided into three categories). | |
| **Customisation**<br><br>A make-to-order lean pull system | *High-end:* If a supply chain is focused on high-end mass customisation, then its selects a relevant approach for a product that is expensive or advanced in a company's product range, or in the market as a whole (Monczka *et al*., 1994).<br><br>*Self-customised:* enable the customer to change the product at any time to suit their own preferences (Alford *et al.*, 2000; Silveira *et al*. 2001).<br><br>*Collaborative customisation:* Manufacturers that involve their customers in a dialogue to identify their needs and establish their requirements are using collaborative customisation, which is specifically |

| | |
|---|---|
| | tailored to that specific partnership (Alford *et al.*, 2000; Silveira *et al*. 2001).<br><br>*<u>Adaptive customisation:</u>* enables the user to customise the product to their requirements (Alford *et al.*, 2000; Silveira *et al*. 2001).<br><br>*<u>The cosmetic customiser:</u>* presents the product differently to each customer, whether through packaging or similar changes in distribution or services (Alford *et al.*, 2000; Silveira *et al*. 2001).<br><br>*<u>Transparent customiser:</u>* provide unique products or services in a standard form to each customer, without the customer's knowledge that the product or service is customised (Alford *et al.*, 2000; Silveira *et al*. 2001). |
| **Push system**<br><br>A company makes-to-stock and maintains inventory level | *<u>Push system:</u>* According to Alford *et al*. (2000) and Stevens (1989), when a company pushes variety of goods into the market in hope that customers will find what they want. |

The data collection will determine which of the gathered variables are most relevant to be incorporated in the development of the MDM, which aims to help businesses diagnose its best suited strategy from the matrix quarters (Agile, Lean, Leagile or Basic Supply Chain-BSC). Moreover, it allows a company to create its own strategy tailored to its specific needs. According to Changchien and Shen (2002), a company can diagnose the most suitable quarter in the MDM by understanding the following: the needs of the consumer and the capabilities needed for the company to operate in a certain market. To enable complete and consistent application of the diagnosed strategy from the MDM, perfect alignment must be achieved with the aid of supply chain re-engineering. Each business is unique and therefore requires different standards of re-engineering. However, companies must analyse the fundamentals that drive their chain re-engineering processes, internal and external resources, availability of automation process and level of employee empowerment (Yusuf *et al*., 2008). The most challenging factor facing manufacturers during the re-engineering process is the integration of the upstream of outsourcing functions and the downstream of delivery functions with regards to product design manufacturing. This integration facilitates the value creation transferring it from the supplier to the end customer (Changchien and Shen, 2002). The major drive for integration is sophisticated and advanced Information Technology (IT) which allows companies to grow through vertical integration as perceived in the Agile supply chain model. However, with integration comes the search for new markets as companies seek to become integrated global enterprises by merging their access to data, costs, personnel, stocks, sales, inventory and profit files (Yusuf *et al*., 2008). This requires absolute trust and advanced (IT) which not only combines the strength of EDI, but also ERP and APS systems (Hayes, 2001; Sarac and Absi, 2015). Additionally, global enterprises aim to reduce costs to a minimum by reducing inventory which is implemented by the use of JIT purchasing, scheduling and distribution. This waste reduction is what the Lean supply chain is renowned for, and as previously mentioned, it leads to more frequent monitoring of specific components, deliveries quality and precise scheduling to the end consumer (Walker, 2008).

## 3.2 Framework Methodology

Conceptual or theoretical framework determines how a given research formulates the research problem, how data collection investigates the problem and how it is analysed and interpreted. A framework is a structure that provides guidance for the research to study questions, identify methods for measuring variables and plan a coherent analysis (Edwards and Akroyd, 1999). Once data are collected and analysed, the framework is used as a mirror to check whether that all stages of the study have been completed. The literature review creates a theoretical framework constructed from a set of concepts drawn from evolution of events to shed some light on a particular phenomenon. The theoretical framework in this study is the evolution of eras in the supply chain, as it gradually builds an explanation of the issues companies face and the path taken by this study to mitigate these issues. The literature review in this study is combined with the theoretical framework of the eras and aims to identify, interpret and evaluate the existing models, theories and issues in supply chain management. The combination of literature reviews with a theoretical framework has two objectives: first, to summarise existing research by identifying patterns, themes and issues. Second, help identify the content to build the conceptual framework (Seuring and Muller, 2008).

To establish the conceptual frameworks from the literature/theoretical framework, this study will incorporate the existing aspects found within the previous five eras in the literature/theoretical framework and build two conceptual models. Each one of these conceptual frameworks will represent an integrated approach of looking at the issues put forward by this study. The first conceptual framework will illustrate how this study will achieve the aim and objective of building the MDM. The second conceptual framework provides the structure on which the MDM will be built and illustrates how it will be modelled.

A conceptual framework is defined by Imenda (2014), as an end result of a number of related concepts to explain a given issue, or give a broader understanding of the phenomenon of interest. The process of creating a conceptual framework can be established by inductive process, whereby concepts are joined together to map the research framework in mitigating the issues in question. Therefore, a conceptual framework is derived from concepts, while a theoretical framework is derived from theory (Imenda, *ibid*). A conceptual framework organises and narrows the scope of the study, as it carefully puts together a general guide for conducting an investigation that involves classification of research questions such as (what, why and how) which aim to mitigate the issue revolving around the research question. Once the issues are understood and a methodological plan for reaching a solution is established, the research can then address the construction of a model to represent a plausible solution for the issue (Edwards and Akroyd, 1999).

In the methodology chapter the tools used to collect data, build the MDM model, analysis and the means of interpreting the results will be examined. Era six uses the literature/theoretical framework to establish a conceptual framework which will map this study’s path in gathering the relevant information to build the MDM. Furthermore, era six creates a conceptual framework for the MDM built on the theories gathered from the theoretical framework. Once the study creates the MDM, it will be checked against the framework to establish that all stages have been achieved. Era seven will discuss the ability of the MDM to survive a sustainable and technological business world. An example of how the MDM will be made interactive to suit the technological progress will be put forward, in addition to the examining the increase in supply chain automation and its complexity. According to Swaminathan *et al*. (1998), the significance of sustainable supply chain management has risen considerably in recent years in academic studies and corporate industries. This led to the integration of environmental and social issues in operations, purchasing and supply chains.

### 3.2.1 The Multi-Dimensional Matrix Conceptual Frameworks

In era four and five the Smart Basic Value Chain has branched into six approaches that are categorised into four supply chain strategies. The first is the Basic Supply Chain (BSC), which caters for functional products and is forecast driven, has high emphasis on customer service and includes an inventory with buffers to account for fluctuations in demand and lead times. Secondly, the Agile strategy with its approaches focusing on innovation and innovative functional products. Therefore, its logistics operations ensure flexibility between inputting the supply within and between companies, as it focuses on maximising the response to a customer's demand. Thirdly, Lean strategy with approaches targeting functional and innovative functional products, hence its logistics aim to eliminate losses and focus on speed. Finally, the Leagile strategy is mainly used for products that are innovative or innovative functional. However, with the increase in customisation, personalisation in the global market, the Legile strategy can be used for functional products with configuration demand, for example personal computers (Table. 4) (Banomyong and Supatn, 2004).

*Table 4: The four strategies and six approaches of supply chains (Source: author)*

| Basic Supply Chain (BSC) | Agile Supply Chain (Agile) | Lean Supply Chain (Lean) | Leagile Supply Chain (Leagile) |
|---|---|---|---|
| 1. Progressive flow approach<br>2. Configuration approach | 3. Agile approach<br>4. Flexible approach | 5. Fast–prompt approach<br>6. Efficient approach | From Lean: *The efficient approach*<br>From Agile: *Flexible approach* |

The specialised four strategies, their characteristics and approaches are inadequate to provide sufficient decisive measurements for companies to establish what their supply chain needs to improve, or requires re-engineering. This study aims to clarify and expand the variables that enable SMEs and organisations to diagnose the nature of their supply chain and what they require to improve it. In order to achieve the MDM model, several measuring variables need to be identified. These measuring variables clarify the choice of relevant strategies, by helping companies establish the parameters under which their business strategy operates and help lead them towards the strategy that is most relevant for their business framework. This study will identify the measuring variables through literature and data collection. This section will create a conceptual framework that illustrates how these variables will be identified and used to create the MDM model. Additionally, a preliminary conceptual framework of the MDM will be created to illustrate the mechanism of how the MDM will be designed and used. This section will also examine the first two measuring variables that are needed to create the preliminary MDM, which will provide the bases of the initial data collection.

#### *3.2.1.1 Conceptual Frameworks*

In order to identify the measuring variables needed to aid companies' decision making, this study will investigate the following. The conceptual framework (Fig.16) outlines the pathway the study will undertake. Firstly the preliminary MDM with the first two identified variables will be analysed through data collection, to identify the relevant variables. Secondly, once they are collected and categorised into groups, the data collection will further investigate the need for these variables, the most relevant variables for the scope of this study and their uses in creating the MDM. Thirdly, the analysis section will then examine how the variables will be applied in order to create the MDM and how beneficial will they be to the companies using them. The data collection and analysis will work towards establishing the variables and building the MDM model. Additionally, they will establish how the MDM can be made sustainable and interactive to suit modern business requirements and technology. Finally, the testing section will review the MDM applicability, its usefulness to companies, its interactive and sustainable capabilities. This will be conducted by introducing the MDM to a prestigious company for assessment to determine its potential use for SMEs and organisations.

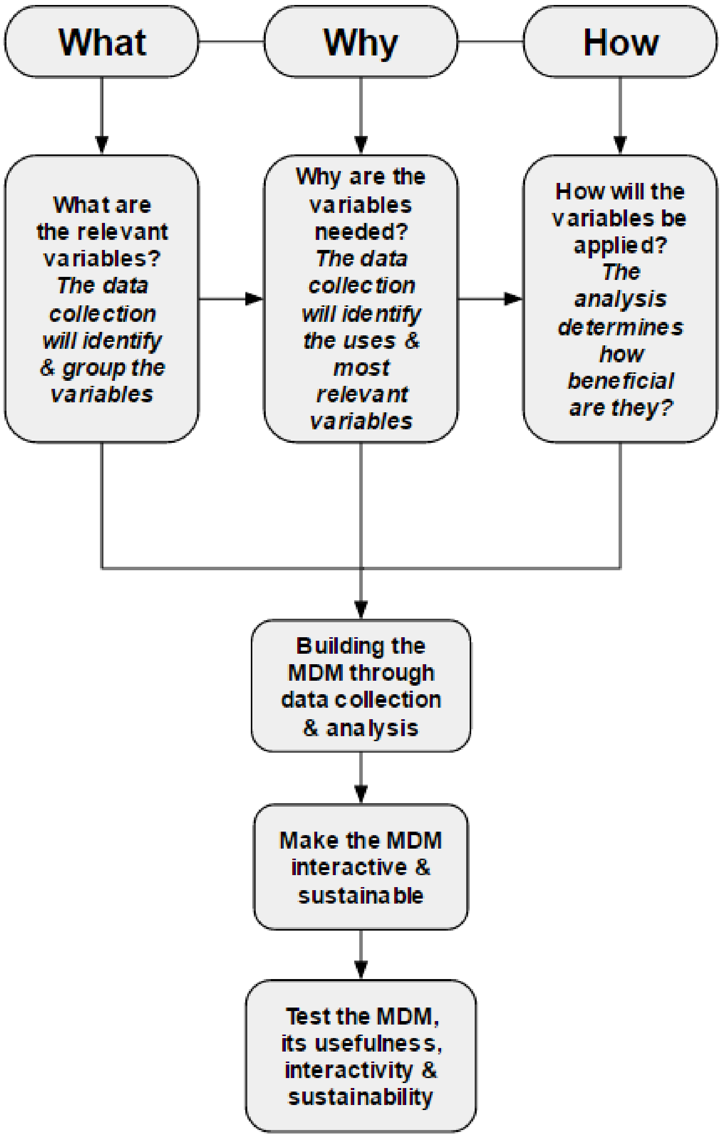


*Figure 16: Conceptual framework of the study (Source: author)*

## Conceptual framework for MDM

According to Kandasamy *et al*. (2007), fuzzy modelling has been used by applied mathematicians to understand the phenomenon in social science. For instance, these models are used by doctors, engineers, scientists, industrialists and statisticians to represent the uncertainty or "fuzziness" in a real system or process. This is seen through various research such as Roubens (1997), who points out recent advances in using fuzzy modelling in multiple attribute decision making methods that deals with ill-defined information. Roubens (1997), used fuzzy ranking methods to review aggregation problems in procedures, choice issues and treatment of interactive models. Moreover, fuzzy methods have been used by Kok *et al*. (2000), in creating decision–support systems in the field of integrated water management from a social science perspective, as many environmental changes are human-induced. Due to the ambiguity in combining qualitative social concepts in a quantitative modelling framework, Kok *et al*. (2000), applied fuzzy set theory and fuzzy modelling maps to integrate qualitative scenarios with quantitative, hence integrating models to establish a decisive decision–support system for the coastal city of Ujung Pandang, Indonesia. Fuzzy methods has also been used in logic-driven approaches to understand system's behaviour, as Gobi and Pedrycz (2007), have applied fuzzy modelling to design a two-phase optimisation process using adaptive fuzzy logic, Leading to creating an effective learning mechanisms structure that achieves high accuracy, interpretability and transparency, through the use of "Fuzzy Rules" in digital systems.

The use of fuzzy methods has become more common in social science according to Kandasamy et al. (2007), leading to the development of "Fuzzy Matrix" modelling for social science. This study aims to use fuzzy methods in developing a "Fuzzy Matrix" model generated from the conclusions of the "Fuzzy Rule" system, which is based on the measurement variables, also referred to as "Fuzzy measures". The structure and parameters of the "Fuzzy Matrix" is created using the basic fuzzy principles of (If-Then) which are statements used to set fuzzy conditions (Jin, 2000). For example, IF a statement gives the desired intelligence to a "Fuzzy rule" formula, THEN the condition is found to be TRUE, hence returning a predefined value. However, if the condition is FALSE, it returns a different predefined value (Carlsson and Fuller, 2001). The growth of fuzzy theory resulted in an increase of the applications of fuzzy sets in social research (Bezdek, 1993). Therefore this study will adopt the fuzzy set and "fuzzy Matrix" method in order to create the MDM.

According to Swaminathan *et al*. (1998) the practice of supply modelling in research is achieved through comparison or translation of different strategies to define a single dimension or describe a single model through multiple dimensions, through the basis of case evidence or theoretical perspective. However, Carlsson and Fuller (2001), concluded that supply strategies are characterised by multiple dimensions, hence to obtain a holistic perspective, a study would be required to analyse the relative different strategies through several dimensions.

The creation of the MDM is based on the "Market Qualifiers" metrics by Jones *et al*. (2000), therefore it will be shaped into a matrix with four quarters, in order to ease the process for companies to allocate their business strategy, commodity and market. A quarter will be designated to the Lean strategy and its relevant approaches which target relatively stable demand to minimise losses and maximise profit by reducing fixed costs. A quarter will be designated to the Agile concept and its relevant approaches with the capabilities to react to market demand in an extremely volatile environment. This quarter is suited for businesses who adopt a virtual integration to unite all their information flows to battle any changing turbulence in demand (Christopher and Towill, 2001). The Leagile strategy quarter is designed to incorporate different key characteristics of Lean and Agile, which are opposing models, however, once combined they can enable the supply chain to develop fast market knowledge and enhance their information provided the decoupling point has been accurately identified between each intersection from each Lean/Agile model. Finally the BSC strategy quarter has approaches designed for functional products. It has the characteristics to integrate added value and information technology to align the different processes in the chain in order to create a reliable and cost competitive based business structure (Cagliano *et al*., 2004).

To help ease the selecting procedure for companies, this study will identify several measurement variables that will provide guidelines for companies to help them determine the best strategy and under which quarter their supply chain lies in relation to their market. The company can then evaluate this strategy and establish the options it has, tailoring its needs and identifying the level of re-engineering it may require. These measurement variables will be established through data collection, however, a preliminary framework of the MDM must be established with introductory variables in order to initiate the data collection process.

From the theoretical framework, it can be established that there are several key measurement variables that companies compete on, for example lead times, cost, added value such as speciality services and customisation. Lean, Agile and BSC have “Cost” as one of the core competitive characteristics and Lean strategy has waste reduction (including lead times) as its primary competitive advantage with the use of JIT. Meanwhile, Leagile combines both Lean/Agile by having some of its competitive advantage based on cost and lead time (Cagliano *et al*., 2004). Hence “Cost” and “Lead times” are two reliable introductory measurement variables that can be used as a basis for the preliminary MDM framework, to initiate data collection for the other relevant measurement variables. The definition for “Cost” in this study includes the production process, its logistics distribution and delivery to the end customer, including the cost of lead times during that process. The end customer can vary from end consumer, to retailer to end warehousing. The specific definition of the end customer will depend on the company’s classification of the term. The definition in this study for “Lead times”, is the more time is lost the greater the waste, as time is a resource. Therefore, leanness means developing a value stream to eliminate all waste, including time and to ensure a sophisticated level of scheduling by the use of JIT. Hence, the more a supply chain strategy moves towards eliminating “Lead times” by using JIT, the Leaner it becomes (Cagliano *et al*., 2004). Therefore, “Lead times” are measured by the JIT system, hence the term is “JIT Lean”. Using these two measuring variables “Cost” and “JIT Lean”, companies can classify under which quarter their business lies by assessing their “Cost” and “JIT Lean” hence establishing their parameter.

Adapting the “Market Qualifiers” metrics by Jones *et al*., (2000) to establish a basis for the multi-dimensional model’s conceptual framework; (Fig. 17) has divided the market into two, “Market Qualifiers” and “Market Winners”, by which a business can identify under which market it belongs. The “Market Qualifiers” indicates the base line for companies to enter in a competitive market arena, while the “Market winners” analyses the specific capabilities a business has in order for it to fill the demand. These two markets cater for three different product types, functional, innovative and innovative functional. The two upper quarters often cater for innovative and innovative functional, with the “Market Winners” competing on service level such as availability, flexibility, responsiveness and customisation, while “Market Qualifers” compete on quality, lead time and price, as their commodities tent to be costly (Fig. 17). The lower two quarters often cater for functional and innovative functional, with the “Market Winner” competing on commodity and product prices, while “Market Qualifers” compete on quality, lead time and services (Fig. 17).

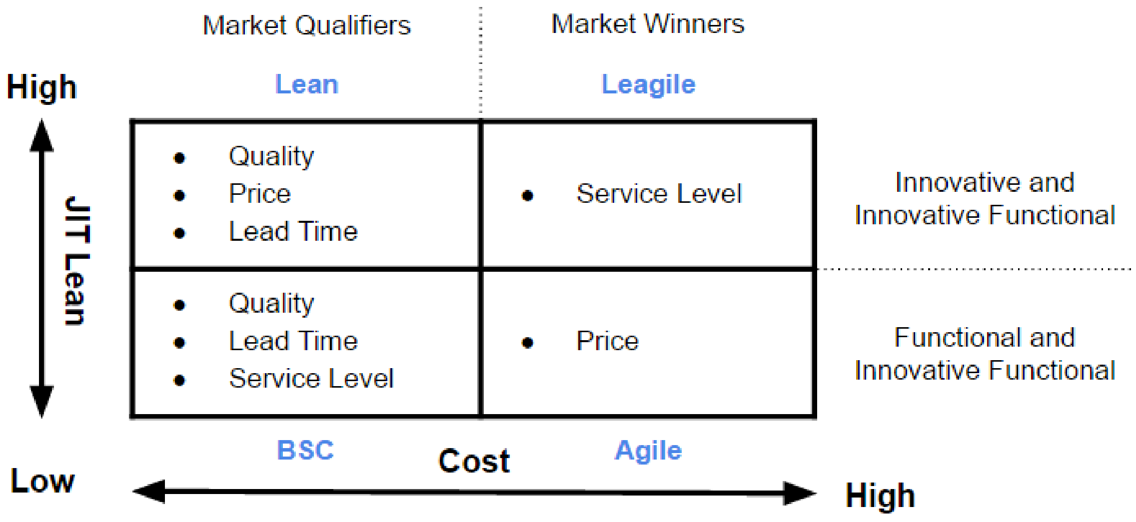


*Figure 17: Multi-dimensional Market Matrix (adapted from Jones et al., 2000)*

As price and lead times are self-clarified variables, in contrast to quality and service level that consist of several functions, this study will consider price as “Cost” and lead time as “JIT Lean” to be the introductory measurement variables on which the MDM will be built. These two variables will be placed on the axis of the MDM. The vertical axis represents “JIT lean”, as the more a company achieves Leanness by reducing lead time the higher it is located on the vertical axis (Fig. 18). The horizontal axis represents “Cost”, the higher a company’s costs are, the further down the horizontal axis they will be. Once companies examine the level of Leanness and their costs, the axis will help them determine which quarter is most relative to them. Based on the matrix by Jones *et al*. (2000), the MDM adapts the upper left quarter as Lean strategy, due to its competing category in high Leanness, low costs due to reduced inventory levels and high quality control due to trained personnel (Fig. 18). The upper right quarter is adapted as Leagile in the MDM, it acts as a hybrid strategy with high Leanness that ensures high service level that are often associated with high cost. The lower left quarter has been adapted to BSC as it competes on relatively high quality, service level, predictable demand scheduling, hence fairly low lead times and low cost due to economies of scale. The lower right quarter is adapted to Agile strategy, as it competes on relatively high Leanness due to its responsiveness which is associated with higher cost competition for delivery to the end consumer (Fig. 18).

In obtaining a holistic outcome, the MDM will apply four supply chain strategies that are relevant in this study and allocate them into four sectors or dimensions, hence creating a Multi-Dimensional Matrix (MDM) (Fig. 18). The MDM conceptual framework shows these four quarters cross over, as some characteristics between quarters show similarity, hence they integrate across strategies. These cross over areas are called "Fuzzy" and are the basis for the MDM to be developed as a "Fuzzy Matrix" model (Fig. 18) (Jin, 2000). The interpretability of the "Fuzzy Matrix" is done through data collection and deductive reasoning, which will allow the MDM to diagnose the company's position, generate recommended strategies as well as provide options that companies can use to tailor their own strategy (Fig. 18). The "Fuzzy Matrix" is generated by the following; Simplifying the fuzziness of the four strategies in the MDM, providing an interpretation to the fuzziness and testing the fuzziness of the data.

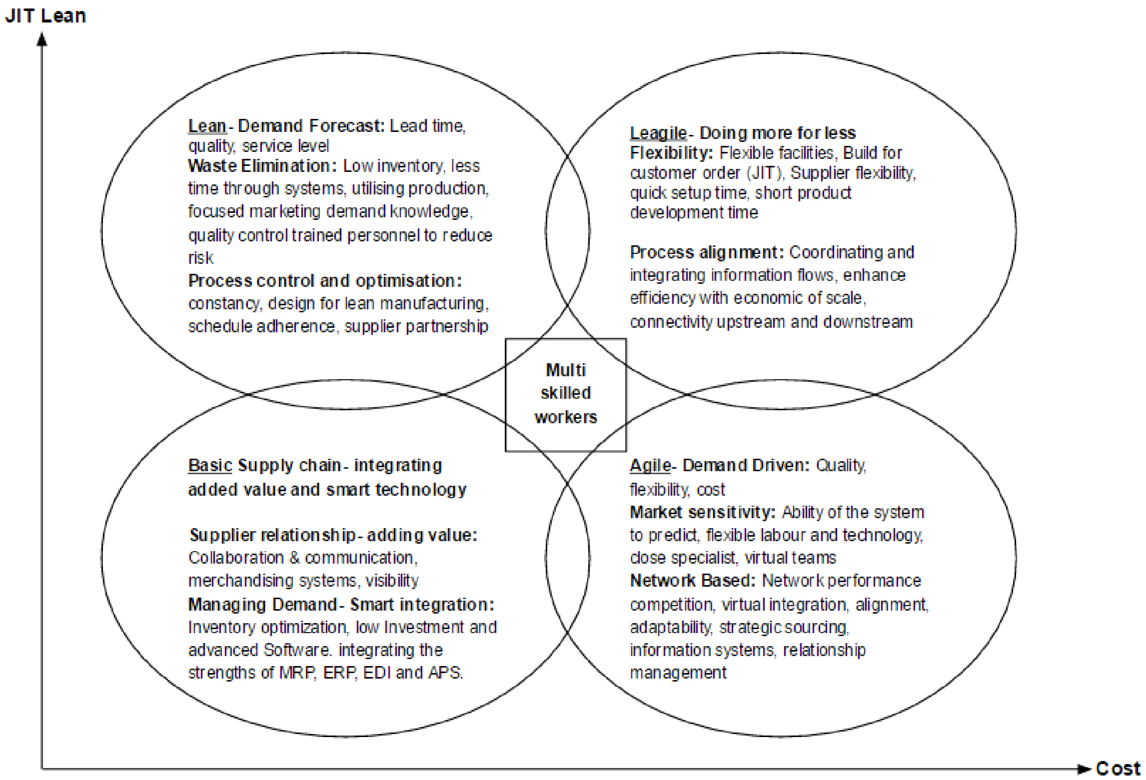


*Figure 18: Conceptual framework for the Multi-dimensional Matrix (Source: author)*

The MDM four quarters takes the shape of a matrix, with the first upper left quarter designated for the approaches of Lean supply strategy, with the characteristic features of eliminating waste while maintaining quality (Fig. 18). The Lean system is an operational technique focused on resource productivity (Sanchez and Nagi, 2001). The lower left quarter is for BSC approaches enhanced by economies of scale, and smart process to increase visibility, connecting information flows to enable flexibility of supplier arrangements. It has the characteristics to connect the upstream and downstream of the supply chain to add value by coordinating and integrating the information flows internally within the company and its suppliers (Lee *et al*., 2007). The lower right quarter is designated for the approaches of Agile strategy which share the characteristics that focus on vertically integrating information and services with regards to market sensitivity. Agility is a collection of inclusive strategies focused on exploring volatility to gain a competitive edge (Stratton and Warburton, 2003). The Agile's characteristic of "Flexibility" has the ability to adapt with minimum time waste and cost. This is shared by the upper right quarter with Leagile strategy, as it combines the shared characteristics of Lean/Agile strategies, indicating that these two Lean/Agile strategies can exchange characteristics via the "Fuzzy area". The Leagile unique capability is switching between decoupling points at the production phase from Lean manufacturing to Agile strategy and Agile manufacturing to Lean strategy. The decoupling point is divided into three categories; craft production mainly for innovative products, mass production mainly for innovative functional and lean production mainly for functional products (Harmozi, 2001). This decoupling point where both strategies intersect is challenging to identify for firms, resulting in complexity in identifying how to combine Leanness with Agility (Harmozi, *ibid*).

Therefore, the "Fuzzy area" in the MDM framework provides hybrid capabilities, to give companies the option to select the characteristics that cross between these strategies to create their own tailored supply chain (Fig. 18). The integrated segments of the matrix allows companies to create their tailored hybrid strategy. However, the disintegrated segments of the matrix allows companies to pick one of the traditional supply chain strategies in accordance with their market and commodity. For example, the middle square that intersects with all four quarters in (Fig. 18) is a "Fuzzy area" that illustrates an example of a shared characteristic between all four strategies. This characteristic is the use of multi-skilled works in the supply chain to provide unique advantage to the company so it can compete globally with the help of close supervision by specialists (Done, 2011). This requires a method shared by all four strategies to integrate information flows, people's skills and virtual teams to process the information given from the demand of the market and relate it to the product development.

In the following chapters, this study will build a fuzzy matrix based on the MDM conceptual framework. The data collection will identify the relevant measurement variables and the option available in the “Fuzzy area” that companies can use to create their own hybrid strategy tailored to their needs. The aim is for the MDM to help SMEs and organisations diagnose their supply chain and strategy they require for their market, in addition to allowing companies the option to create their own tailored strategy. This study aims to mitigate the complexity companies’ face in competing with their commodities or products in their chosen market.

In the next section, a conceptual framework for the interactive capabilities for the MDM will be examined in order for the model to survive in the technological world. Rapid developments in computer and data networks have resulted in a third revolution of technology. Along with the challenging economic climate and the increasing competitive pressures, the MDM urgently needs to incorporate advances in technology, as businesses require fast and reliable communication among different nodes, resulting in a cyber-network that links the whole supply chain together as well as calculates or compares the companies supply chain with its competitors. This requires full automation of processes and nodes along the entire supply chain. To achieve complete automation is complex as Era seven indicated. However, the main aim of establishing an interactive MDM is to provide an example for SMEs and organisations without automated capabilities of a simpler alternative to synchronise the different supply chain strategies into an interactive model that can diagnose the best suited strategy for their marketplace.

#### *3.2.1.2 Preliminary Interactive Multi-dimensional Matrix*

According to Carlsson and Fuller (2001), research contributions generally investigate supply chain strategies one dimension at a time. However, by discussing a multiple strategy in the form of multi-dimensions, a broader perspective can be provided to evaluate the impact on manufacturing performance. For example, if a company’s strategy moves towards Leanness then by definition it will move towards adopting a Leaner manufacturing model; resulting in lower costs, higher quality, higher speed and reliability. Similarly, if a company moves towards Agility, its manufacturing will acquire flexibility while ensuring the needed quality level. While if a company moved towards Leagile, its manufacturing will adopt both aspects, high quality, higher speed, reliability and flexibility. Meanwhile, if a company moves toward BSC, its manufacturing would acquire cost reduction, and planned inventory to suit a predictable demand (Cagliano et al., 2004). Though companies can tailor their own unique strategies via adding extra measurement variables to the MDM, the variables that form a supply strategy would not necessarily present constant patterns of relationships between each other. The company can choose to add additional measurement variables in the form of different combinations that align with the goals and supply chain structure of the company (Lee, 2002). This in turn helps companies select the best strategy that could cope with the challenges of globalisation, such as visibility, cost, risk and customer intimacy (Cavinato, 1992). Additionally due to the development of 3D printing and the increase in sustainability, the automated MDM can be combined with the sustainable decision tree model created by this study to help SMEs and organisations incorporate sustainable attitudes within their decision making process.

This study will use the basic principles of fuzzy theory to create a fuzzy matrix that will have "disintermediation" and "error tolerance" capabilities. Throughout this study, additional measurement variables will be identified and incorporated into the Hybrid Fuzzy Delphi to create the interactive MDM. For more clarification, the measurement variables will be divided into "Logistics strategies" and "Supply chain strategies". The MDM will then be made interactive and established as a website by the use of "Fuzzy rules-If/Then" programming. This will enable the MDM to adapt to technological advances in the business world. Furthermore, the interactive feature will enable the MDM to be more user-friendly and easy for companies to enhance or edit the model to accommodate their specification and preferences. The website will feature the MDM as an interactive matrix that companies can use to diagnose their supply chain in relation to their market as well as to choose the best strategy for their business structure. The interactive MDM for each group, "Logistics strategies" and "Supply chain strategies", will feature a dropdown box where the most relevant measurement variables can be accessed and selected (Fig. 19). Once the scale is chosen from the measurement variable boxes, the interactive MDM will generate a recommended strategy based on these premises along with a choice of option for the company to use if it wished to create a tailored strategy. The website will ensure disintermediation, as any member of staff can efficiently use the website and the interactive MDM model. Additionally, the error tolerance element is included in the interactive MDM, as a company can easily incorporate additional variables as fuzzy rules and program them to establish the MDM as “exclusive” to the company.

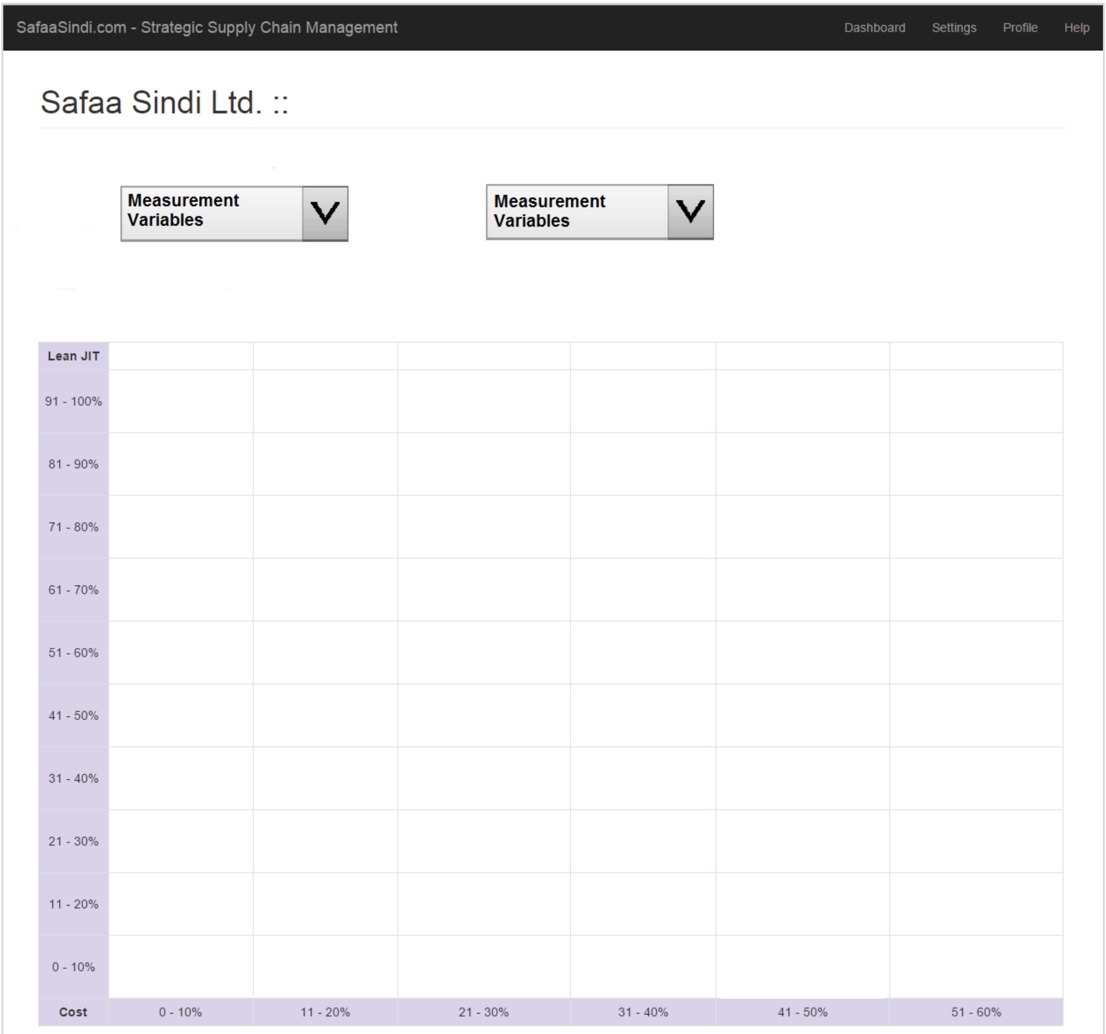


*Figure 19: Interactive Multi-dimensional matrix (Source: author)*

Once the measurement variables are identified and grouped into “Logistics strategies” and “Supply chain strategies”, the analysis section will translate the results into fuzzy rule statements that will be used to create the logic for the interactive MDM. The interactive MDM was implemented as a webpage, accessible from the domain "http://www.safaasindi.com". To develop the website this study sought help from a web developer, who constructed some of the functional aspects of the website and advised on where to add the logic rules and strategy recommendations. It is important to note that only the functional parts of the website was developed by the web developer, whereas all of the parts that made up the data and logic in the MDM was implement by this study. This is analogous to using Microsoft Excel to create a spreadsheet, where the tool itself is developed by a third party and the data entered is the author's own work.

The UML diagram in Fig. 20 shows the interactive MDM is made up of a number of components. The elements in the dotted region handle the logic and access to the recommendation database. The other elements handle user interaction and output of the recommendations on the webpage. The online interactive MDM webpage was created using a combination of HTML and JavaScript.

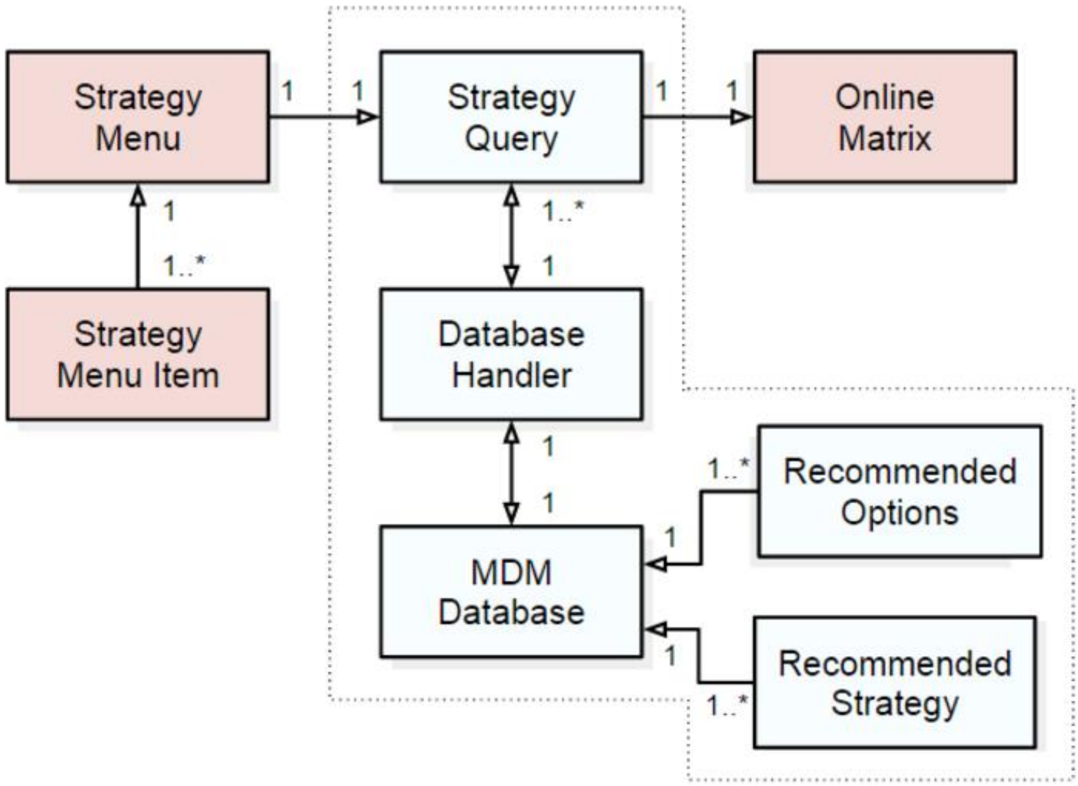


*Figure 20: UML Diagram of Interactive MDM Implementation (Source: author)*

The web-developer implemented the JavaScript that processed the user events, which were triggered by selecting values from the dropdown boxes. These events generated a strategy query against the database, which returned recommended options and strategies, which were displayed in a matrix on the webpage Fig. 21.

```
function GetStrategy(strategyIndex, jit, cost)
{
  // Get the matrix of strategies
  var matrix = GetStrategyMatrix();
  
  // Find the correct strategy for the given input
  for (var i = 0; i < matrix.length; i++) 
  {
    // Get the selected jit and cost ranges
    var jitRange = matrix[i][0];
    var costRange = matrix[i][1];
    
    // If in the correct jit range
    if(jit >= jitRange[0] && jit <= jitRange[1])
    {
      // If in the correct cost range
      if(cost >= costRange[0] && cost <= costRange[1])
      {
        // Get the strategy result string and break loop
        result = matrix[i][2][strategyIndex];
        break;
      }
    }
  }
  // Set the column and row titles
  var columnTitles = ["51 - 60%", "41 - 50%", "31 - 40%", "21 - 30%", "11 - 20%", "0 - 10%"]
  var rowTitles = ["91 - 100%", "81 - 90%", "71 - 80%", "61 - 70%", "51 - 60%", "41 - 50%", "31 - 40%", "21 - 30%", "11 - 20%", "0 - 10%"]

  // Create the html table
  tableCreate(matrix, result, columnTitles, rowTitles);
```

*Figure 21: JavaScript code for selecting a strategy (Source: author)*

Figures 22 and 23 show a sample of the JavaScript code which I wrote for one of variable group that forms the logic rules for the interactive MDM and the database used for querying strategies. These rules were established during the data collection and analysis, to form the basis for the strategy recommendation for the interactive MDM.

```
function GetStrategyMatrix()
{
  var matrix = []
  // JIT: 91-100
  matrix[matrix.length] = [[91,100], [0,10], "Manufacturing Lead time:
  Agile option Leagile option BSC", "Operational Distribution: BSC option
  Leagile strategy", "Tactical Distribution: Agile And/Or Leagile And/Or
  BSC", "Strategic Distribution: BSC option Agile And/Or Leagile
  strategy", "Delivery on Order fill lead time: BSC option Leagile
  strategy", "Delivery To Request: BSC And/Or Lean And/Or Agile strategy",
  "Delivery To Commit Date: Agile option BSC"];

  matrix[matrix.length] = [[91,100], [11,20], "Manufacturing Lead time:
  Agile option Leagile option BSC", "Operational Distribution: BSC option
  Leagile strategy", "Tactical Distribution: Agile And/Or Leagile And/Or
  BSC", "Strategic Distribution: BSC option Agile And/Or Leagile
  strategy", "Delivery on Order fill lead time: BSC option Leagile
  strategy", "Delivery To Request: BSC And/Or Lean And/Or Agile strategy",
  "Delivery To Commit Date: Agile option BSC"];

  matrix[matrix.length] = [[91,100], [21,30], "Manufacturing Lead time:
  Agile option Leagile And/Or BSC", "Operational Distribution: BSC option
  Leagile strategy", "Tactical Distribution: Agile And/Or Leagile And/Or
  BSC", "Strategic Distribution: BSC And/Or Agile option Leagile
  strategy", "Delivery on Order fill lead time: BSC option Leagile
  strategy", "Delivery To Request: BSC And/Or Lean And/Or Agile strategy",
  "Delivery To Commit Date: Agile option BSC"];
```

*Figure 22: JavaScript database code sample for selecting strategy (Source: author)*

```
  // JIT: 41-50
  matrix[matrix.length] = [[41,50], [0,10], "Manufacturing Lead time:
  Agile option Leagile strategy", "Operational Distribution: BSC And/Or
  Leagile strategy", "Tactical Distribution: Leagile option Agile
  strategy", "Strategic Distribution: Leagile And/Or BSC option Agile
  strategy", "Delivery on Order fill lead time: BSC And/Or Leagile
  strategy", "Delivery To Request: BSC And/Or Lean strategy", "Delivery To
  Commit Date: Agile strategy"];

  matrix[matrix.length] = [[41,50], [11,20], "Manufacturing Lead time:
  Agile option Leagile strategy", "Operational Distribution: BSC And/Or
  Leagile strategy", "Tactical Distribution: Leagile option Agile
  strategy", "Strategic Distribution: Leagile And/Or BSC option Lean
  strategy", "Delivery on Order fill lead time: BSC And/Or Leagile
  strategy", "Delivery To Request: BSC", "Delivery To Commit Date: Agile
  strategy"];
```

*Figure 23: JavaScript database code sample for a selected range (Source: author)*

The next chapter will explore the different methodological approaches that are relevant to this study. Once a suitable method is identified, it will be used to establish the aim of this study, which is to create the interactive MDM and sustainable decision tree.

# Chapter 4

## Data Collection Methodology

> *"That is, what one wants to learn determines how one should go about learning it"* – Eileen M. Trauth, 2005

A methodology is a set of methods, rules, or ideas that are important to a particular subject that involves a procedure or set of procedures to be conducted in order to identify an outcome or solution to an issue (Saunders *et al.,* 2012). These procedures usually take a “Qualitative” and/or a “Quantitative” approach in analysing and identifying a solution. According to Schwandt (2007), qualitative research is complex to define as it aims at understanding the meaning of human action. Therefore, its interpretation depends on the philosophical assumptions of the researcher. Often, the use of the term qualitative can be ambiguous as the adjective is used in so many different ways; it does not clearly signal a particular meaning or denote a specific set of characteristics. The popular understanding according to Schwandt (2007), follows that qualitative methods are a diverse term covering an array of techniques seeking to describe, decode, translate, and come to terms with the meaning, rather than the measurement or frequency of phenomena in the social world. Hence, qualitative research tends to work with text rather than numbers. For example, procedures that include unstructured, open-ended interviews, questionnaires and participant observation that generate qualitative data.

Quantitative methods use a variety of means to generate numerical data that can be measured, by the use of structured questionnaires, psychometric measures, case study research, interviewing, narrative inquiry, participant observation, discourse analysis and tests (Ritchie *et al.,* 2013). However, due to the difficulty in defining human logic or behaviour, one could generate qualitative data via an open-ended interview, transform those data into numbers, and analyse them by means of various statistical tools.

Combining both qualitative and quantitative approaches forms a mixed method which will be used in this study as it is specific and is often associated with the epistemological perspective, which helps formulate a clear understanding of different perspectives with the aid of numerical scales and statistical analysis (Ritchie *et al.,* 2013). According to Trauth (2005), there are three factors influencing the choice of a research method. Firstly, the nature of the research problem, secondly the researcher's theoretical lens, and thirdly the degree of uncertainty surrounding the phenomenon. Furthermore Trauth (*ibid*), argues that the nature of the research problem is of vital importance and therefore should be the most significant influence on the choice of a research methodology. These three factors will be used in this study to examine the use of mixed methods.

## 4.1 The Nature of the Research Problem

The nature of the research problem is identified by two factors put forward by Rowlands (2005). These two factors may be distinct but they are nevertheless interlinked. Firstly by identifying the research problem via the literature review. In this study the literature review combined with the theoretical framework illustrates how supply chain strategies have evolved throughout time, creating many definitions and strategies that are hard to unify or incorporate within a business. Moreover, with globalisation, a majority of the world's cargo is transported by sea, spanning not only countries but continents as well, resulting in supply chains getting more complicated. In addition to the increasing pressure of becoming more sustainable, companies are in need of a model that can help diagnose the best strategy to apply in facing the challenges ahead of them. Therefore the research problem is to create a model capable of diagnosing and recommending the most suitable supply chain and logistics strategies to help companies establish where they are positioned in the market and what strategy to implement.

The second factor according to Rowlands (*ibid*), is how the research questions are posed. The research question is "Development of an interactive multi-dimensional model for supply chain management", that is capable of helping SMEs and large multinational companies in identifying the best strategy for them. In answering the research question, the objective of this study is to establish a time-scale by gathering previously known supply chain and logistics strategies and dividing them into eras accordingly. The overall aim is to use the time-scale to create the interactive MDM, to be used as tool by companies to diagnose and recommend the best suited strategies, as the MDM would have taken into consideration the downsides from previous methods. Furthermore, to cater for sustainability issues, the MDM will have a complimentary decision making tree that will aid companies to establish the best suitable route to accompany their chosen strategy.

In order to create the MDM this research requires experts' opinions, obtained via questionnaires such as Delphi and semi-structured interviews. This study requires a first-hand account of a variety of opinions internationally, such as the Delphi study which is a practical approach to targeting a large number of experts in different countries. Due to experts' opinions being subject to interpretation, a numerical scale will be added to the questionnaire to enable the experts to voice their views in a manner that can be analysed and interpreted in crisp numbers. The research question supports the use of mixed methods in order to maximise the benefits from the experts' opinions.

## 4.2 The Researcher's Theoretical Lens

Theoretical lens according to Trauth (2005), referrers to the philosophical standpoints such as "Ontology", "Epistemology" and "Axiology", where the research turns toward a certain philosophical perspective and paradigm. Researchers are required to initially identify their philosophical assumptions and paradigm leading to a choice of an appropriate methodological interpretation such as "Inductive", "Deductive" and "Abduction" (Trochim and Donnelly, 2006). The verity of philosophical standpoints and their assumptions about the nature of knowledge examine the methods in which a phenomenon can be studied.

### 4.2.1 Research Philosophies

There are three well known research philosophies that have been around since the seventeenth century in an attempt to explain different religious philosophical perspectives reflecting on individual but ultimate entities such as the soul, the world and God (Hacking, 2002). The three research philosophies are "Axiology", "Ontology" and "Epistemology".

#### Axiology

It looks at the study's' judgment about value as the researcher's own values play into all stages of the research process in order to make the results creditable. The researcher articulates their value as a basis for judgments about what and how their research is conducted, by writing their own statement in relation to the topic (Ritchie *et al.,* 2013). This is particularly relevant for personal career development and financial issues but not relevant to this study.

### Ontology

Concerned with the nature of reality by looking for reality existing independently of human conceptions and interpretations. It is divided into objectivism, subjectivism and social constructivism (Hacking, 2002). Objectivism is the position taken when social entities exist outside of a reality, such as managerial structure issues. Subjectivism perceives that organisations are less important than the way managers associate themselves with the organisation (Hacking, 2002), while the social constructivist focuses on the different interpretations individuals place on the situations (Ritchie *et al.,* 2013). This approach is applicable for organisational management studies but not for this research.

### Epistemology

Concerned with the different ways of knowing and learning and focuses on questions such as how and what forms the basis of our knowledge (Ritchie *et al.,* 2013). This study follows an epistemological thought process as it formulates epistemological research questions. Firstly, according to Bryman and Bell (2011), epistemology focuses on how we can learn about the problem, which is shown as this study attempts to understand how we can learn about the different supply chain strategies, hence creating the seven eras. Secondly, as Bryman and Bell (*ibid*) state, epistemology looks at what forms the basis of the problem, which relates to how this study is conducted as the aim is to discover why supply chains became complicated by looking at what forms the basis of supply chain strategy and provide a solution by identifying how selecting a supply chain strategy can be simplified.

Epistemology within social research looks at how ‘facts’ and ‘values’ connect and influence each other. It also focuses on what it means to accept particular claims as accurate or ‘true’ (Hacking, 2002). An epistemology researcher considers the data needed to gain more knowledge of the collected data to analyse facts, by representing them as models or crisp numbers. Therefore, an epistemology researcher would argue their study is less biased and rather more objective

(Saunders *et al.,* 2012). This study takes an epistemological approach in creating the Hybrid Fuzzy Delphi questionnaires, by gathering the experts' opinions 'values' and interpreting them into 'facts', then allocating them into a MDM model using statistical analysis to understand the fuzzy area of the experts' opinions. This epistemological approach uses both qualitative and quantitative research methods in order to understand the data effectively.

Therefore, the epistemological research philosophy is best suited to this study; however a research paradigm that fits with the epistemological philosophy must be selected. There are four paradigms, these are Positivism, Realism, Interpretivism and Pragmatism.

### 4.2.2 Research Paradigm

A research paradigm summarises and clarifies the epistemologies and ontologies, by offering a useful way of understanding the behaviour of researchers towards their work. Selecting a paradigm helps outline the best route for the research by understanding where it is heading and investigating what is possible (Trochim and Donnelly, 2006).

#### Positivism

The data is about an observable reality, searching for regularities and casual relationships in the data, creating law-like generalisation. It uses existing theory to develop hypotheses, which are tested and confirmed or referred for further development of theory which is tested by further research (Trochim and Donnelly, 2006). A positivist can start with an observation made prior to a hypothesis being formulated and tested. However, the research must be taken in a value-free way, therefore the outcome is objective and uses quantifiable observations, leading to statistical analysis (Saunders *et al.,* 2012). Hence, the positivist paradigm is not suitable as this research does not require a pre-determined theory or observation to formulate a hypotheses.

#### Realism

Uses scientific enquiry in understanding reality, believing that objects have an existence independent of the human mind. It is a branch of epistemology similar to positivism. There are two types "Direct" and "Critical". The former portrays that what an individual experiences through their senses is an accurate explanation of reality. The latter, argues that what one experiences are sensations of the things in reality and not the things themselves. Direct realism argues that what is perceive as illusions by critical realism is a result of insufficient information, which can be overcome by experiencing the world from all directions and angles (Saunders *et al.,* 2012). This research is concerned with the connections companies have with supply chains. The social world has the capacity to change constantly with many variables, hence to perceive the supply chain issue from all angles is impossible. For the scope of this study, the variables must be assumed constant in relation to the environment surrounding them. Therefore, this paradigm is not applicable to this research.

### Interpretivism

Taking a critical approach to positivism; Interpretivism argues that rich insights to the complex world are lost if it is reduced to law-like generalisation. It advocates understanding of differences between human roles in the social sector and objects (Wilson, 1990). Interpretivism gives meaning to the environment around it, "Phenomenology" and "Symbolic". The former refers to the way humans make sense of the world. While the latter is a continual process of interpretation of the social world, by interpreting the actions of others, leading to adjustments and the creation of meanings of one's actions (Saunders *et al.,* 2012). This study looks at the business environment and the ability of the companies to adjust to it rather than the human perspective. This study is not looking at the management reaction, but rather the business' ability as a whole to diagnose the environment and adjust its strategic position. Therefore, interpretivism is not suited to this specific study but rather more suited to organisational behaviour and human resource management studies.

### Pragmatism

Concepts are only relevant when they support an action, as there are many different ways of interpreting the world and undertaking research, where not a single point of view can ever give the entire picture, as there are multiple realities. Pragmatists prefer to use credible methods that result in reliable and relevant data (Saunders *et al.,* 2012). For pragmatists, it is important to overcome issues by presenting justified research findings. This study looks at helping companies identify the best strategy for their market and commodity. A synergy of tools as well as approaches have been used to overcome the complicity of the volatile business environment in order to identify credible results for the companies to choose from (Bryman and Bell, 2011). As this study uses a variety of relevant methods to achieve its aim, the pragmatism perspective is most suited as a research philosophy. The use of combined data collection of Delphi and fuzzy principles combined with mixed quantitative and qualitative methods as well as statistical SPSS and Excel analysis have all been specially selected for their relevance in achieving the study's aim and to provide reliable data for companies. The creation of the MDM as an interactive web-based tool has also been uniquely chosen to enable companies to diagnose their business needs and to tailor a supply chain strategy according to their requirements.

The overall research philosophies and paradigms are summarised in Table 5. To conclude, this research takes an epistemological philosophical research approach and a pragmatic paradigm in achieving this study's aim and objective.

*Table 5: Summarising the research philosophies and paradigms (Source: author)*

| **Research Philosophies** | **Pragmatism** | **Positivism** | **Realism** | **Interpretivist** |
|---|---|---|---|---|
| **Ontology**<br>The nature of reality | External view chosen to best answer the research question | Objective view, independent of social actors | Exists independently of human thought and belief or knowledge of their existence (realist), but interpreted through social conditioning (critical realist) | Social constructed, subjective view and may change |
| **Epistemology**<br>The researcher's view regarding what constitutes acceptable knowledge | Either or both observable phenomena and subjective meaning can provide acceptable | Only observable phenomena can provide credible data. Focuses on law-like generalisation, reducing | Observable phenomena provide creditable data. Insufficient data means inaccuracies. Alternatively, phenomena create sensations which | Subjective meanings and social phenomena. Focus upon the details of a situation, a reality behind these details, |

| | | | | |
|---|---|---|---|---|
| | knowledge dependent upon the research question. | phenomena to simple elements. | are open to misinterpretations (critical realism). Focuses on explaining issues within a context | subjective meanings and motivating actions. |
| **Axiology** The view on the role of value in research | Views play a large role in interpreting results, the researcher adopts both objective and subjective points of view | Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance. | Research is value laden; the researcher is biased by word views, cultural experience and upbringing. These will impact on the research | Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective |
| **Data collection** Techniques often used | Mixed methods, quantitative and qualitative | Highly structured, large sample measurements of quantitative or qualitative | Methods chosen must fit the subject matter, quantitative or qualitative | Small samples with in depth investigation using qualitative |

## 4.3 The Degree of Uncertainty Surrounding the Phenomenon

Deciphering and analysing data must be adequately explained to avoid ambiguity (Trauth, 2005). This study's aim and objectives investigate whether SMEs and organisations are prepared to use the MDM model and if it is a reasonable tool. The uncertainty in the research question remains on how data collection can be conducted and analysed adequately. The methodology tools have helped identify the data collection process, yet translating the analysis in a form that will enable companies to easily understand what they require is still undetermined. In order to sufficiently translate the analysis into an applicable model of recommendation, this study will choose a research angle that would help the development of the MDM model. There are three main research angles, "Deductive", "Inductive" and "Abductive".

### 4.3.1 Research Angle

#### Inductive

The research starts by collecting data to explore a phenomenon to better understand the nature of the problem either by conducting interviews or going into the field and collecting samples of data, then analysing this data in order to generate a theory in the form of a conceptual framework (Saunders *et al.,* 2012). This is commonly associated with grounded theory as it encourages researchers to persistently interact with their data, while remaining constantly involved with their emerging analysis which in some cases leads to confusion (Wilson, 1990). However, El Hussein *et al.* (2014), argue that research should be conducted without a pre-conceived problem statement, interview protocols or extensive review of literature, to ensure no pre-conceptualised judgments are formed. The differences between Deduction and Induction are explained by Trauth (2005). In the former, a researcher works within an explicit theoretical framework, while in the latter, the researcher tries not to be constrained by prior theory and instead commences to collect data initially to develop purpose, propositions and concepts for a relevant theory. However, as this study is looking to create a diagnostic supply chain strategy model along with recommendations, past research and theories must be considered in diagnosing the issues companies face and the means to mitigate them. Hence the most appropriate research angle to help achieve this study's aim would be a "Deduction" approach.

#### Abductive

Combining both deductive and inductive, rather than choosing one of the two options, to start from theory to data – as a deductive angle would, or take a look at the data first then formulate a theory as the induction angle would; abduction lies between the two by moving back and forth with a series of tests until a theory is proven (Saunders *et al.,* 2012). Nevertheless, the abductive research angle is not suitable for this study as abduction is concerned with understanding why something happens, while this study is looking at what is happening in the business environment and the means to mitigate its effects.

### Deductive

Research starts with developing theory from an idea and literature by studying what others have done, reading existing theories about the phenomenon, then tests the hypotheses and then forms the outcomes which can be later enhanced by being subjected to a series of proposed testing to further develop the theory (Saunders *et al.,* 2012).

Deductive approach takes place when a formulated set of hypotheses need to be confirmed or rejected during the research process (Trauth, 2005). This study's aim formulates the hypothesis of the usefulness of developing a diagnostic multi-dimensional model with interactive capability to help SMEs and organisations identify the best supply chain strategy for them. The objective of this study will result in confirming the usefulness and acceptance of the MDM or its rejection during the testing process. The deductive approach can be used on a social study as the research moves from a more general level to a more specific one by using the implications of data (Trauth, *ibid*). Therefore, deductive reasoning is chosen to be the most suited angle to use during the analysis of the data. The deductive approach in this research will follow the six steps put forward by (Blaikie, 2000):

1) Putting forward an idea, premise or a hypotheses, upon which the researcher can form a basis of a theory.
2) Using literature, the researcher can specify the conditions under which the proposed theory can be tested
3) Examine the premises of the logic in the argument put forward by comparing this argument with existing theories.
4) Test the premises by collecting data to measure the variables and analyse it.
5) If the results of the analysis are not consistent with the premises the theory is false.
6) If the results of the analysis are consistent with the premises then the theory is corroborated.

Table 6, illustrates the three research angles, their differences and recommended use of data for each, along with the theories associated with them.

*Table 6: Summary of research angles and their application (Source: author)*

| Application | Deduction | Induction | Abduction |
|---|---|---|---|
| **Logic** | When the premises are true, the conclusion must also be true "'top-down' process" | Known premises are used to generate untested conclusions "'bottom-up' process" | Known premises are used to create testable conclusions "hybrid of Deduction and Induction" |
| **Generalisability** | Generalising from the general to the specific | Generalising from the specific to the general | Generalising from the interactions between the specific and the general |
| **Use of data** | Data collection is used to evaluate propositions or hypotheses related to an existing theory | Data collection is used to explore a phenomenon, identifying themes and patterns by creating a conceptual framework | Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through data collection |
| **Theory** | Theory falsification or verifications | Theory generation and building | Theory generalisation or modification, incorporating existing theory where appropriate, to build new theory or modify existing theory. |

## 4.4 Application of Chosen Approaches

The previous sections explained the different methodological perspectives, paradigms and research angles while the following section illustrates the methodological position of the present project.

Epistemology is chosen for this study as it is the most suited philosophy that relates to the way in which knowledge is best acquired. This knowledge is acquired through mixed methods, and the qualitative approach is conducted via several rounds of questionnaire using the Delphi method. However, to avoid any ambiguity with the panel's opinions, these questions contain basic elements of fuzzy principles by creating "Truth Functions" that can then be analysed via SPSS and Excel which is the quantitative approach. Therefore, the paradigm for this study is characterised by pragmatism as it focuses on different ways of understanding and collecting data. It is rational for mixed methods that no single approach can view the entire picture, but rather a mixture of approaches can provide more information than a single approach (Franklin and Hart, 2007). In order to translate the analysis into the decision making MDM, a 'top-down' deductive angle is taken to logically derive the truth from the recommendations, which will then be tested to formulate conclusions (Table. 7).

*Table 7: The chosen methodological approaches and their application (Source: author)*

| | Research Philosophy | Research Paradigm | Research Angle |
|---|---|---|---|
| | ***Epistemology*** | ***Pragmatism*** | ***Deductive*** |
| ***Logic*** | Focuses on practical applied research, integrating different perspectives to help interpret the data | Understands that there are different ways to interpreting data and that there is no single concept that reflect the entire picture | When the conclusion is logically presented from a set of premises that are true, hence the conclusion is also true |
| ***Data Method*** | Mixed data method of quantitative and qualitative | Mixed data method of quantitative and qualitative. The use of relevant methods to create the truth functions for the Hybrid Fuzzy Delphi | Deductively analyses the mixed method data to achieve the aim and objectives |
| ***Use of data method in this study*** | Uses previous knowledge to develop parameters that help understand how the problem happened, and how can it be solved by developing truth functions for a Hybrid | Using relevant mixed methods to analyse the Hybrid Fuzzy Delphi using SPSS and Excel to create the MDM model | Using deductive reasoning to interpret the answers of the Hybrid Fuzzy Delphi and use deductive reasoning to test |

| | | | |
|---|---|---|---|
| | Fuzzy Delphi and analysing it via SPSS to build a model that archives the aim and objective of the research | | the MDM via semi-structured interviews |

### 4.4.1 Implementation of Selected Approaches

In this research, the theoretical framework contained several adapted models in order to achieve the objective of this study. The adapted supply chain models throughout this research improve upon the previous models and are created using a Soft Systems Methodology (SSM) modelling technique, used for tackling real-world problematic situations that lack a formal definition (Zimmer, 2010). In applying the “Pragmatic” paradigm to achieve the aim of this project, the conceptual framework for the MDM model will be created using SSM’s to provide a framework for users to help them deal with the unstructured problems of supply chains (Checkland and Poulter, 2006). Once a conceptual framework of the MDM is created, this research will use the Unified Modeling Language (UML) to make the MDM interactive as a web-based model. The selection of UML is due to it being a generic modelling system that helps develop models that intend to provide a standard way to design a visualised system. It is widely used for software modelling, as it includes various views and diagrams for different purposes and usages (Gu *et al.,* 2012). The UML takes conceptual models form various kinds of objectives, and creates a web-based syntax. According to Hiremath and Skibniewski (2004), the UML is used in building interactive models for automated construction processes, vendor management as well as supply chain and logistics modelling. This research uses UML as a basis for making the conceptual framework of the MDM interactive by modelling it as a web-based tool for companies to use.

Using the “Epistemological” approach, this research aim will be achieved by gathering data through a Delphi study that is combined with fuzzy principles to ensure that the MDM is created based on accounting for any fuzziness in expert opinion. The Delphi technique is a structured communication originally developed as a systematic study, based on an interactive forecasting method which relies on a panel of experts (Skulmoski *et al*., 2007), while fuzzy principles verify statements with degrees of belief, meaning that once each statement is proven to be either true or false, it is given a degree of truthfulness and a degree of falsehood (Trochim and Donnelly, 2006).

The analysis uses a “Deductive” approach, which looks at the issue in general terms and then more specifically. This approach initially finds the relevant theories that help businesses identify the best applicable supply chain for their commodity and market (El Hussein *et al*., 2014). The answers from the Hybrid Fuzzy Delphi are analysed via SPSS and Excel to determine the frequency of each statement. The analysis results will be deductively explained to further expand on the experts’ reasoning. The deductive reasoning will create scatter diagrams and “Truth Functions” that will be incorporated to build the interactive MDM as a web-based model.

The methodological stages of this study will be conducted in two parts in order to achieve the aim and objective of building the MDM model as illustrated in Fig 24. Part one conducts the data collection by setting an initial pilot study with two membership functions to establish what variable functions are needed. Once the recommendation from the panel assess the necessary variable functions, the first round of Hybrid fuzzy Delphi is conducted. The amendments from the first round will establish the design of the second round which may then result in a consensus. Once a consensus is established, part two commences with analysing the data by using SPSS and Excel to establish frequency tables that can be explained deductively. This helps establish scatter diagrams which form the basis of developing the MDM and its interactive capability, which will be then tested using semi-structured interviews (Fig.24).

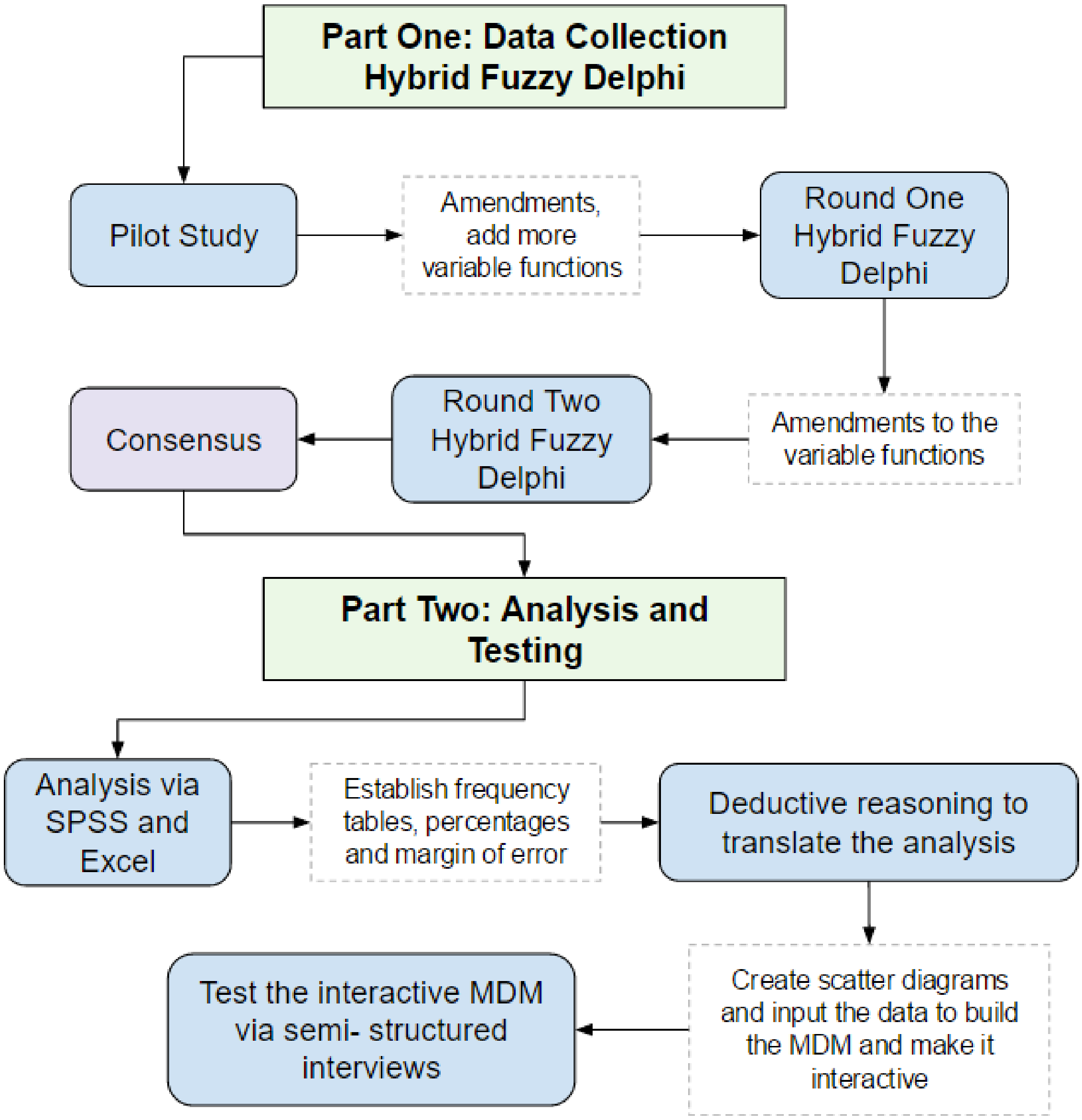


*Figure 24: Methodology stages - flow chart (Source: author)*

To summarise Fig 24, the methodological stages of the study have been further illustrated in Table 8. Part one follows a qualitative method, while part two follows a quantitative method, and thus combined create a mixed method approach to the data collection, analysis of results and testing. All of which are selected due to their relevance to the study and unique characteristics to help achieve the aim and objective of this study.

*Table 8: Methodological stages of the research (Source: author)*

| Methodology | Part One: Hybrid Fuzzy Delphi<br>Qualitative Method | Part Two: Analysis and Testing<br>Quantitative Method |
|---|---|---|
| | Applied to group decision making to clarify fuzziness in concepts and understand expert's opinion (Hsu *et al*., 2010).<br>1) Statements are created for a pilot study with two variables called "Membership Functions". The feedback creates the bases for the MDM and establish what the experts require in order for them to answer the next rounds with complete and relevant information. The pilot study also establishes the fuzziness which then initiates the first round of Hybrid Fuzzy Delphi<br>2) The first round uses the amendments from the pilot study to added relevant variables to create statements that use experts' opinion to build the MDM.<br>3) The final round is created from the amendments of the previous rounds in order to assess if the experts have established a consensus. | The analysis and testing affirm whether the MDM and its interactive capability is applicable.<br>1) The results of the Hybrid Fuzzy Delphi are analysed via SPSS and Excel to find the frequency of opinions, the mean and determine the consensus.<br>2) Through deductive reasoning the analysis is translated into scatter diagrams and fuzzy rules, which are then incorporated via UML into the MDM to be displayed on a website as an interactive model able to diagnose the best supply chain strategy for companies to choose from according to their market and commodity.<br>3) The testing is a qualitative method of semi-structured interviews by a panel of experts, to determine the applicability of the MDM model. Deductive reasoning is used to draw conclusions from the experts' answers. |

The next sections will expand on the method of data collection and the use of Hybrid Fuzzy Delphi to create the MDM model which will then be analysed and tested. Further explanation will be made regarding choosing the panel of experts and the methods of minimising non-response in the data collection will be examined, as well as the ethical implications.

## 4.5 Delphi Study Methodology

The Delphi technique is designed as a group communication process that aims to conduct detailed examinations and discussions of a specific issue for the purpose of goal setting, policy investigation, or predicting the occurrence of future events. It was cultivated by Dalkey and Helmer (1962) at the Rand Corporation Air force project, and has since become a widely used and accepted method for achieving convergence of opinion from experts, within their domain of expertise, concerning real-world issues from various topic areas. Delphi is unique to other surveys as instead of trying to identify “what is”, it address “what could/should be” (Hsu and Sandford, 2007). Additionally it is well suited as a method for consensus-building by using a series of questions repeated multiple times to collect accurate data from a panel. These questionnaires are developed and refined during the sequential stages until consensus is achieved (European Commission, 2008). This study will take advantage of one of the strengths of the Delphi method which is the ability to gather opinions from experts from different backgrounds and use it to get a selected set of indicators from a broad collection.

The selection of participants for the panel, time frames for conducting and completing a study, the possibility of low response rates, and questionnaire amendments based on the feedback from the respondent group are all areas which should be considered when designing and implementing a Delphi study (Davidson, 2013). The Delphi process has been used in various fields of study such as programming, management, organisational strategy planning, policy assessment, and resource utilisation to develop a full range of alternatives, explore or expose underlying assumptions, as well as correlate judgments on a topic spanning a wide range of disciplines (Hsu and Sandford, 2007). In this study the selection of participants has been conducted through establishing contacts with academic and industrial experts via email and Linked-in (Appendix C). The time frame to complete the Delphi for this study was limited to the Doctoral program;

hence a maximum of 3-4 months was dedicated to the creation, collection and organisation of data. The feedback loops are a unique and crucial element in the Delphi technique for establishing consensus, as it is a structured group interaction process that is organised in several rounds for the purpose of collecting opinions and feedback from the participants that result in the amendments of the question. Opinion collection in Delphi is achieved by conducting a series of surveys using questionnaires (European Commission, 2008). The survey is then sent out to be answered and feedback is sent back from the participants. These feedbacks determine if a consensus is established or if further amendments are to be made to the survey. Once the amendments are made the survey is sent back to the participants until no further feedback is given and a consensus is established. Fig. 25, illustrates the feedback loop process in the Delphi technique.

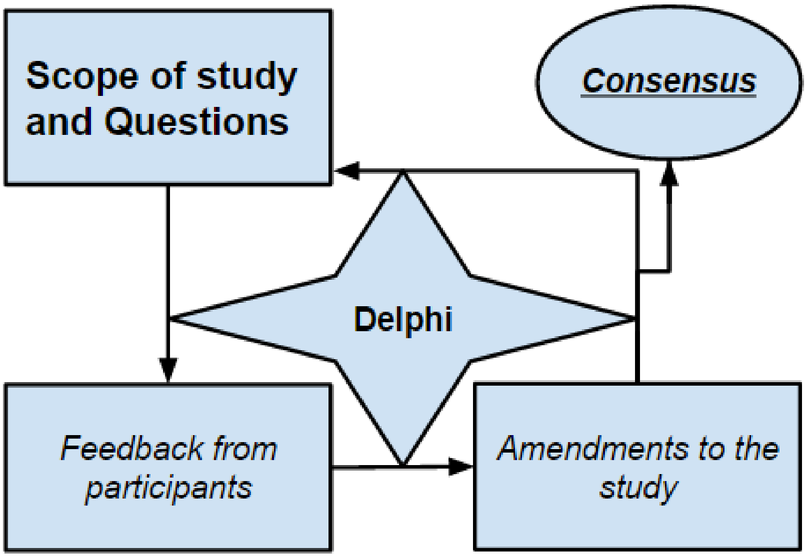


*Figure 25: Delphi study feedback loops (Source: author)*

## 4.6 Rationale for Adopting Delphi

Turoff and Linstone (2002), stated that Delphi is a unique technique that encourages participants to voice their opinion without fear of peer-pressure. This reduces the effects of pressure for the experts to change their views and encourages independent thinking and gradual formulation of reliable judgments, as it is free from personality influence, and individual dominance (Delbecq *et al*., 1975). Therefore, the key advantage of the approach is that it avoids direct confrontation of the experts, resulting in the Delphi technique specialising in generating consensus or identifying divergence of opinions among groups opposing or differing to each other (Kalaian and Kasim, 2012). Furthermore, it keeps attention directly on the issue, while allowing the sharing of information and reasoning among participants.

Hsu and Sandford (2007), specifically indicate the unique ability for the Delphi technique to achieve the following objectives: Determine or develop a range of possible program alternatives; explore or expose underlying assumptions or information leading to different judgments; seek out information which may generate a consensus on the part of the respondent group; correlate informed judgments on a topic spanning a wide range of disciplines, and educate the respondent group to the diverse and interrelated aspects of the topic.

The advantages of Delphi refined it into a popular tool for researchers to use in subsequent studies, in addition to enabling managers to make decisions based on information gathered using group-consensus. The definition commonly used in research and in this study to describe Delphi as: a method for structuring a group communication process, so that the process is effective in allowing a group of individuals deal with a complex problem (Okoli and Pawlowski, 2004). To accomplish structured communication, feedback from individuals contributes to the information and knowledge to assess the group judgment or view and provide opportunity for them to revise their views with some degree of anonymity (Okoli and Pawlowski, *ibid*).

The Delphi technique like any other has disadvantages, such as information coming from a selected group of people may not be representative. However, it can be argued that experts represent the opinion of many, hence there is little need for a large sample (Kalaian and Kasim, 2012). The Delphi does not depend on a statistical sample that attempts to be representative of any population, as Okoli and Pawlowski (2004), state it is a group decision requiring qualified experts who have deep understanding of the issues. Hence, one of the most critical requirements is the selection of qualified experts. Another disadvantage is that Delphi is more time-consuming than group process methods, as it requires skill in written communication and participant commitment (European Commission, 2008). Researchers have applied the Delphi method to a wide variety of situations as a tool for expert problem solving. Some of these methods are tailored to specific problem types and outcome goals, leading to the widespread use of the ‘‘ranking and multiple choice-type’’ Delphi as it has developed a tailored understanding by grouping options aimed at achieving a consensus about the relative importance of an issue or its effect on the topic of a question (Okoli and Pawlowski, 2004). The Delphi technique in this study will be based on a multiple choice type questionnaire that will aim to achieve the following:

1) Incorporate experts' opinion about definitions and characteristics of the various indicators of supply chain strategy,
2) Feedback on the processes will be identified in each round and amendments will be made accordingly, and
3) Reaching a consensus regarding the best suited supply chain strategy for each variable indicator.

### 4.6.1 Choosing Expert Participants

The expert panellists who participated in the Delphi were academic and industrial specialists in the areas of supply chain, logistics consultation and senior management positions. Based on the panel selection procedures put forward by Okoli and Pawlowski (2004), an international selection of experts was made to give the study more depth and verity. Having an international selection of participants provides a broad range of views, in accordance with two criteria, the expert's profile and the Delphi's needs, resulting in the final list of experts shown in (Appendix A) which includes the following for each panellist: institution or job title and field of expertise. Some of the names are not included due to data protection confidentiality, as requested by the participants themselves, which complies with the Delphi study, as it protects participants' anonymity. The considered experts have met the following requirements:

- Technical knowledge and professional experience in the area of supply chains and logistics,
- Willingness and ability to participate during the time of the survey, and
- To be neutral in their assessment and to choose the product, good or commodity in a market suitable to their expertise while answering the Delphi questions.

The number of experts used in a Delphi study is generally determined by the number required to constitute a representative pooling of judgments and the information processing capability of the research team (Hsu and Sandford, 2007). However, what constitutes an optimal number of participants in a Delphi study has never been formally defined. This is due to the number of Delphi iterations depending largely on the subject being investigated and the degree of consensus sought by the investigators, hence it can vary considerably. Nevertheless, Delbecq *et al*. (1975), recommend that researchers should use the minimum sufficient number of participants and then seek to verify the results through follow-up explorations. They further suggest that 10-15 experts can be sufficient if the background of the Delphi subjects and the knowledge of the experts are homogeneous. Ludwig (1997), states the approximate size of a Delphi panel is generally under 50 and usually between 15-20 experts, if the participants come from various backgrounds. Hsu and Sandford (2007), further explain that if the sample size of a Delphi study is too small, the study may not be considered as having provided a representative pooling of opinions regarding the issue. If the sample size is too large, the drawbacks from the Delphi technique such as potentially low response rates from experts pulling-out, conflict of opinions and extension of time to achieve consensus may skew the results (Stata Press, 2013).

However, this study's mixed methodology requires the use of statistical analysis. In mixed methods, statistical analysis is a key component in designing the Delphi study and choosing the sample size of the panel. The sample size determines the invested time and the increase or decrease of the likelihood of the successful achievement of a study's objective (Stata Press, 2013). The tool used for statistical analysis in this study is SPSS which requires a larger sample to enable an accurate result of the issues in question (IBM, 2012). Complex samples are clarified by Hanafin (2004), to be usually large, due to the nature of different viewpoints included, as experts are required to choose their own markets to answer the questions. It has been suggested previously that a Delphi panel varies depending on the issues examined. The key aspect for participants involved in Delphi is to have requirements, 'willingness' and 'ability' to make a valid contribution to the issues in question (Hanafin, *ibid*). Therefore, to attain an adequate sample size that remains within both boundaries of Delphi and statistical analysis requirements, this study concludes a panel size between 50-100 experts to be suitable. This is because 50 and a 100 are round numbers that are easily manipulated statistically. In addition, a sample below 50 would be too small for statistical analysis, while above 100 would be too large within the time constrained to reach a consensus and would lead to a possible reduction of responses from the panel (Stata Press, 2013).

### 4.6.2 Delphi Rounds

The adoption of a ‘‘multiple choice-type’’ approach according to Hanafin (2004), allows for the use of measures of dispersion (e.g. Standard deviation, mean, median, maximum, minimum, frequencies and percentages) which is crucial in identifying a reliable consensus. The purpose of Delphi rounds is to establish agreement that can be measured and is usually determined through statistical variance in responses across rounds. Less variance in the rounds indicates a greater consensus, although according to Rowe and Wright (1999), respondents with more extreme views were more likely to drop out of the study than participants with more moderate views, resulting in the decrease in variance as a consequence of decrease in participants rather than consensus.

According to Hsu and Sandford (2007), the numbers of rounds are determined by the level of consensus that is considered suitable for the study. However, most amendment changes as a result from feedbacks occur in the transition from the first to the second round. Similarly to the number of participants in the Delphi panel, there are no set numbers of rounds to be conducted in order to achieve a consensus (Kalaian and Kasim, 2012). The Delphi technique may require as few as two rounds, if panellists have been provided with sufficient explanation leading to an early group consensus to be achieved (Hanafin, 2004). Furthermore, Black *et al*. (1999), clarifyed that two or three rounds are likely to result in some convergence of individual judgements, while more than three rounds are likely to have little impact on the level of agreement and to have adverse effects on the response rate. Other examples of Delphi have required up to four rounds, which resulted in lower response rates between each iteration of rounds (Hanafin, 2004). According to Kalaian and Kasim, (2012), most Delphi examples suggested comparing the averages or percentages of responses for each question from any two consecutive rounds will determine if another round is required. Additionally, once feedbacks from participants cease, it is an indication that no further amendments are needed; hence no further rounds will aid the establishment of a consensus. Using both approaches of ceased feedbacks from the last round and statistical comparison of mean, frequencies and percentages between two consecutive rounds, the Delphi researcher has the data required to conclude if no additional round for administering the Delphi survey is needed. To date, this method is typically used for analysing the collected Delphi survey data (Kalaian and Kasim, *ibid*).

Iteration is a key feature of the Delphi technique and feedback on the questionnaire is provided by participants at each round for amendments to be completed for the next round. Feedback has been defined as: the means by which information is passed between panellists so that individual judgement may be improved and debiasing[11] achieved (Rowe and Wright, 1999). Feedback from participants varies and may be provided in a number of different ways such as an attachment to the questionnaire or via email. The purpose of feedback is to improve the Delphi and allow each expert to revise his/her own judgement via the amendments made in light of the judgement of others (Turoff and Linstone, 2002).

The analysis of Delphi has two purposes according to Munier and Rondé (2001); firstly, to illustrate the feedback and amendments between rounds and secondly, to identify when consensus has been reached. However, there hasn't been an apparent agreement about the best method of identifying consensus; whether it is mathematical aggregation, statistical analysis or deductive qualitative reasoning. Rowe and Wright (1999), indicate in their review that a number of different descriptive statistics combined with deductive reasoning are used to determine a consensus. Statistical analysis can include median, mode, frequencies, percentages, ranks, upper and lower quartile ranges, regression weights or induced (If-Then) rules, combined with deductive reasoning to examine the reasons behind the expert's decisions in order to establish a coherent consensus (Rowe and Wright, *ibid*). This research uses multiple choice Delphi integrated with (If-Then) rules. Therefore, the methods proposed by Rowe and Wright (1999) in using deductive reasoning combined with statistical analysis of frequency and percentages is most suitable for this study to determine the degree and type of consensus. The (If-then) rules were integrated with Delphi to create a better understanding of the "reasons" behind the expert's feedbacks and decisions.

#### *4.6.2.1 Creation of Rounds*

Having a hybrid research design which uses statistical analysis and deductive reasoning, will enable accurate assessment of the experts' judgments. Additionally

[11] Debiasing is the art of reducing biases in human thinking, by finding a variety of useful bias-reducing techniques such as feedback and amendment loops within the Delphi study.

it can capture the areas of collective knowledge held by the experts which is not often verbalised or explored, hence encouraging new ideas about the issue in question (Franklin and Hart, 2007). Both Rowe and Wright (1999) have compared hybrid iterations with statistical analysis of consensus based on deductive reasoning; with iteration analysis based on standard statistics without deductive reasoning. Their findings indicated the former has greatly improved the accuracy of understanding the consensus. Moreover, combining the “multiple choice” Delphi with (If-Then) rules for the statements, provides accurate results, as it allows the experts to give their rationale on the choosing of what they believe is most suitable for the (If-Then) statement. This allows for the statistical analysis to be conducted via frequency and percentages on the “multiple choice options” and a detailed deductive explanation on the ‘reasons’ from the experts based on the (If-Then) statements. Furthermore, Rowe and Wright (1999), state that analysing a multiple choice type Delphi with (If-Then) rules using statistical models without reason will not give an authentic measurement of the consensus. Applying deductive reasoning with statistical analysis however, will enable a holistic view of the experts’ judgment, suggesting a significantly greater degree of accuracy.

The data collection will begin by firstly creating a pilot study, to ensure the participants understand the requirements and provide “deductive reason” feedback for the variables, measurements and scope that is relevant in achieving the objective of identifying the best suitable supply chain strategy. The pilot study will be created using the hybrid method of a multiple choice Delphi and (If-Then) statement which includes three options for the experts to select. The feedback from the pilot will be analysed using deductive reasoning and amendments will be applied for the first round to commence. The Delphi in this research relies on the knowledge and expertise of the participants to use deductive reasoning in giving clear and accurate indicators on the improvements needed for each round. Once feedback ceases, the study will be analysed using the hybrid method of statistical frequency and percentages as well as deductive “reasoning” to evaluate the type of consensus achieved.

## 4.7 Delphi Types

The main purpose of adopting a Delphi technique to decision-making is to provide a structured approach to collecting data in situations where obtaining a consistent sample is difficult and complex to achieve. The aim of employing a Delphi technique is to achieve consensus through a process of iteration. There are various types of Delphi, each suited to different studies (Table. 9). The research method position of the study and the objective determine the type of Delphi technique used (Hanafin, 2004). The position of the Delphi technique is supported through the utilisation of a qualitative and quantitative approach to data collection and the application of statistical measures to identify a 'consensus'. The inclusion of various types of 'experts' is based on the position of the reality on which 'experts' agree (Munier and Ronde, 2001). A key advantage of all Delphi technique types is the potential of recognising and acknowledging the contribution of each participant to the data collection and study (Hanafin, ibid).

*Table 9: Various types of Delphi techniques (Source: author)*

| Delphi Type | Explanation |
|---|---|
| **Classical (Original) Delphi** | Evolved by Dalkey and Helmer (1962)- anonymity - making decision- consensus |
| **Modified Delphi** | The modified Delphi involves having face-to-face interviews or a focus group for the first round. The number of rounds also varies however this form of Delphi technique uses more quantitative method of analysis. The critical unified factors remain, the use of an expert panel and the anonymity of the panel members. While focus groups and group interviews have occurred in the first round, the responses after are anonymous (Davidson, 2013). |
| **Policy Delphi** | The policy Delphi differs from other Delphi techniques in the formation of its expert panel and the overall goal of the research issues as the aim is not for making a decision or achieve consensus but rather to clarify an understanding of different plurality standpoints. It also has various number of rounds and ensures anonymity within the panel. (Rauch, 1979) |
| **Decision Delphi** | The decision Delphi aims to bring a group of decision-makes together to make decisions about future developments, in contrast with the policy Delphi that aims |

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|---|---|
| | to understand social situations. Whereas the classical Delphi deals with facts, a policy Delphi deals with ideas. The decision Delphi is not used as a tool for obtaining a group opinion about forecast statement (as in the case of the classical Delphi) but as a means for the analysis of decisions. (Rauch, 1979) |
| **Real Time Delphi** | The real time Delphi varies in its structure and is sometimes referred to as a consensus conference. Its aim is to ensure expert availability in order to reduce the drop-out rates and increase the efficiency of the processes. This is done by ensuring that participants are provided with a hyperlink to a welcome page where they read the details of the study and what is required and access the initial questionnaire. The process uses a refined interface, and the authors argue the outcomes. (Gnatzy, et al. 2011). |
| **e-Delphi** | Similar to the real time Delphi, the e-Delphi replicates the process of the classical Delphi, but the questionnaire, feedback, and participation of the expert panel is all done via email or online surveys. It can be argued that this approach is categorised under modified Delphi. (Gnatzy, et al. 2011). |
| **Technological Delphi** | Technological Delphi has similarities to the real time Delphi yet there are differences. The key difference is that the technological Delphi uses handheld devices to respond immediately to the questions (Passig, 2004). For example Voting can take place in real-time and this process tends to have a more quantitative analysis approach as it is more difficult to ask and explore open-ended questions (Davidson, 2013). |
| **Disaggregative Delphi** | Disaggregative Delphi is critical of the classical Delphi. The consensus is formed when panellists are asked to give estimates of probable and preferable futures. The method uses cluster analysis to disaggregate responses of key variables, which is considered more accurate. This study uses two rounds. In the first, quantitative questions are |

| | |
|---|---|
| | asked, while the second is qualitative and involve interviews of the panel members. (Davidson, 2013) |
| **Fuzzy Delphi** | Fuzzy Delphi is mostly utilised to generate a professional consensus for complex topics (Wu *et al*., 2013a). The advantage of fuzzy Delphi method is that every expert opinion can be considered and integrated to achieve consensus for group decisions (Wu *et al*., *ibid*). Moreover, it reduces the time of investigation and the consumption of cost and time. Additionally, the advantage of fuzzy Delphi method is its simplicity. All expert opinions can be encompassed in one investigation. Hence, this method can create more effective criteria selection (Wu *et al*., *ibid*). However, rounds vary and anonymity must remain. The Fuzzy Delphi method is a traditional forecasting approach that does not require large samples. However, once combined with quantitative questions and statistical analysis, the study moves towards larger samples to ensure accuracy (Wu *et al*., *ibid*). |

From Table. 9, it can be said that different Delphi studies vary in their difficulty to plan and conduct. They are generally fairly time-consuming and labour intensive and require (external) expert preparation and therefore can be relatively expensive. Different Delphi studies require various formalisations of methodology, amount of data, number of experts involved, different knowledge from experts, and different combinations of interviews and questionnaires. However, the Delphi method's ability to diverge opinions make it a popular and credible approach for various fields of study (Turoff and Linstone, 2002). The common factor in the various types of Delphi, which is considered an advantage is guaranteed anonymity which encourages opinions that are free of influences from others and therefore more likely to be 'true'. Another common factor which is also considered an advantage, is the Delphi questionnaire that has the capacity to capture a wide range of inter-related variables and multi-dimensional features from across a geographically dispersed panel of experts (Gracht, 2012). Amongst all Delphi types there are common disadvantages, for example a consensus can represent the lowest common denominator. However, according to Hanafin (2004), it could be argued that all approaches gaining consensus run this risk. Another common disadvantage of the Delphi approach is time, which when extended may threaten the credibility of the study. However, according to Hanafin (*ibid*), this can be mitigated by ensuring the commitment and expertise of the panel, reducing the number of rounds and achieving consensus. The general pros and cons that are commonly shared by the different Delphi techniques are illustrated in Table (10).

*Table 10: General Pros and Cons of various Delphi techniques (Source: author)*

| **General Pros and Cons of Delphi** | |
|---|---|
| ***Pros of Delphi*** | ***Cons of Delphi*** |
| As with other well-formalised methods, it forces people to think about the future. | A Delphi survey is actually always a mix of methods because a topic generation procedure is needed. |
| It gives participants the opportunity to think in more depth and gather further information between the rounds (psychological effect). | However, there is a danger of regarding results as facts. |
| It highlights clearly whether there is consensus on an issue or not. | Single opinions that might be of special value are also pooled and normally ignored. Only the accumulated results are published to preserve anonymity. It is difficult to find out reasons for dissenting answers later on, as this anonymity has to be respected. |
| There is a psychological effect and a communication effect in being forced to express ideas in a clear and concise way. | A poorly designed Delphi will provoke antagonism and elicit poor quality information. It may fuel criticisms of the overall Foresight activity with which it is associated. Therefore, a great deal of attention must be given to the choice of participants; the questionnaire must be meticulously prepared and thoroughly tested to avoid ambiguity. |
| The judgements allows for analyses, rankings and priority-settings. | Care has to be taken over group effects. As in all panels or expert groups, the opinions will reflect the set of participants |

| | |
|---|---|
| | involved: a narrow set of criteria for these may lead to unrepresentative views or miss out important sources of knowledge. |
| The output is in a form which is operational for many actors including policy makers. | Some participants drop out during the process (especially after the first round). In addition, although further qualitative assessment of Delphi inquiry may produce useful information, this step is often not carried out due to lack of time. |
| Even oriented towards action, Delphi surveys allow for longer-term thinking. | It is often difficult to convince people to answer a questionnaire twice or more and incentives may be needed (e.g. that the experts receive the results). The dropout-rate increases after the second or third round, so most current studies are limited to preparation and two rounds. |

From both Tables 9 and 10, it can be observed that although there are differences in the focus of definitions in the Delphi and the procedure of the technique, a number of distinct characteristics usually remain the same. Creation of statements to acquire the opinions from experts, anonymity, iterations, controlled feedback and amendments, qualitative and/or quantitative statistical analysis of the group response's response. While there are no required number of rounds, the most common number of iterative rounds appears to be two to three. The number of rounds, anonymity and selection of the expert panel are issues critical to all Delphi methods (Gracht, 2012).

### 4.7.1 Choosing a Hybrid Fuzzy Delphi

The Delphi method developed by Helmer and his associates has been widely used to date as one of the long-term forecasting methods (Dalkey and Helmer, 1962). The disadvantages of the traditional Delphi method include low consistency of expert opinions, high enforcing cost and modification of experts' individual opinions in order to reach consistent overall opinions (Chung and Chiang, 2011). One of the weaknesses of Delphi is that it requires repetitive surveys of the experts - usually more than twice - to allow accuracy of the forecasted values to converge.

However, with repetition comes cost and lower response rate, particularly for a complicated survey (Chung and Chiang, *ibid*).

To overcome these difficulties, the Fuzzy Delphi method proposed by Murray *et al*. (1985), aims to integrate the Delphi method and fuzzy theory. Murray *et al*. (*ibid*), added the membership function found in fuzzy theory to establish fuzzy rules in the form of statements to be given to each participant. Ishikawa *et al*. (1993), associated the membership functions with "the extent of expertise". This allowed for a tailored expert panel that is specialised in the understanding of the specific membership functions that are given the questionnaire in the form of fuzzy rule statements. Therefore, Ishikawa *et al*. (*ibid*), ensured that accurate fuzziness is incorporated in the findings of the Delphi study which can be analysed statistically using max-min and fuzzy integration algorithms. The integration of experts' opinions with fuzzy numbers is based on the concepts of cumulative frequency distribution and fuzzy integral, enabling a well-formed linguistic and systematic structure of rounds, resulting in a reduction of iterations (Ishikawa *et al*., *ibid*).

Hsu *et al* (2010), further acknowledges the advantages of Fuzzy Delphi compared to the other Delphi methods:

1) it reduces investigation time and costs as explained by Ishikawa et al. (1993);
2) individual experts' opinions can be clearly expressed without distortion due to the membership functions being integrated by fuzzy rule sets;
3) this creates a semantic structure that helps opinions to be clearly expressed;
4) the fuzziness in the issues being studies are investigated and addressed during the process; and
5) the Fuzzy Delphi is simple to create, conduct, its analysis process is simple and can statistically address issues such as multi-level, multi-attribute, and multi-scheme decision-making problems under uncertainty (Hsu *et al.,* 2010; Murray *et al*., 1985).

Shapiro and Koissi (2013), modified the Fuzzy Delphi to include the Analytic Hierarchy Process (AHP) which is a theory of measurement through pair-wise comparisons that relies on judgment to derive priority scales. The implementation of the (AHP), required the construction of hierarchies, allowing the study to make judgments or performs measurements on pairs of elements with respect to a criterion, deriving preference scales, which are then synthesised throughout the structure to select the preferred alternative (Shapiro and Koissi, *ibid*). The AHP has been incorporated in a study by Hsu *et al* (2010), as they applied a triangular fuzzy number into the Fuzzy Delphi to encompass experts' opinions and establish the value of the triangular fuzzy number of each alternate factor given by the experts. This allows the significant triangular fuzzy number of the alternate factors to be calculated using max and min values of expert opinions, as two terminal points of triangular fuzzy numbers, and the geometric mean is taken as the membership degree of triangular fuzzy numbers, to derive an accurate statistical value to the experts' opinion, and hence provides an unbiased effect and avoids the impact of extreme values. This according to Hsu *et al* (2010), will counter the disadvantage found in other Delphi methods such as that experts' judgments cannot be properly reflected in quantitative terms, in addition to some ambiguity in the outcome due to the differences in the meanings and interpretations of the expert's opinions. Shapiro and Koissi (2013), state that AHP can be applied for risk assessment and decision-making as it eliminates ambiguities, such as incomplete or unreliable data, and vague or subjective information due to the human error element of the experts in the communication of linguistic variables. Since AHP proved to be a reliable tool in Fuzzy Delphi, there has been considerable research based on adjusting the AHP in the application of Fuzzy Delphi (Shapiro and Koissi, *ibid*). However, if there are inconsistency in the judgmental of the fuzzy pair-wise comparisons, it is impossible to ensure a consensus using AHP and another method is then required (Hsu *et al*., 2010).

This has led to the widespread of using Fuzzy Delphi method in various fields for index selection. For example, Ma *et al.* (2011), adopted Fuzzy Delphi to quantify experts' attitudes toward road safety. Kuo and Chen (2008), applied Fuzzy Delphi to create key performance indexes for the service industries offering mobile services, while Chang *et al.* (2009), applied Fuzzy Delphi with AHP method for decision making issues of tackling uncertainty and imprecision of service evaluations during pre-negotiation stages, where the expert's comparison judgments are represented as fuzzy triangular numbers. Furthermore, Liu (2013) applied Fuzzy Delphi and fuzzy AHP to evaluate the important indicators of managerial competences. Fuzzy Delphi is useful as it demonstrates its effectiveness in establishing accurate outcomes. It aids human thinking and perception of things by reducing ambiguity as it is equipped in representing uncertainties and dealing with problems in a vague environment (Bezdek, 1993). Fuzzy Delphi has the ability to transform linguistic variables into fuzzy sets to replace the crisp set, as the values of linguistic variables are not numbers but words or sentences in a natural or artificial language. The concept is very useful in situations that are complicated or difficult to be appropriately described by traditional quantitative expressions (Chen, 2014).

#### *4.7.1.1 Philosophical Critiques of Fuzzy Delphi*

The Fuzzy Delphi method is considered a technique of mixed method data collection as it uses crisp numbers that can be analysed to establish the mean and median to evaluate research criteria. In order to deal with the fuzziness of human participants, Ishikawa (1993), combined fuzzy set theory proposed by Zadeh (1965) to improve the convergence of the uncertainty in experts' options and present them in meaningful crisp numbers. However, due to this study's analysis of different supply chain strategies the problem of uncertainty will be overcome by using different statistical tools such as SPSS and Excel, while the evaluation of the results will be presented using deductive reasoning to create a decision making matrix.

Fuzzy Delphi has since then been increasingly applied in a variety of disciplines such as, decision analysis, organisational management and forecasting (Burney and Mahmood, 2006; Edwards and Akroyd, 1999). Fuzzy Logic has also been used by Boissonnade (1984), for pattern recognition in the evaluation of the seismic intensity and damage forecasting in the development of models that estimate earthquake insurance rates and insurance strategies. Furthermore, Zhao (1996) used Fuzzy Logic to address the issue of maritime collision prevention and liability. This shows that fuzzy principals can be applied with Delphi in the field of social science to identify any patterns in the study and determine any skewness of experts' opinions (Edwards and Akroyd, 1999). These patterns will be incorporated into the supply chain MDM model to avoid any collision between the experts' opinions and the implementation of the model.

A summary of the advantages and disadvantages of Fuzzy Delphi are illustrated in Table 11, to indicate the usefulness of applying the method and its downsides.

*Table 11: Pros and cons of Fuzzy Delphi (Source: author)*

| Advantages of Fuzzy Delphi | Disadvantages of Fuzzy Delphi |
|---|---|
| 1. It is a well-formalised method, as it forces people to think about the future. If structured correctly, it can allow for longer-term thinking. | 1. There is a danger of regarding results as facts. |
| 2. It gives participants the opportunity to think in more depth as they gather further information between the rounds. | 2. A poorly designed Delphi will provoke opposed views and elicit poor quality information. It may fuel criticisms of the overall objective and the future foresight of the research. Therefore, a great deal of attention must be given to the choice of participants, the preparation of the questionnaire and it must be thoroughly tested to avoid ambiguity (Skulmoski *et al.*, 2007). |
| 3. It highlights clearly whether there is consensus on an issue or not. | 3. Single opinions that might be of special value are excluded and normally ignored. The accumulated results are published to prevent anonymity. It is difficult to find contradictions in answers later on, as any anonymity is omitted (Skulmoski *et al.*, 2007). |
| 4. It provides a psychological effect and a communication effect as it is a tool which helps expressing ideas in a clear and concise manner (Skulmoski *et al.*, 2007). | 4. Care has to be taken to prevent group effects. For example, in all panels or expert groups, the opinions will reflect the set of participants involved: a narrow set of participants may lead to unrepresented views or a smaller scale of important knowledge (Skulmoski *et al.*, 2007). |
| 5. The judgements gathered from the Delphi study allows for the analyses to rank and priorities ideas. | 5. Some participants drop out during the process, especially after the first round. Additionally, further qualitative assessment of the Delphi study may |

| | |
|---|---|
| | produce useful information; however, this step is often not carried out due to lack of time. |
| 6. The output of the Delphi study is in a form which can aid operational change for example in policy making research (Skulmoski *et al.*, 2007). | 6. It is often difficult to convince people to answer a questionnaire more than once and incentives may be needed (i.e. give the experts the results); as the dropout rate increases after the second or third round. |
| 1. A Delphi study is actually always a mix of methods because a research question needs several tools to prove the hypotheses put forward. The Fuzzy Delphi method was applied to select the competence of managers, because it not only solved the disadvantages resulting from the conventional Delphi Method, but also because its results would not easily be affected by extreme opinions (Skulmoski *et al.*, 2007). | 7. It is not applicable in all fields or cases, because the statements have to be formulated relatively quickly. Even when it is applicable, this short formulation reduces the statements from being formed with close to complete information (Skulmoski *et al.*, 2007). |

Due to the mixed methods of this study, the application of Delphi will be combined with elements of fuzzy logic, deductive reasoning and a couple of relevant tools that best suit the needs of collecting sufficient data and establishing consensus. Hence the creation of a Hybrid Fuzzy Delphi that is tailored to this study.

#### *4.7.1.2 Creating a Hybrid Fuzzy Delphi*

The Hybrid Fuzzy Delphi implemented in this study will incorporate different characteristics found in other Delphi studies in order to generate a reliable and tailored Hybrid Fuzzy Delphi that is suitable for this research. The panel for this research will be constructed by decision-making experts as illustrated by the decision Delphi. This research will send the questionnaire to the participants via a hyperlink to a welcoming page that has all the details of what is required for the study and access to the questionnaire online via Qualtrics, hence combining the elements of both real time and e-Delphi. The testing of the Hybrid Fuzzy Delphi will be conducted via semi-structured interviews to ensure the accuracy of the results and statistical analysis, hence combining the elements of Modified and Disaggregative Delphi.

Therefore, the Hybrid Fuzzy Delphi in this research will include multiple choice questions as in the previous section it was shown that it produced the most accurate results. Additionally, multiple choice questions are most suited to the Hybrid Fuzzy Delphi as this gives the experts options and room to account for any uncertainty or “fuzziness” (Wu, 2011). Each question will be given with an objective to measure a membership function, also known as “variable function”. The questions will be asked in a format of (If-Then) statements. This will give accurate results, in addition to being the most suitable method for writing statements that can be translated into fuzzy rules (Murray *et al.,* 1985). Each membership function “variable function” will be expressed and asked in a statement where experts will have three to four options to choose from. The results will be statistically analysed using frequency tables, scatter diagrams, mean and max. The analysis will contain deductive reasoning in order to further understand the expert’s decision, while the testing will be conducted via semi-structured interviews. Deductive reasoning plays an important part in analysis and provides accurate understanding of the issues being studied (Gracht, 2012). This research combines qualitative and quantitative analysis, hence statistical methods combined with deductive reasoning are most suited for this study in accurately understanding the fuzziness in the expert’s decision and eliminating any ambiguity in the results of the Hybrid Fuzzy Delphi.

In adding fuzzy principals into Delphi feedback loops, the Hybrid Fuzzy Delphi can be illustrated as an integrated system between Delphi study and the fuzzy controller system (Fig. 26). The purpose of the fuzzy control as defined by Terano *et al*. (1994), is to influence the behaviour of a system by changing an input or inputs of that system according to a rule or set of rules (If/Then statements) that model how the system operates, in the case of this study, the interactive MDM. The fuzzy controller is used to define a relationship that transforms the desired state and observed state of the system into an input or inputs that will alter the future state of that system (Terano *et al*., *ibid*). The input value is based on the difference between two values (defuzzification and fuzzification) (Fig. 26), where, the output of the fuzzy system establishes the desired state of the system (Yager and Zadeh, 1992).

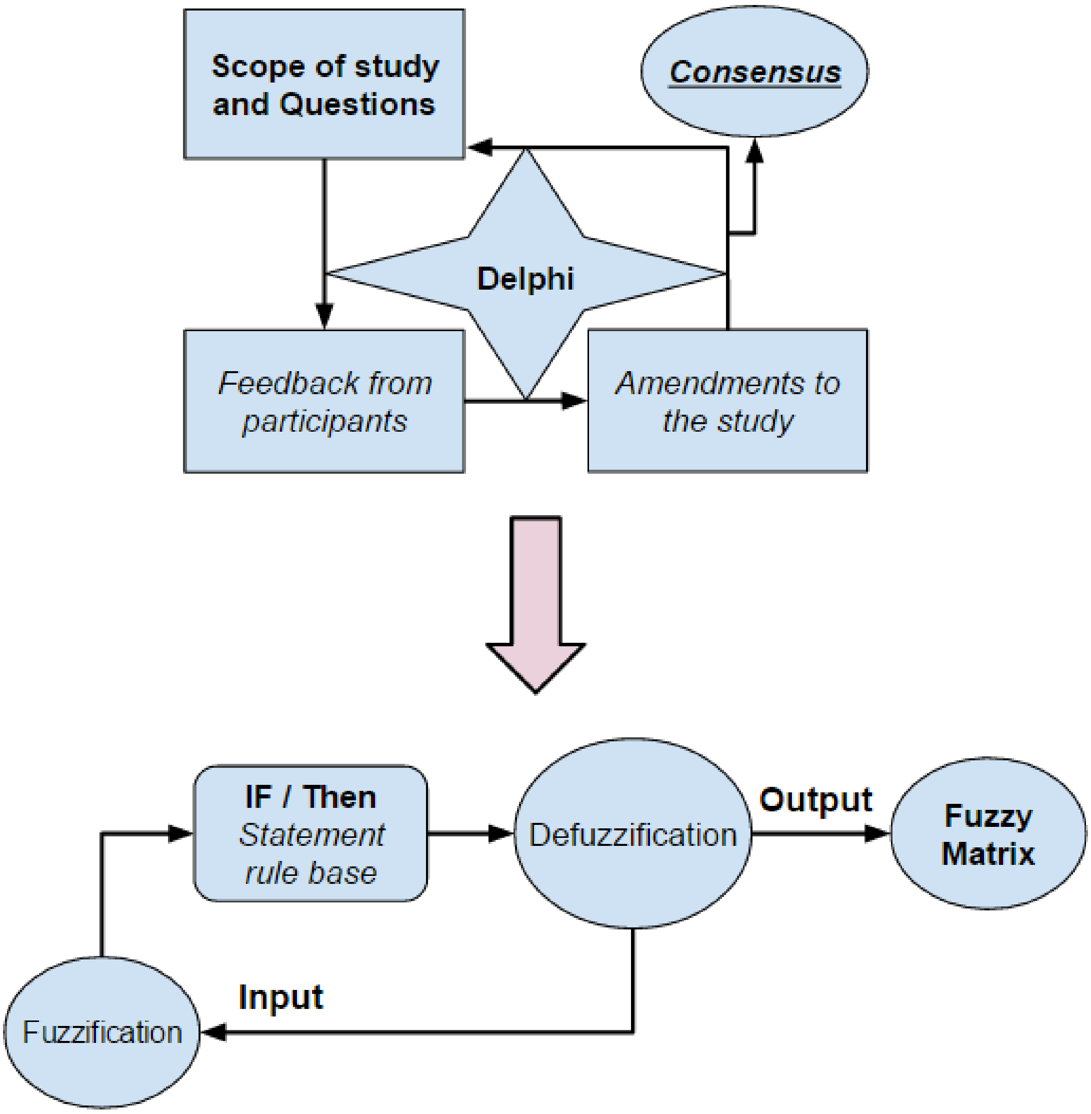


*Figure 26: Combining Delphi and Fuzzy controller into Hybrid Fuzzy Delphi (Source: author)*

The Hybrid Fuzzy Delphi process is based on combining both the Delphi feedback loop process and the fuzzy controller system in order to defuzzify the expert's opinions and create fuzzy rules that build the interactive MDM. The first stage is creating the (If-Then) statements which are the input to be sent. This stage is similar to the Delphi process as it defines the scope of study and sets the questions. Next, the statements are sent to the panel to be defuzzified and feedback is given. The feedback amend the statements which become the fuzzy input to be re-written as (If-Then) statements to be sent again. Once a consensus is achieved, it becomes the output that creates the fuzzy rules that build the fuzzy matrices called the interactive MDM.

The drawback of the fuzzy controller system as examined by Driankov *et al* (1996), is that it usually assumes that the system is being modelled in linear or at least behaves in some fashion that is a monotonic function. As the complexity of the system increases it becomes increasingly difficult to formulate the desired outcome, as the fuzzy controller can only describe a small section of the whole system (Driankov *et al*., *ibid*). The next chapters will further illustrate how the membership functions, (If-Then) statements will result in the fuzzy rule that will be added to create the interactive MDM.

### 4.7.2 Hybrid Fuzzy Delphi Variable Functions

In conducting the Hybrid Fuzzy Delphi, several variable functions were gathered from the literature review and theoretical framework to be used when required in the data collection. The purpose of these variable functions is to ensure clarity of the study and help experts answer the statements. These variable functions were selected based on their relevance to this study. In order to select the most relevant variable to the study, a table has been drawn to illustrate each variable function, its definition and benefits to the Hybrid Fuzzy Delphi (Table. 12).

*Table 12: Hybrid Fuzzy Delphi variable functions (Source: author)*

| Variable function | Definition | Beneficial to experts in the Hybrid Fuzzy Delphi |
|---|---|---|
| **Cost** | From the stages of manufacturing (cost of production) to customer. The cost includes the supply chain sector between producing a product, logistics distribution and delivery to the customer, including the cost of lead times during that process. | Customers vary between different companies from end retail, distribution centres or end wholesaler, it is important for experts to estimate the cost for their chosen products or good to be produced, distributed through the chain as it helps them understand what they believe to be the best suited strategy for |

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| | | companies to implement based on the cost factor they believe companies are willing to invest.<br><br>Experts establish their end customer, product or goods, in addition to estimating cost. The estimation of delay identifies the supply chain strategy that is best suited for various distribution systems. |
| **JIT Lean** | This study considers time to be lean – the more time is lost the greater the waste as time is a resource. JIT Lean is defined as the development of a value stream that eliminates all waste, including time, to ensure a sophisticated level of scheduling. Therefore the assumption that time is lean is measured by JIT system, hence the term JIT Lean. | The more experts define the best suited strategy using JIT, the more they understand the best strategy suited for waste reduction and lower inventory; impacting sourcing of raw materials, production and distribution cost which influences sales. JIT requires coordination with suppliers to avoid delays in the production schedule (Kootanaee, 2013). |

| | | |
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| **Delivery strategies**<br><br>According to Gunasekaran *et al.* (2001), there are three types of deliveries:<br><br>Delivery to request, delivery to commit date and order fill lead time. | To classify the response time between order and corresponding delivery to develop the appropriate trade-offs for the delivery system so they can be applied as a basis for planning a supply chain and delivery from manufacturing to customer (Beamon, 1999). | Measuring the effects of different types of logistics on the supply chain strategy, experts in this study estimate cost which is taken into consideration in planning the logistics delivery from manufacturing to customer, while choosing the supply chain strategy best suited for each logistic system. Experts take into consideration the JIT lean, so that overall cost effectiveness and waste elimination is considered in choosing the best strategy. |
| **Manufacturing cost**<br><br>The total cost of direct material, labour, and manufacturing overheads in the fabrication, assembly, and testing of an end item. This includes the utilisation of three inventory accounts for raw materials, inventory, work in process inventory, | According to Fisher (1997), if a company produces an "*innovative*" product, its demand is very unpredictable and in need of a responsive supply chain.<br><br>According to Fisher (1997), a "*functional*" product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in | It is important for companies to categories their product type. From the literature there are three types of product. As companies categorise their market they take into consideration the cost and JIT lean to identify under which group their product belongs to. In order to help companies define which supply |

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| and finished goods inventory. | need of an efficient supply chain.<br><br>According to Fisher (1997), an "*innovative functional*" product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as toothpaste. | chain strategy best suits each product group, the experts were required to estimate a cost (for manufacturing) and JIT lean along with their chosen market to establish which supply chain strategy suited each product group. |
| **Distribution strategies**<br><br>It integrates manufacturing in supply chains, as the material flow must be viewed from three aspects as a whole; strategic, tactical and operational (Stevens, 2007). | *Strategic distribution*: objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location of its key facilities. The competitive aspect is integrating its manufacturing and distribution with that strategy (Gunasekaran *et al*., 2001; Stevens, 2007).<br><br>*Tactical distribution*: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining the tools, | In order to measure the material flow of components, raw materials, or commodities, between, resources, different plants, manufacturing and customer. It's important for experts to assess the best supply chain strategy that is suited for each distribution system to help companies enhance the material flow within their supply chain to create an integrated system between the different nodes in the supply chain. This study focuses on the sector between manufacturing to customer, hence the |

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| | approaches, resources necessary to manage and provide the information infrastructure for the supply chain by using (MRP, DRP, JIT) (Gunasekaran *et al*., 2001; Monczka *et al*. 1994).<br><br>*<u>Operational distribution</u>*: concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately in terms of supplier performance, inventory investment, service level, throughput efficiency and cost (Stevens, 2007). | integration and flow of material will be between the resources delivered to the manufacturing, distribution of components to different plants, delivery of components or materials to customers (i.e. third part logistics who may be integrated into manufacturing and warehousing during a customisation for responsiveness). Experts would estimate a cost and JIT lean as they select the best suited supply chain for each delivery system. |
| **Measuring Output**<br><br>Output is measured by the number of items produced, the time required to produce a particular item and/or set of items and customer satisfaction which is measured by the number of on time deliveries and less | *<u>Customer satisfaction</u>*: Good flexibility and response to customer needs, good customer service and response to customer queries as well as post transaction customer service, such as problems arising from warranty claims. Less customers complaining about product features or quality, delays or shipping | The approach in measuring output is through generating more demand which is achieved when customer satisfaction is high (Tan *et al*., 1998). To measure customer satisfaction, the experts will be required to identify the best suited supply chain strategy that would reduce the |

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| led-time between order and corresponding delivery (Tan *et al*., 1998). | errors (Beamon, 1999). In providing a higher service level will require higher costs (Stevens, 2007; Tan *et al*., 1999).<br><br><u>*Customer order path*</u>: Is the path that orders travel by, where time is spent in non-value adding activities, such as paper work, checking, which can be eliminated by using JIT an EDI (Gunasekaran *et al.*, 2001).<br><br><u>*Manufacturing lead-time*</u>: Total amount of time required to produce an item or batch (Beamon, 1999; Simeonovova and Simeonov, 2012).<br><br><u>*Shipping errors*</u>: If a supply chain focuses on customer satisfaction in the retail industry number of incorrect shipments reflects on customer service as it is the combined effect of all functions along the supply chain (Beamon, 1999; Elfving, 2003). | cost and JIT lean in the customer order path, manufacturing lead time and reducing shipping errors. |

**Measuring Product Demand**

By looking at the (1) End-user requirement, or (2) substitute product, or (3) competing product; then assessing the total volume of a product that can be bought by a consumer group where the location, time period and marketing effort are defined.

**Product Life Cycle**

The product life cycle has 4 defined stages (Introduction, Growth, Maturity and Decline), each characteristics means different things for business that are trying to manage the life cycle of their particular products

There are three product types:

"*Innovative products*" carry risk as the product has a short life cycle due to unpredictable demand, requiring a flexible supply chain with- Flexible Manufacturing System (FMS) and Computer Integrated Manufacturing (CIM) (Fisher, 1997).

"*Functional products*" have a longer life cycle of more than 2 years with an average margin forecast error of 10% (Fisher, 1997).

"*High-end products*" have a fluctuating demand, to counter this uncertainty Fisher (1997) suggested a blend of three strategies- reducing uncertainty by identifying and analysing new sources of data, avoiding uncertainty by cutting lead times and incorporating flexibility and hedging against uncertainty with buffers of inventory or excess capacity

Further to measuring output by product demand, the life cycle of a product influences its demand, as it increases turnover. Products are made to expand consumption hence life cycle is crucial for planning obsolescence[12] (Maycroft, 2005). It is important for experts to choose the best supply chain strategy for each product category bearing in mind an estimated cost and JIT lean. This will help companies understand what supply chain their products require.

[12] BBC Two (2014)- The Men Who Made Us Spend http://www.bbc.co.uk/programmes/p01zxmrv

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| **Customisation**<br><br>A make-to-order lean pull system or and Agile system. | <u>*High-end:*</u> If a supply chain is focused on high-end mass customisation, then its selects a relevant approach for a product that is expensive or advanced in a company's product range, or in the market as a whole (Monczka *et al.*, 1994).<br><br><u>*Self-customised:*</u> enable the customer to change the product at any time to suit their own preferences (Alford *et al.*, 2000; Silveira *et al*. 2001). | It is important to identify the most suited supply chain strategy for high-end products as they are the most expensive in a company's product range, they often require customisation to make the items more personalised for the customer. Hence experts estimate a cost and JIT lean for the supply chain as they choose the most suited strategy. |
| | <u>*Collaborative customisation:*</u> Manufacturers that involve their customers in a dialogue to identify their needs and establish their requirements are using collaborative customisation, which is specifically tailored to that specific partnership (Alford *et al.*, 2000; Silveira *et al*. 2001). | There are different types of customisation that companies use. In order to gain variety of results and understand the best suited strategy for each, experts estimated the cost and JIT lean for each (Collaborative, Adaptive, Cosmetic and Transparent customiser) |
| | <u>*Adaptive customisation:*</u> enables the user to customise the product to their requirements (Alford | As competition is a crucial element, customisation is key. It is evident that customisation has |

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| | *et al.*, 2000; Silveira *et al*. 2001).<br><br>*The cosmetic customiser:* presents the product differently to each customer, whether through packaging or similar changes in distribution or services (Alford *et al.*, 2000; Silveira *et al*. 2001).<br><br>*Transparent customiser:* provide unique products or services in a standard form to each customer, without the customer's knowledge that the product or service is customised (Alford *et al.*, 2000; Silveira *et al*. 2001). | increased as a unique selling advantage commonly through self-customisation (Silveira *et al*., 2001). Therefore in order to identify the best strategy, experts were asked to choose based on their estimated cost and JIT lean. |
| **Push system**<br><br>A company makes-to-stock and maintains inventory level | *Push system:* According to Alford *et al*. (2000) and Stevens (1989), when a company pushes variety of goods into the market in hope that customers will find what they want. | The supply chain is divided into push and pull systems. The pull is indicated by the Lean strategy while Push can be a result of various strategies. In order to identify the best supply chain for a Push system. Experts were asked to estimate the Cost and JIT lean with regards to customisation to identify the best strategy. |

## 4.8 Minimising Non-response in Data Collection

In every data collection, the issue of non-response is critical; in the case of this research the data collection method is Delphi study. This problematic issue arises because qualified subjects can be difficult to find. If a small number of the invited participants chose not to respond at any stage of the data collection, the quality of the information generated will be downgraded. In order to mitigate the effects of non-response, a recommended individual (e.g. director of studies, supervisor, or a trusted colleague) can help identify other experts or colleagues in the research area (Franklin and Hart, 2007). Alternatively, asking recognised experts, potential leaders in the project field, and verifying those who have first-hand relationship with the targeted issue can help. A recommended individual can also help through a preliminary introduction of both the researcher and the targeted panel; especially in a society where personal relationships are of vital importance, such influence and assistance are extremely useful (Kalaian and Kasim, 2012).

It is equally important to illustrate why the experts are chosen for the Delphi study as well as why that specific topic is necessary and important. If the participants are unwilling to participate in the Delphi study they can inform the statement sender of their decision during the initial contact. Additionally, even if experts chose to participate they can become unavailable during different stages of the study (e.g. due to clash of holiday schedules). To deal with this issue there are several reminder strategies; for example, providing incentives, setting deadlines, the use of telephones, post cards, or e-mail (Turoff and Linstone, 2002).

In this research, minimising non-response was managed though establishing face to face contact with some of the panel members via conferences and university associations. Additionally, contacts were established via personalised emails sharing interest in the issues addressed in this study. The panellists were given a reason and cause to aid in this research as well as an incentive to be updated with the results and informed of the outcome of this study. Panellists were notified of their important role in partaking in the Hybrid Fuzzy Delphi study and the crucial effects their withdrawal would have on the results. Hence, each participant understood the impact of their commitment in the study.

Though there is no binding contract to the Delphi, participants who did not respond were kindly reminded via e-mail of the significance their input would be in the creation of the interactive multi-dimensional model that is being created to aid companies identifying the best suited supply chain strategy for their market. All panellists were ensured of anonymity and confidentiality through the study.

## 4.9 Ethical Implications

This study believes the Delphi approach is ethical and facilitates ‘fairness’ to the panellist’s representation of their views. Each participant has an equal opportunity to have their views taken into account. Alternative mechanisms for reaching consensus do not provide a transparent decision indicator as Delphi, as the capacity of the Delphi technique to achieve rational decisions by ensuring the inclusion of every participant leads to greater acceptance of the Delphi techniques’ findings than any other method (Hanafin, 2004).

Participants will be informed about the purpose of the study, the procedures to be followed, the anticipated time commitment, and contact details if they wish to ask any questions about the study. Participants are free to withdraw from the study at any time. Therefore the potential for harm in this study is relatively low, because participants will be mature adults and, as each will be chosen on the basis of their expertise, they are not considered vulnerable. Nevertheless, other ethical issues revolving around consent, privacy and confidentiality of data will also be considered, as every effort will be made to protect the confidentiality of the participants. The basis of anonymity is that information provided by participants should not reveal their identity, which is the essence of the Delphi technique.

This research is conducted by one member, therefore all individual names, contact details and positions will be held safely throughout the Delphi processes and questionnaire feedback. Participants were informed that although their names and contact details will remain confidential, for research purposes their institution and position title or expertise should be listed to clarify the authenticity of the Delphi in this study. The majority of participants gave their consent and provided their full details, while others wished their names to remain anonymous, hence a list of the panellists was formed (Appendix A).

During the Hybrid Fuzzy Delphi process, assurances of confidentiality was given to all participants via a code number generated by Qualtrics, which also complies with participant confidentiality by making the completion of the contact detail fields non-mandatory. Therefore, completed questionnaires were identifiable only by their code number and the participants' institution and position title or expertise. In order to maximise response, some of the experts were contacted and reminded to complete the study with an incentive to be included in the study with their consent.

# Chapter 5

# Data Analysis of Hybrid Fuzzy Delphi

*“The goal is to turn data into information, and information into insight.” – Carly Fiorina*

As explained in the previous section, there are many different types of Delphi study. However, this thesis will explore and conduct a Hybrid Fuzzy Delphi type questionnaire. Due to the nature of conducting a questionnaire that relies on experts choosing their own products and customers in order to select a valid option, the Delphi study requires flexibility in designing its statements to take into account the various variables. This leads to allowing a degree of fuzziness in order to create a generic model accounting for different perspectives that can also be tailored to a company’s needs. The Hybrid Fuzzy Delphi’s characteristics were considered most suitable to accomplish this collection of data.

## 5.1 Collection Process

The collection process started in the year 2014 for four months which involved the selection of experts and conduction of the study. The most important steps in the Delphi process is choosing an appropriate issue, as they directly relate to the quality of the results generated (Turoff and Linstone, 2002). To outset the collection process, this study must first establish the panel of experts. Then the statements are sent and later formulated as fuzzy rules in order to design the interactive MDM.

The selection of Delphi subjects is generally dependent upon the disciplinary areas of expertise required by the specific issue (Davidson, 2013). Hence, the establishment of the panel was conducted by researching a considerable amount of worldwide experts in the field of supply chains and contacting them via email, Linked-in, journals and conferences. The panel should be highly trained and competent within the specialised area of knowledge related to the target issue, to enable them to answer the statements with experienced judgment (Davidson, *ibid*). Therefore, this study chose senior academics of a Doctoral degree or above, and senior consultants and managers from supply chain and/or logistics industries. The Delphi study requires the experts to stay throughout the multiple-round process. Hence, a letter was emailed to each expert, explaining the terms and the importance of experts completing all the rounds (Appendix C). A collection of 90 experts were found from academia and industry to establish a panel with a variety of supply chain disciplines worldwide (Appendix A).

### 5.1.1 Pilot Delphi

In order to create the fuzzy parameters; a pilot Delphi study was created on the "Cost" and the "JIT Lean" of a supply chain as a crisp set (Figs. 22 and 23), in order to determine the fuzziness which will initiate the Hybrid Fuzzy Delphi parameters. The statements were designed using "If" and "Then", to enable accurate fuzzy answers to the Delphi.

The crisp set according to Terano *et al*. (1994), indicates a group which has clear characteristics such as {0, 1} and computing language which operates under crisp logic. The foundations of crisp logic are that it has two defined values such as "yes" or "no" and "true" or "false" as commonly found in a standard Delphi study. However, the opposite of that would be fuzzy set and fuzzy logic. The crisp set and fuzzy set are linked, as the fuzzy set is the extended concept that includes the concept of a crisp set (Terano *et al*., *ibid*). To gain an understanding of the fuzziness, this study will start with a crisp set in the pilot Delphi to determine what experts perceive as a fuzzy set that will be used for the actual Hybrid Fuzzy Delphi iterations.

The pilot Delphi was initiated by giving the panel the (If-Then) Cost and JIT Lean statements based on the following scope: "SME's [50-250 Employees, ≤ £10m-50m turnover, ≤ £10m-43m balance sheet total] and multinational corporation (MNC) which manufactures products or source commodities domestically or internationally to be sold at a local or international market, excluding service providers."

The pilot Delphi was conducted with crisp set percentages for Cost and JIT Lean, with 0-60% for Cost and 0-90% for JIT Lean. The Cost range was created from 0-60% rather than a 100% as deductively, the total cost of a product from manufacturing to end customer cannot exceed 50% of production and distribution cost. For example, using the 0-60% maximum range of this study, if a production and distribution of a product is 12%, this will include the cost of materials, the cost of operating the equipment to make the product, the cost of storage and distribution to the end customer; the remaining 48% would be cost of labour, equipment repair, rental of premises or warehouses, cost of resources and materials, cost of outsourcing to any third party company, taxation, customs and marketing. Due to each company having a different operational cost, in order for a company to maximize profit, it should set its Marginal Revenue (MR) equal to the Marginal Cost (MC). The Marginal Cost is the increase in Total Cost (TC) from producing one additional unit, while the Marginal Revenue is the increase in revenue from the sale of one additional unit. To determine the increase in profit, the Marginal Profit "(Mπ) = (MR) – (MC)", determines when the total profit reaches its maximum point. If MR > MC at some level of output, Marginal Profit (Mπ) is positive and thus greater quantity should be produced. However, if MR < MC, Then Marginal Profit (Mπ) is negative and a lesser quantity should be produced. At the equilibrium output level where (MR = MC), the Marginal Profit (Mπ) is zero and this quantity is the one that maximizes profit. As total profit increases when marginal profit is positive and total profit decreases when marginal profit is negative, it must reach a maximum where Marginal Profit (Mπ) is zero, hence when (MR = MC). As each company has a different equilibrium point for output levels to be maintained, for simplicity, this study assumes this point to be 60% total cost of production (Fig. 27).

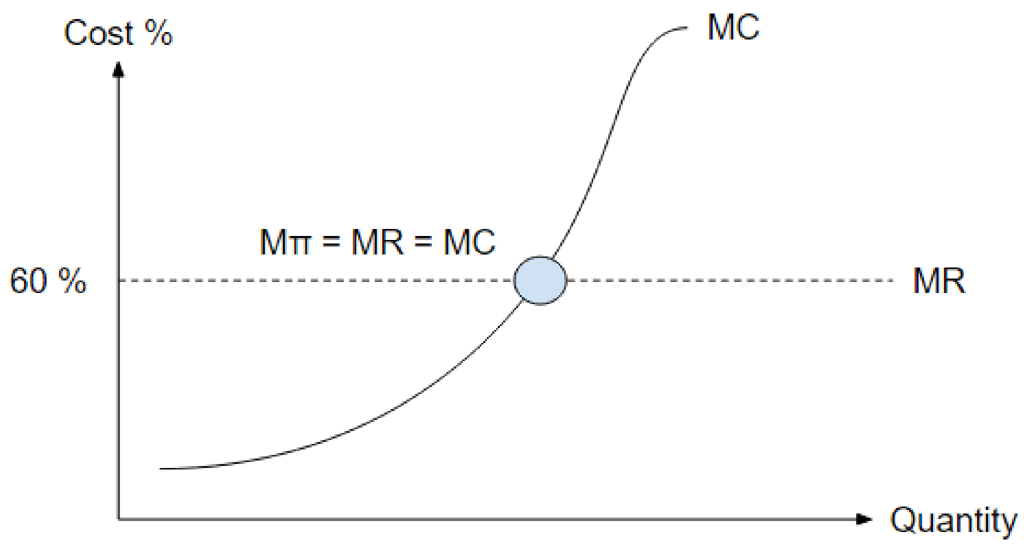


*Figure 27: Marginal profit equilibrium*

Similarly the JIT Lean was plotted to be 0-90% maximum initially, as it is impossible to achieve 100% leanness due to companies operating with a certain degree of waste. Although, Herzog and Tonchia (2014), examined a case study of 72 medium and large-sized Slovenian manufacturing companies that operated with efficiency yet maintained a degree of waste. However, Herzog and Tonchia (2014) noted that only a few companies that operate with a Lean strategy can achieve > 90% leanness.

The pilot study starts with a crisp set of 0-90% JIT Lean, it looks at identifying whether the leanness range can increase throughout the pilot Delphi and the Hybrid fuzzy Delphi rounds, and to determine the maximum range for it. The experts were given a crisp set of the Cost range as shown in (Fig. 28). The expected outcome would be for the "Low cost" range to be between 0-20% Cost, the "Medium cost" to be between 21-40% Cost, and for the "High cost" to be between 41-60% Cost.

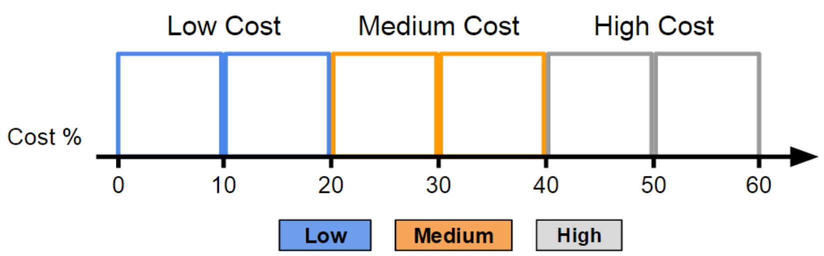


*Figure 28: Cost variable crisp set (Source: author)*

Moreover, the experts were given a crisp set for the JIT Lean range as shown in Fig. 29. The expected outcome would be for the "Low JIT Lean" range to be between 0-30%, the "Medium JIT Lean" to be between 31-70%, and for the "High JIT Lean" to be between 71-90%.

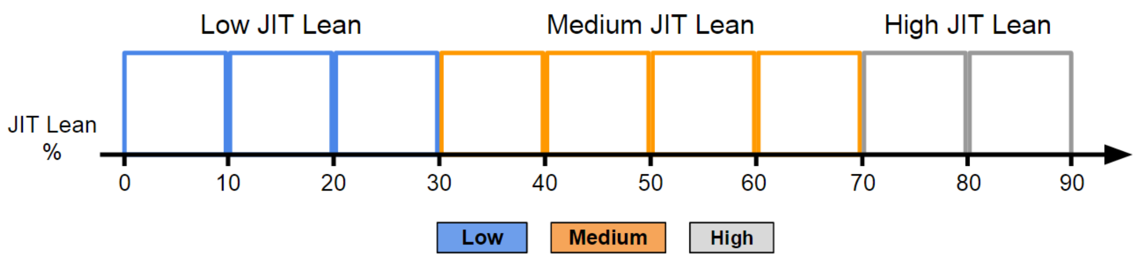


*Figure 29: JIT Lean variable crisp set (Source: author)*

Furthermore, the pilot panel was asked to answer the statements with regard to the four dimensions of supply chain strategies (Agile, Lean, Leagile, and BSC,). Each dimension was assigned using the theoretical framework in the literature review to its relative quarter in the matrix. Connecting this matrix with the conceptual framework from the literature, this study placed Basic Supply Chain (BSC) strategy in the lower left quarter with low cost and relatively low JIT Lean. Meanwhile, Lean supply chain strategy was allocated in the upper left quarter with low cost and high JIT Lean. The Leagile supply chain strategy took the upper right quarter with high cost and high JIT lean; while Agile strategy was allocated at the bottom right quarter with high cost and relatively lower JIT Lean (refer to Fig.18). The experts were asked to rank the “Cost” and “JIT Lean” according to what they deemed “High”, “Medium” or “Low” with regards to the four main strategies of supply chains, Agile, Basic, Lean and Leagile. This process was conducted for both “Lean JIT” and “Cost” of a supply chain (Appendix D).

For the “Cost function”, the experts were presented with six statements coinciding with the “Cost range” from (0-60%). For example the first statement presented to the experts was; “If a company's supply chain cost is 0-10% of the revenue then it is: “Low cost, medium cost or high cost”. The multiple choice statement allows experts to think rationally before choosing what they believe is the best suited option to their selected commodity or product. This results in experts exercising careful judgment and giving a well thought response, which gives a preliminary prospect to what the consensus might be (Munier and Rondé, 2001). Moreover, with the “JIT Lean function”, experts were presented with nine statements coinciding with the “JIT Lean range” from (0-90%). For example, the first statement was “If a company's supply chain is 0-10% JIT then it is: “Low lean, medium lean or high lean”. Experts then consider which choice best suits the percentage of JIT Lean in order for deliveries to be on time. This means that if a company’s supply chain is 10% JIT Lean, then there is a 80% lead time, hence the majority of experts have considered the most appropriate choice is “Low lean”, indicating it’s not a favourable position for the company.

Moreover, the answers from the pilot Delphi not only created a fuzzy area but also established a slightly changed range for the Cost and JIT Lean percentage (e.g. Cost percentage = 0-9%, 10-19, 20-29, and JIT Lean percentage range = 0-9%, 10-19%, 20-29%) (Figs. 30 and 31).

For the Cost percentage the “Low” range became from 0-19% where an intersection occurs between sets as some experts opinions differed, in classifying 9-10% as medium, though the majority consensus agreed it is “Low cost”. Moreover, a fuzzy area appeared as the majority of experts started choosing >19% as “Medium” range. Though there is a fuzzy area between 29-30% and 39-40 as some experts ranked it as “High”, the consensus remained “Medium” until 49% where the fuzzy area shows majority of experts started choosing “High” Cost (Fig. 30).

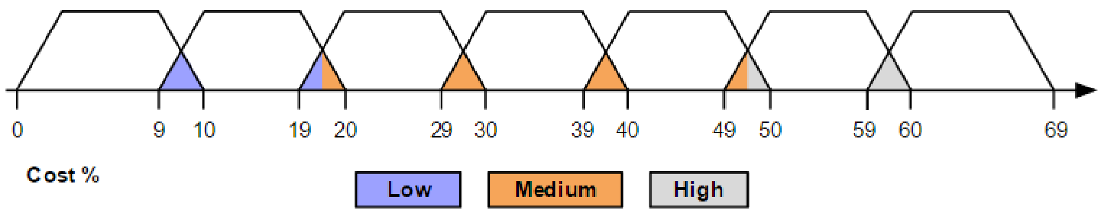


*Figure 30: Cost variable pilot Delphi fuzzy set (Source: author)*

For the JIT Lean percentage the “Low” range became from 0-29% where a fuzzy area appeared as experts started switching to “Medium” range. Though there are intersections between 9-10 and 19-20% due to some experts ranking the ranges as “Medium” the majority consensus remained “Low”. At 59-60%, another prominent fuzzy area became clear as experts started choosing “High” JIT Lean (Fig. 31). Similarly, the intersection between 39-40 and 49-50 was due to some experts ranking it as “High”, though the consensus remained “Medium” JIT Lean. The intersections between 69-70%, 79-80% and 89-90% show an area where a number of experts ranked these ranges as either “Low” or “Medium”, though the consensus remained “High”. However, although the answers for the Cost didn’t show experts exceeding 60%, with the JIT Lean, several experts stated that only >90% is considered “High” JIT Lean. This was taken into consideration in the amendments to conduct the Hybrid Fuzzy Delphi.

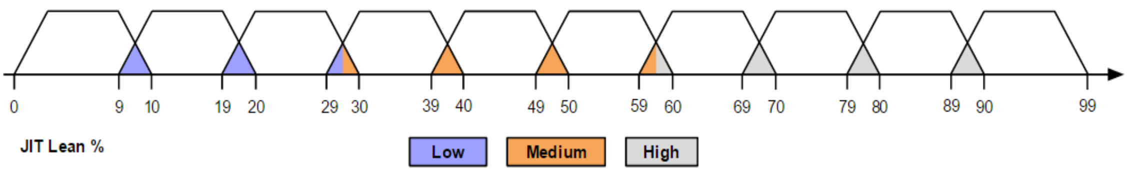


*Figure 31: JIT Lean variable pilot Delphi fuzzy set (Source: author)*

In order for the statements to be translated into fuzzy rules they must allow a degree of fuzziness. Therefore by having multiple choices, the supply chain and logistics variables measurements can be ranked into “Low, Medium and High”, with “Medium” as the fuzzy area.  These three parameters allow the fuzzy principles to create the variables that account for a grey area (refer to Fig.18), which is the fuzziness in the experts’ answers. This provides more accuracy as it allows for a medium flexibility for decision making rather than the traditional “yes” or “no” answers, giving managers room to manoeuvre around decision making, allowing for creative judgment based on intuition and experience.

The preliminary consensus from the pilot study created the range for the fuzzy area by identifying the medium percentages for both “Cost” and “JIT Lean”. From the experts’ answers (Fig. 30-31) illustrates the fuzzy area of the “Medium Cost” between “20-49%” and the “Medium JIT Lean” between “30-59%”.

The experts’ answers conclude that some companies may find themselves in the fuzzy area illustrated in (Fig. 32) if they catered for a high-end product, but it’s not considered a favourable position. The preliminary results from the pilot study indicates that experts recommend for a company to be in the “Low Cost” range between “0-19%” and in the “High JIT Lean” range between “60-99%”.  The experts considered the “High Cost” range and “Low lean” range to be a dangerous position for the company which should be avoided (Fig. 32).

| | Lean JIT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| High Lean | 90 - 99 % | Lean | | | | | | Leagile |
| High Lean | 80 - 89 % | | | | | | | |
| High Lean | 70 - 79 % | | | | | | | |
| High Lean | 60 - 69 % | | | | | | | |
| Medium Lean | 50 - 59 % | | | | | | | |
| Medium Lean | 40 - 49 % | | | | | | | |
| Medium Lean | 30 - 39 % | | | | | | | |
| Low Lean | 20 - 29 % | | | | | | | |
| Low Lean | 10 - 19 % | | | | | | | |
| Low Lean | 0 - 9 % | BSC | | | | | | Agile |
| | Cost | 0 - 9 % | 10 - 19 % | 20 - 29 % | 30 - 39 % | 40 - 49 % | 50 - 59 % | 60 - 69 % |
| | | Low Cost | Low Cost | Medium Cost | Medium Cost | Medium Cost | High Cost | High Cost |

*Figure 32: Preliminary MDM (Source: author)*

The four dimensions of supply chain strategies (Agile, Lean, Leagile and BSC) are designated into quarters due to their different “Cost” and “JIT Lean” requirements. However, all four dimensions share characteristics, hence they merge together within the fuzzy area. For example, the Agile strategy is commonly used for innovative products, which require higher cost and accounts for flexible lead-times that are above the medium JIT Lean, hence a company adopting this strategy may be allocated in the medium fuzzy area (Jüttner *et al*., 2006). The experts’ answers deductively conclude that Agile strategy should have a maximum cost up to “20-<29% cost” and a minimum lead-time of “>59% JIT Lean” (Fig. 32). The fuzzy area between BSC and Lean is due to both strategies being most suited to a functional product, hence when a company uses a BSC strategy it would commonly require low cost and scheduled and predictable lead-times preferably above the medium JIT Lean, while companies implementing a Lean strategy would naturally tailor their systems to reduce waste with minimal lead-times and cost (Hines, 1998). The experts’ statements deductively conclude that BSC strategy shares a fuzzy area with regard to having a minimum lead-time of “50-59%”, companies with a BSC strategy should aim to be above that percentage (Fig. 32). Lastly the Leagile strategy is commonly most suited to an innovative functional product that commonly requires higher cost and minimal lead-times, hence companies who adopt a Leagile strategy could be allocated at the lower end of the medium cost fuzzy area and aim to be above the fuzzy area of medium JIT Lean.

The amendments from the pilot study were given based on the scope of the variable functions as they are insufficient in determining the most suitable strategy for the supply chains. The experts requested definitions of what constitutes the "Cost" and "JIT Lean" variable functions. Therefore, for the Hybrid Fuzzy Delphi, extra definitions and variable functions were added in order to establish a more accurate representation of the experts' judgment.

The pilot study was conducted using Google surveys linked to Google spread sheet (Excel) in order to automatically generate the preliminary MDM as the questionnaire is being answered in real time. The formulas used are "date" to initiate the timestamp, "chart" to like the Excel sheets", "array formulas", "count if" and "If-Then", to link the survey with the excel sheet in order to interactively build the preliminary MDM (Appendix E). Each participant has a time stamp as they answer the pilot study, in addition to the excel sheets being interactively linked to generate the preliminary MDM (Appendix F). For the final Hybrid Fuzzy Delphi rounds the survey tool used was Qualtrics, as it provided advanced tools that help import the data directly into SPSS and Excel which easies the analysis process. The interactive MDM would be a web-based tool created via HTML and JavaScript, the interlinked Google Survey method is deemed unnecessary for the final Hybrid Fuzzy Delphi study.

## 5.2 Hybrid Fuzzy Delphi Rounds and Responses

The amendments from the pilot study were made for the first round of Hybrid Fuzzy Delphi, with added variable functions such as: Logistics based variable functions titled "Delivery strategies" that consist of, Delivery to request, commit date and order fill lead time, in addition to "Distribution strategies" that consist of Strategic, Tactical and Operational distribution. Additionally there are Customer Order Path, Manufacturing Lead Time, Shipping Errors and Customer Service. The supply chain based variable functions include Innovative, Innovative Functional and Functional product. Additionally it includes a group of "Product strategy" variables such as High-end product and Push system. It also includes a "Customisation" group variables consisting of Self-customisation, Collaborative customisation, Adaptive customisation, Cosmetic customiser and Transparent customiser. The "Life cycle" variable function looks at the different strategies for the innovative and functional product (refer to Table. 12).

The amendments to the variable functions included different parameters. In addition to choosing between "Low, Medium or High", the experts will choose which supply chain strategy (Agile, Lean, Leagile or BSC) is most suitable for each of the variable functions. The fuzzy aspect of these parameters is the rating of which strategy is recommended to be most favourable and which becomes an option. Therefore giving managers a range to choose what best suits their need, in addition to the recommendation.

The amendments regarding the definition of "Cost" and "JIT Lean" were made to identify the "Cost" from the stage of manufacturing (cost of production) to end-customer. The definition of end-customer varies between different companies from end-retail customer, distribution centres or end-wholesaler. Therefore, when experts answer the statement, they not only chose their own products but also who they considered as an end-customer. Hence, the supply chain "Cost" definition consists of producing a product, logistics distribution and delivery to the end-customer, including the cost of lead-times during that process.

The definition of JIT Lean is the assumption that time is lean, the more time is lost the greater the waste, as time is a resource. Leanness means developing a value stream to eliminate all waste, including time, and to ensure a sophisticated level of scheduling (Mason-Jones *et al*., 2000). Therefore, the more a supply chain strategy moves towards leanness, by eliminated waste and reducing lead-time, the more lean it becomes as defined by the JIT system. Hence, the definition is: Time equals leanness measured by the JIT system.

The "Cost" and "JIT Lean" definitions were added to the new variable function to construct the Hybrid Fuzzy Delphi to be sent for its first round. Hence, the experts would be required to choose a product, commodity or good[13], determine their end-

[13] Commodity: is a resource that is taken from its natural state and, if necessary, brought up to meet minimum marketplace standards, hence no value is added to the commodity. Examples include copper, iron, crude oil, wheat, coffee beans and gold. Newer commodities include foreign currencies, cell-phone minutes, bandwidth or services. Commodities are traded on exchanges primarily in the form of contracts to buy or sell by a specified time in the future at a certain price, hence has the potential to experience significant market volatility.
Goods: can be used to satisfy some desire or need. A good is a tangible physical item that can be contrasted with a service which is intangible. As such, it is capable of being delivered to a purchaser and involves the transfer of ownership from seller to customer. For example car parts

customer, then begin the Hybrid Fuzzy Delphi study by answering the statements for each added variable function based on the "Cost" and "JIT Lean" definition provided. Bearing in mind their chosen factors and the percentages they selected for the "Cost" and "JIT Lean", the experts were asked to choose the best supply chain strategies (Agile, Lean, Leagile and BSC) for each variable function based on their chosen conditions. The purpose of allowing the experts to choose their own product, commodity or good and to determine who is their end customer, is to allow the Hybrid Fuzzy Delphi study to gain a variety of opinions that would enable it to create the MDM model that would have accounted for various circumstance, which would be difficult to underline and account for otherwise, without the experts setting their own conditions and answering the Hybrid Fuzzy Delphi statements based on their experience. This ensures that experts' answers would have undergone a series of decision making that will help in the creation of the multi-dimensional model for companies to use in identifying or diagnosing the supply chain strategy that best suits them (Appendix G). The statements in the rounds of the Hybrid Fuzzy Delphi are considered a hybrid between a multi-choice and ranked type Delphi. Although experts are asked to choose one option of a supply chain strategy (Agile, Lean, Leagile and BSC), the results indicate a ranking between the strategies that is most preferred or favoured and the ones considered an option. This ranking is essential in creating the (If-Then) fuzzy rule statements that require options that the interactive MDM can recommend based on the selected criteria, and the company can select the options most suited to its requirements.

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are goods while the car is a product. However commonly a merchandise that is not branded is referred to as a good and once it is marketed and branded it becomes a product. For example leather is a commodity, manufactured to make leather bags makes it a good, finally marketing and branding transfers it onto a product.
Products: something produced by effort, or some mechanical or industrial process using commodities. A product is a good that can be differentiated and value can be added by the manufacturer as well as through branding and marketing. Products are classified as either a durable or consumable good. Durable goods, such as branded furnishings, are built to last, while consumable goods are used quickly or need frequent replacement, such as branded seasonal garments.
http://english.stackexchange.com/questions/32791/distinctions-between-goods-and-commodities
http://www.investopedia.com/ask/answers/021615/whats-difference-between-commodity-and-product.asp

### 5.2.1 Round One: Processing Data

After the amendments from the pilot Delphi were made, the fuzzy parameters were created along with the amended statements which initiated the first round of the Hybrid Fuzzy Delphi. The responses from the first round slightly altered the range for the Cost and JIT Lean fuzzy set percentages, illustrated in the following matrix (Fig.33).

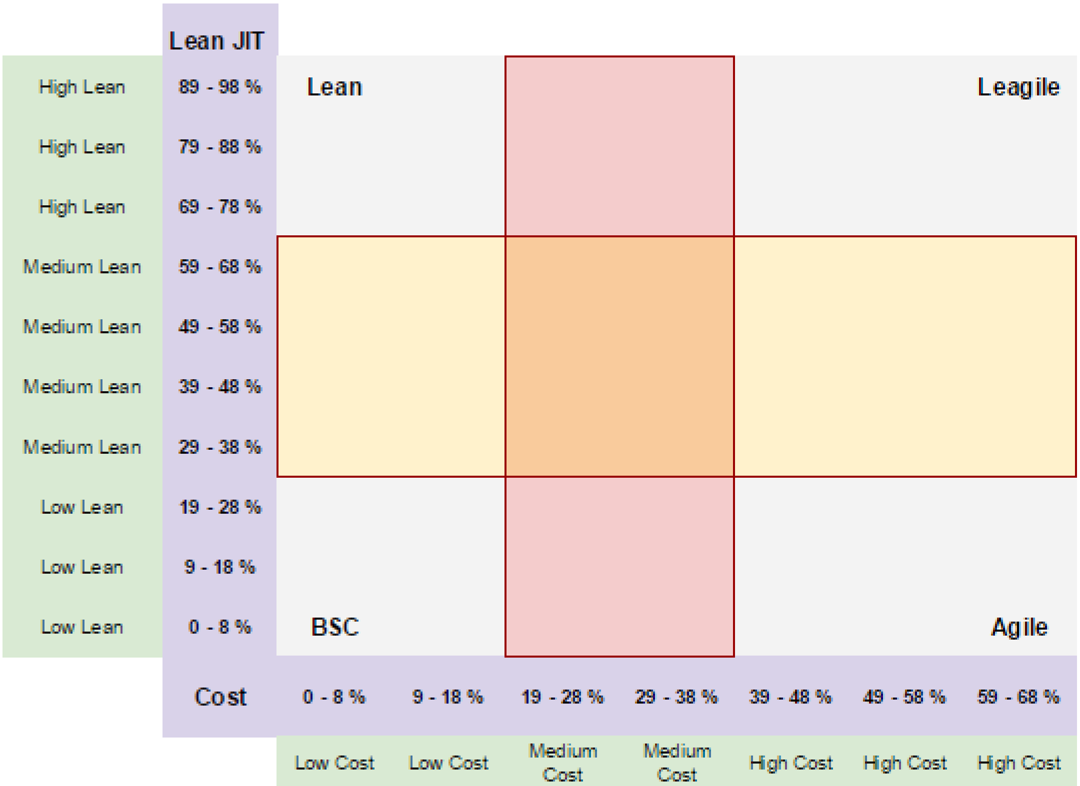


*Figure 33: Hybrid Fuzzy Delphi round one MDM (Source: author)*

The matrix indicates a fuzzy area between 29-69% JIT Lean and 19-39% Cost. Some companies may find themselves in this area due to the type of product they produce. However, the favourable position as indicated by the consensus, is > 59-68% JIT Lean and below 19-28% Cost. The highlighted area can be identified from these two diagrams.

The intersections in the first diagram are between the cost percentage sets where experts' opinions enter a fuzzy area. From 8-10% the majority of experts believe it is "Low", although some divergences of opinion occur, as each expert is required to select their own product and distribution method for their chosen end customer. However, at 18-20% a distinct difference occurs as the majority of experts shift to

"Medium" cost. Between 28-30% the majority consensus remains as "Medium" with some difference in opinion, creating a fuzzy area. However, at 38-40% another distinct shift occurs as expert opinions go towards "High" cost. None of the experts' feedback suggested any cost exceeding the 58-60% maximum range. Hence, the "Low" range can be said to be between 0-18% cost, while the "Medium" range is from 19-39% cost, and "High" from 40-60% cost (Fig. 34).

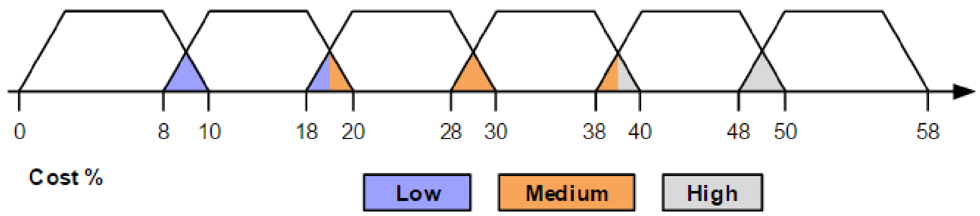


*Figure 34: Cost variable round one Hybrid Fuzzy Delphi (Source: author)*

The intersecting triangles in the second diagram illustrates where experts' opinions crossed over as each range (fuzzy set), intersected creating a fuzzy area. From 8-10% and 18-20% majority of experts achieved a consensus of "Low" JIT Lean with a few exceptions ranking it as "Medium". Although at 28-30% JIT Lean expert opinions shifted with the majority ranking it as "Medium" this can be seen throughout with a few exceptions in the fuzzy triangle area until 68-70%, where another shift occurs with the majority of experts choosing "High". The amendments from the pilot study accounted for a range >90% JIT Lean (Appendix G), therefore the intersections between 78-80% and 88-90% are due to some experts rating it as medium, through opinions began to shift to "High" JIT Lean up until > 90%. Hence, 0-28% can be categorised as "Low", while 29-68% JIT Lean is "Medium", and finally from 69- > 90% JIT Lean is "High" (Fig. 35).

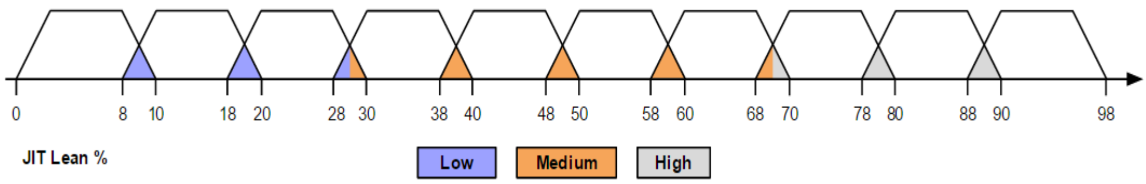


*Figure 35: JIT Lean variable round one Hybrid Fuzzy Delphi (Source: author)*

These ranges for the "Cost" and JIT Lean" were taken into consideration for the second round of Hybrid Fuzzy Delphi, in addition to the amendments given by the panel's feedback (Appendix H).

### Further Amendments

The experts reached a partial consensus on some of the variable functions yet differed on others. Their advised amendments on establishing a majority consensus was to further explain each variable function with a clear and simple definition in addition to clarify the scope and definition of a supply chain within this study and to further explain the definitions for the strategies within the study (Agile, Lean, Leagile and BSC).

The functions variables were given a more comprehensive and detailed definition and the statements related to them were further explained and clarified. Hence, for the Hybrid Fuzzy Delphi to be sent for the second round, further explanation was added. For example the "Delivery strategies" group variable functions was written as: "There are three types of deliveries according to Gunasekaran *et al.* (2001), delivery to request, delivery to commit date and order fill lead time".

The statements were described as follows: Firstly, "If" a supply chain delivery cost is calculated by "Delivery to Request", "Then" the supply chain is operating under: Lean, Agile, Leagile, Basic supply chain strategies. Secondly, "If" a supply chain delivery cost is calculated by "Delivery to Commit Date", "Then" the supply chain is operating under: Lean, Agile, Leagile, Basic supply chain strategies. Lastly, "If" the supply chain delivery cost is calculated by "Order Fill Lead Time", "Then" the supply chain is operating under: Lean, Agile, Leagile, Basic supply chain strategies"

The amendments to the second round for the "Delivery strategies" group included the following clarification:

"Distribution strategy consists of various cost elements to develop the appropriate trade-offs in the delivery system that can be applied as a basis for planning a supply chain end delivery strategy from manufacturing to customer, in addition to re-assessing the distribution system, so that overall cost effectiveness can be achieved (Beamon, 1999). There are three types of deliveries according to Gunasekaran *et al*. (2001), delivery to request, delivery to commit date and order fill lead time".

The (If-Then) statements remained the same with a slight added clarification:

“To classify the response time between order and corresponding delivery”: If the supply chain delivery cost is calculated by “Delivery to Request”/ “Delivery to Commit Date”/ “Order Fill Lead Time then”; Then the supply chain is operating under: Lean, Agile, Leagile, Basic supply chain strategies” (Appendix H).

Additionally, the experts required the supply chain and the four strategies to be clarified and defined within the scope of this study. Furthermore, due to the slight change in the “Cost” range, extra clarification was added, though the definition for “JIT Lean” remained the same. Therefore, the second round of Hybrid Fuzzy Delphi included the following:

“This research aims at helping companies identify the best supply chain strategy for their commodity and market. There are four strategies:

**Lean:** Lean focuses on the elimination of waste with a bias towards “pulling” goods through the system based on demand.

**Agile:** Focus is on flexible, efficient response to fluctuations and unique customer demand.

**Leagile:** A hybrid of Lean and Agile: Using make-to-stock/Lean strategies for high volume, stable demand products, and make-to-order/Agile for customised, innovative and innovative functional products. Has flexible production capacity to meet surges in demand or unexpected requirements. Uses postponement strategies, where “platform” products are made to forecast, and then final assembly and configuration done upon final customer order.

**Basic supply chain (BSC):** Basic or daily products that require a reliable chain to plan, source, make and deliver (from in-house manufacturing or outsourcing to retail)”

**Cost:** is calculated from the stage of manufacturing (cost of production) to end-customer. The end-customer varies between different companies from end-retail customer, distribution centres or end-wholesaler. Please chose the supply chain of your own products and what you considered as an end-customer.

The supply chain “Cost” consists of producing a product or good (raw materials, equipment or machinery operations at the manufacturing node), logistics distribution (from resource to component plants to manufacturing and the overall supply chain), and delivery to the end-customer (delivering the commodity from plant to warehouse, retailer, wholesaler or consumer), including the cost of lead-times during that process. The cost excludes overall gain from gross profit, labour or premises rental, it is only the estimated cost being invested in creating the product or good, its supply chain and logistics

**JIT Lean:** the more a supply chain strategy moves towards leanness, by eliminated waste and reducing lead-time, the more lean it becomes as defined by the JIT system, as time equals leanness measured by the JIT system.

Moreover, as requested by the experts, the supply chain definition and scope was included and explained in the second round:

“According to Fisher (1997), the supply chain converts raw materials into parts, components and eventually finished goods, then transports all of them from one node of the supply chain to the next. The specific supply chain point analysed in this study is from manufacturing to retail. This study focuses on the retail industry (e.g textile and automobiles), excluding food, jewellery, pharmaceutical, telecommunication services electronic devices, watches and white goods.”

For further clarification and to help the experts avoid ambiguity, the Hybrid Fuzzy Delphi was divided into two parts. Part one, included the questions regarding the “Cost” and “JIT Lean” with the following explanation:

#### Part One:

“This part of the questionnaire requires a generic answer regarding what constitutes “high cost” for a company that wishes to transfer its goods from the “Manufacturing” node to the “Retail” node. As well as what constitutes “high lean”, which is the minimal delays in shipment and product delivery to the customer.”

Further explanation to the “JIT lean” was added to avoid ambiguity of what (JIT) stands for: “JIT - "Just in Time", is a Japanese production strategy created by Toyota that strives to improve a business's return on investment by reducing inventory and associated carrying costs (Hines, 1998). JIT relies on signals or "Kanban" between different points, which tell production when to make the next part (Kootanaee *et al*., 2013). In this study, Leanness is measured by "JIT Lean", for example: If a company is 20% "JIT Lean" (20% Leanness), then there is 80% delays."

Meanwhile, the second part of the Hybrid Fuzzy Delphi study was divided into three sections to aid the expert's thinking process.

### Part Two:

"This second stage requires a general answer regarding the retail industry of consumable goods, the main focus of the supply chain is between the manufacturing to the retail. In this study only delivery, distribution, manufacturing, product demand and output are measured and used as an example to formulate the multi-dimensional matrix. The output in this research is measured by customer satisfaction. Specific attention will be placed on high-end products due to their unpredictable nature and their extreme fluctuating demand (e.g. high-end mountain bikes, men suits, women's ball gowns and wedding dresses)."

Further explanations were added to each of the three sections in part two. These sections are, firstly, "Measuring resource performance" which included "Delivery strategy", "Manufacturing cost of innovative, functional and innovative functional product" and "Distribution strategies". Secondly, "Measuring output" by customer satisfaction which includes, "Customer order path", "Manufacturing lead-time", "Shipping errors" and "Customer service". Thirdly, "Measuring product demand" by the life cycle of "Innovative", "Functional" and "High-end product", as well as identifying the best supply chain strategy for a high-end product. The third section provides definition for customisation to help experts identify the most suitable supply chain strategy for each type of customisation; this includes "Self-customisation", "Collaborative customisation", "Adaptive customisation", "Cosmetic customiser" and "Transparent customiser". Additionally, this section also contains a definition on the statement of the "Push" system in order for the study to differentiate and identify cohesively the best supply chain strategy for both the Lean "Pull" strategy and the "Push" system.

With these amendments to help the experts avoid ambiguity, the Hybrid Fuzzy Delphi was sent again for the second round in an attempt to reach consensus. Once a consensus is established, the answers from the (If-Then) statements will result in creating the fuzzy rules that will build the interactive MDM model.

### 5.2.2 Round Two: Establishing Consensus

The second round was completed with positive feedback and no further amendments, indicating that all panel members answered the statements with ease and reached a unified agreement. The Hybrid Fuzzy Delphi was conducted using a questionnaire tool called Qualtrics which eased the process of clarifying the amendments from round one and helped detect if a consensus has been established from the second round. Qualtrics also aids the analysis process as it allows the data to be directly downloaded into an SPSS and Excel file.

From the second round of Hybrid Fuzzy Delphi, the added clarification for the "Cost" from round one did not present a change in the maximum 0-60% scope, as majority of experts classified above 40% Cost as high, and no feedback was given to alter the maximum scope for the cost percentage. However, the range sets for the "Cost" and "JIT Lean" became slightly altered again. The intersections have nearly disappeared with consensus reducing the fuzzy area and creating a different range for each set.

The "Cost" percentage developed a range from 0-10%, 11-20%, 21-30% etc. The "Low Cost" range from the second Hybrid Fuzzy Delphi changed slightly with the fuzzy area between the "Low Cost" and "Medium Cost" is shown between 20-21% as experts shift from low to medium. Furthermore, the fuzzy area between the "Medium" and "High" cost is shown between 40-41% as experts shifted towards high (Fig. 36). Furthermore, similarly to the pilot and first round, the experts' answers did not exceed the maximum scope of 60% Cost conducted in this study. Although there are small intersections with a tiny fuzzy area, due to a small divergence in opinion, it's insignificant considering the majority consciences. This led the fuzzy area in the MDM model to shrink and for the four quarters (Agile, Lean, Leagile, and BSC) to start merging.

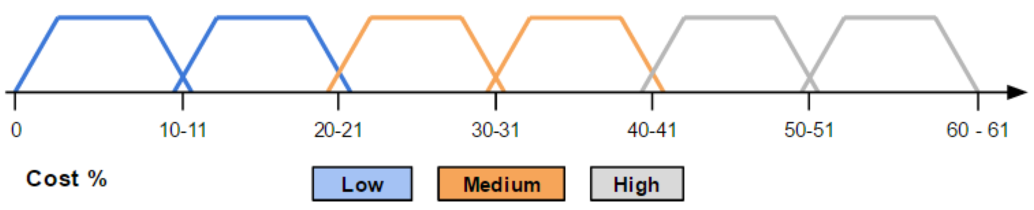


*Figure 36: Cost variable round two Hybrid Fuzzy Delphi (Source: author)*

The “JIT Lean” parentage developed a similar range to that of the Cost, with 0-10%, 11-20%, 21-30% etc. The “Low JIT Lean” distinct fuzzy range became between 30-31% JIT Lean as experts opinions shifted to “Medium”. Moreover, the fuzziness between the “Medium” and “High” JIT Lean is between 70-71% as the majority of experts shifted from medium to high (Fig. 37). The experts ranked 90- >91% as “High” and most favourable position. By taking the data and feedback from the last round into consideration, it can be deductively implied that a preferred high JIT Lean between 90-98% is favoured. Similar to the “Cost” there are small intersections with a tiny fuzzy area, created due to a small divergence in opinion, however it is insignificant considering the majority consciences. This also led the fuzzy area in the MDM model to shrink and for the four quarters to start merging.

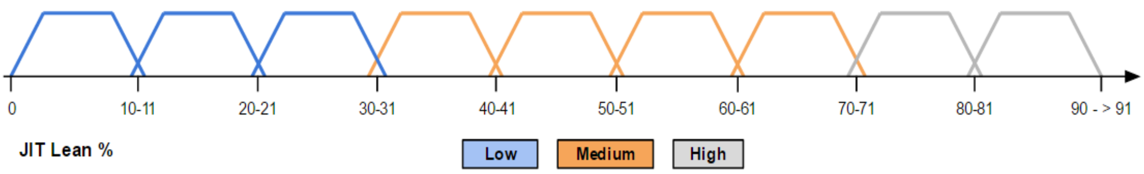


*Figure 37: JIT Lean variable round two Hybrid Fuzzy Delphi (Source: author)*

As a consensus has been achieved in the second round of Hybrid Fuzzy Delphi, the “Cost” and “JIT Lean” ranges developed will be used as a basis for the analysis and creation of the scatter diagrams which are then translated into the fuzzy rules and inputted into the interactive MDM. Reduced fuzziness resulted in the MDM merging into one matrix without the fuzzy area intersection present in the preliminary MDM. This resulted in the four quarters (Lean, Leagile, Agile and BSC) intersecting and merge into a single matrix, as the variables led to the supply chain strategies constantly shifting between quarters. The Cost and JIT Lean range in the preliminary interactive MDM became as follows (Fig. 38).

| Lean JIT | | | | | | |
|---|---|---|---|---|---|---|
| 91 - 100% | | | | | | |
| 81 - 90% | | | | | | |
| 71 - 80% | | | | | | |
| 61 - 70% | | | | | | |
| 51 - 60% | | | | | | |
| 41 - 50% | | | | | | |
| 31 - 40% | | | | | | |
| 21 - 30% | | | | | | |
| 11 - 20% | | | | | | |
| 0 - 10% | | | | | | |
| Cost | 0 - 10% | 11 - 20% | 21 - 30% | 31 - 40% | 41 - 50% | 51 - 60% |

*Figure 38: Preliminary interactive MDM*

## Defining Consensus

Consensus measurement plays an important role in Delphi research, as it is considered an important component for analyses and data interpretation. The term "consensus" is defined by Fowler (1995), in his Dictionary of Modern English Usage, as "a general agreement". Meanwhile Armstrong (2001), describes consensus in his study as the agreement of collective unanimous opinion of a number of persons, indicating that a group's conclusion represents a fair summary of the conclusions reached by the individual members. However, Armstrong (2001) further shows in his study the term consensus embodying the decision-making process rather than the end result of the group, as he stresses the inadequacy of forcing consensus by increasing rounds unnecessarily when a result can be established from the panel's indecisiveness, or closes proximity to an agreement. According to Gracht (2012), it is important to distinguish between the different concepts "consensus/ agreement" and "stability" in Delphi studies. Many Delphi studies have stopped the survey once a pre-defined level of agreement, i.e. consensus, was achieved. However, Gracht (*ibid*) noted that consensus is meaningless, if a group stability has not been reached beforehand; group stability is the "consistency of responses between successive rounds of a study"; thus stability is the necessary criterion defining a consensus. This stability is found in two ways, when a certain level of agreement, e.g. convergence of opinions toward consensus is found and when a complete consensus of all the panel is established (Fig. 39).

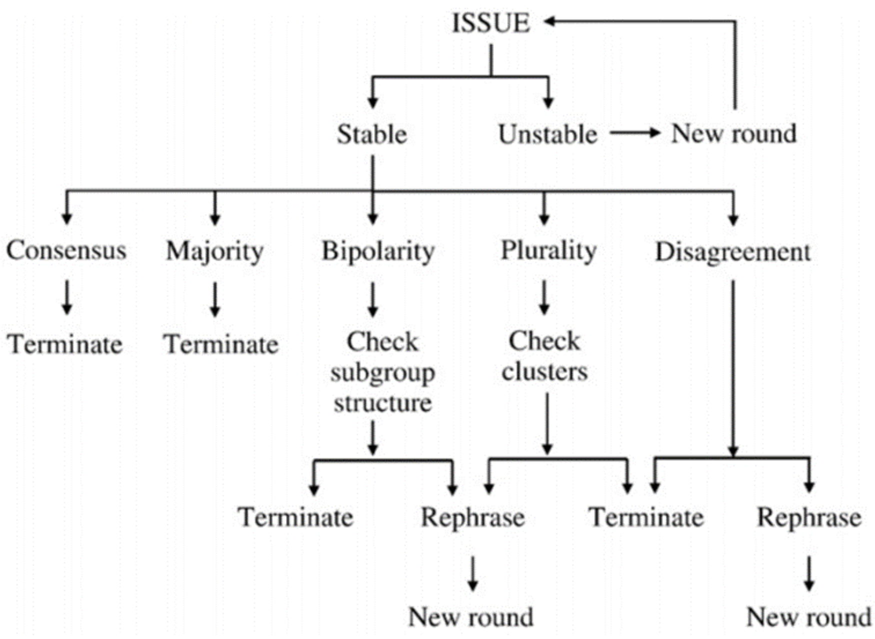


*Figure 39: Variety of consensus (Gracht, 2012)*

According to Gracht (2012), a consensus can be achieved with a certain level of agreement when a majority (>50%) of the respondents agree, referred to as a “majority consensus”. While the term “plurality consensus” refers to a larger portion of the respondents (<50%) agree[14]. Furthermore, Poundstone (2008) indicates the importance of these different types of consensus and their importance in the voting system, as he states that the outcome of an election does not depend on the choice of consensus in the voting system but on the expressed will of the voters. This means that in most cases the way people favour an option depends on how they think other people will choose. It is natural that people would try to ensure they chose the option that most other people will agree with, and identifying the best supply chain strategy is no different, as experts would choose their commodity or good, their market and choose the options based on what they think relevant companies would accept. Poundstone (2008) further explains the importance of a plurality consensus in a study, by stressing the importance of the information gained from “clones.” Clones are people with similarity who find the same choices appealing.

[14] "With three-cornered contests as common as they now are, we may have occasion to find a convenient single word for what we used to call an absolute majority. In America the word majority itself has that meaning while a poll greater than that of any other candidate, but less than half the votes cast, is called a plurality. It might be useful to borrow this distinction" (Fowler H.W., A Dictionary of Modern English Usage, Oxford University Press, 1965).

This could result in the clones splitting the results into equal halves, as any expert who likes one option, will like the other nearly as much, creating an equal plurality in a study. In the second round of Hybrid Fuzzy Delphi this can be seen as a group of experts generally favouring a set of strategies while another group favours another set of strategies, creating an equal plurality split. This is important in Hybrid Fuzzy Delphi as it indicates that both experts' choices have equal merit and can both be advisable, allowing the company to choose one of the paths that is best suited to its needs.

For example, in the variable "Tactical distribution" it can be seen that some experts are pro Agile strategy while others favour Leagile. However, with the "Innovative product" variable it can be seen that experts were grouped into pro Leagile and pro BSC strategy. The same can be seen in companies as they adopt a supply chain strategy stance into their framework as part of their business structure, (e.g. Jaguar Land Rover adopts a generic Agile system in its business structure and management, while Toyota adopts a generic Lean system within its business structure and management) (Hines, 1998). Nevertheless, Poundstone (2008) further explains that plurality consensus system is not biased in comparison to the usual first-place rankings as it takes into consideration the significance of the plurality party and interprets its impact on the outcome. Therefore, the hybrid system of making first-place choices count as exercised with the polls and counting the plurality vote, will give a more coherent understanding of peoples' choices and preference, which fits well with this study's Hybrid Fuzzy Delphi as the statements combine a multiple-choice and ranking method (Poundstone, 2008). For example, the "Delivery to request" variable shows that BSC strategy came first-place, while Agile and Lean formed a plurality that came second and third respectively.

According to Robert's rule of Order based on parliamentary procedure which is the standard for facilitating discussions and group decision-making, Robert explains the different types of majority, commonly a majority constitutes more than half of the members (Robert, 1915). However, the term plurality itself is also called "relative majority" in contrast with an "absolute majority" or "vast majority" which is more than half to almost all the members consenting. This hybrid system of first-place, majority and plurality consensus are commonly applied in cinema film awards, sports completion and parliamentary votes (Poundstone, 2008). This study will use the approaches mentioned above in establishing a consensus system to expand on the definitions put forward by Poundstone (2008) and Robert (1915) in order to interpret the results of the second round of Hybrid Fuzzy Delphi.

### 5.2.3 Interpreting Consensus

From the various methods mentioned in defining consensus, it can be noted that it is one of the most contentious components of the Delphi method. The measurement of consensus similarly to its definition, greatly varies between different studies (Munier and Rondé, 2001). This is due to the controversial understanding of the term, hence researchers have used many different measures in order to determine the level of agreement among the expert panel, as standards for consensus in Delphi research have never been rigorously established (Gracht, 2012). The literature on Delphi studies established that the stricter the criteria, the more difficult it is to achieve consensus among the expert panel. However, majority of Delphi studies measure consensus through the use of descriptive statistics, including mean, median, standard deviation (Armstrong, 2001). To avoid the trap of strict boundaries, this research used Hybrid Fuzzy Delphi, to allow the experts room to manoeuvre in their choices and to allow the end result to offer options as well as the recommended choice.

The second round of Hybrid Fuzzy Delphi generated a response from 90 experts in total. From the terminology above, it has been established that a majority consensus equates to more than half >50%, whereby an absolute majority equates to 90 to 85 (100-94.5%) experts agreeing, by which 90 experts agreeing [100%] would constitute a full consensus. However, a vast majority would constitute 85-58 experts agreeing [94.5, 64.5%]. The plurality consensus defined above is restrictive, hence for this study the plurality for <50% will be divided into three categories, “High, Medium and Low plurality” consensus.

The “Vast Majority consensus” which is when [85, 58] [94.5, 64.5%] experts agree, while a “Majority consensus” is formed when [57, 46] [64.5, 51.1%] experts agree, as it has to be more than half of the responses which is (90/2=45 experts, i.e. >50%). The “High Plurality” consensus is when the agreement is close to the majority, when [45, 35] [51.1, 38.9%] experts agree, as 46 experts agreeing is the fuzzy consensus area, due to 46 experts being over half (51.1%), it will be considered as a “majority consensus” in this study.

The “Medium plurality” is between [34, 24] [37.7, 26.7%] experts, while the “Low plurality” consensus is achieved when [23, 11] [25.6, 12.2%] experts agree. This study will consider any number below 10 experts agreeing (<11%, less than 1/8th) to be a minority and insufficient to be considered a plurality, as only the highest values will be measured. Table 13, illustrates the calculation for each category:

*Table 13: Consensus type and calculation (Source: author)*

| Type of consensus | Expert agreement for 90 experts | Formula |
|---|---|---|
| Vast majority consensus | When 85 - 58 experts agree | If [85, 58] [94.5, 64.5%] experts agree, then it is called a Vast Majority |
| Majority consensus | when 57 - 46 experts agree | (90/2=45(50%)) ∴ Majority (x) = [51.1≤x≤64.5% expert, then [57, 46] [64.5, 51.1%] experts agree, that it is called Majority. |
| High plurality consensus | when 45 - 35 experts agree | (90/8=11.25≈11) (12.8%) which is ⅛ of the consensus. Then (35+11=46) is (51.1%). ∴if [46, 35] experts agree then it is called High plurality. |
| Medium plurality consensus | when 34 - 24 experts agree | Since (90/8=11.25≈11) (12.8%) which is ⅛ of the consensus. Then 23+11=34 is (37.8%). ∴If [34, 24] [37.8, 26.7%] experts agree then it is called Medium plurality. |
| Low plurality consensus | When 23 - 11 experts agree | (90/8=11.25≈11) (12.8%) which is ⅛ of the consensus. ∴If [23, 11] [25.6, 12.2%] experts agree then it is called Low Plurality. |
| Minority | When 10-1 experts agree | Below 1/8th < 11% |

For this study, the consensus is studied via the questionnaire tool Qualtrics, as it provides the number of responses, the min, max, mean, median and standard deviation, which helps analysing the establishment of consensus, majority agreement consensus and the plurality consensus, which will enable the understanding of the choice of strategy selected as recommendation and which is categorised as an option within the interactive MDM. These factors further indicate the advantage of using Hybrid Fuzzy Delphi study, as any approximation in decision results in a fuzzy area that becomes an “option choice” in the MDM for the users to favour if they wish, depending on their requirements. This is crucial in creating a model that is adaptable and tailorable for supply chains.

#### *5.2.3.1 Part One:*

The first part of the Hybrid Fuzzy Delphi looks at the “Cost” and “JIT Lean” of a supply chain. Using the questionnaire tool Qualtrics, a sample will be selected to illustrate how consensus has been established.

#### Cost Variable Function

This study chose a random sample of 0-8% Cost and 9-18% Cost to examine the established consensus from the second round of Hybrid Fuzzy Delphi. From Fig. 40, it can be shown that 78 out of 90 (constituting 87%) ranked “0-8% Cost” as “Low”. This indicates that a “vast majority” consensus has been achieved, which is when [85, 58%] experts out of 90 agree, or when [94.5, 64.5%] out of a 100 experts agree. Meanwhile, 9 experts (constituting 10%) ranked it “Medium” and 3 experts (constituting 3%) ranked it as “High”, hence creating an intersection as shown previously.

Q5. If a company's supply chain cost is 0-8% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 78 | 87% |
| 2 | Medium Cost | | 9 | 10% |
| 3 | High Cost | | 3 | 3% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.17 |
| Variance | 0.21 |
| Standard Deviation | 0.46 |
| Total Responses | 90 |

*Figure 40: Cost variable function 0-8% (Source: author)*

In contrast to the second example of "9-18% Cost", it can be seen there are two types of consensus, firstly a "majority consensus" with 53 members of the panel agreeing that it is considered "Low". Secondly, there is a "medium plurality" consensus where less than the majority, 29 experts have agreed that it can be considered medium (Fig. 41). This is shown as the fuzzy area intersection when expert opinion diverges from one range to the other, as indicated previously. The different types of consensus are crucial in Hybrid Fuzzy Delphi as it helps the creation of options and gives flexibility to the MDM to be generic and applied to a variety of supply chains. The different types of consensus with regards to the "Cost" indicates that various products or goods require different supply chain cost, as customers are willing to pay more or less depending on the value of the product or good.

Q6. If a company's supply chain cost is 9-18% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 53 | 59% |
| 2 | Medium Cost | | 29 | 32% |
| 3 | High Cost | | 8 | 9% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.50 |
| Variance | 0.43 |
| Standard Deviation | 0.66 |
| Total Responses | 90 |

*Figure 41: Cost variable function at 9-18% (Source: author)*

### JIT Lean Variable Function

A sample of the "JIT Lean" variable function has been selected. This study chose a random sample of 19-28% and 69-78% JIT Lean as it contains various consensus patterns.

In Fig. 42, it is shown that the majority consensus has been achieved with 46 experts agreeing 19-28% JIT Lean is medium. Additionally a high plurality consensus has been achieved with 38 experts agreeing that it is low. This can be deductively explained as a fuzzy area where the experts' chosen product or commodity and their chosen distribution method to the end customer played a part in the divergence of opinion. This provides flexibility as various supply chains have different distribution methods, margins of delay, waste and delivery schedules.

Q14. If a company's supply chain is 19-28% JIT Lean then it is

| # | Answer | Response | % |
|---|---|---|---|
| 1 | Low Lean | 38 | 42% |
| 2 | Medium Lean | 46 | 51% |
| 3 | High Lean | 6 | 7% |
| | Total | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.64 |
| Variance | 0.37 |
| Standard Deviation | 0.61 |
| Total Responses | 90 |

*Figure 42: JIT Lean variable function 19-28% (Source: author)*

From Fig. 43, it is clear that a vast majority consensus has been achieved as 69 experts (constituting 77%) chose high Lean. However, 13 experts (constituting 14%) chose low lean, while 8 experts (constituting 9%) chose medium. As explained previously for certain companies, leanness is considered high when JIT Lean is > 90%. This is determined by the strategic position of the company, its product and scheduled lead-times. For example a company operating with a lean strategy, for instance Motorola Telecommunications Company who operate under lean six sigma has an expectation of > 98% leanness, hence 69-78% JIT Lean is considered low or medium (Barney, 2002). However, other companies operating with a BSC would consider 69-78% as a transitional stage between the medium and high JIT Lean ranges.

**Q19.** If a company's supply chain is 69-78% JIT then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 13 | 14% |
| 2 | Medium Lean | | 8 | 9% |
| 3 | High Lean | | 69 | 77% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.62 |
| Variance | 0.53 |
| Standard Deviation | 0.73 |
| Total Responses | 90 |

*Figure 43: JIT lean variable function 69-78% (Source: author)*

It can be noted that vast majority consensus is achieved at the lower and high percentage ends for "Cost" and "JIT Lean". However, the middle percentages showed different ranges of consensus (Appendix I), providing a fuzzy area as shown previously by the intersection between sets, which allow the interactive MDM to cater for various requirements and be tailored to the specific needs of the supply chain.

### 5.2.3.2 Part Two:

Part two has several variable functions groups that are divided into three sections (Appendix I). From each section a random sample will be selected and the patterns of consensus will be examined.

**Section One:**

*From the delivery group variables, the following was randomly selected:*

*<u>Delivery to request</u>:* it can be seen from Fig. 44 that a medium plurality consensus was formed for BSC, Agile and Lean supply chains. Due to the former achieving the highest number of agreement, it takes first-place. Hence, it is the most advised strategy while the latter, are options if the companies preferred another choice depending on their business model. This gives flexibility and freedom to choose based on the experts' preferences that will enable companies to use and tailor the MDM.

Q24. If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 24 | 27% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 8 | 9% |
| 4 | Basic supply chain strategies | | 33 | 37% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.56 |
| Variance | 1.53 |
| Standard Deviation | 1.24 |
| Total Responses | 90 |

*Figure 44: Delivery to request variable function (Source: author)*

**Section Two:**

*From the distribution group variables (Appendix I), the following was randomly selected:*

*<u>Tactical distribution</u>:* it can be seen from Fig. 45 that experts' choices were formed by a medium plurality consensus for Agile, Leagile and BSC supply chains. It is evident that experts were divided into two cloning groups, the pro-Agile and pro-Leagile. This indicates that with a Tactical distribution it is advised to have either an Agile or a Leagile strategy depending on the company's overall business structure, as it impacts the supply chain model, choice of product or good and market. However, companies have the option to choose a BSC strategy and tailor the Tactical distribution to fit their business model depending on their market.

Q33. Tactical distribution system: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 16 | 18% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 25 | 28% |
| 4 | Basic supply chain strategies | | 24 | 27% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.63 |
| Variance | 1.13 |
| Standard Deviation | 1.06 |
| Total Responses | 90 |

*Figure 45: Tactical distribution variable function (Source: author)*

*From the product design group variables, the following example was randomly selected:*

*<u>Innovative product</u>:* in this example there are two plurality consensus. The first is a high plurality consensus with 43 experts recommending an Agile strategy, indicating a first-place agreement, recommending innovative products to have high flexibility. The second, is a low plurality consensus for both Leagile

and Basic Supply Chain (BSC) strategies, as both equally achieved a total of 19 experts agreeing, creating two equal options (Fig. 46). This indicates two cloning groups where pro-Leagile experts advised that an innovative product of their choice requires high flexibility and a high lean system of waste reduction, while experts that are pro-BSC strategy advised than an innovative daily or necessity product would require a stable supply chain. By having these options a company would be able to choose the most relevant path for its innovative product's supply chain based on its market and business structure.

Q28. According to Fisher (1997), if a company produces an innovative product, its demand is very unpredictable and in need of a responsive supply chain. If a company manufactures an innov...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 9 | 10% |
| 2 | Agile | | 43 | 48% |
| 3 | Leagile | | 19 | 21% |
| 4 | Basic supply chain strategies | | 19 | 21% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.53 |
| Variance | 0.88 |
| Standard Deviation | 0.94 |
| Total Responses | 90 |

*Figure 46: Innovative product variable function (Source: author)*

**Section Three:**

*This section covers several variable functions (Appendix I), however one random sample was selected.*

*<u>High-end products</u>:* In this example, a "high plurality" consensus was achieved with 41 experts recommending that a Leagile strategy is most suitable for a high-end product as it provides high flexibility and efficient system of waste reduction, while a low plurality consensus of 22 experts who believe that an Agile strategy will provide the focus on flexibility and responsiveness that a high-end product requires (Fig. 47). Hence, the MDM will use the first-place method of recommending Leagile as the priority strategy, while Agile will be given as an option for companies to choose if they believe it's most suitable for their market.

Q47. High-end products have a fluctuating demand, to counter this uncertainty Fisher (1997) suggested a blend of three strategies- reducing uncertainty by identifying and analysing new sources of dat...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 15 | 17% |
| 2 | Agile | | 22 | 24% |
| 3 | Leagile | | 41 | 46% |
| 4 | Basic supply chain strategies | | 12 | 13% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.56 |
| Variance | 0.86 |
| Standard Deviation | 0.93 |
| Total Responses | 90 |

*Figure 47: High-end product variable function (Source: author)*

To conclude, in creating a model that can be tailored, the emphasis on options, flexibility and suggestions are important in the establishment of a holistic model that can meet the majority of companies' supply chain needs and requirement to enable companies to diagnose the best suitable strategy for their market. The experts' answers to the statements resulted in a slight change to the MDM. The four quarters established at the preliminary MDM has merged together creating a larger fuzzy area, which resulted in the quarters gradually fading and dissolving. The answers from both rounds divided the interactive MDM into a “Logistics strategy MDM” and “Supply chain strategy MDM”. Although the interactive MDM is shaped into a matrix without quarters, the fuzzy area remains in the strategic recommendation and options available for the company to choose from. The quarters in the preliminary MDM provided an insight into the ranges of each supply chain strategy in terms of “Cost” and “JIT Lean”. The results from round two provided basis for the variables and their importance in helping the experts identify the best suited strategy. Further explanation on the selection of these variables and their use in the study will be explained in the next section.

### 5.2.4 Choosing the Relevant Variables

The most suited and relevant variable functions are selected from the pool of variables used in the Hybrid Fuzzy Delphi to be incorporated into the interactive MDM. The selected variable functions will be allocated into two groups, “Logistics strategy” and “Supply chain strategy”, each with its own interactive MDM to simplify the process of selecting the variables a company wishes to examine. The variables that are considered most relevant to the study and to the development of the interactive MDM have been organised into the following Table (14):

*Table 14: The interactive MDM chosen variable functions (Source: author)*

| Variable Function | Why is it most relevant to this study? |
|---|---|
| **Cost** | The cost is one of the main variables that are crucial in the calculation of the best strategy for each variable. Experts aim to estimate excess cost from manufacturing to customer for their chosen market. |
| **JIT lean** | The JIT lean is also one of the main variables that are crucial in the calculation of the best suited strategy. Experts aim to estimate the JIT lean from manufacturing to customer for their chosen market and use it as a basis for selecting strategies. |

| | |
|---|---|
| **Delivery strategies group**<br><br>Delivery to commit date, delivery to request and order fill lead-time | Logistics elements are crucial for inter-deliveries between the supply chain and the customer. The decision making process of selecting a suitable strategy influences lead times. Hence the delivery between manufacturing through the supply chain to the end customer is a key aspect that must be included within the scope of this study. |
| **Product strategies**<br><br>Labelled in the interactive MDM as *"Product Design"*<br><br>Is calculated by manufacturing cost. Is the cost of direct material, direct labour, and manufacturing overheads in the fabrication, assembly, and testing of an end item. This includes the utilisation of three inventory accounts: Raw Materials, Inventory, Work in Process Inventory, and Finished Goods Inventory.<br><br>Manufacturing cost: the manufacturing cost in production is determined by the market the company is catering for. As the market determines the product type (innovative, functional and innovative functional) which in turn determines the cost of manufacturing and production. | It is important for companies to understand what is the best supply chain strategy suited for their market, by determining what product group they are manufacturing, hence these variables are essential for this study.<br><br>Understanding the different costs and JIT Lean associated with each product type in terms of the best suited supply chain strategy is extremely important for companies, as it establishes the foundation on which the product type is selected, strategy approach implemented and manufacturing method is built based on demand. |
| **Distribution strategies group**<br><br>Strategic distribution, tactical distribution, and operational distribution. | It is important for companies to understand the intra-logistics distribution throughout its supply chain network, in order to create a coherent flow of materials, components and goods. |
| **Measuring Output** | It is important for companies to reduce the time a product stays in manufacturing in order to increase turnover. Additionally |

| | |
|---|---|
| There are various variables in measuring output and increase or decrease of demand.<br><br>The selected variable for the scope of this study is *“manufacturing lead-time”* | lead times can be reduced by decreasing the time spent on paper work of clearing products (Simeonovova and Simeonov, 2012). As companies are moving toward re-engineering their supply chain to manufacture-to-order, the manufacturing lead time has become crucial to the industry and to the scope of this study (Elfving, 2003). |
| **Measuring product demand approach**<br><br>Is a related factor to the *“Demand approach”* variable group, as companies must take into account the demand of the target market before selecting their product type (innovative, functional and innovative functional, high-end product strategy, push system and self-customiser) | The life cycle of products in relation to their type is of crucial importance to companies, as that determines the level of output and the nature of their supply chain. Hence, it is a crucial element to be included in the scope of this study |
| **Customisation**<br><br>Labelled in the interactive MDM as *“Demand approach”*<br><br>There are many type of variables for customisation as it has gained popularity throughout the years. However, three variables were selected under the “Demand approach” group for the scope of this study. “High-end customisation strategy, push system and self-customisation” | High-end was selected to offer a variety of options to this study, as companies using the Multi-dimensional model may require a high end customisation option.<br><br>As the Pull system is measured through Lean system, it’s important for the multi-dimensional model to be inclusive by having the Push system incorporated within it. Self-customisation became the most popular method of customisation, as it gives the customer control and flexibility to have the product made and customised to their specific preferences. Hence this variable was selected to be most relevant to the scope of this study. |

#### 5.2.4.1 Categorising the Fuzzy Variables

The Hybrid Fuzzy Delphi statements of the chosen variables resulted in establishing a consensus of experts' recommendation and options. The options provide a fuzzy area that led the preliminary quarters of the MDM to merge together. The (If-Then) statements created the basis for the creation of scatter diagrams. These diagrams plot the frequency number each time the supply chain variables (Agile, Lean, Leagile and BSC) were chosen. This turns the hybrid multiple-choice into a ranking process that establishes the recommendations and options incorporated into the interactive MDM. The analysis chapter examines the process of converting the data collection from Qualtrics to SPSS and to Excel, in order for the (If-Then) statements to establish the frequency tables, percentages and build the scatter diagrams. This leads to the creation of the fuzzy rule sets that builds the web-based[15] interactive MDM for both strategy groups, the "Logistics strategies" and "Supply chain strategies" by translating the fuzzy sets into HTML and JavaScript. The chosen variable functions were divided as follows Table (15):

*Table 15: Category groups of the chosen variables (Source: author)*

| | **Logistics strategy** | **Supply chain strategy** |
|---|---|---|
| | ***Delivery strategy group*** | ***Product design group*** |
| | 1. Delivery to commit date | 1. Innovative |
| | 2. Delivery to request | 2. Functional |
| ***Cost percentage*** | 3. Order fill lead-time | 3. Innovative functional |
| ***JIT Lean percentage*** | ***Distribution strategy group*** | ***Demand approach group*** |
| | 1. Strategic distribution | 1. High-end strategy |
| | 2. Tactical distribution | 2. Push system |
| | 3. Operational distribution | 3. Self-customiser |
| | ***Manufacturing lead-time*** | |

[15] Web-based interactive MDM : http://www.safaasindi.com/staging/

For both groups, the interactive MDM requires the selection of the "Cost" and "JIT Lean" percentage. Once a company establishes the percentage range for its cost and lead-time, it can select a product, good or commodity and select a variable from one of the groups. The interactive MDM will then diagnose the best recommended supply chain strategy (Agile, Lean, Leagile and BSC) based on the experts' answers to the (If-Then) statements from the Hybrid Fuzzy Delphi. The company can apply the recommendation or decide to implement the optional strategy. Furthermore, the analysis chapter will discuss how the web-based interactive MDM can be tailored by adding further variables or changing the (If-Then) statements depending on the company's requirement to build a unique interactive MDM exclusive to its specification.

## 5.3 Unforeseen Obstacles

The main issue during the Hybrid Fuzzy Delphi study is uncertainty with regards the consistency in responses from experts and their commitment to stay for the whole duration of the study. The consistency issue involves the decision-making process, which can be due to little attention given to the intentions, actions, context or processes surrounding the participation of experts (Rowlands, 2005). For example explanation on how these variables interact with the outside world. In addition, the commitment issue has resulted in experts decreasing from the pilot round to the second round. Initially 137 experts from various academic and industrial backgrounds were contacted, the pilot Hybrid Fuzzy Delphi study generated a response from 83 experts who remained for the first round but three participants dropped in the second round of Delphi resulting in 80 responses.

One of the major sources of error in any Delphi is non-response, as the higher the response rate, the better the Delphi study. Non-response errors result from the complete number of participants not completing the questionnaire. There are several reasons why a response rate of a web-based survey decreases. These include open-ended questions, questions arranged in tables, fancy or graphically complex design, pull-down menus, unclear instructions, and the absence of navigation aids (Archer, 2007). The study by Archer (*ibid*), stressed the length of the questionnaire contributes to the problem, in addition to open-ended questions, as Archer (*ibid*), stated that the higher the share of open-ended questions, the higher the drop-out rate. However, it was also stated that as the number of web-based open-ended questions increased, in some cases the response rate increased. This may be due to most people recently becoming more comfortable answering questions via email, text message, or participating in a text-based internet environment as opposed to handwriting narrative scripts (Archer, *ibid*).

### 5.3.1 Overcoming Issues

To overcome the two main issues in a questionnaire, consistency in responses and commitment of participants, the following solutions were implemented. Firstly, to ensure consistency between the Hybrid Fuzzy Delphi rounds, the amendments ensured that questions were based on the theoretical framework and remained within the scope of the research to gather relevant information that is needed for the creation of the multi-dimensional model (Rowlands, 2005). Conceptualising the problems found in supply chains throughout the theoretical framework gave the research a scope to which the Hybrid Fuzzy Delphi can remain orientated towards (Rowlands, ibid). In addition the amendments between rounds ensured that experts had a complete understanding of the problem, through adding definitions and explanation of the study's aim included in the cover letter.

Secondly, as the commitment of participants decreased throughout the Hybrid Fuzzy Delphi rounds, according to Archer (2007), some factors can contribute to increase response rates. These include personalised email cover letters, follow-up reminders, pre-notification of the intent to survey and simpler formats. However Archer (*ibid*), further indicated that in some cases the number of reminders had little or no relationship to the response rate, as the Hybrid Fuzzy Delphi contacted the experts via a personalised email cover letter that included a notification of the Hybrid Fuzzy Delphi's requirement, aim and explanation. Therefore the remaining option to regain the experts that dropped out was to send a follow up reminder email. As Archer (*ibid*), noted that follow up emails may not have the desired effect, this research further added an incentive. This helped re-gain 10 experts' interest in the study which resulted in 90 experts in total who successfully completed both rounds of the Hybrid Fuzzy Delphi study.

## 5.4 Data Analysis

This section analyses the data collected concerning the problematic issue companies face in distinguishing which strategy to apply at each node within their supply chain. This confusion is due to the many models, definitions, and strategies developed over the years. From the data collection, it has been established that experts provide crucial insight into the application of theory in business. Their answers provide information on how the MDM can be created and used as a diagnosing tool, which will be explored further in the testing chapter. The analysis will provide the means to aid companies as maximise the efficiency of their supply chain processes and increase their business value by improving their end-to-end operation (manufacturing to retail).

The analysis looks at the different tools used on the data collected and will revolve around the aim of merging the supply chain strategies and variables to create an interactive MDM, which will then be tested by an organisation.

## 5.5 Interplay of Data

The Hybrid Fuzzy Delphi gathered 14 measurement variable categories including the "Cost" and "Jit Lean" explained in the data collection. Due to the substantial task of accommodating all 14 variables, this study has organised them into five categories in addition to the "Cost" and "JIT Lean" in the design of the interactive MDM. These five variable groups were chosen based on their relevance and scope of the study and are as follows: Distribution strategies, Delivery strategies, Manufacturing lead-time, Product demand and Demand approach. To enable functions to interact in the MDM, JavaScript and Unified Modelling Language (UML) has been used to build the MDM as a web-based interactive tool. As mentioned in the Hybrid Fuzzy Delphi, the experts were asked to answer the questions related to the Supply Chain and Logistics variable categories by rating which supply chain strategy they deemed most suitable for each of the variables. The experts would choose whether, Lean, Agile, Leagile or Basic Supply Chain (BSC) strategy (1, 2, 3 and 4 respectively) is most appropriate for the variable in question. Furthermore, Experts were asked to answer the "JIT Lean" and "Cost" variable categories by rating which percentage constitutes Low, Medium and High (1, 2, 3 respectively).

The definition of "JIT Lean" in this study is the delay time it takes a product to move between the resource or component plants to the manufacturing node, to assembly, handling, and distributed to the warehouse, retailer or wholesaler. The definition of "Cost" in this study is the expense of acquiring raw materials, equipment or machinery operations at the manufacturing node, distribution costs (varies on mode of transport selected) from resource or component plants to manufacturing and the overall supply chain (varies on product design and strategy) of delivering the commodity from plant to warehouse, retailer or wholesaler. The cost excludes labour, premises or equipment hire, it is only the estimated total cost being invested in creating the product, its supply chain and logistics. The “Cost” variable does not indicate the overall cost gained from the gross profit margin, as it could be skewed if the company sells many different products.

This chapter will use deductive reasoning in the analysis of SPSS, to understand the perspective, choices and conclusions, of what experts constitute to be true for the variables in question. The analysis of SPSS and Excel will create scatter diagrams that aim to form the fuzzy rules that design the interactive codes for the MDM. The fuzzy rule codes will be input into a web page ready to be tested by a selected company, to determine its applicability.

### 5.5.1 SPSS

SPSS is a software package used for statistical analysis, as it can perform highly complex data manipulation with simple instructions. The Hybrid Fuzzy Delphi data collection provided a series of numbers that can be analysed statistically, which were inputted into SPSS to create “frequency tables”. These tables illustrate the total amount of repetition for each category or group of data.

#### *5.5.1.1 Frequency Tables*

Frequency tables are one of the most basic tools for displaying descriptive statistics, and are used to describe the number of occurrences within a data set, referred to as frequency distributions. These frequency distributions summarise and compress data by grouping them into classes to record how many data points fall into each class, hence showing how many observations are given on a single variable with a particular attribute (Field, 2009).

Although frequency tables are not appropriate for every application, as they can obscure extreme values, the advantage of these tables is the simplicity of managing and operating on frequency data organised in a table rather than operation on raw data, as simple algorithms can be added and used to calculate median, mean and standard deviation (DeCarlo, 1997). This helps identify obvious trends within a data set, which can be used to compare between sets of the same type. These tables are widely utilised as “at-a-glance” reference into the distribution of data. They are easy to interpret and can display large data sets in a concise manner. The frequency tables help statistical hypothesis as they test the assessment of differences and similarities between distributions (Field, 2009). When a frequency distribution is considered "skewed", its mean and median are different. The kurtosis[16] of a frequency distribution is the concentration of scores at the mean, or how peaked the distribution appears if depicted graphically, for instance in a histogram which is an effective graphical technique for showing both the skewness and kurtosis of data set (DeCarlo, 1997).

This section looks at the frequency tables created by SPSS. Each set of variables will be provided with their set of frequency tables and explained. Firstly, the frequency tables of the "Cost" and "JIT Lean" variables will be analysed. This will be followed by the logistics variables which include both groups, "Distribution Strategies" and "Delivery Strategies". Finally, the supply chain variables which includes the two groups, "Product Design" and "Demand Approach".

#### *5.5.1.2 Cost Variable*

In business strategy, cost is crucial to the process, especially with regard to supply chain and logistics. Due to the complexity of different nodes found within the supply chain, managing cost along the entire process is extremely important. Moreover, the cost of logistics has become crucial due to the speed expectations of distribution across continents in a globalised economy and ensuring the products reach the right destination, at the right time and in the right condition.

The panel of experts were asked to rate a recommended cost for a retail product of their own choice. This study defines "Cost" as the company's investments from the manufacturing stages (total cost of production) to end-customer. Although the definition of end-customer varies between different companies, from end-customer to end-wholesaler, as the experts chose their own products they also chose what they consider an end-customer, hence the recommended cost. Therefore, deductively the "Cost" cannot be more than 60% of the total manufacturing and supply chain distribution cost, which includes producing a

[16] Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. Data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. Whereby a uniformed distribution would be the extreme case (DeCarlo, 1997).

product, cost of lead times during that process, logistics distribution and delivery to the end-customer.

Due to the number of frequency tables created by SPSS, this section will select the most relevant tables as an example to analyse the “Cost variables”. The samples illustrate that when the cost is under/equal 10% the majority of experts chose “Low cost”, indicating that it is mostly favoured for the supply chain of their product. Meanwhile, when the cost is under/equal to 20%, experts scored it as “Low cost”, as it was still within their favoured region (Table. 16). This could be due to the products chosen being within the high-end category which has a higher cost of sourcing, production and distribution, such as high-end customised cars, wedding gowns and expensive sport equipment etc. However, when the cost reached 30% or above, the experts ranking dropped to between “Medium” and “High” Cost, indicating that it’s not a favourable cost percentage for supply chain and logistics (Appendix J).

*Table 16: Cost variables (Source: author)*

**If a company's supply chain cost is 0-8% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Cost | 79 | 87.8 |
| | Medium Cost | 9 | 10.0 |
| | High Cost | 2 | 2.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 9-18% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Cost | 54 | 60.0 |
| | Medium Cost | 30 | 33.3 |
| | High Cost | 6 | 6.7 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 29-38% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Medium Cost | 51 | 56.7 |
| | High Cost | 39 | 43.3 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 49-58% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Medium Cost | 10 | 11.1 |
| | High Cost | 80 | 88.9 |
| | Total | 90 | 100.0 |

The frequency tables also show the "valid percent", which is calculated by SPSS to provide a percentage of the total cases for each variable. The valid percentage illustrates the proportion of a sample that is valid, as data can be invalid for a variety of reasons. Some data are simply impossible, such as negative heights or weights, while some comparison data can be shown to be invalid when correlated with other data. Finally, some data can be identified invalid due to machine error or human entry error (Field, 2009). In the Excel analysis chapter the invalid data will be examined by calculating the margin of error and determining its significant implication on the data collection's validity.

#### *5.5.1.3 Just in Time Lean variable*

In addition to cost, lead-time is equally crucial to supply chains. With consumer tastes changing regularly and with expectations of products arriving as fast as possible, lead-times have become key to a successful business strategy with an orientated value chain. This study considered that the best way to measure lead-time within supply chains is assuming that time equals leanness, as examined by James-Moore and Gibbons (1997), the more time is lost the greater the waste as time is a resource. Therefore, the more a supply chain strategy moves towards Lean strategy, the less lead-time it has due to JIT, hence this assumption measures time by JIT Lean system.

To test this assumption, experts were asked to choose a percentage they deemed appropriate for deliveries to be on time. As "time" is endless, for simplicity this study ranks the JIT Lean to be from (0- >90%), where the SPSS calculated ten frequency tables. However, three samples were selected for this analysis based on the contrast and compatibility of their data (Appendix J). The first example is if a company's supply chain is ≤10% JIT, indicates there is an estimation of ≤90% lead-time, the majority of experts ranked it at "Low lean", indicating it is not favourable. Moreover, the second example is if JIT Lean is above/below 30% range, where more than half of the experts reached a consensus that's its

"Medium", the others were split with 18 experts ranking it as "High" and 15 experts chose "Low", this is due to the strategy of the business they selected, the product, distribution and end consumer they had in mind. However, the third example, is when JIT Lean is above/equal to 90% meaning ≤10% lead-time, a majority of experts ranked it as "High lean", indicating this is the position most companies aim to achieve (Table. 17). The Hybrid Fuzzy Delphi study questions on JIT Lean show that time can be considered Lean and measured by JIT, as all the experts understood the concept of the questions and answered them accordingly (Appendix J).

*Table 17: JIT Lean variables (Source: author)*

**If a company's supply chain is 0-8% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 84 | 93.3 |
| | Medium ... | 4 | 4.4 |
| | High Lean | 2 | 2.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 29-38% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 15 | 16.7 |
| | Medium ... | 57 | 63.3 |
| | High Lean | 18 | 20.0 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 89-98% JIT then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Lean | 2 | 2.2 |
| | High Lean | 88 | 97.8 |
| | Total | 90 | 100.0 |

#### 5.5.1.4 Logistic Variables

This section looks at the logistics variables, which are divided into three categories, Distribution strategies, Delivery strategies and Manufacturing lead time. These variables are chosen due to their relevance in building the MDM and the analysis scope of this research. The logistics in this study combines the planning, implementation, controls, efficiency, effectiveness and storage of goods, services, and related information flows from the point of origin to the point of consumption (Slack, 2005). Both distribution and delivery strategy variables consist of inbound and outbound logistics. Therefore, experts select the most suitable supply chain model for the logistics distribution and delivery strategies to help improve tactical operations, reliability, reduce lead times and maximise utilisation (Mangan *et al.*, 2008).

### Distribution Strategies

The distribution strategies are divided into Operational distribution, Strategic distribution and Tactical distribution systems (Appendix J). They include the distribution movement of information flows and the inbound process of purchasing, movement of material parts from suppliers to manufacturing, or assembly plants to warehouses (Gunasekaran *et al*., 2001). If it's a finished product, then distribution strategies also includes the outbound process of storing and distributing the final product from the end of the production line to the end-customer which could be a warehouses, retail stores or consumers (Mangan *et al.*, 2008).

### Operational Distribution System

Experts were asked to pick a retail product of their choice and categorise which supply chain strategy best suits the operational distribution of their chosen commodity. From the SPSS in Table 18, most experts chose BSC to be most suitable for an operational distribution, while Leagile was chosen to be second most suitable, making Agile the third most suitable for operational distribution. Meanwhile, Lean ranked as the least likely strategy, as the level of lead time reduction would be too complex for operational distribution, as it requires time to ensure the detailed products are accurate for their customer's demand (James-Moore and Gibbons, 1997).

The operational distribution system is often used for customised products or mass customisation as well as products that require specific handling, packaging and distribution, all of which require predictable or flexible lead times which contradict a Lean strategy (Swaminathan, and Tayur, 2003).

*Table 18: Operational distribution variable (Source: author)*

**Operational distribution system: concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 13 | 14.4 |
| | Agile | 18 | 20.0 |
| | Leagile | 26 | 28.9 |
| | Basic supply chain strategies | 33 | 36.7 |
| | Total | 90 | 100.0 |

## Strategic Distribution System

When experts were asked to categorise the best supply chain strategy for the strategic distribution of their chosen commodity, the majority of responses were for both Agile and BSC, while the rest believed a strategic distribution is more appropriate for a Lean system, while Leagile ranked last (Table. 19). This can be analysed deductively, as an Agile system requires responsiveness to customer's needs, taste and requirements; therefore, a strategic system will allow for warehouses to be in close locations to the targeted market in order to reduce lead time (Heikkilä, 2002).

This is also beneficial for products that require a BSC system, such as everyday requirements of soaps, toothpaste and seasonal everyday items (Alford et al., 2000). Additionally, the strategic system is most suitable for Lean strategy as it focuses on reducing cost and waste as well as lead time, which are the main elements of JIT, although a Leagile system combines both Lean and Agile's best attributes, as operating with a flexible production capacity to meet surges in demand as Kotzab (2003), explains with his example of value-adding strategies in the grocery industry. Experts believe Leagile is least suitable, due to products requiring a Leagile strategy being innovative, customised or within the high end sector, due to Leagile operating as a 'postponement' strategy, where products are part-assembled to forecast, then completed to order, hence deferring some of the expense until a sale is assured (Swaminathan and Tayur, 2003).

*Table 19: Strategic distribution variable (Source: author)*

**Strategic distribution system: objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 22 | 24.4 |
| | Agile | 25 | 27.8 |
| | Leagile | 18 | 20.0 |
| | Basic supply chain strategies | 25 | 27.8 |
| | Total | 90 | 100.0 |

## Tactical Distribution System

When the experts categorised the tactical distribution of their chosen commodity, a majority of experts believed that an Agile or Leagile system is most suitable, with BSC as an option (Table. 20). This is due to the tactical distribution strict operation guidelines that determine when day-to-day scheduling can be executed, either from manufacturing or procurement (Gunasekaran *et al*., 2001).

These key operating targets are provided with several software tools that are available to the company. Agile strategy is focused on responsiveness and knowing which processes to operate at which time (such as safety stocks, planned lead times and batch sizes) are crucial to the company's cost and getting the right product to the right customer (Naylor *et al.*, 1999). Also, Leagile strategy relies on postponement strategy, a tactical distribution will help identify which components and products should be part-assembled and sent to the warehouse, while for a BSC system, it is important to coordinate the daily consumer requirements across the different units within a supply chain (Pagh, 1998). Meanwhile, the lean strategy is ranked as least suitable due to a tactical distribution requiring pre-determined and flexible lead times (Gunasekaran *et al*., 2001).

*Table 20: Tactical distribution variable (Source: author)*

**Tactical distribution system: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity and service)**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 16 | 17.8 |
| | Agile | 25 | 27.8 |
| | Leagile | 25 | 27.8 |
| | Basic supply chain strategies | 24 | 26.7 |
| | Total | 90 | 100.0 |

## Delivery Strategies

The delivery strategies are divided into three variable categories, Delivery to commit date, Delivery to request and Order fill lead time (Appendix J). Similarly to the distribution strategy, experts include in their assumptions of selecting the best supply chain strategy, the inbound and outbound logistic factors.

## Delivery to Commit Date

Experts were asked to identify under which supply chain strategy the delivery to Commit Date will most likely be suitable (Table. 21). A majority of expert opinions believe that Agile is most suitable, as it caters for flexibility as well as responsiveness, which is critical for the percentage of orders that are put in place to be fulfilled on/before the original scheduled “commit date”, while BSC is ranked second most suitable due to the difficulties of developing large scale integrated models, consisting of multiple entities for daily products (Lu *et al*., 2003). Meanwhile, Leagile and Lean are equal in being least suitable due to delivery to commit date requirements of simplicity, flexibility and responsiveness which will be complex to implement with a Lean or Leagile strategy (Melton, 2005).

*Table 21: Delivery to commit date variable (Source: author)*

**If a supply chain delivery cost is calculated by “Delivery to Commit Date”, then the supply chain is operating under:**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 18 | 20.0 |
| | Agile | 33 | 36.7 |
| | Leagile | 18 | 20.0 |
| | Basic supply chain strategies | 21 | 23.3 |
| | Total | 90 | 100.0 |

## Delivery to Request

A majority of experts identified BSC strategy as most suitable for delivery to request. This is because daily products are required to be delivered as soon as the requests are sent from the retailer to the supplier (Table. 22). Therefore, the percentage of stock level in retailers must remain constant and orders must be delivered on time to maintain inventory level, with complete documentation and perfect condition (Shah and Ward, 2003). The Agile strategy came second, due to its responsiveness nature, as delivery to request is usually from the warehouse or wholesaler to the retailer. This helps Agile strategy to cope with any demand surplus or change in season or consumer habits, in contrast to the former "delivery to commit date" for which Agile scored as most suitable, due to it being from manufacturing to the warehouse or wholesaler. The third suitable strategy is Lean, as during shipment or distribution between warehouse and wholesaler to the retail, Lean operates under "deliver to request" for orders to be delivered within next day delivery of the order receipt with minimum stock and waste (Heikkilä, 2002). This means orders must be filled from the warehouse or wholesaler and complete shipment or distribution within 24 hours which is a very complex and difficult requirement, as examined by Armstrong (2013), in his case study of Amazon Prime.

*Table 22: Delivery to request variable (Source: author)*

**If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 24 | 26.7 |
| | Agile | 25 | 27.8 |
| | Leagile | 8 | 8.9 |
| | Basic supply chain strategies | 33 | 36.7 |
| | Total | 90 | 100.0 |

## Order Fill Lead Time

For "order fill lead time", experts ranked BSC as the most suitable strategy, due to daily products having fewer lead time due to processes checks before being sent through to distribution (Table. 23). Meanwhile, Leagile strategy came second due to its 'postponement' strategy where products are already processed, semi assembled, with their documentations and await to be put through the final stages of “order fulfilment” (Naylor *et al*., 1999). The Agile strategy came third due its responsiveness of adapting to changes in demand or customer preference, products have to be designed to take less lead time especially with documentation processes, shipments and distribution clearance. The Lean strategy came last, due to its emphasis on speed, reduce stock/inventory level and waste reduction (Melton, 2005). However, as products are not put through the Lean system until an order has been placed, it is very difficult to plan or clear process before orders come in, hence experts believe Lean is least suitable (Naylor *et al*., 1999). For the “order fill lead time” to be fully utilised, efficiency is required to clear products from the system, transforming resources into goods and services from the moment a customer order is received, including lead times, through to the end-customer with low/zero inventory (Lu *et al.,* 2003).

*Table 23: Order fill lead time variables (Source: author)*

**If the supply chain delivery cost is calculated by "Order Fill Lead Time", then the supply chain is operating under:**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 19 | 21.1 |
| | Agile | 20 | 22.2 |
| | Leagile | 21 | 23.3 |
| | Basic supply chain strategies | 30 | 33.3 |
| | Total | 90 | 100.0 |

## Manufacturing Lead Time

When experts were asked which strategy best suited manufacturing lead-time, a majority believed that Agile mostly required a “manufacturing lead time” reduction system due to its responsiveness to changes in consumer taste, having a system that focuses on fast manufacturing process with least lead-time as possible that focuses on minimal time to manufacture an item, including order preparation time, queue time, setup time, run time, move time, inspection time, and put-away time (Table. 24) (Shah and Ward, 2003). For a Leagile strategy, manufacturing lead time is very important once the semi-assembled postponed product becomes activated to be launched into its final production stage, as the Lean aspect of the Leagile strategy is applied, hence lead times must be reduced to a minimum for the product to reach its destination on time (Heikkilä, 2002). The BSC is usually associated with daily products and make-to-stock products hence reducing lead time in manufacturing is crucial, especially for those with a short shelf life. Additionally, reducing the time of releasing an order to production and receipt into finished goods inventory for make-to-order products, is crucial to maintaining stock levels (Ergen *et al*., 2007). The Lean strategy is least suitable because throughout the processes components are only assembled when an order is in place; therefore, due to the efficiency and waste reduction engineered into the Lean strategy, the manufacturing process is already designed to assemble components and manufacture them systematically (Simeonovova and Simeonov, 2012). Within the lean strategy, the process which requires reduction in lead-time during manufacturing is quality control. As the quality control node in the manufacturing lead time system is crucial, the JIT in Lean strategy embeds a flagging system where a component is flagged as it is manufactured if it fails quality checks (Gunasekaran *et al*., 2008). This helps lead time reduction as the component is fixed straight away due to the efficiency strategy of Lean. Therefore, as the make-to-order products in the Lean strategy have an in-built manufacturing lead-time reduction system from the moment an order is released to production, manufacturing, assembling, distribution and shipment, experts believe Lean strategy did not require a "manufacturing lead time" (Lee *et al*., 2007).

*Table 24: Manufacturing Lead-time variables (Source: author)*

**Manufacturing lead time: is the total amount of time required to produce an item or batch (Beamon,1999). If a supply chain focuses on customer satisfaction in the retail industry, then manufacturing lead time should be:**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 14 | 15.6 |
| | Agile | 35 | 38.9 |
| | Leagile | 21 | 23.3 |
| | Basic supply chain strategies | 20 | 22.2 |
| | Total | 90 | 100.0 |

### 5.5.1.5 Supply Chain Variables

While the term "Logistics" refers to tactical and operational issues; "Supply chain" is used to refer to strategic issues, which includes the systematic, strategic coordination of business functions and tactics across the supply chain for the purposes of improving the long-term performance of the company as a whole (Georgia Tech Supply Chain and Logistics Institute, 2010). This section looks at a list of supply chain strategy variables, which are divided into two categories, product design and demand approach. These variables are chosen due to their importance in this study and to narrow the scope of research.

### Product Design

Product design is divided into three categories, “Innovative Products”, “Functional Products” and “Innovative Functional Products” (Appendix J). Each product type will be allocated by the experts its best supply chain strategy along with optional strategies that companies may find useful, depending on their business structure.

### Innovative Products

Experts were asked to choose the most suitable strategy for an innovative product. The majority chose Agile, due to innovative products requiring flexibility in understanding what the customer needs and reacting to demand during the creation and distribution of the innovative product (Sanchez and Nagi, 2001). For example accessories and fashion (Fisher, 1997). Leagile and BSC strategy came second equally (Table. 25). With Leagile, it can be deductively analysed that experts believed the strategy to be complex for innovative products, as the possibilities of changes in demand once the product is made require an Agile focused approach (Agarwal, et al., 2006).

For example, the postponement and lean distribution system in Leagile would make it difficult to adapt the product as inventory levels can’t respond fast enough to changes in customer’s taste (Naylor *et al.*, 1999). The BSC main focus is on daily products or product/ components that are of stable or predictable demand and require simple production, handling and distribution, which doesn’t apply to innovative products. The Lean strategy was chosen to be less suitable due to innovative products requiring time for research and design to fully capture the consumer’s requirements and hence inevitably leading to some wasted resources (Sugimori *et al*., 1977). Additionally, innovative products start at the high-end market with complex production, assembling, handling and distribution, making them unfit for the tight scheduling of the lean strategy (Pagh, 1998).

*Table 25: Innovative product variable (Source: author)*

**According to Fisher (1997), if a company produces an innovative product, its demand is very unpredictable and in need of a responsive supply chain.**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 9 | 10.0 |
| | Agile | 43 | 47.8 |
| | Leagile | 19 | 21.1 |
| | Basic supply chain strategies | 19 | 21.1 |
| | Total | 90 | 100.0 |

## Functional Products

For the functional product, experts chose BSC strategy to be most suitable, due to them being mass-produced daily requirements of the public (Table. 26). For example, plastic utilities and stationary (Cagliano *et al*., 2004). Lean strategy is second most suitable, due to the functional product being mass produced with predictable demand, hence lead times and waste reduction can be easily accounted for and scheduled with no inventory (Melton, 2005). Additionally functional products usually follow a straightforward production, assembling and handling, hence making its distribution simple and enabling easier lead time reduction with less labour intensive activities such as certification documents (Fisher, 1997). The Agile and Leagile were classed as less suitable due to their responsiveness attributes which are not required for a functional product with a predictable demand (Sanchez and Nagi, 2001).

*Table 26: Functional product variable (Source: author)*

**According to Fisher (1997), a functional product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in need of an efficient supply chain**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 21 | 23.3 |
| | Agile | 17 | 18.9 |
| | Leagile | 14 | 15.6 |
| | Basic supply chain strategies | 38 | 42.2 |
| | Total | 90 | 100.0 |

### Innovative Functional Products

Experts classified Leagile strategies as most suitable for innovative functional products (Table. 27). This is due to these products having a functional basis that can be mass produced and held at the postponement stage for the "Innovative" elements to be added at the final production and assembly, although Pagh (1998) states in some cases elements can be added at the handling stage before being put through a lean distribution system. Innovative functional products are usually mass customised such as cars, household furniture, laptops and personal computers. Agile strategy came second as innovative functional products can also be aimed at the high end market where demand and taste can fluctuate requiring flexibility in manufacturing and responsiveness, such as wedding gowns and professional sports equipment as well as special brands of automobiles (Silveira *et al*., 2001).

Lean strategy was chosen third due to the difficulty in implanting it on an Innovative Functional product, however car manufacturers for a mass customised market such as Toyota were able to implement lean strategy successfully (Hines, 1998). This is due to their make-to order system's fast response to orders and their tactical placement of plants around the word for fast manufacturing of components, which enables them to strategically distribute components to their assembling plants for final manufacturing and delivery to customers' request (Tomino *et al*., 2009).

Meanwhile, BSC strategy was chosen lastly as Innovative Functional products can additionally be mass produced for the day to day markets such as detergents (i.e. soaps and house hold cleaning equipment) and electronic accessories (Jüttner *et al*., 2007). These types of Innovative Functional products have a stable demand and mostly have very similar production process with slight changes for Innovation, such as few additional ingredients/components, variety of flavours, scent and branding, hence requiring a simple assemble, handling and distribution (Tomino *et al*., 2009).

*Table 27: Innovative functional product variables (Source: author)*

**According to Fisher (1997), an innovative functional product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as toothpaste**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 20 | 22.2 |
| | Agile | 25 | 27.8 |
| | Leagile | 26 | 28.9 |
| | Basic supply chain strategies | 19 | 21.1 |
| | Total | 90 | 100.0 |

## Demand Approach

Demand approaches are divided into three categories, high-end, self-customised and push system (Appendix J). Experts will examine each demand approach, as they allocate the best supply chain strategy and optional strategies that they recommend for companies to implement, depending on their business structure.

## High-end Mass Customisation

Experts categorised Agile strategy as most suited for "high-end" products, because they are mostly innovative with volatile demand, an unpredictable consumer demand and change in taste (Table. 28). For example, sports equipment such as heart rate monitors have to undergo a series of pilot tests before consumer preference is understood (Mourtzis *et al*., 2008). However, once the product is manufactured, additional design information can be added depending on consumer taste. Additionally demand can fluctuate when the product has been used widely, due to consumer change in requirements or need for the product. Hence manufacturing, assembling, inventory, handling, storage and distribution must maintain its flexibility and responsiveness (Silveira *et al*., 2001). Experts selected Leagile as the second most suitable supply chain strategy for a high end product demand, as it combines the best Lean and Agile strategy. As Mourtzis *et al*. (2008) states, a high-end manufactured product could require customisation at the last stage of production, such as authentic leather brief cases, personalised wedding gifts, technological accessories such as personalised keyboards and mice, also customised high-end desk chairs. For the example of the high-end leather briefcase, the Agile operation will be during the manufacturing and assembly stage of the supply chain, while any personalisation such as design or engraved initials will be done after at the holding up stage or "postponement" stage. The Lean operation will then take place at the handling and distribution stage (Naylor *et al.*, 1999; Mourtzis *et al*., 2008). Experts selected the Lean strategy as third due to its difficulty in implementing it fully throughout the high-end product supply chain. However, most innovative and high end products have a Lean strategy for their assembly and distribution nodes, as customers are paying premium prices for these products (Kootanaee *et al*., 2013). The BSC strategy was least suitable for high-end products due to the nature of responding to demand, complexity of manufacturing, stock level, handling and in some cases distribution (Chakravarty, 2014). However, some products such as wedding gowns require basic components to be manufactured using a basic supply chain, for example wedding veils, dress extension and various accessories. These items are a basic necessity and can be stocked as the demand for them can be forecasted (Tan *et al*., 1998).

*Table 28: High-end product variables (Source: author)*

**If a supply chain is focused on high-end mass customisation, then its approach should be:**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 22 | 24.4 |
| | Agile | 26 | 28.9 |
| | Leagile | 24 | 26.7 |
| | Basic supply chain strategies | 18 | 20.0 |
| | Total | 90 | 100.0 |

### Self-customised

Experts chose Leagile strategy to be most suitable for self-customised products in Table. 29, for example a high end laptop such as Dell, sourcing and manufacturing follows an agile strategy to incorporate changes in technology, while assembly is Lean and built-to-order as customer personalisation takes place using JIT system and is distributed accordingly (Davis, 2010). Agile came second as it allowed room for customisation flexibility; for example specialist mountain bikes are customised at production in accordance to the consumer's needs, if the consumer changes their mind, the supply chain must be able to adapt to that. The same can be applied to personal gaming computers, where the consumer can build the parts of the computer they which to buy, however if they change their mind then the assembly node of the supply chain must be able to account for that (Davis, *ibid*). The Lean strategy came third due to the difficulty of accommodating the consumer's expectation of self-customised products to be delivered at the next available delivery. Therefore self-customised supply chains most likely require the assembly, handling and distribution stages to be as lean as possible (Mourtzis *et al*., 2008) The BSC strategy came last as most daily products don't require self-customisation but rather mass production. However, some products such as household or birthday gifts can be self-customised and require a simple basic supply chain where demand is predictable, inventory is kept stable, the goods are mass produced, and manufactured at low cost for the mass market then stocked at the warehouse to be distributed with a planned scheduled with predictable lead time to the wholesaler, where at the stage of the retailer the item would be customised to the customer's request (Tan et al., 1998). For example customised jumpers, printed t-shirts and mugs.

*Table 29: Self-customised product variable (Source: author)*

**Self-customised goods: enable the customer to change the product at any time to suit their own preferences (Alford et al, 2000).**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 17 | 18.9 |
| | Agile | 25 | 27.8 |
| | Leagile | 36 | 40.0 |
| | Basic supply chain strategies | 12 | 13.3 |
| | Total | 90 | 100.0 |

## Push System

Experts chose BSC as most suitable due to goods that require a push system usually having a predictable demand (Table. 30), such as cutlery, stationary and school or work uniforms. These products have a stable demand and therefore have a stable inventory level that requires them to be manufactured using a push system, in order for the wholesaler to maintain their predicted stock level (Cagliano *et al*., 2004). Leagile was chosen as the second most suitable strategy as some of these products such as work uniforms can be classified as functional innovative, where different styles and designs can be applied at the assembly stage and the products can be held at the postponement stage for seasonal purposes. However, manufacturing of the garments would have a push system, in order to push these products into the market (Lu *et al*., 2003). After the items are released from the postponement stage they are pushed to the wholesaler where inventory level has to be maintained to satisfy the forecasted demand (Alford *et al*., 2000). Experts chose Agile strategy as third most suitable, due to the case of the fashion industry examined by Bruce *et al*. (2004), where clothes are designed and pushed to production in preparation for different seasons, although due to customers' change in taste and unpredictable weather, the Agile strategy explained by Cagliano *et al*. (2004) combines the push system at manufacturing with flexibility to enable the supply chain to respond to changes in the market. The Lean strategy was chosen as least suitable due to the nature of push products being made for a "make-to-stock" model rather than a "make-to-order". However, all "make-to-order" products require their basic component and parts to be manufactured and pushed into their components inventory until an order arrives for the manufacturing to begin, and usually forecasting can be predicted for resources and component's that are needed to manufacture the products that will be ordered (Elfving, 2003).

*Table 30: Push system variable (Source: author)*

**According to Alford et al (2000), when a company pushes variety of goods into the market in hope that customers will find what they want.**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Lean | 9 | 10.0 |
| | Agile | 22 | 24.4 |
| | Leagile | 24 | 26.7 |
| | Basic supply chain strategies | 35 | 38.9 |
| | Total | 90 | 100.0 |

### 5.5.2 Excel Analysis

In addition to SPSS, this study chose Excel because it's widely used and understood, in addition to the simplicity of manoeuvring data. Excel was used to further explain the data collection and describe how scatter diagrams were created in order to establish the fuzzy rule sets used for building the interactive MDM.

The scatter diagrams illustrate the repetition of each relevant variable against the "JIT Lean" and "Cost" which then creates the Excel frequency (Appendix L and M). For example the Delivery to request versus the low, medium and high "JIT Lean" and "Cost". Extracting a scatter diagram from the variables helps the creation of the frequency and percentage Excel table of the chosen variables in order to illustrate the most favoured supply chain strategy and other possible options for each node in the supply chain (Table. 31).

The spreadsheet that summarises frequency in Excel was derived by adding up the expert's opinions from Hybrid Fuzzy Delphi data, and then converted into percentages. The data collected reflects the opinion of 90 experts, hence the percentage factor is 100/90=1.11, which is then multiplied by the frequency number to gain the total percentage. For example in Table 31: Delivery to request = frequency of 24 Lean, hence 24x1.11=26.7%.

*Table 31: Summary of frequency variables converted into percentages (Source: author)*

| | DELIVERY | | | PRODUCT DESIGN | | | DISTRIBUTION | | | LEAD-TIME | DEMAND APPROACH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Request | Comite Date | Order fill Lead-time | Innovative Product | Functional Product | Innovative Functional | Strategic | Tactical | Operational | Manufacturing Lead-time | High-end Strategy | Self-Customised | Push System |
| **Frequency** | | | | | | | | | | | | | |
| **Lean** | 24 | 18 | 19 | 9 | 21 | 20 | 22 | 16 | 13 | 14 | 22 | 17 | 9 |
| **Agile** | 25 | 33 | 20 | 43 | 17 | 25 | 25 | 25 | 18 | 35 | 26 | 25 | 22 |
| **Leagile** | 8 | 18 | 21 | 19 | 14 | 26 | 18 | 25 | 26 | 21 | 24 | 36 | 24 |
| **BSC** | 33 | 21 | 30 | 19 | 38 | 19 | 25 | 24 | 33 | 20 | 18 | 12 | 35 |
| **Total** | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | To change the frequency to 100 we have to multibly the figurs by : | | | | | | | 1.111 | | | | | |
| % | 26.7 | 20.0 | 21.1 | 10.0 | 23.3 | 22.2 | 24.4 | 17.8 | 14.4 | 15.6 | 24.4 | 18.9 | 10.0 |
| % | 27.8 | 36.7 | 22.2 | 47.8 | 18.9 | 27.8 | 27.8 | 27.8 | 20.0 | 38.9 | 28.9 | 27.8 | 24.4 |
| % | 8.9 | 20.0 | 23.3 | 21.1 | 15.6 | 28.9 | 20.0 | 27.8 | 28.9 | 23.3 | 26.7 | 40.0 | 26.7 |
| % | 36.7 | 23.3 | 33.3 | 21.1 | 42.2 | 21.1 | 27.8 | 26.7 | 36.7 | 22.2 | 20.0 | 13.3 | 38.9 |
| **Total** | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

The Excel summary of frequency and percentages drawn in Table 31 can be used as an advisory database to help management identify the most suited strategy for the selected variable. For example, if the operation manager choses to select a variable from the "Delivery approach" such as "Delivery to Request", then the experts' recommendation is to implement a BSC strategy to enhance the company's logistics performance. However, at the distribution node, if the operation manager selects a "Strategic" option, then the experts' recommendation would be to apply either an Agile or BSC strategy depending on the company's business structure. Meanwhile if the operation manager selected the product design to be "Innovative product", then the recommendation would be to apply an Agile strategy in the company's supply chain. Moreover, if the operation manager selects a "High-end strategy" from the "Demand approach", then the recommendation would be to apply an Agile supply chain strategy. The experts' recommendation for the "Manufacturing lead-time" variable is to implement an

Agile supply chain strategy in order to ensure flexibility during the manufacturing process and promote efficiency. The frequencies have been converted into percentages to represent the answers in simple terms, in order to help management understand the strength of the advice. However, the frequency tables from SPSS and Excel are not enough to form a coherent analysis, as they only illustrate the relationship between two variables. To overcome this limitation, scatter diagrams are drawn to illustrate the frequency between three variables in every graph. For example, the "Manufacturing Lead-time" frequency is plotted against the "Lean, Agile, Leagile and BSC" in addition to either the "Cost" or "JIT Lean" percentages. This enables better deductive reasoning in understanding the experts' recommendation, as it accounts for the total cost of production they are willing to invest and the percentage of JIT Leanness they require.

### Margin of Error

Because the data collected the opinions of 90 experts which is relatively close to 100, it is reasonable to discuss the statistical elements in percentage terms for this section of the analysis. The red highlighted numbers in Table 32 illustrates the data that is ruled to be inaccurate, statistically known as "margin of error", which measures the survey's uncertainty. Questionnaires are designed to provide an estimation of the true value of one or more variables, however when errors occur it does not render the questionnaire useless or inaccurate, especially when the margin of error is insignificant in comparison to the majority who have reached a consensus (Munier and Rondé, 2001). The extent of sampling error can be defined as a "margin of error", and it's calculated as (estimate +/- margin of error) (American Statistical Association, 1998). There are several factors that affect the margin of error. Firstly size, as larger samples are more likely to yield results close to the target as the quantity will have smaller margins of error than modest-sized samples. Secondly, sampling designs can affect the margin of error, as each design has a probability of having a degree of marginal error. Finally, the sampling type such as random sampling, random digit dialling, and stratified sampling (American Statistical Association, 1998). The Hybrid Fuzzy Delphi used in this research follows a random sampling strategy as experts in supply chains were selected from different random industries and institutes across the world to expand the scope and include a variety of backgrounds and different perspectives to the study. Sometimes, the questionnaires carry too much information and samples of the variables that are selected and drawn in cluster or scatter diagrams (Appendix L and M).

Table 32, shows the Lean variable at (70%) was answered inaccurately at least once, as the number of experts choosing that “70% Lean = Low” should be less than the amount of experts that chose “60% Lean = Low”. The higher the percentage of Lean the less lead time, hence more experts would move towards the high and medium variable as the percentage increases. This margin of error is highlighted in the percentage summary of 4.4%. However, a maximum of 2 experts made a consecutive error of choosing “Low” from 70% to 90% Lean (Table. 32). Therefore, the two experts will equal 2.2% marginal error out of 4.4%, while the rest will be ruled out as human error due to the experts correcting their answers in the questions that followed. Accordingly the marginal error in this case is 2.2% and can be calculated as follows:

**(Estimate +/- margin of error) = (88-92%) = the margin of error is -4%**

Without calculating the margin of error, the statistics represented by the questionnaire would find that 2.2% of the experts believe that 70% Lean results is “more” lead time than 60% Lean, resulting in incomplete information. However, when the margin of error is specified as 2.2%, this indicates that 90% of expert opinions should be interpreted as 88-92%, giving complete information for the majority to have a consensus that 70 Lean will result in “less” lead time.

*Table 32: Cost and JIT Lean frequency converted into percentages (Source: author)*

| | | COST | | | | | | LEAN | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-10% | 11-20% | 21-30% | 31-40% | 41-50% | 51-60% | 0-10% | 11-20% | 21-30% | 31-40% | 41-50% | 51-60% | 61-70% | 71-80% | 81- > 90% |
| **Frequency** | Low | 79 | 54 | 17 | 0 | 0 | 0 | 84 | 76 | 39 | 15 | 5 | 3 | 4 | 3 | 2 |
| | Medium | 9 | 30 | 55 | 51 | 21 | 10 | 4 | 12 | 47 | 57 | 40 | 33 | 12 | 5 | 0 |
| | High | 2 | 6 | 18 | 39 | 69 | 80 | 2 | 2 | 4 | 18 | 45 | 54 | 74 | 82 | 88 |
| | **Total** | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | | To change the frequency to 100 we have to multibly the figurs by : | | | | | | | | | | 1.111 | | | | |
| **Percentages** | % | 87.8 | 60.0 | 18.9 | 0.0 | 0.0 | 0.0 | 93.3 | 84.4 | 43.3 | 16.7 | 5.6 | 3.3 | 4.4 | 3.3 | 2.2 |
| | % | 10.0 | 33.3 | 61.1 | 56.7 | 23.3 | 11.1 | 4.4 | 13.3 | 52.2 | 63.3 | 44.4 | 36.7 | 13.3 | 5.6 | 0.0 |
| | % | 2.2 | 6.7 | 20.0 | 43.3 | 76.7 | 88.9 | 2.2 | 2.2 | 4.4 | 20.0 | 50.0 | 60.0 | 82.2 | 91.1 | 97.8 |
| | **Total** | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

The margin of error is usually expressed as a percentage, but in some cases, may also be expressed as an absolute number. In statistics, margin of error makes the most sense for normally distributed data, such as the bell shape diagram (Chandrasekaran, 2011).

The pilot Delphi was created on the basis of experts initially identifying the relevant “Cost” and “JIT Lean” fuzzy sets. Therefore, to further illustrate their features, the “Cost” and “JIT Lean” fuzzy set variables were plotted against their frequencies. The frequencies for each “Cost” and “JIT Lean” was represented based on the number of experts choosing what percentage constitutes “High”, “Medium” and “Low”. Both diagrams (Fig. 48 and Fig. 49) show that both the “High Cost” and the “High JIT Lean” percentages are directly tangent proportional with the frequency percentage; while both the “Low Cost” and “Low JIT Lean” percentages have a negative relation with the frequency. Meanwhile, the “Medium Cost” as well as the “Medium” JIT Lean percentages have negative parabola (concave shape) with the frequency percentage, reaching its apex at ≈60% frequency with ≈34% Cost, and ≈60% frequency with ≈40% JIT Lean.

The “Cost” fuzzy set diagram illustrates a bell shape between the “Cost” trend and its frequency in relation to the “Low”, “Medium” and “High” variables (Fig. 48). The values of the “Low” and “Medium” trends of the “Cost” percentage intersects at ≈22% cost with ≈40% frequency, while the “High” and “Medium” values intersects at ≈42% cost and ≈45% frequency. However, the trends of the “High” and “Low” of the “Cost” percentage against its frequency intersects at 30% Cost and 18 % frequency.

The “Low Cost” curve is downward-bowed, indicating decrease in a strictly concave trend, while the “High Cost” curve is upward-bowed, indicating increase in a strictly convex trend. The “Medium Cost” has a Bell-shaped normal distribution that intersects with both the “Low Cost” and “High Cost” trends. Each intersection shows the relationship between the “Low”, “Medium” and “High” trends. For example, from the graph (Fig. 48), it can be seen that at above/below 30% “Cost”, ≈18 experts believe its “Low”, ≈60 experts chose “Medium” and ≈20 experts chose “High”, indicating a very close relationship between what constitutes a “Low” or “High” Cost at 20% frequency, though most experts rank 30% cost as “Medium”. However, at 40% cost a close relationship can be seen forming between the “Medium” and “High” options, which becomes less close as the cost percentage increases (Fig. 48).

This signifies a consensus in the relationship between the Cost and its frequency regardless of the marginal error (Appendix K). The Cost diagram (Fig. 48), illustrates two elliptical bounded areas (can be called a fuzzy area) created by the three trends. The first has an average of 23-44% Cost and 15-58% frequency. The second has an average of 3-30% Cost and 2-40% JIT Lean (Fig. 48). In the first elliptical bounded fuzzy area, the target of the companies should be at least >23 and <44% Cost. The second elliptical bounded fuzzy area, the target of the companies should be at least >3 and <30% Cost. The second elliptical bounded fuzzy area is most favoured as indicated by the Hybrid Fuzzy Delphi, Qualtrics and SPSS consensus.

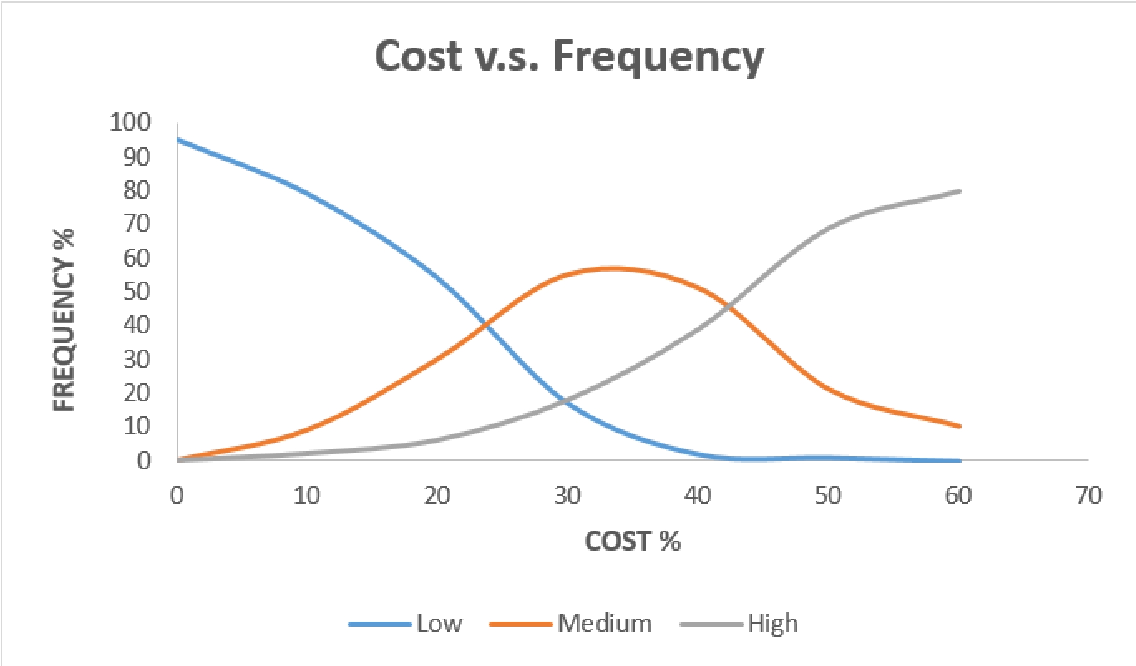


*Figure 48: Cost V.S. Frequency variables (Source: author)*

Similarly, the Lean fuzzy set diagram shows the “Low Lean” curve as downward-bowed, indicating its decreasing in a strictly concave trend, while the “High Lean” curve is upward-bowed, indicating its increasing in a strictly convex trend (Chandrasekaran, 2011). Similar to the Cost, the “Medium Lean” has a bell-shaped normal distribution that intersects with both the “Low” and “High” trends. Each intersection shows the relationship between the trends, for instance at ≈40% JIT Lean, the “Low” and “High” are closer together while majority of experts ranked it as “Medium”. This is also shown at ≈50% JIT Lean between the “Medium” and “High”, while the gap in the relationship becomes further apart as the JIT Lean percentage increases (Fig. 49). This signifies a consensus in the relationship between the JIT Lean and its frequency regardless of the marginal error (Appendix K). Meanwhile, from the graph (Fig. 49), the values of the“Low” and “Medium” trends of “JIT Lean” intersects at ≈28% JIT Lean and ≈43% frequency, while the “High” and “Medium” values start intersecting at ≈50% JIT Lean and at ≈ 45% frequency. Nonetheless, the “High” and “Low” trends of the JIT Lean against its frequencies intersects at ≈40% JIT Lean and 17% frequency. The JIT Lean has three elliptical bounded fuzzy areas, the first is between 17-60% frequency and ≈ 30-50% JIT Lean. The second is between 5-45% frequency and ≈5-40% JIT Lean. The last unbounded and most favoured elliptical fuzzy area by companies as indicated by the Hybrid Fuzzy Delphi consensus, is for the JIT Lean to be at least >55%, hence 17-60% frequency and 40- >90% JIT Lean (Fig. 49).

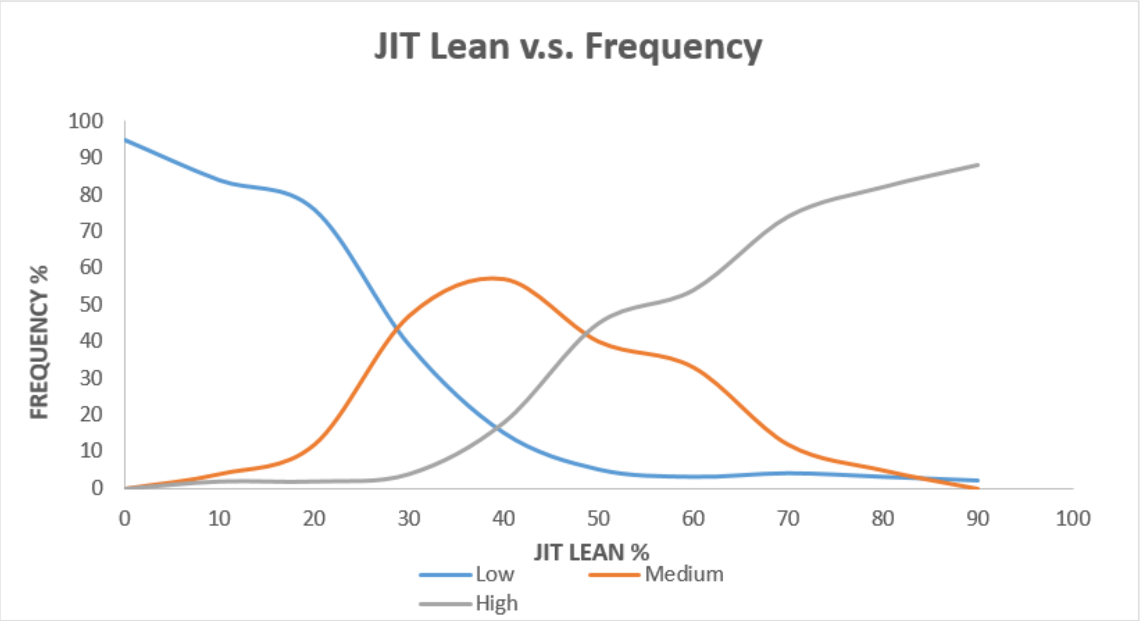


*Figure 49: JIT Lean V.S. Frequency variables (Source: author)*

### 5.5.3 Scatter Diagram Analysis

Scatter diagrams are used to represent and compare two sets of data, for example from the logistics group variables, “Delivery to Request” was plotted against the “JIT Lean” (Fig. 50). The scatter diagram illustrates whether there is any connection (correlation) between two sets of data, by plotting the ranges of a variable against its frequencies. The scatter diagrams show the relationship between two variables in pairs of observations and may indicate cause and effect relationship that leads to further investigation. For example for the “Delivery to Request” variable, is plotted by having the JIT Lean percentage (Low, Medium and High) on the horizontal axis, while the vertical axis represents the supply chain strategy (Lean, Agile, Leagile and BSC) best suited for the business.

| Abbreviations | | | |
|---|---|---|---|
| **1** | **Lean** supply chain strategy | **L** | **Low** |
| **2** | **Agile** supply chain strategy | **M** | **Medium** |
| **3** | **Leagile** supply chain strategy | **H** | **High** |
| **4** | **Basic** supply chain strategy | | |

| Delivery to Request | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 32 | | 1 | 29 | 3 | 2 | 14 | 17 | 2 | 5 | 23 | 5 |
| 3 | 7 | 1 | | 7 | 1 | | 3 | 5 | | 2 | 3 | 3 |
| 2 | 21 | 3 | 1 | 20 | 4 | 1 | 13 | 11 | 1 | 4 | 17 | 4 |
| 1 | 24 | | | 20 | 4 | | 9 | 14 | 1 | 4 | 14 | 6 |

| Delivery to Request | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 1 | 16 | 16 | 1 | 12 | 20 | 2 | 2 | 29 | 2 | | 31 | 1 | | 32 |
| 3 | 1 | 1 | 6 | 1 | 1 | 6 | 1 | 1 | 6 | | 1 | 7 | | | 8 |
| 2 | 2 | 12 | 11 | | 12 | 13 | 1 | 4 | 20 | 1 | 2 | 22 | 1 | | 24 |
| 1 | 1 | 11 | 12 | 1 | 8 | 15 | | 5 | 19 | | 2 | 22 | | | 24 |

**JIT Lean %**

*Figure 50: Delivery to Request and JIT Lean scatter diagram (Source: author)*

The scatter diagrams also plot the “Cost” against each of the variables according to the supply chain strategies. For example, the “Delivery to Request” variable is plotted by having the “Cost” percentage (Low, Medium and High) on the horizontal axis, while the vertical axis represents the best supply chain strategy in the experts’ opinion based on what they constitute the best strategy for that range (Lean, Agile, Leagile and BSC) (Fig. 51). The scatter diagram illustrates the responses to changes between both axes, which build the structure of the fuzzy rules (Appendix L and M).

| Delivery to Request | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 30 | 3 | | 22 | 9 | 2 | 6 | 23 | 4 | | 23 | 10 | | 7 | 26 | | 5 | 28 |
| 3 | 6 | 2 | | 5 | 3 | | | 6 | 2 | | 1 | 7 | | | 8 | | | 8 |
| 2 | 20 | 4 | 1 | 16 | 6 | 3 | 5 | 14 | 6 | | 16 | 9 | | 7 | 18 | | 3 | 22 |
| 1 | 23 | | 1 | 11 | 12 | 1 | 6 | 12 | 6 | | 11 | 13 | | 7 | 17 | | 2 | 22 |

**Cost %**

*Figure 51: Delivery to Request and Cost scatter diagram (Source: author)*

The SPSS frequency and the Excel percentages helped draw the scatter diagrams that structured the fuzzy rules on which the interactive MDM was established. These fuzzy rules are inputted into the database's code system of the interactive MDM to create a tool that can be tested by this study for validity, to ensure its beneficial applicability to SMEs and industries.

This study created scatter diagrams for all the relative groups within the logistics and supply chain variables. Each group within the logistics and supply chain variables was plotted against the "JIT Lean" and "Cost" in accordance with the four supply chain strategies of (Lean, Agile, Leagile and BSC). For example, from the supply chain group variables, under "Product Design", the "Innovative Product" variable was plotted against the JIT Lean. In Figure 52, when JIT Lean is low from 10-20% the supply chain strategy values are highest at the "Low Lean" option, with the majority of experts choosing Agile strategy as most suitable. Meanwhile, from 31-50% it can be seen that supply chain strategy values are moving towards the "Medium Lean", with a majority of experts maintaining their choice of Agile strategy. Nevertheless, the shift in value continues towards "High Lean" from 51- > 90%, as the concave trend emerges from Lean strategy to BSC, while majority of experts maintain the choice of Agile as most suitable (Fig. 52).

| Innovative Product | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 18 | 1 | | 16 | 3 | | 5 | 14 | | 1 | 14 | 4 | 1 | 4 | 14 | 1 | 2 | 16 | 1 | | 18 | 1 | | 18 | | | 19 |
| 3 | 18 | | 1 | 16 | 2 | 3 | 6 | 12 | 1 | 1 | 13 | 5 | | 8 | 11 | | 7 | 12 | 1 | 3 | 15 | 1 | 1 | 17 | 1 | | 18 |
| 2 | 39 | 3 | 1 | 36 | 6 | 1 | 22 | 18 | 3 | 9 | 26 | 8 | 3 | 22 | 18 | 2 | 20 | 21 | 2 | 7 | 34 | 1 | 4 | 38 | 1 | | 42 |
| 1 | 9 | | | 8 | 1 | | 6 | 3 | | 4 | 4 | 1 | 1 | 6 | 2 | | 4 | 5 | | 2 | 7 | | | 9 | | | 9 |

JIT Lean %

*Figure 52: Innovative Product and JIT Lean scatter diagram (Source: author)*

This explanation has been applied to all scatter diagrams shown in (Appendix L and M), in order to formulate the fuzzy rules. The Cost percentage variable ranges from 0- <60%, similar to the JIT Lean as it ranges from 0- >90%. Each interval has been divided into three clusters which is "Low", "Medium" and "High". The scatter diagram plotting the "Cost" percentage against the logistics and supply chain variable groups give an overall of 78 scatter diagrams, in which each figure (rectangle) reflects the frequency replies of the 90 participants. Meanwhile, the

“JIT Lean” against the logistics and supply chain variable groups give an overall of 117 scatter diagrams. When combined, the total scatter diagrams between the Cost against the logistics and supply chain variable groups, as well as the JIT Lean against the logistics and supply chain variable groups give an overall of 195 scatter diagrams (Appendix L and M).

#### 5.5.3.1 Fuzzy Rule Sets

To illustrate how the fuzzy rules were created, a random sample of the logistics and supply chain strategy variables will be chosen, due to the large number of fuzzy rules extracted from the data. The scatter diagrams are created from the frequency and percentage tables generated by SPSS and Excel, the fuzzy rules are created from the scatter diagrams by extracting the correlating variables of the logistics and supply chain groups against the “JIT Lean” and “Cost” variables. The fuzzy rules establish a relationship between the “JIT Lean” and “Cost” via a selected logistics or supply chain variables using (If-Then) and the scatter diagrams for each logistics and supply chain group against the “JIT Lean” and “Cost”, then merged together (e.g. the logistics variables vs. “JIT Lean” with logistics variables vs. “Cost”) to create the (If-Then) fuzzy rules of the interactive MDM. These (If-Then) fuzzy rules are then implemented in a combination of JavaScript[17] and HTML[18] code to create a web-based interactive system, where the MDM can operate interactively. The random sample to be examined from the logistics variable will be “Manufacturing lead-time”, while the supply chain variable will be “Innovative product”.

#### Logistics strategies: Manufacturing lead time

The scatter diagram plots the frequency of a logistics variable “Manufacturing lead-time” generated from the SPSS and Excel against the supply chain strategy (Lean, Agile, Leagile and BSC) with regard to the “JIT Lean” (Fig. 53).

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[17] JavaScript is a programming language primarily used to add interactive content to web-pages.

[18] Hyper Text Markup Language (HTML), is the standard markup language used to create web-pages.

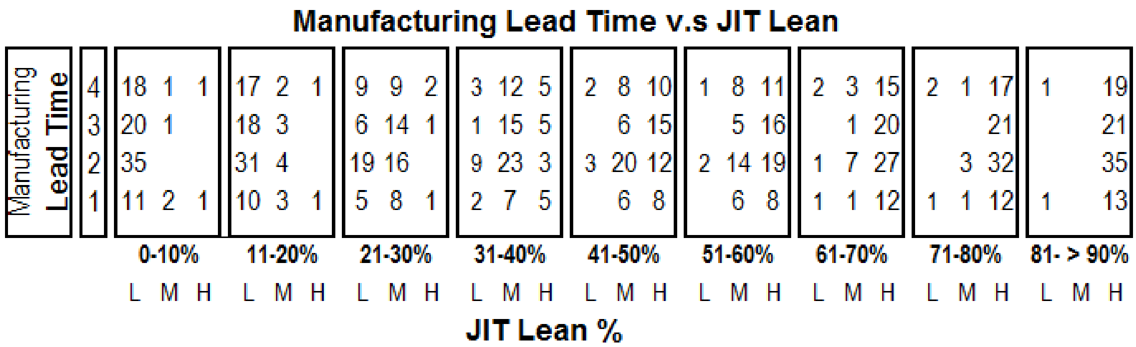


*Figure 53: Manufacturing lead-time vs. JIT Lean scatter diagram (Source: author)*

The scatter diagram (Fig. 53) shows clustering of frequencies which illustrate the relationship between the manufacturing lead time and the best suited supply chain strategy chosen by the experts, in accordance with what is considered an acceptable lead time measured by "JIT Lean" (Appendix N). The (If-Then) fuzzy rules that can be extracted from the scatter diagram are written in the following method:

**If** 0-10% JIT Lean = **Then**- Low lean, majority recommend Agile, option Leagile

**If** 11-20% JIT Lean= **Then**- Low lean, majority recommend Agile, option Leagile

**If** 21-30% JIT Lean= **Then**- Low lean, majority recommend Agile, option Leagile

**If** 31-40% JIT Lean= **Then**- Medium lean, majority recommend Agile, option Leagile

**If** 41-50% JIT Lean= **Then**- Medium lean, majority recommend Agile, option Leagile

**If** 51-60% JIT Lean= **Then**- High lean, majority recommend Agile, option Leagile

**If** 61-70% JIT Lean= **Then**- High lean, majority recommend Agile, option Leagile or BSC

**If** 71-80% JIT Lean= **Then**- High lean, majority recommend Agile, option Leagile

**If** 81- >90% JIT Lean= **Then**- High lean, majority recommend Agile, Leagile or BSC

The manufacturing lead-time scatter diagram against the "Cost", shows the clustering of frequencies of the most suited supply chain strategy chosen by the experts (Fig. 54).

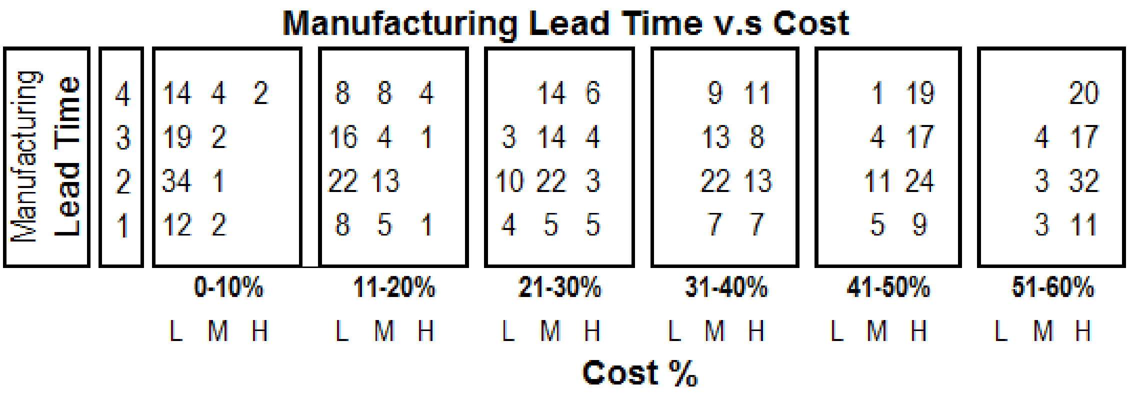


*Figure 54: Manufacturing lead-time vs. Cost scatter diagram (Source: author)*

The (If-Then) fuzzy rules extracted from the manufacturing lead-time against the "Cost" (Fig. 54), are written in the following method:

**If** 0-10% Cost= **Then**- Low cost, majority recommend Agile

**If** 11-20% Cost= **Then**- Low cost, majority recommend Agile

**If** 21-30% Cost= **Then**- Medium cost, majority recommend Agile, option Leagile And/Or BSC

**If** 31-40% Cost= **Then**- High cost, majority recommend Agile, option Leagile

**If** 41-50% Cost= **Then**-High cost, majority recommend Agile, option BSC

**If** 51-60% Cost= **Then**-High cost, majority recommend Agile, option BSC

The (If-Then) fuzzy rules have been organised and summarised into a table, to enable easy access to the data (Appendix N) and (Table. 33). Combining both "Cost" and "JIT Lean" (If-Then) fuzzy rules together, the best supply chain strategy for manufacturing lead-time can be identified (Table. 33). The combination is done by taken the common factors and merging them together for every "Cost" and "JIT Lean" percentage. Since the "JIT Lean" has a range from 0->90% and "Cost" ranges from 0-60%, the study created each combinations to cover every "JIT Lean" percentage for each logistic group variable (Appendix P and Q).

*Table 33: Manufacturing lead-time fuzzy rules summary (Source: author)*

| Manufacturing Lead Time vs. JIT Lean and Cost variables | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-10 | 0-20 | Agile Strategy | Legile Strategy | |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | |
| | 41-50 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 51-60 | Agile Strategy | BSC Strategy | Legile Strategy |
| 11-60% | 0-60 | Agile Strategy | Legile Strategy | |
| 61-70 | 0-40 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 41-60 | Agile Strategy | BSC Strategy | Legile Strategy |
| 71-80 | 0-20 | Agile Strategy | Lean Strategy | Legile Strategy |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or Lean Strategy And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 41- 60 | Agile Strategy | BSC Strategy | And/Or Lean Strategy And/Or Legile Strategy |
| 81- > 90 | 0-20 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 41-60 | Agile Strategy | BSC Strategy | Legile Strategy |

A sample has been selected as an example, one sample of the 0-10% “JIT Lean” and 0-60% “Cost” is chosen to illustrate the combined fuzzy rules (Table. 34). These rules are written in the following method. This example was chosen to illustrate how the “If-Then” rules are drawn for the interactive MDM.

*Table 34: Manufacturing lead-time of 0-10% JIT Lean vs. Cost (Source: author)*

<table>
<tr><th rowspan="2">JIT%</th><th rowspan="2">Cost%</th><th colspan="3">MLT</th><th colspan="2">Abbreviations</th></tr>
<tr><th>F</th><th>1</th><th>2</th><th>MLT</th><th>Manufacturing lead time</th></tr>
<tr><td rowspan="6">0-10</td><td>0-10</td><td>ASC</td><td>LeSC</td><td></td><td>F</td><td>Favoured</td></tr>
<tr><td>11-20</td><td>ASC</td><td>LeSC</td><td></td><td>1</td><td>Option</td></tr>
<tr><td>21-30</td><td>ASC</td><td>LeSC</td><td>And/Or BSC</td><td>2</td><td>And/or</td></tr>
<tr><td>31-40</td><td>ASC</td><td>LeSC</td><td></td><td>ASC</td><td>Agile</td></tr>
<tr><td>41-50</td><td>ASC</td><td>LeSC</td><td>And/Or BSC</td><td>LeSC</td><td>Legile</td></tr>
<tr><td>51-60</td><td>ASC</td><td>BSC</td><td>LeSC</td><td>BSC</td><td>Basic Supply Chain</td></tr>
</table>

*JIT 0-10% JIT Lean and Cost with Manufacturing Lead-time Variable:*

**If** 0-10% JIT + 0-10% cost = **Then**- majority recommend Agile option Leagile

**If** 0-10% JIT + 11-20% cost = **Then**- majority recommend Agile option Leagile

**If** 0-10% JIT + 21-30% cost = **Then**- majority recommend Agile option Leagile And/Or BSC

**If** 0-10% JIT + 31-40% cost = **Then**- majority recommend Agile option Leagile

**If** 0-10% JIT + 41-50% cost = **Then**- majority recommend Agile option Leagile And/Or BSC

**If** 0-10% JIT + 51-60% cost = **Then**- majority recommend Agile option BSC And/Or Leagile

These combined fuzzy rules will be translated into JavaScript code to create the interactive MDM matrix, which will be accessed via a website to be used as a tool to aid company decision making. This will improve the suitability of a supply chain strategy at each node of the business framework.

## Supply chain strategies: Innovative product design

As mentioned in the previous section, the scatter diagram of the innovative product variable will show the relationship between the "JIT Lean" and the best suited supply chain strategy for that variable (Fig. 55).

| Innovative Product | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 18 | 1 | | 16 | 3 | | 5 | 14 | | 1 | 14 | 4 | 1 | 4 | 14 | 1 | 2 | 16 | 1 | | 18 | 1 | | 18 | | | 19 |
| 3 | 18 | | 1 | 16 | 2 | 3 | 6 | 12 | 1 | 1 | 13 | 5 | | 8 | 11 | | 7 | 12 | 1 | 3 | 15 | 1 | 1 | 17 | 1 | | 18 |
| 2 | 39 | 3 | 1 | 36 | 6 | 1 | 22 | 18 | 3 | 9 | 26 | 8 | 3 | 22 | 18 | 2 | 20 | 21 | 2 | 7 | 34 | 1 | 4 | 38 | 1 | | 42 |
| 1 | 9 | | | 8 | 1 | | 6 | 3 | | 4 | 4 | 1 | 1 | 6 | 2 | | 4 | 5 | | 2 | 7 | | | 9 | | | 9 |

JIT Lean %

*Figure 55: Innovative product vs. JIT Lean scatter diagram (Source: author)*

The (If-Then) fuzzy rules will be generated from the frequency clusters were written as follows (Appendix O):

**If** 0-10% Lean = **Then**- Low lean, majority recommend Agile, option Leagile And/Or BSC

**If** 11-20% Lean= **Then**- Low lean, majority recommend Agile, option Leagile And/Or BSC

**If** 21-30% Lean= **Then**- Low lean, majority recommend Agile

**If** 31-40% Lean= **Then**- Medium lean, majority recommend Agile

**If** 41-50% Lean= **Then**- Medium lean, majority recommend Agile

**If** 51-60% Lean= **Then**- High lean, majority recommend Agile, option BSC

**If** 61-70% Lean= **Then**- High lean, majority recommend Agile, option BSC

**If** 71-80% Lean= **Then**- High lean, majority recommend Agile, option BSC

**If** 81-90% Lean= **Then**- High lean, majority recommend Agile, option BSC

The second scatter diagram, as mentioned previously, shows the relationship between the "Cost" and best suited supply chain strategy for the innovative product. This is illustrated as follows (Fig. 56).

| Innovative Product | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| 4 | 18 | 1 | | 9 | 9 | 1 | 2 | 13 | 4 | | 7 | 12 | | 2 | 17 | | | 19 |
| 3 | 17 | 2 | | 11 | 8 | | 2 | 14 | 3 | | 10 | 9 | | 4 | 15 | | 4 | 15 |
| 2 | 35 | 6 | 2 | 28 | 10 | 5 | 10 | 23 | 10 | | 27 | 16 | | 11 | 32 | | 6 | 37 |
| 1 | 9 | | | 6 | 3 | | 3 | 5 | 1 | | 7 | 2 | | 4 | 5 | | | 9 |

**Cost %**

*Figure 56: Innovative product vs. Cost scatter diagram (Source: author)*

The (If-Then) fuzzy rules will be generated from the frequency clusters were written in the following method:

**If** 0-10% Cost= **Then**, Low cost, majority recommend Agile

**If** 11-20% Cost= **Then**- Low cost, majority recommend Agile

**If** 21-30% Cost= **Then**- Medium cost, majority recommend Agile

**If** 31-40% Cost= **Then**- High cost, majority recommend Agile

**If** 41-50% Cost= **Then**- High cost, majority recommend Agile

**If** 51-60% Cost= **Then**- High cost, majority recommend Agile

Combining both the fuzzy rules for the JIT Lean and Cost, the best supply chain strategy for an innovative product design can be found. Given the "JIT Lean" has a range up to >90% and the "Cost" up to 60%, the fuzzy rule combination has to be made for each "JIT Lean" percentage against each "Cost" percentage. A sample of innovative product 0->90% "JIT Lean" against 0-60% "Cost" is chosen to illustrate this combination process (Table. 35). From the innovative product vs. “Cost” scatter diagram variable above, it can be deducted that Agile is the common factor, however from the innovative product vs. “JIT Lean” scatter diagram, the fuzzy rules gave the option of Leagile And/Or BSC, which can be combined to give a unified fuzzy rule to be input into the interactive MDM. Combining the options of the innovative product against both the “JIT Lean” and “Cost” variables, gives companies room to manoeuvre to choose what suits their business and product (Appendix O).

*Table 35: Innovative product fuzzy rules summary (Source: author)*

| **Innovative Product vs. JIT Lean and Cost variables** | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-20 | 0-60 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| 21-50 | 0-60 | Agile Strategy | | |
| 51- >90 | 0-60 | Agile Strategy | BSC Strategy | |

Table 35, illustrates the combination results between 0- >90% “JIT Lean” and 0-60% “Cost” against the innovative product variable. The (If-Then) fuzzy rules for the sample of 0-10% “JIT Lean” and 0-60% “Cost” for the innovative product were written as follows:

**If** 0-10% JIT + 0-10% cost = **Then**- majority Agile option Leagile And/Or BSC

**If** 0-10% JIT + 11-20% cost = **Then**- majority Agile option Leagile And/Or BSC

**If** 0-10% JIT + 21-30% cost = **Then**- majority Agile option Leagile And/Or BSC

**If** 0-10% JIT + 31-40% cost = **Then**- majority Agile option Leagile And/Or BSC

**If** 0-10% JIT + 41-50% cost = **Then**- majority Agile option Leagile And/Or BSC

**If** 0-10% JIT + 51-60% cost = **Then**- majority Agile option Leagile And/Or BSC

These combined variables are organised and summarised into a table, in order to ease access to the information and for the fuzzy rules to be easily inputted into JavaScript to build the interactive MDM web-based tool, which will be tested on a selected company (Table. 36 and Appendices P and Q). In Table 36, the most favoured strategy is shown at 0-10% “JIT Lean” which is considered (Low Lean) and 0-60% “Cost”, is Agile with the option of Leagile strategy and or BSC. This selection can be deductively explained due to the flexibility requirement of a product on the low Lean end, which can be accommodated by an Agile strategy.

*Table 36: Innovative product vs. 0-10% JIT Lean and cost (Source: author)*

| JIT% | Cost% | Innovative Product | | |
|---|---|---|---|---|
| | | F | 1 | 2 |
| 0-10 | 0-10 | ASC | LeSC | And/Or BSC |
| | 11-20 | ASC | LeSC | And/Or BSC |
| | 21-30 | ASC | LeSC | And/Or BSC |
| | 31-40 | ASC | LeSC | And/Or BSC |
| | 41-50 | ASC | LeSC | And/Or BSC |
| | 51-60 | ASC | LeSC | And/Or BSC |

Testing the interactive MDM will examine if the matrix can help identify the appropriate supply chain strategy for the nodes related to these variables. The testing will be achieved by the participation of a selected company, in addition to several case studies that provide examples of the interactive MDM being implemented in other organisations or market sectors.

### 5.5.4 Interactive Multi-dimensional Model

Once the combined fuzzy rules from the scatter diagrams are fully created, they are translated into JavaScript creating the web-based interactive MDM (Appendix P and Q). Once the coding of the fuzzy rules are complete they are then launched into a website[19] using HTML as it is the standard mark-up language used to create web pages. On the website, companies can browse the variables they wish to explore and select them. The interactive MDM can be accessed via the following:

| Interactive MDM | Username | Password |
|---|---|---|
| http://www.safaasindi.com/staging/ | plym-guest | guest2016 |

The website shows two tabs one for the logistics strategy and one for the supply chain strategies (Fig. 57).

[19] http://www.safaasindi.com/staging/
Username: plym-guest
Password: guest2016

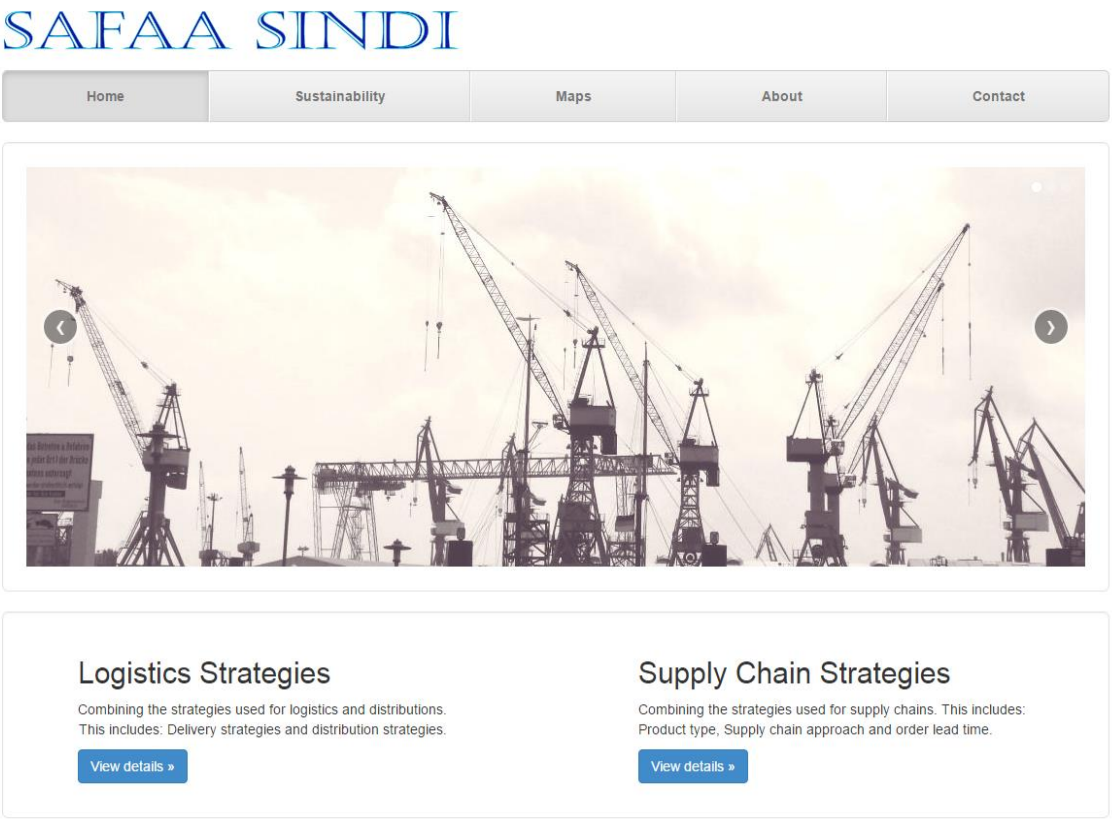


*Figure 57: Interactive MDM home-page (Source: author)*

In each of the logistics and supply chain strategy tab, the variables are classified into a logistics strategies tab that include, Delivery strategy group, Distribution strategy group, and Manufacturing lead time (Fig. 58).

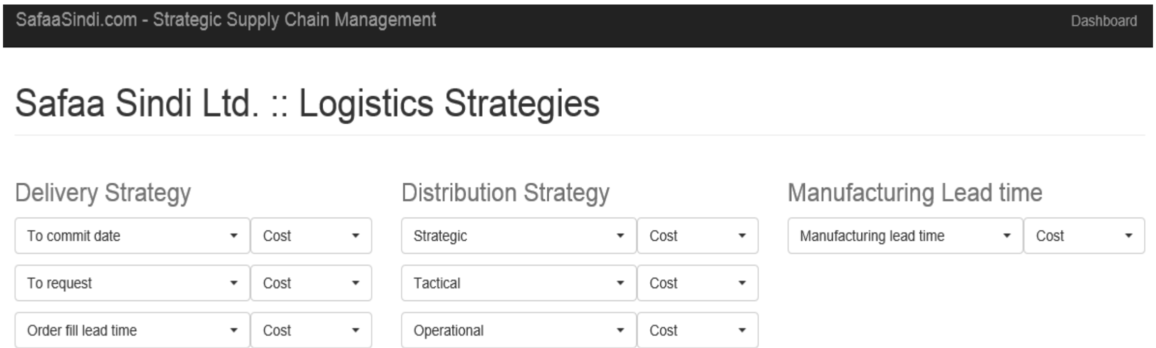


*Figure 58: Interactive MDM logistics strategy page (Source: author)*

The second tab is the Supply chain strategies that include, Product design and Demand approach group (Fig. 59).

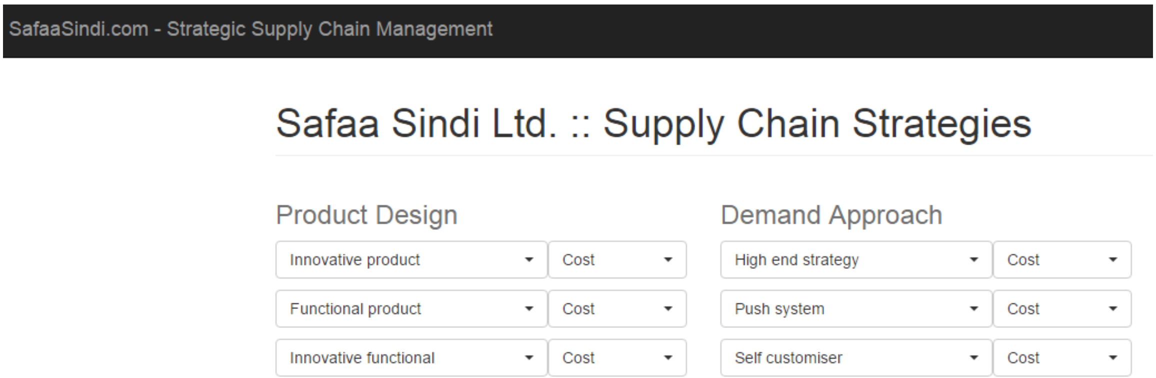


*Figure 59: Interactive MDM supply chain strategy page (Source: author)*

Each group has two drop down lists, one with the “JIT Lean” percentage variable and the other is the “Cost”. Once the company selects the range they want, the interactive MDM will highlight the best strategy for the variable node in accordance to that range selected. In Fig. 60, an example of the selected variables is shown in the supply chain category, under the “Innovative product” from the product design group. The “JIT Lean” selected was 21-30% while the Cost was 0-10%, the interactive MDM calculated for this range “Agile” as a recommended strategy.

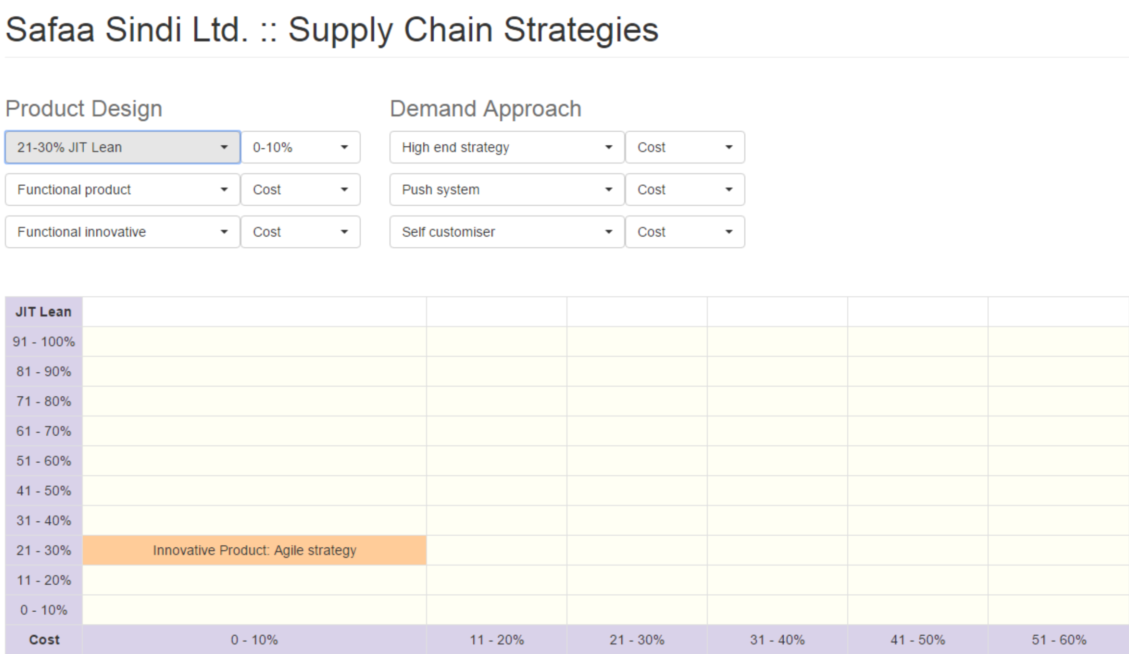


*Figure 60: Interactive MDM (21-30% JIT vs. 0-10% Cost) (Source: author)*

However, if the range changes to another percentage, the MDM calculation will alter to recommend another supply chain strategy. For instance, when “JIT lean” is >90% and “Cost” is 0-10%, the MDM recommends “Agile option BSC” (Fig. 61).

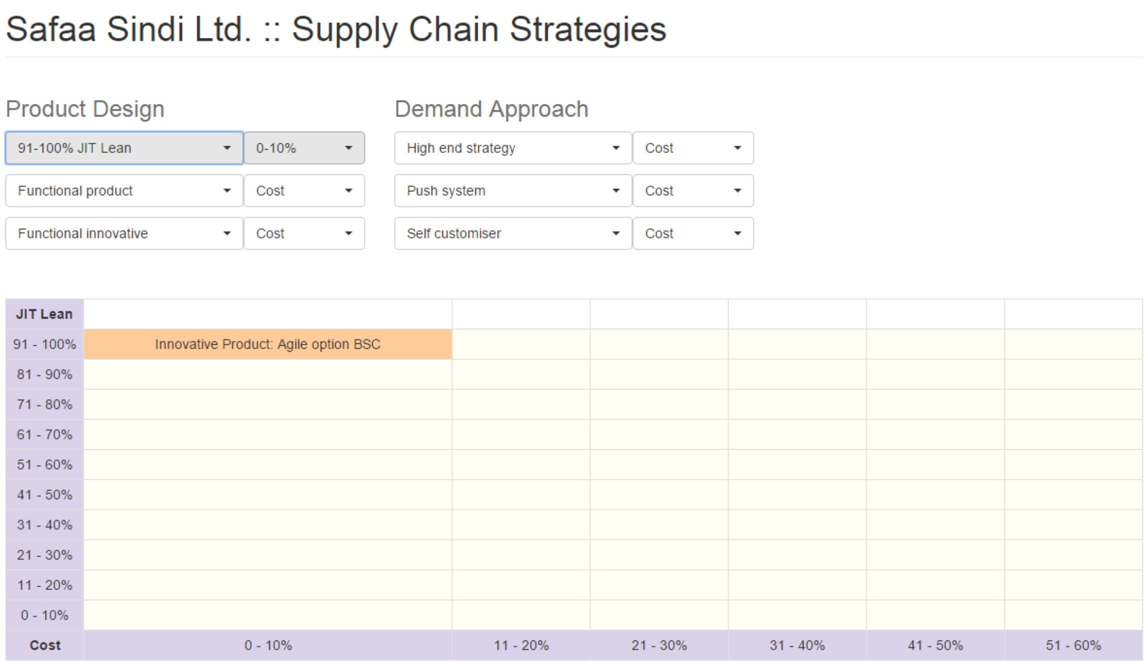


*Figure 61: Interactive MDM (>90% JIT Lean vs. 0-10% Cost) (Source: author)*

The interactive MDM can be used as a tool for companies to select their required ranges and the recommended strategy will be highlighted for them to select the best suited option. The interactive MDM website will be tested in the next chapter, as it will be applied to a selected company and a case study, in order to determine its applicability in real situations that companies face. The company will use the inactive MDM website to identify the best suited supply chain strategy for coordinating their distribution. Furthermore, case studies will be used to help illustrate the situations where the MDM can be used to aid companies’ supply chain decision making.

# Chapter 6

## Testing and Discussion

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*"Learn what the market wants and make it great. The beauty of experimenting in this way is that you never get too far from what the market wants. The market pulls you back."* – Marissa Mayer[20]

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In this chapter the interactive MDM will be tested via a renowned automobile company which will determine the usefulness of the model and its application. To ascertain the performance of the interactive MDM in the real-world system it represents, a process of verifying and validating is undertaken to establish the application of the model, which is crucial according to Carson (2002), as this improves the model's credibility with decision makers. Unlike physical systems, for which there are well established procedures for model validation, limited guidelines exist for social modelling (Brade and Lehmann, 2002). With model verification, the more tests that are performed, the more errors identified, and corrections are made to the underlying model, resulting in establishing the model's integrity. The end result of verification is technically not a verified model as stated by Sargent (2015), but rather a model that has passed the selected verification tests. There are several methods in which a model can be verified and validated, according to Hillebrand *et al* (2001), for example researchers can verify and validate their models with the use of case studies. Although researchers are advised to follow a rigorous and systematic approach in conducting case studies, as the underlined criticism is the alleged lack of generalisability. The process of validation ensures that a model meets its intended requirements in terms of the methods employed and the results obtained. The ultimate goal of validation is to test if the model is useful to the users, by ensuring it addresses the right problem

[20] During an interview with Fast-Company 2008, Marissa Mayer, vice president of Google now president and CEO of Yahoo, encouraged the push for innovation and helped the launch of new products in Google Labs.

and provides accurate information about the system being modelled (Sargent, 2015). However, if the model contains elements of human decision making, validation becomes a matter of establishing credibility, by testing that the model produces sound insights and sound data based on the issue being studies, which in some cases requires mixed methods to establish a sound verification and validation.

In this research the interactive MDM is a social model that requires human decision making to apply the model's recommendation. Therefore, for the process of verification and validation the use of a semi-structured interview is considered the most suited method according to Gomm (2008), as it allows informants the freedom to express their views in their own terms. The success and validity of the semi-structured interview rests on the extent to which the respondent's opinions are truly reflected (Gomm, *ibid*). Therefore the validation process took three months and was conducted with a credible organisation in the automobile industry. The interactive MDM was developed to be applied to SMEs and larger organisation such as those in the automobile industry. Although one organisation was selected for the semi-structured interviews, case studies are used to illustrate a comparison between the two types of supply chain structures (push and pull). To avoid the issue of lack of generalisability, this study also attempts to use examples when analysing the testing results of the semi-structured interviews using deductive reasoning methodology. These mixed method of verification and validation tools are selected due to the relevance and ability to ensure a reliable testing of the interactive MDM and establish its credibility.

## 6.1 Panel Suggestions

The testing was done on the automotive industry with special attention placed on Jaguar Land Rover (JLR). The semi-structured interviews was conducted during a three month internship working with the Global Material Planning and Logistics department. The interactive MDM was examined by the EU distribution team and the strategic planning division. The automobile organisation JLR was chosen as it had an interesting history with moving from one parent company to another (Ford Motor to Tata Motors). After the economic downturn, JLR was relatively unaffected with continual stable sales with its target prime market of high-end products. This was due to the recession not affecting the high-end consumers interested in JLR vehicles, as they still could afford high range products. This contrasted to the middle market automotive companies, whose target markets suffered a decrease in sales. Currently, JLR is attempting to compete in both markets, in order to strengthen its strategic position to compete with all the major automotive companies that manufacture in the UK, such as Ford, BMW, Honda and Toyota (Table. 37).

*Table 37: Major automotive companies manufacturing in the UK (sources, Automotive Council UK, 2016[21])*

| Company | Plant | Production |
|---|---|---|
| Bentley Motors (2014-present) | Crewe, Cheshire, England | 10,014 |
| Ford of Britain (2007-present) | Southampton, England | 75,662 |
| General Motors Company (2014-present) | Luton, England | 74,000 |
| Honda of UK (2014-present) | Swindon, England | 237,783 |
| Jaguar Land Rover (2014-present) | Castle Bromwich, Solihull and Halewood England | 288,677 |
| Toyota of UK (2014-present) | Burnaston, England | 277,637 |
| Vauxhall Motors (2007-present) | Ellesmere Port, Cheshire, England | 115,476 |

### 6.1.1 Background

The foundations of JLR are modelled around the purpose of combining both features of Jaguar and Land Rover. During the three month internship at JLR, several semi-structured interviews were conducted with JLR officials about the identity of the company. The strategic planning supervisor of the EU distribution team stated that marketing the name Jaguar aims to make a person feel “alive” as it is all about the experience and luxury of life, while Land Rover has the marketing

[21] http://www.automotivecouncil.co.uk/mapping-uk-automotive/

image of “overcoming barriers” as they are built to be robust to tackle any obstacles. According to the strategic planning supervisor both Jaguar and Land Rover have a shared vision of quality and high-end mass customisation production that follows a “Push system” (Fig. 62). The semi-structured interviews found that JLR’s push system model starts by the car-dealer forecasting average sales and then puts in a request order and waits. The average turnover for a vehicle completion in production is estimated to be six months. To ensure JLR delivers its promises of quality, heavy investments are made and time is taken to ensure that the product reaches the standard. This contrasts with Toyota’s lean-pull manufacturing system where the information is fed through to the supply chain from a bottom-up approach (Jayaram *et al*., 2010a).

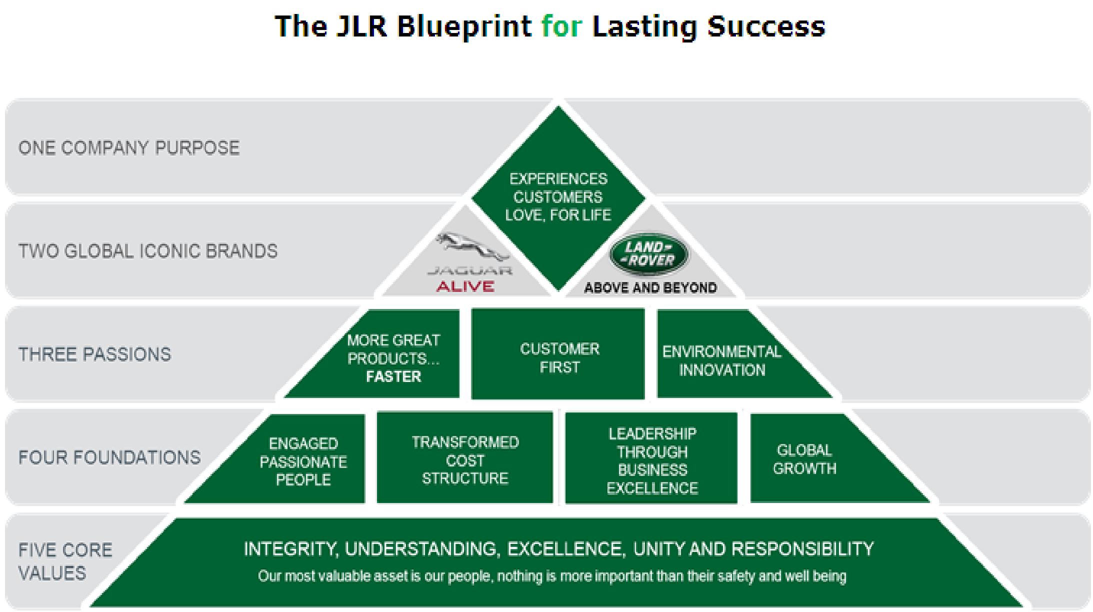



*Figure 62: Blueprint for JLR's success (jaguarlandrover.com)*

The operations specialist of the EU distribution team stated that the car company has an economic cycle, for example sales peak in April, due to it being the beginning of the fiscal year and the end of the winter months, where JLR sees a reduction in stock and an increase in demand. The operations specialist of the EU distribution team further explained that during the recession the company continued to sell cars due to its high-end target market despite its slow progress at producing newer models. Furthermore, the new vision of JLR is to forecast mass customised production of 50 new vehicle models in the next five years to overcome the lag during the recession.

During the testing of the interactive MDM this study worked closely with the EU distribution team and the strategic planning division of finished goods. This department looks at the vehicles distributed from manufacturing to the customer; this is divided into two segments, the “distribution team” in charge of operations and the “strategic planning division” in charge of logistics and supply chain strategy and planning.

Firstly, the “strategic planning” division takes charge of the vehicle from manufacturing in a process called Accepted By Sales (ABS), where it becomes the responsibility of the EU distribution team and the supply chain strategy shifts from “Agile” during manufacturing to “Lean” for distribution. This transfer phase is crucial as any defect or issues that arise from that stage will be the responsibility of the distribution team. Secondly, both the operations manager and operations specialist of the EU distribution team stated that their responsibility as part of the “distribution team” who is in charge of operations, is to ensure the continuous flow of logistics distribution of the vehicle from “Port of exit” to the dealer. They further investigate if the designated market is suitable for the vehicle or not, and if it is not, their duty is to assess the reasons and certify the vehicle’s documents to enable them to enter the market before shipping. They also ensure that the invoices indicate that the vehicle has been sold to the right place/customer (dealer), as well as check the amount of vehicles being sold is correct. According to the strategic planning supervisor of the EU distribution team, JLR has 20 suppliers including logistics carriers that liaise with the distribution department; these suppliers get reviewed every six months for their performance in terms of quality agreements, achieving targets, costs and reducing lead-times. If the suppliers underperform on any of these terms, they are notified.

The semi-structured interview with the logistics co-ordinator specialist further explained the distribution operation. The EU distribution team has responsibility to ensure that vehicles are moving with less lead-time by monitoring the vehicles as they go on the distribution line. This includes forecasting manufacturing, in order to predict the ABS point at the dispatch stage, where the responsibility switches to the distribution team as they are required to predict the time when the vehicles arrive at the “Port of exit”. During the switch of responsibility, the distribution team is in charge of how long the vehicle dwells in the port, when the port transports the vehicles at the right time, if the vehicle has been transported by the right method and if a warning occurs (e.g. weather, strikes or theft etc.), what other methods of transport can or cannot be approved and if a route change is required. If another route is proven to be the best option to deal with the circumstance, then the distribution team looks at short sea shipping, trucks and various hub solutions. In most cases trucks are used despite them not being the most sustainable, due to their land efficiency. Although the distribution team has the responsibility from the ABS point, the carriers share that responsibility as the vehicles are being transported by them.

### *Centralised logistics*

JLR has a centralised strategy with its headquarters in the UK, yet it has a worldwide market of approximately 28 countries for the EU department alone. Therefore, flexibility, speed and reliability are of great importance. Hence, the distribution team has the vital role or reporting to JLR carriers all the schedules required for the vehicles, as each of the carriers have their own system to monitor and dispatch their transportation to deliver the vehicles to the port and reduce lead-time. Therefore, JLR implements a predominantly Agile strategy to move the vehicles from plant to car centre then customer. However, JLR are looking to incorporate a Lean strategy to help reduce lead-times. The interactive MDM will examine which best strategy suits JLR that can be efficiently incorporated. Furthermore, in dealing with their centralised logistics, JLR are looking into introducing new modes of transport, such as air freight for the “special moves” VIP operations, especially to the Middle East, where a large volume of high-end vehicles are delivered. In addition, transhipments are helpful in dealing with JLR’s centralised position as it helps reduce cost when volume fluctuates in different markets. The current Agile strategy helps JLR deal with the volume fluctuation, by moving the vehicle’s final destination, by the use of transhipments, to satisfy changes in demand. However, to reduce lead-time, JLR are looking for leaner solutions to add into their business structure. The Lean solutions that JLR are hoping to incorporate are further rail networks and inland waterways such as barges. To be able to accommodate both, the interactive MDM will be tested to identify the best strategy that will enable JLR to benefit from both its Agile and newly introduced Lean solutions to help further strengthen their business structure.

Working with the senior logistics co-ordinator of the EU distribution team and the distribution strategic planning specialist, the interactive MDM was applied to JLR’s

EU distribution. The interactive MDM is built for the generic use of the retail industry, but will be focused on JLR. The interactive MDM was tested with >90% JIT Lean and with <10% Cost. Within JLR's framework 95-98% JIT Lean must be maintained by their carriers; the contractors are paid regardless to deliver within that range. The issues facing JLR are with short-distance distribution, as the service cost remains the same regardless of the distance, hence it is calculated to be cheaper for long distance distribution. Therefore JLR believes, that a Leagile strategy per mile is more worthwhile than an Agile strategy per vehicle, however the switch from the two strategies is a slow process. Therefore, changing the system from carriers charging per vehicle to charging per mile, will make the delivery process "Low Cost ≤10%" with "High JIT Lean >90%", to match JLR's chosen parameters for the interactive MDM. The aim of testing the interactive MDM is to help establish if the model can diagnose and recommend the best logistics and supply chain strategy JLR requires in their delivery operations with regards to (Low Cost, High JIT Lean) and how can they efficiently moving towards the recommended strategies.

## 6.2 Testing

When using the interactive MDM, companies are required to identify several factors before accessing the web-based model. The interactive MDM is a tool, which requires the user to establish the following:

1) Choose the product, commodity or good they wish to diagnose.
2) Establish if it is "Innovative", "Functional" or "Innovative functional".
3) If it is most likely to follow a "High-end", "Push system" or "Self-customised" strategy.
4) If their distribution of components from allocation of plant or warehouses follows a "Strategic", "Tactical" or "Operational" system.
5) If their delivery system is likely to follow a "Delivery to Commit Date", "Delivery to Request" or "Order Fill Lead-time".

Once the company has clarified these factors it can use the interactive MDM to diagnose which is the best strategy for each relevant node of its supply chain. The company can chose between the "Logistics strategy" and "Supply chain strategy" tabs on the website. If the logistics strategies option was chosen, then three categories will be visible; if the company chooses supply chain strategy then two categories will be visible. For both tabs, the “Cost” and “JIT Lean” options need to be determined by clicking on the drop down boxes, as the MDM uses them to determine the range to calculate the best suited logistics and supply chain strategy.

| Interactive MDM | Username | Password |
|---|---|---|
| http://www.safaasindi.com/staging/ | plym-guest | guest2016 |

### 6.2.1 Implementation

The distribution strategic planning specialist defined the manufacturing of automobiles as “Innovative Functional” products, as they are a commodity that everyone needs, with similar attributes, yet require differentiation (Novack and Simco, 1991). The interactive MDM was put forward to JLR’s EU distribution department for testing on their Invoice triggers. These triggers determine the stages the automobile has to go through before reaching the market. Within the EU, JLR has three essential markets, firstly the National Sales Countries (NSC), which are countries that are part of the EU, Secondly the countries that have joined the EU market but do not have JLR presence; lastly importing counties that are considered in the European zone but are not part of the EU market.

***Testing National Sales Countries NSC***

This begins with the NSC, which are the EU importing countries with JLR presence or head-quarters. This presence of JLR is vital with regard to quality control or damage issues, as maintenance can be done quickly and efficiently, reducing lead-time rather than having the vehicle recalled back to the UK to be fixed. The testing of the interactive MDM will be on the supply chain segment between the component stocks (inventory of automobiles and parts) to the “Port of entry” at the designated country. The distribution strategic planning specialist at JLR was asked to use the interactive MDM to identify if it can diagnose the most suited strategy for each node, starting with the “Components Stock”, “Off Assembly”, “Accepted By Sales (ABS)”, “Available For Delivery”, “Gate Dispatched”, “Port of Exit” to “Arrived at Port of Entry” (Fig. 63).

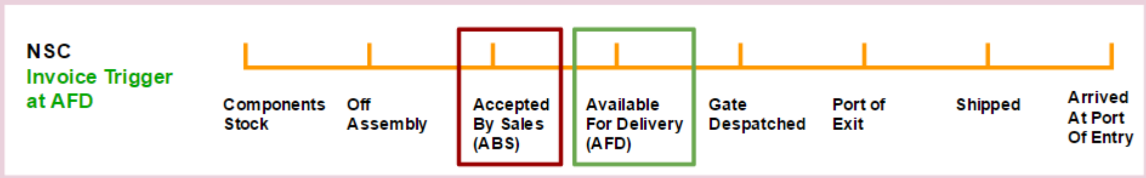



*Figure 63: NSC invoice trigger nodes (Source: author)*

Looking at the "Components stock" node, JLR is required to coordinate all the inventory for the automobile across all plants and supplies (Fig. 63). The testing commenced with the "Supply chain strategies" groups, where the "Product design" was set to "Functional Innovative" in the interactive MDM, which generated "Leagile option Agile" where the best strategy selected by the planning specialist for JLR is Agile for its functional Innovative products (Fig. 64).

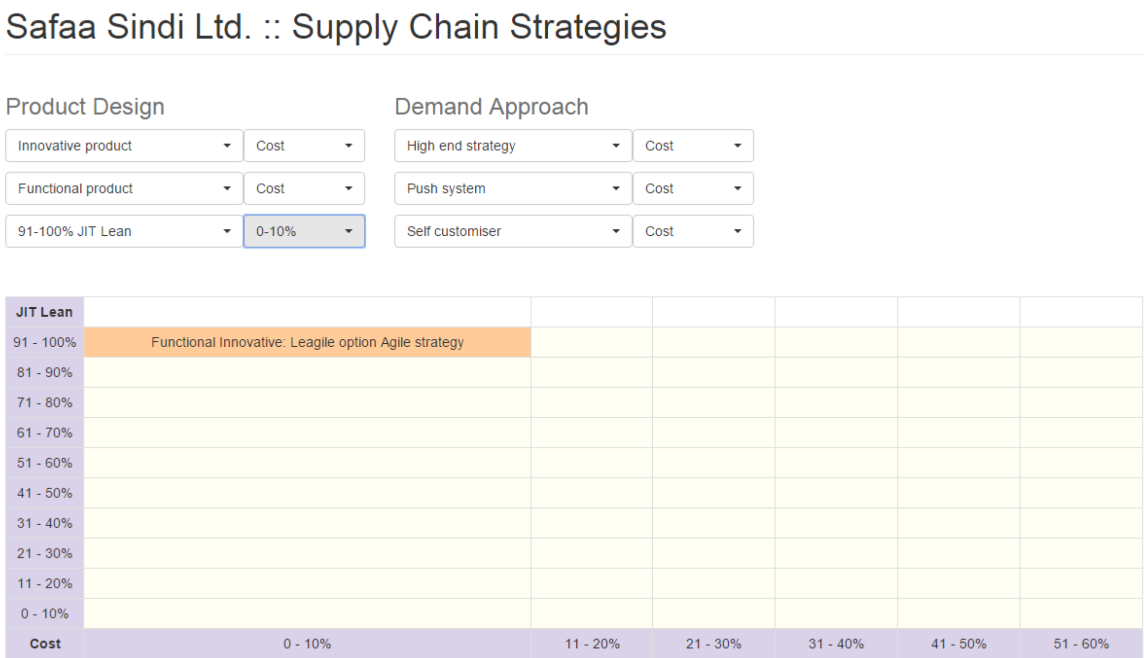



*Figure 64: Functional innovative with ≤10% Cost and >90% JIT Lean (Source: author)*

For the NSC most automobiles follow a "Push system", selected from the "Demand approach" group, with the "Cost" of production and stocking of components being ≤10% while the "JIT Lean" is >90%; the interactive MDM generated "BSC, option Agile and/or Leagile" as the best strategies. However, due to the type of push system in JLR, the distribution strategic planning specialist chose Leagile as the best recommended strategy from the interactive MDM (Fig. 65). This helps the push system achieve its Agile requirement from the perspective of the Functional

Innovative product while maintaining short lead-times in supplying parts from the components stock to manufacturing and assembly as JLR operated under a centralised business structure.

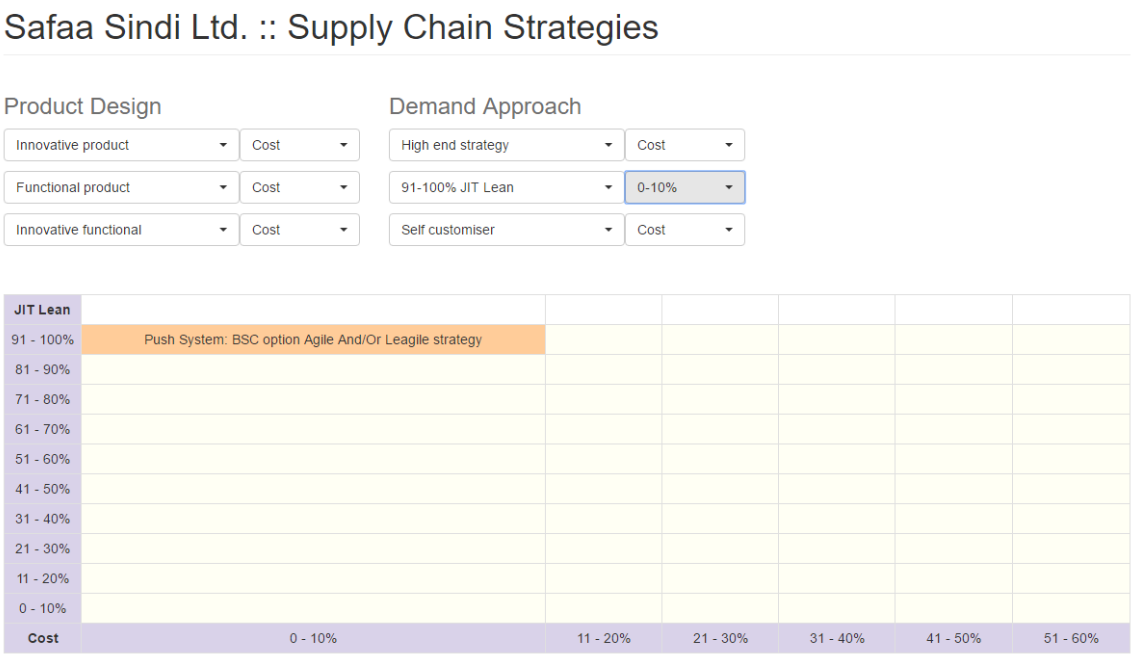



*Figure 65: Push system with ≤10% Cost and >90% JIT Lean (Source: author)*

Currently, JLR is moving towards a make-to-order pull strategy for some of its models that require customisation (which is a Self-customised strategy from the Demand approach group in the interactive MDM), the options given by the interactive MDM with the same range (≤10% Cost and >90% JIT Lean), are “Leagile option Agile”. Hence, the distribution strategic planning specialist chose Agile as the best recommended strategy from the interactive MDM to be the most appropriate. This can be deductively explained, as customisation of a high-end product requires flexibility to be a priority which is a core element catered for by the Agile strategy (Fig. 66).

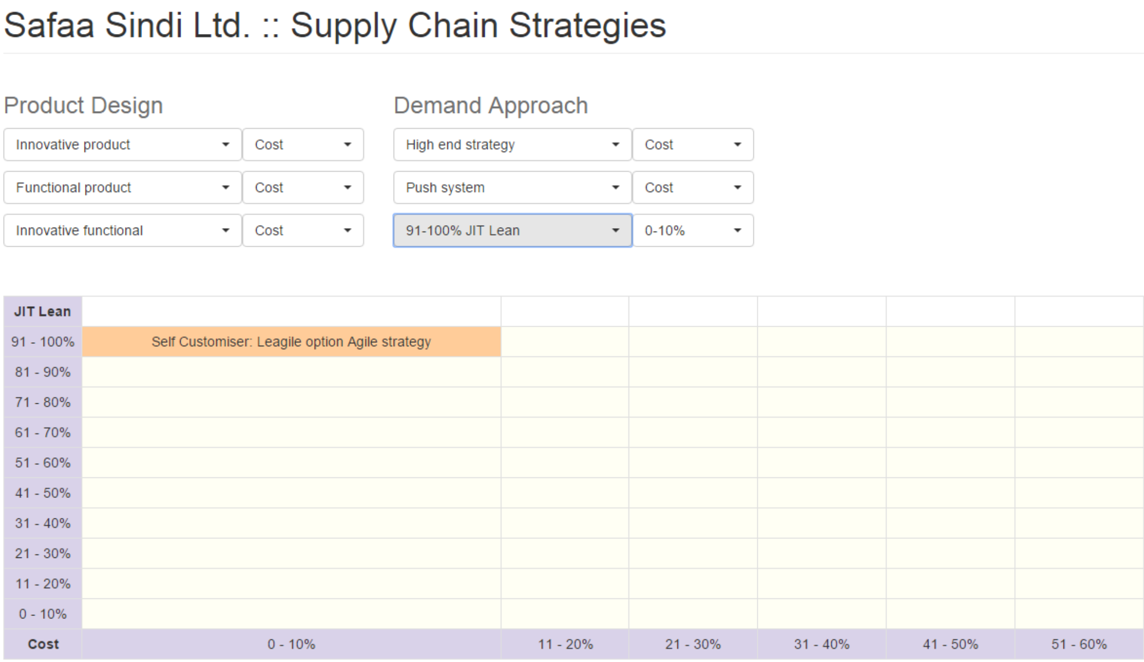



*Figure 66: NSC self-customisation with ≤10%Cost and >90% JIT Lean (Source: author)*

Testing the “Logistics strategy” for the “Components stock”, the distribution strategic planning specialist chose the “Order Fill Lead-time” from the “Delivery strategies” (as it was the most relevant group to this node), to be ≤10% “Cost” with >90% “JIT Lean”, as the components must move fast from the plants or suppliers to manufacturing in order to fulfil the inventory component level for the push or pull system products. The choices given by the interactive MDM were “BSC option Leagile”, where the distribution strategic planning specialist chose Leagile; due to the need for components to be cleared quickly from the inventory system, especially clearing the Lean products that operate under a “Pull” system from the moment a customer order is received (Jüttner *et al*., 2007). The distribution strategic planning specialist stated that Leagile will accommodate the Lean factor for the push forecasted components and planned scheduling, while the Agile will accommodate any change in customisation or components for the pull components (self-customised) (Fig. 67). Moreover, the Leagile strategy with its Lean and Agile characteristics would also account for the high-end products for JLR’s VIP customers, labelled “special moves”.

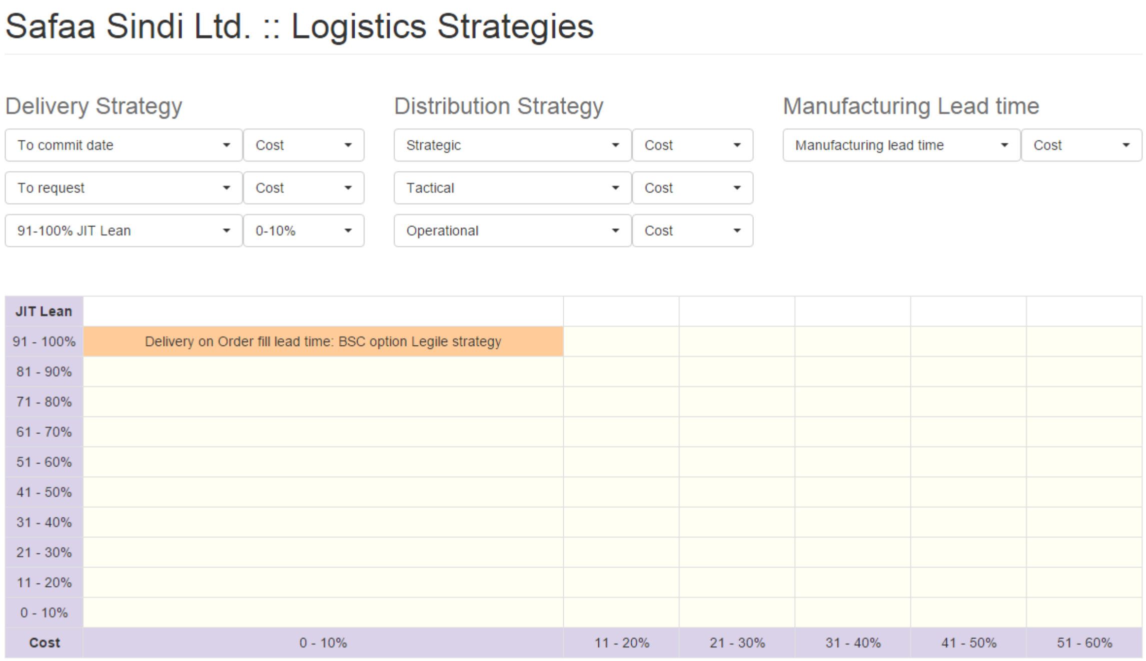



*Figure 67: Order fill lead-time with ≤10% Cost and >90% JIT Lean (Source: author)*

The next node to be tested by the interactive MDM, is the “Off Assembly”, where the automobile is manufactured, assembled and leaves the production phase. At this node the invoice for the vehicle is created and awaits to be triggered (Fig. 68).

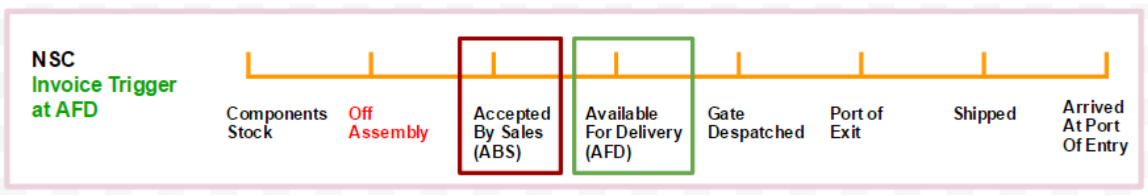



*Figure 68: NSC, Testing "Off Assembly" node (Source: author)*

However, it is still under the responsibility of the manufacturing department, as they are in charge of any faults or mishandling, including any added customisation. Similar to the previous node, when testing the “Supply chain strategy” the “Product design” of the interactive MDM is set to “Innovative Functional”. The testing is done on the “Self-customised” strategy from the “Demand approach” group, where the “Cost” remains ≤10% and the “JIT Lean” >90%, the interactive MDM generated “Leagile option Agile”. The distribution strategic planning specialist chose Leagile to be most suitable for the scheduling of planned parts for push products and Agile for the customisation of components for pull products.

When testing the “Logistics strategy” the distribution strategic planning specialist chose the “Manufacturing lead-time” to be the most suitable group for this node. The “Cost” would be ≤10% and “JIT Lean” is >90%, the option given by the interactive MDM is “Agile option Leagile option BSC”, where the Leagile was chosen to be the most suitable (Fig. 69). In addition to the reasons mentioned in the previous node, the Leagile will allow for fast and responsive quality control checks, where any faults can be quickly rectified before the vehicle is “Accepted By Sales”. This is not only crucial for the NSC markets who have JLR presence who can deal with issues promptly, but for the new countries in the EU market and European zone countries where a Leagile strategy would suit vehicle re-calls and dispatch.

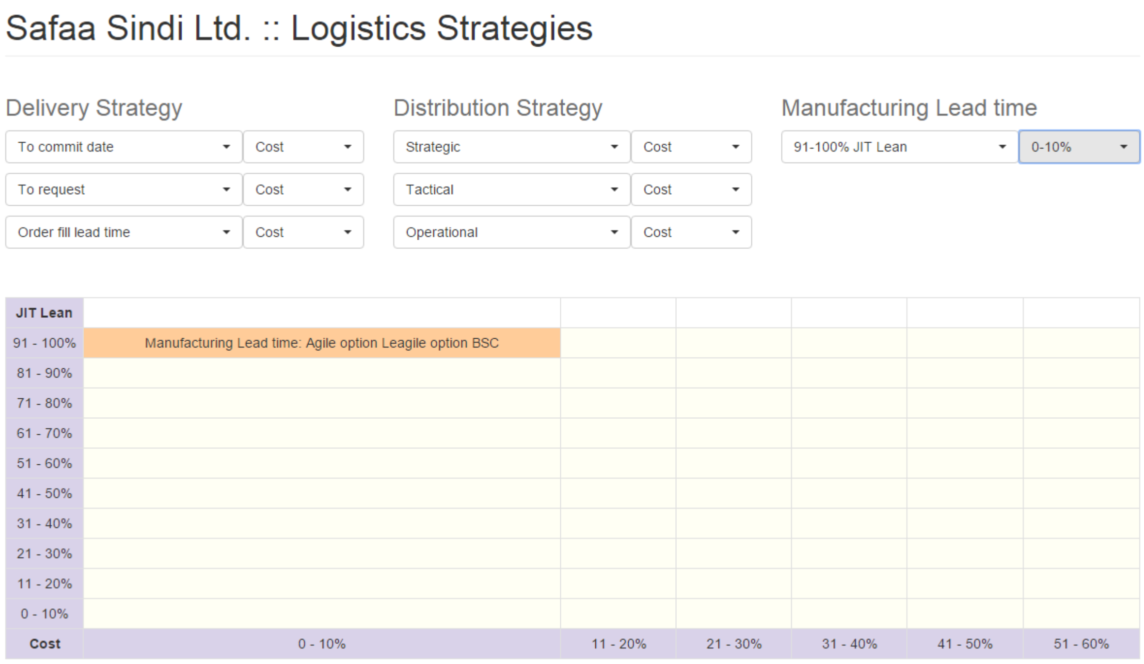



*Figure 69: Manufacturing lead-time ≤10% Cost and >90% JIT Lean (Source: author)*

The next node is “Accepted By Sales” (ABS) which is an important node as it is the switching point where the responsibility shifts from the manufacturing department to the EU distribution department, hence it is highlighted in (Fig. 70).

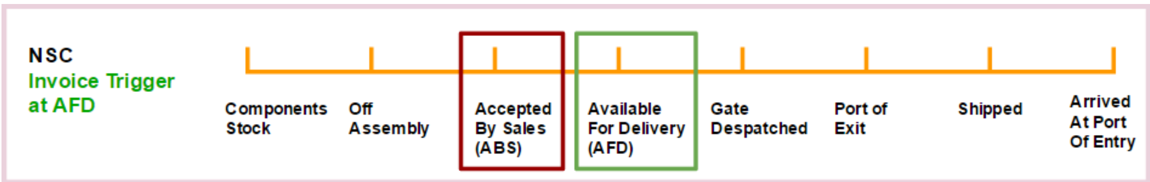



*Figure 70: NSC, testing "Accepted By Sales" (Source: author)*

When testing the “Supply chain strategy”, the options given by the interactive MDM were similar to the previous node, where the “Product design” is set to “Innovative Functional”, where the “Cost” is ≤10% and “JIT Lean” is >90%. The testing is done for both pull and push systems, where the push system is tested via selecting “Push system” from the “Demand approach” group, resulting in the interactive MDM generating “BSC option Agile And/Or Leagile” (Fig. 71).

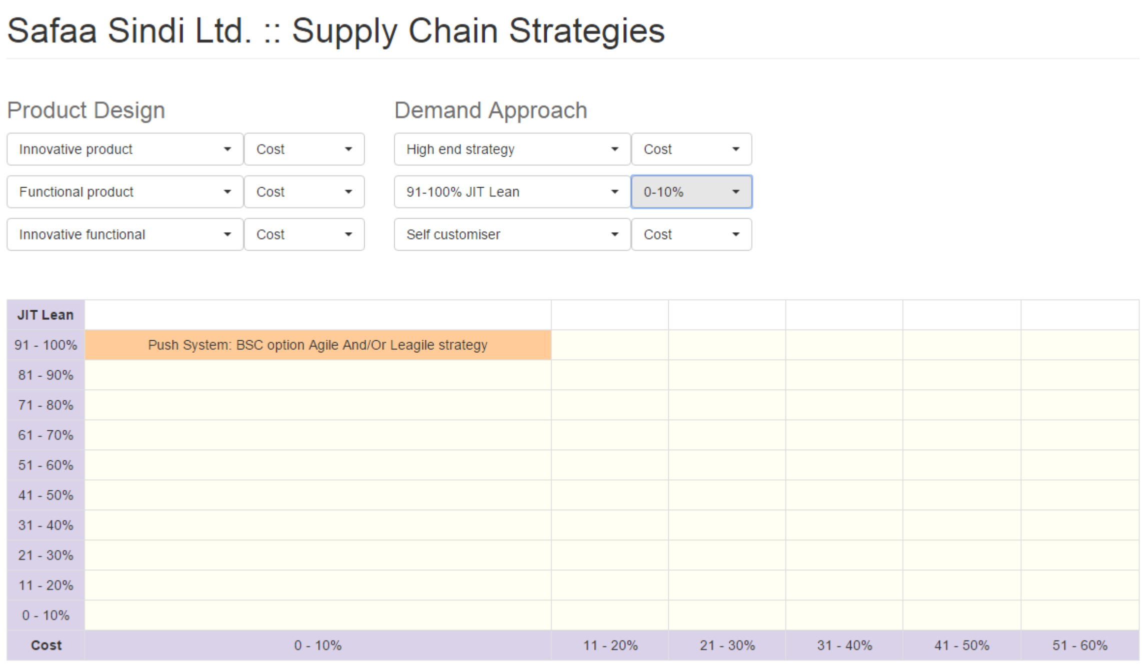



*Figure 71: Push system with ≤10% Cost and >90% JIT Lean (Source: author)*

Meanwhile, testing the pull systems was done via selecting “Self- customiser” from the “Demand approach” group with the same range for “Cost” and “JIT Lean”, where similarly to the previous nodes, the interactive MDM generated “Leagile option Agile” strategy. The distribution strategic planning specialist chose Leagile as the most suitable strategy for both the pull and push systems, as not only is it the common factor, but at the ABS point the priority is to identify the best transportation method and carriers that can quickly move the vehicles to the right destination with the least lead-time. Therefore, at ABS the ability to reduce lead-time in getting the vehicles to the post of exit requires leanness, and the ability to quickly adapt to changing situations by flexibly using different distribution modes requires agility. Hence, the choice of Leagile is due to both leanness and agility being crucial at the ABS point regardless of the pull or push systems.

Moreover, in testing the “Logistics strategy” for the ABS node, the distribution strategic planning specialist selected “Operational distribution” from the group “Distribution strategy” to be most suitable for this node. Currently JLR operates under an operational distribution where their “Cost” is ≤10% and “JIT Lean” is >90%. Their carrier companies must achieve 98% “JIT Lean” for an operational distribution or they will be notified of under-achieving. Therefore, to ensure the vehicles reach their destination without any delay the distribution strategic planning specialist chose Leagile from the recommendations given by the interactive MDM which were “BSC option Leagile”, due to the fast, reliable and responsive attributes of this strategy (Fig. 72).

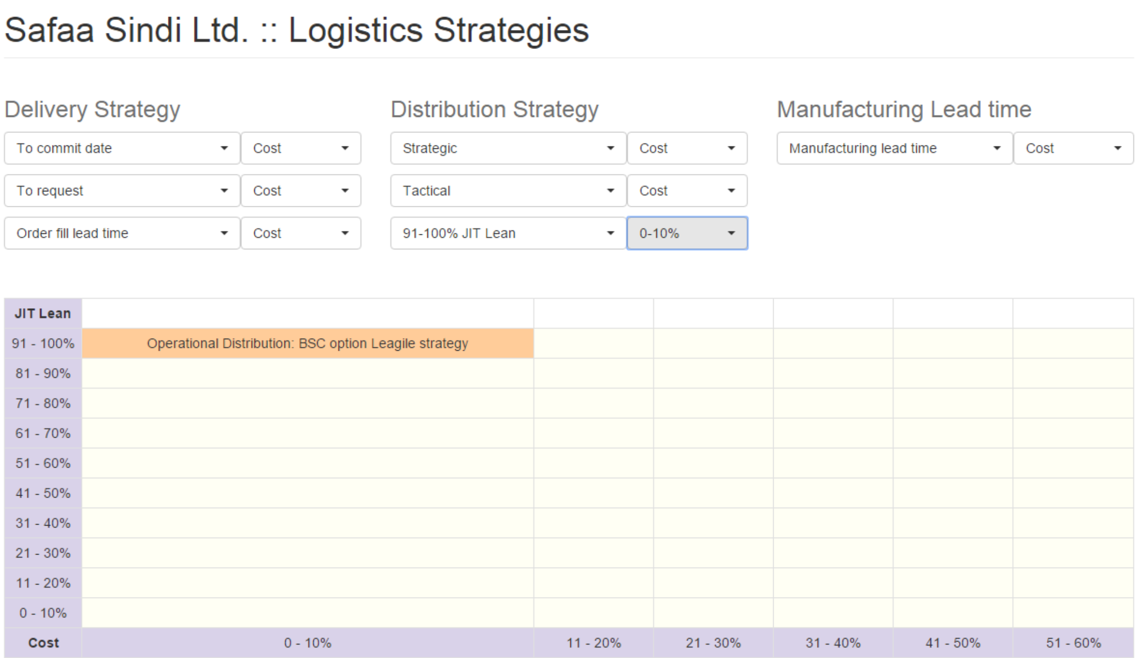



*Figure 72: Operational distribution <10% Cost and >90% JIT Lean (Source: author)*

For example, during the testing period with JLR, several rail and truck strikes occurred which delayed the vehicles, however by having a Leagile strategy this situation can be rectified by changing the mode of transport, route, scheduling and carrier companies. The agile aspect of this strategy would aid flexibility, while the leanness aspect would ensure minimal lead-times regardless of any disruptions. However, JLR is attempting to move towards a “Strategic distribution” as part of their “Hubs” project, which would require them to investigate different option of modes such as barges, several closed wagon rail options and acquiring more car centres in various countries with quality control checks in order to deal with maintenance issues, preventing lead-time recalls. A snap shot of their “Hubs” project strategy can be found at the website under the Maps tab-“Europe”[22]. By switching to “Strategic distribution” with ≤10% “Cost” and >90% “JIT Lean”, the options generated by the interactive MDM are “BSC option Agile And/Or Leagile” illustrated in Fig. 73, where the distribution strategic planning specialist stated, JLR would use either Agile for pull products or Leagile for the push products (Fig. 73).

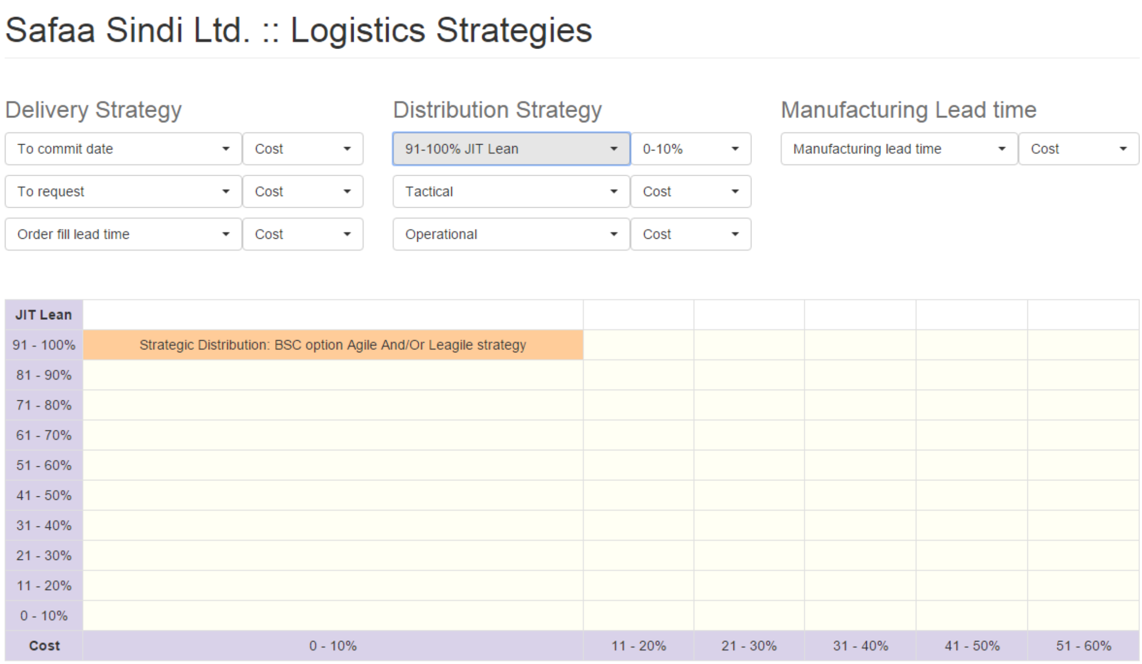



*Figure 73: Strategic distribution <10% Cost and >90% JIT Lean (Source: author)*

Once the different carrier companies, modes of transport from “Component stock” at the plant to “port of exit”, “port of entry” and to the NSC dealer are identified, the shipment scheduling is then made and the vehicle is moved to the “Available For Delivery” (AFD) node. At this node the invoice for the vehicle is triggered, and as previously, under the “Supply chain strategy” the “Product design” is set to “Innovative Functional”, for both pull and push systems were tested with less ≤10% “Cost” and >90% “JIT Lean”. The testing of AFD for push products by selecting the “Push system” from the “Demand approach” group, generated “BSC option Agile And/Or Leagile”; whilst the testing of the AFD for pull systems was done by selecting “Self-cusomiser” from the “Demand approach” group, generated “Leagile

[22] http://www.safaasindi.com/staging/maps/europe/

option Agile". The distribution strategic planning specialist selected Leagile strategy as best suited for the process throughout to the "Port of Entry" node.

Testing of the "Logistics strategy" at this node takes into consideration that carriers are required to deliver the vehicles to the "Port of Entry" on the contracted date. Therefore, the distribution strategic planning specialist selected "Delivery to commit date" from the "Delivery strategy" group, as it is the aim of the logistics planning conducted at this node. With the "Cost" and "JIT Lean" remaining the same, ≤10% and >90% respectively, the interactive MDM generated the following "Agile option BSC" (Fig. 74). The distribution strategic planning specialist chose Agile, as at this stage the scheduling of the vehicle must be adjustable to accommodate any disturbance; hence, using different flexible modes to ensure the vehicle arrives on the agreed day.

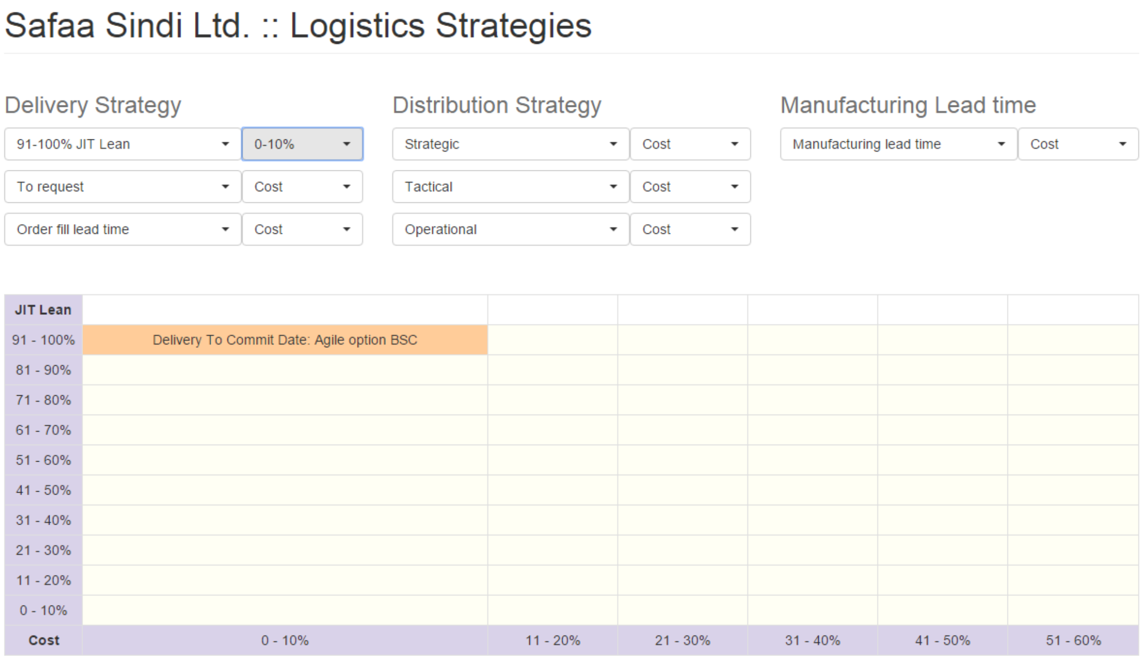



*Figure 74: Delivery to commit date <10% Cost and <90% JIT Lean (Source: author)*

This strategy remains until the vehicle arrives at "Port of Entry"; at this node "Delivery to Request" is chosen with ≤10% "Cost" and >90% "JIT Lean", where the interactive MDM generated "BSC And/Or Lean And/Or Agile" (Fig. 75). The distribution strategic planning specialist chose Lean as most suited strategy, as once the vehicles reach the port of entry they must be distributed quickly to their dealers, as any delay will reduce customer satisfaction. Throughout this process the supply chain push system with the Leagile strategy still holds, as it accounts for both the “Delivery to commit date” with Agile and “Delivery to request” with its Lean strategy.

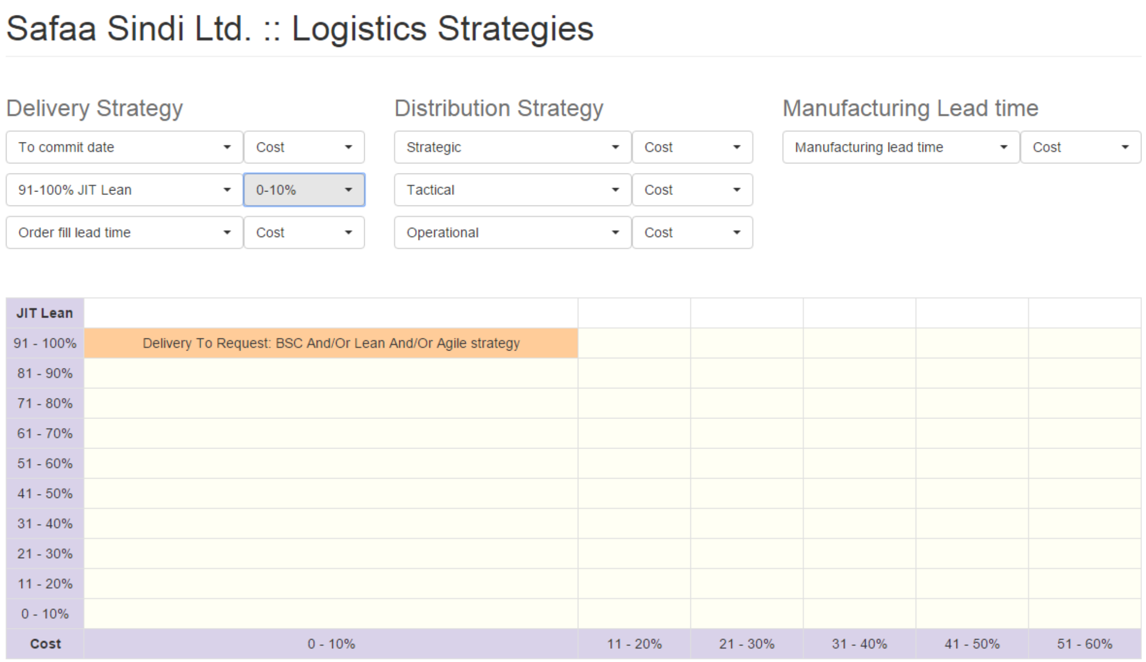



*Figure 75: Delivery to request <10% Cost and >90% JIT Lean (Source: author)*

To summarise the “Component Stock” node requires an Agile strategy, while the “Off Assembly” node uses Leagile, which similar to the “Accepted By Sales (ABS)” node, as the Leagile strategy accounts for scheduled components that require a Lean system while maintain flexibility using the Agile approach. The centralised business structure of JLR indicates that it operates under a general agile strategy. Therefore, to obtain more leanness, JLR is attempting to apply a more Leagile approach especially for scheduled products within the NSC market. This will help reduce the dependability on their centralised system while maintain flexibility and increase leanness.

### *Testing importing non-EU countries within the EU zone*

The next example to be tested is the invoice trigger from the importing non-EU countries that are within the European zone, such as Turkey. These countries import JLR vehicles to supply their own customers or are used as a base for the vehicles to pass onto another country. There are no JLR headquarters, but rather only dealers and car centres where the vehicles await their next shipment to the next country. The supply chain and logistics leg that’s being tested will be from the

"Component Stock" to the "Arrival at Port of Entry" nodes, where the vehicle goes to the dealer or the car centre. The leg where the vehicles moves from the car centre to another country is not included, as it's the responsibility of the dealers on these designated countries. The EU distribution department at JLR is only responsible for delivering the vehicles to the dealer or car centre of the contracted country and ensuring that the vehicles move from the car centre within the designated time frame, to ensure the turnover rate is maintained.

The supply chain and logistics strategy for the components stock for this invoice trigger is similar to the previous one. The difference between the NSC and the Importer non-EU countries is the "Off Assembly" node, although for both the invoice is created and awaits to be triggered; for importer non-EU countries a "Performa" must also be created in order to be sent to the dealer or attached to the vehicle's paper work. The "Performa" is the paperwork necessary to allow a vehicle to enter a country, custom cleared with all the information relevant to the vehicle enclosed (Fig. 76).

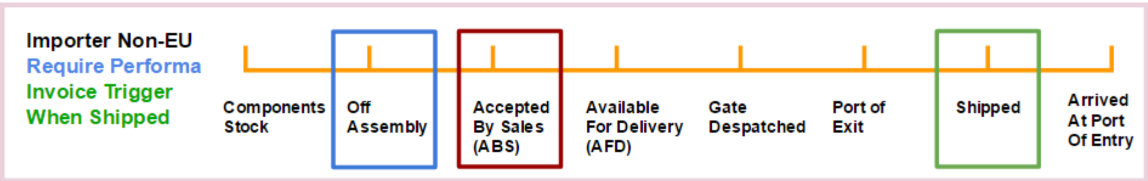



*Figure 76: Importer non-EU countries invoice trigger (Source: author)*

The testing of "Supply chain strategy" remains the same, with "Product design" set to "Functional Innovative", and the "Cost" ≤10% and "JIT Lean" >90%. The testing of "Push system" and "Self-cusomiser" generated the same recommendations by the interactive MDM, where the distribution strategic planning specialist chose Agile strategy for pull products (labelled self-customisation) and Leagile for the push products, with similar justifications as the previous NSC sector.

While testing the "Logistics strategy", the distribution strategic planning specialist selected "Manufacturing lead-time", with "Cost" ≤10% and "JIT Lean" <90%, resulting in "Agile option Leagile option BSC". The distribution strategic planning specialist selected Leagile as best suited for the "Off Assembly" manufacturing lead-time, in order to reduce the lead-time of creating and clearing the "Performa" necessary for the vehicles.

The ABS node is crucial as it's where the responsibility shifts from manufacturing to the EU distribution department. Here, the distribution strategic planning specialist selected the same options to the previous NSC for both the logistics and supply chain strategies, and chose the same options throughout to the "Port Of Entry" node. The only exception was in the invoice being triggered to the dealers once the vehicle is "Shipped", rather than at AFD which was the case with the NSC market. After the vehicle is shipped, the dealers will then communicate with the finance department to pay the outstanding balance within a designated time frame, at which the vehicle must be sold.

### *Testing importer EU countries*

The last example to be tested is the importer European countries that do not have JLR headquarters but are members of the EU. Similar to the previous importer non-EU, they do not have the capability to handle maintenance for quality or damage issues (Fig. 77). However, due to these countries being members of the EU they do not require a "Performa" to enable the vehicle to enter the country or pass customs. Similar to the NSC, they only require an invoice trigger.

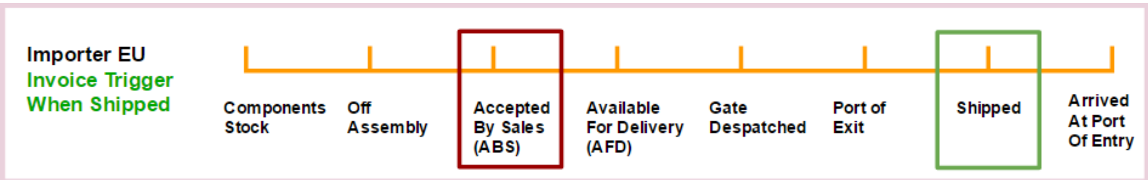



*Figure 77: Importing EU invoice trigger (Source: author)*

The supply chain and logistics strategy for the importer EU countries have the same range to the previous two, ≤10% "Cost" and >90% "JIT Lean". The distribution strategic planning specialist selected the same options to the previous NSC and importer non-EU, and selected the same strategies for each node through to "Port of Entry". Similar to the importer non-EU, the invoice is triggered once the vehicle is "Shipped", as the dealers communicate with the finance department and the vehicle must be sold at the designated time frame.

From the conducted testing, the distribution strategic planning specialist and the EU distribution department stated that the interactive MDM is of use as a diagnostic model that will help companies identify the strategies that they are currently using along with the option to change them if they wish. By identifying each strategy that is suitable for every node, the company can understand their supply chain framework better and diagnose the nodes that require improvement. The EU distribution department noted that the interactive MDM is a useful tool that would further aid their strategic planning in designing new logistics roots to reduce lead-time, and planning better robust supply chain structure that can adapt to changes.

### 6.2.2 Case Study – Toyota

In this section the interactive MDM will be tested on the case study of Toyota automobiles, to draw a comparison between JLR and Toyota's logistics distribution (plant to dealer) and their supply chain system (manufacturing to dealer).

In 1950, Toyota adopted the concepts of continuous material flow, process standardisation and waste elimination. This created the foundation of its success and the movement towards a "pull system" supply chain. After refinement, the "pull system" and Just-In-Time (JIT) were combined to create the Toyota Production System (TPS) (Hines, 1998).

The traditional concept was that only mass production could reduce manufacturing costs (Elfving, 2003). However, Toyota managed to achieve low cost manufacturing with smaller volume, higher complexity and shorter lead-times, by implementing waste elimination, efficiency and durability throughout their value chain (Tomino *et al*., 2009). This system worked for Toyota due to the fundamental changes built into the enterprise's long term framework and engraved within its culture, while other automobile companies struggle with the same implementation (Wee and Wu, 2009).

#### *6.2.2.1 Toyota's Supply Chain*

Within the Toyota supply chain, the term "Lean" means a series of activities or solutions to eliminate waste, reduce Non-Value Added (NVA) operations and improve the Value Added (VA) operations. Value Stream Mapping (VSM) is a lean supply chain tool used by TPS to identify which are the necessary value-adding activities from the wasteful ones in order to eliminate them (Elfving, 2003). VSM begins by listing all operations, and classifies them into VA and NVA, as well as the status of their lead-times from incoming parts to finished goods delivery. The VA activities are those that customers are willing to pay money for tangible goods or intangible functions, while the NVA are the activities that increase lead-time without positive output (Wee and Wu, 2009). By using the Kanban system that links assembly lines tightly to suppliers, Toyota succeeded in limiting the costs and the risks in the wider supply chain (Ludwig, 2013).

In testing the “Supply chain strategy” of the interactive MDM, the automobile is classified as “Innovative Functional” product (Jayaram *et al*., 2010a). Therefore, as Toyota operates under waste elimination, then deductively “Cost” would be ≤10%, while “JIT Lean” would be >90%. Using the interactive MDM, selecting “Innovative Functional” from the “Product design” group, this generated “Leagile option Agile”, which Leagile would be chosen to accommodate Toyota’s Lean production system. The choice of Leagile would allow Toyota to have the responsiveness it needs when creating car models and leanness it requires to get the car design into production.

When testing the “Demand approach” group, there are two applicable options, the “High-end” or the make-to-order pull system labelled “Self-customiser”. Due to Toyota’s Lean strategy “Cost” will be ≤10% while “JIT Lean” is >90%. Firstly for the “High-end” products, the interactive MDM generated “Agile and/or Leagile option Lean”, which is in accordance to Toyota’s system and the importance of a “High -end” product, Lean would be chosen to ensure the least amount of waste and lead-time to manufacture a vehicle and send it through the supply chain to the dealer. Secondly, the “Self-customiser” for the pull products, the interactive MDM generated, “Leagile option Agile”. In this case, Leagile would be the most suitable option, as the make-to-order pull system indicates that an automobile is manufactured when an order is put through from the customer. However, tastes and needs change and the pull system would be required to adapt to these changes in customisation (Jayaram *et al*., 2010a). Hence, by having a Leagile system, Toyota can benefit from having a waste reduction Lean system as well as a responsive Agile system embedded into one strategy.

#### 6.2.2.2 Centralised and De-centralised Logistics

The logistics of JLR followed a centralised system opposite to that of Toyota which follows a de-centralised system, where each plant is a separate entity that can manufacture, assemble and distribute up to 12 vehicle models (Tomino *et al*., 2009). For example, in North America, Toyota spends about $26 billion each year on parts and $1.5 billion in services from 660 suppliers across more than 30 states. About 75% of its inbound material is sourced in North America, while a large concentration of suppliers are situated around the Midwest states (Ludwig, 2013).

In obtaining raw materials to its plants, they contract with third parties to supply small parts such as seats, steering wheels and tyres. However the important aspects of the vehicle such as the machine engine are imported from Japan, making the logistics for it Centralised (Ludwig, *ibid*). The reason for the centralised system for the engine is to maintain the quality, standard and Japanese manufacturing in-house. Having a de-centralised plant system situated across the globe in every accessible market, Toyota can create a sophisticated distribution system by benefiting from the local market's transportation networks (Elfving, 2003). Creating a foothold in every market, this allows plants to produce accurate volumes and respond faster to changes in demand within their region, as well as enabling them to deliver the vehicles straight to the dealer using trucks or trains, reducing lead-times (Lee, 2004).

In testing the "Logistics strategy", the "Manufacturing Lead-time" was considered as irrelevant to Toyota's production, due to its lean system, which is sophisticated with its automation operations throughout the entire manufacturing, assembly, quality checks, and vehicle tracking to minimise lead -time and human error. Although employees oversee the entire operation from plant to dealer, Toyota's full integration of an automated system within their supply chain, has reduced lead-times, especially within manufacturing and assembly (Jayaram et al., 2010a). However, if the interactive MDM were to be applied, With "Cost" ≤10% and "JIT Lean" >90%, the generated strategies would be "Agile, option Leagile, option BSC", where Leagile is considered the most suited for Toyota's reduction of manufacturing lead-time. The combination of Agile and Lean will increase flexibility to solve any issues of quality, assembly and certifying vehicles, in addition to eliminating any NVA activities to reduce lead-times.

The remaining two groups "Delivery and Distribution strategies" are considered relevant to Toyota's logistics system, with the latter being applied to the distribution between the acquisition of raw materials from second and third party suppliers to the plant and then to its distribution through the region (Sugimori *et al* ., 1977).

From the “Distribution strategy” group, as Toyota has a de-centralised plant system that follows a “Tactical Distribution”, with “JIT Lean” > 90% and “Cost” ≤10%, in order to incorporate Toyota’s waste reduction and in house-distribution. The interactive MDM generated the following “Agile And/Or Leagile And/Or Basic” (Fig. 78). Leagile is chosen to be most suitable, as it will support both centralised and de-centralised distribution of Toyota. The engines follow a centralised distribution from Japan, so the Lean characteristics in Leagile will help engines reach the plants with minimal lead-time to enable a speedy production (Ludwig, 2013). In addition the Agile characteristics of Leagile suits the de-centralised distribution by supporting the second and third party supplies to respond faster to low stock of component parts. Hence, the suppliers need to be flexible in distributing these parts to all the plants across the region (Jayaram et al., 2010a). The Agile characteristics will help the plants understand the shift in demand in their local market and communicate the changes to their supplier, who in turn are able to react to the shifts. Having a Leagile strategy the plants would be able to satisfy the demand of their region by increasing or decreasing their volumes, automobile design, and fast and reliable distribution of vehicles to their dealers.

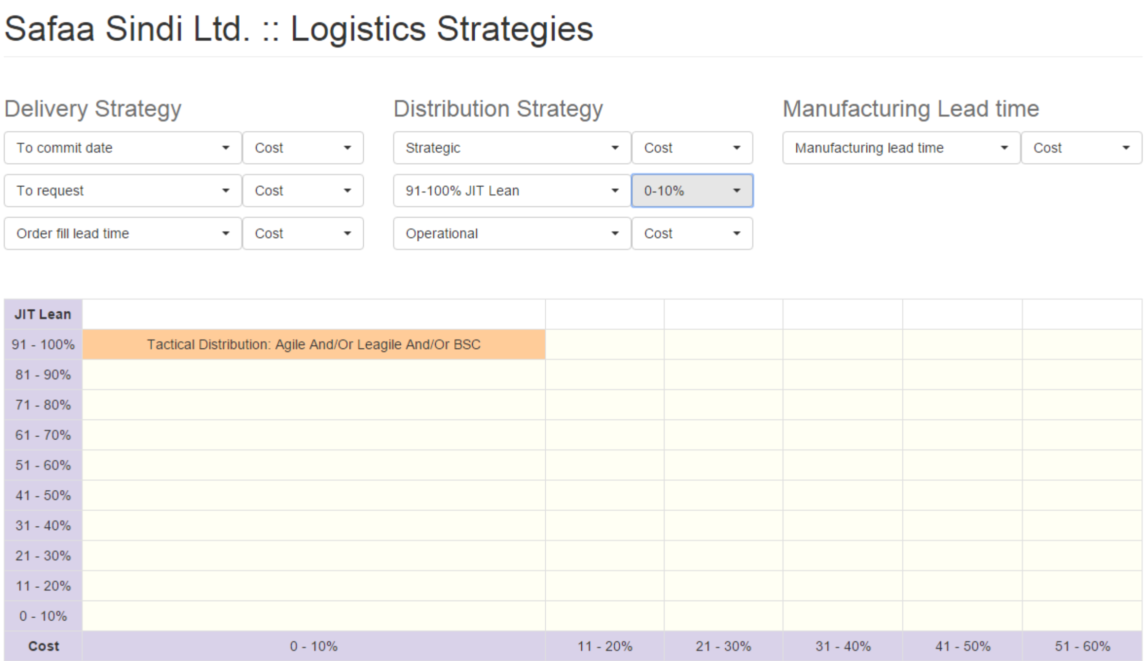



*Figure 78: Tactical distribution <10% Cost and >90% JIT Lean (Source: author)*

From the “Delivery strategy”, the “Delivery to request” is chosen to best represent Toyota’s transportation of Make-to-order (pull system) vehicles from its holding centre to the dealer. With "Cost" ≤10% and "JIT Lean" >90%, the interactive MDM generates the following "Basic and/or Lean and/or Agile" (Fig.79). Toyota's system implements a sophisticated transportation network that uses the local region's road and rail to its advantage, as well as waste reduction that implies a quick turnover of a few days in its warehousing car centres due to low inventory levels (Hines, 1998). Therefore, the best suited strategy would be Lean, in order to ensure Toyota's business structure maintains its JIT demeanour.

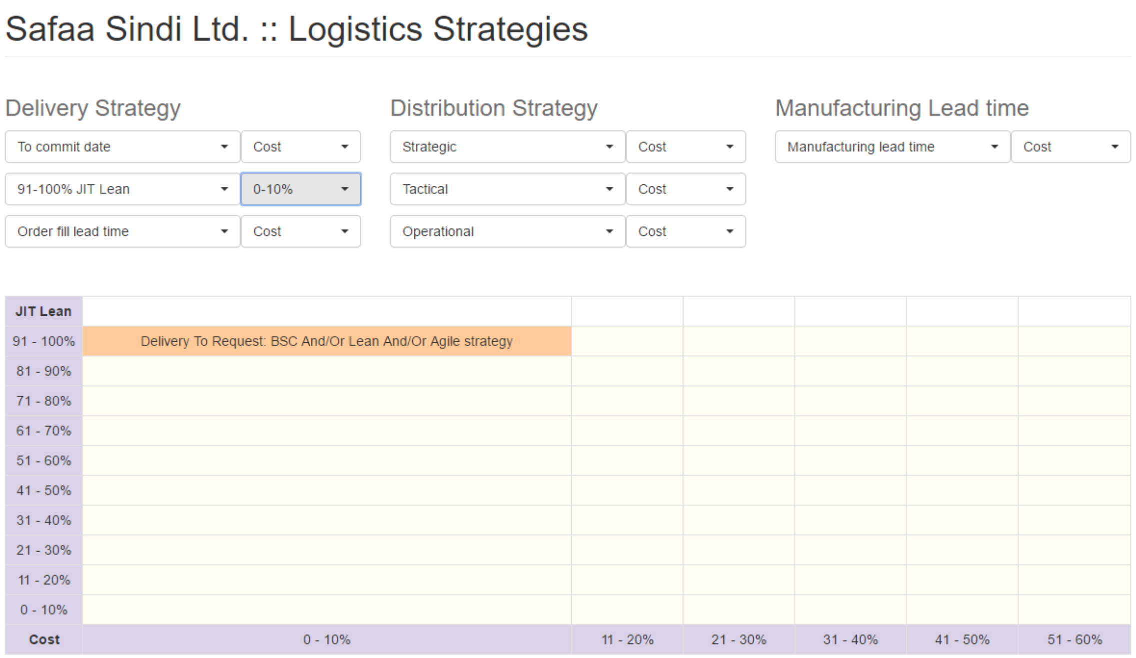



*Figure 79: Delivery to request <10% Cost and >90% JIT Lean (Source: author)*

## 6.3 Conclusion and Suggestions

The testing concludes that the deductive reasoning behind the experts' opinions is valid as it shows that the interactive MDM is a useful diagnostic model tool that helps companies identify the strategies they are currently using along with the option to change them. The interactive MDM has proven its capability in identifying a suitable strategy for every node, giving the model credibility in helping companies understand their supply chain framework better and diagnose the nodes that require improvement. Although companies may find it hard to implement different strategies for each node, due to their established business structure and the cost of change. For example, JLR has a mainly push Agile/Leagile system, with centralised production and distribution, that is hard to change into a pull make-to-order Lean/Leagile system such as Toyota with a decentralised production and distribution system. The change would not only require a shift in the business framework, but a switch in business culture as well, which is time consuming and costly.

From this testing, it has been established that the interactive MDM is able to aid companies in diagnosing and recommending the logistics and supply chain strategies most suited for them. Additionally, as JLR is looking to expand globally to build assembly plants in regional markets internationally, the interactive MDM will help JLR diagnose which strategy is most useful in their new venture of adding a pull system within each market. This will help JLR identify the most suited strategy that will help transfer information faster in every regional market to their designated plant, in order to respond to demand and customise the vehicles accordingly.

However, during the testing of the interactive MDM, the semi-structured interviews proposed a suggestion.  According to the interviewed panel at JLR, the interactive MDM was not a holistic model, as it did not provide an approach to sustainable thinking in the decision making process. The JLR interview panel stated that every model they consider to apply to their business structure must accommodate issues of sustainability especially issues of carbon footprint. Therefore in order for JLR and other organisations to use the interactive MDM and implement its recommendations, it must include a complementary model that will help decision makers identify a suitable option to reduce issues of carbon footprint.

In developing a complementary sustainable model that will aid decision makers establish a suitable method of reducing the carbon footprint, this study undertook a project given by JLR to analyse their $CO_2$ data for the logistics distribution of their product in order to create a decision making model that will help establish different approaches in reducing the carbon footprint.

## 6.4 Sustainable Decision Making

The historic importance of sustainability can be traced back to the “Brundtland Report” established in 1987, which was concerned with securing global equity for future generations by redistributing resources towards poorer nations to encourage their economic growth. It highlighted the urgency of making progress toward economic development that could be sustained without depleting natural resources or harming the environment. Since the end of the last century, private consumption had quadrupled and became a globalisation trend (European Commission, 2014). Sustainable thinking became crucial for business as it allows it to exhibit social responsibility. Business sustainability is often defined as a process by which companies manage their financial, social and environmental risks, obligations and opportunities. These impacts are sometimes referred to as profits, people and planet[23]. Companies rely on their suppliers and sub-suppliers, leading to logistics and supply chain management to become broader and more international. However, technological advances have dramatically reduced the footprint of road vehicles in the past 20 years. Seeing as more than 50% of world surface freight will transport from Asia alone by 2050, compared with 35% today (European Commission, *ibid*), the environmental issue will become freight transportation as it will replace passenger traffic as the main source of $CO_2$ emissions in 2030 (Fig. 80).

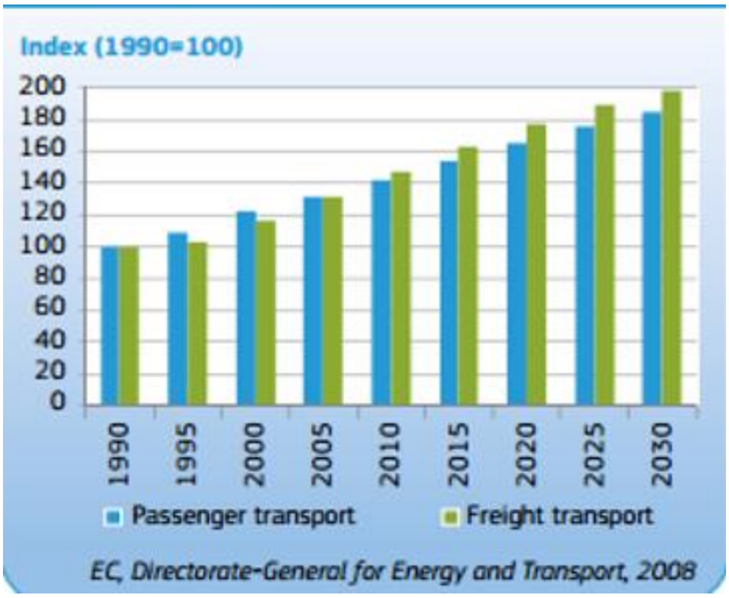



*Figure 80: EU expected growth by 2030 (European Commission, 2012)*

This dramatic increase in $CO_2$ consequently forced the UN to push for sustainable development to be translated into principles and guidelines for companies, making it mandatory for them to contribute towards developing sustainable methods for their business (European Commission, 2012). Not only can corporations make a difference, but they are held responsible for their production and decision making. The UN suggests that companies should aim to go beyond legal obligation,

[23] http://lexicon.ft.com/Term?term=business-sustainability

encouraging regulators to set higher standards, increasing competitors' costs and barriers to entry (European Commission, *ibid*). Therefore, companies are required to integrate social and environmental concerns into their business strategy and operations creating a socially conscious market (Britoa *et at.*, 2008). Some organisations have implemented the use of alternative fuels into their logistics strategy, for example gasoline and diesel. Moreover, advanced technologies in the EU are being explored to enable a sustainable shift from a fossil-driven to a decarbonised transport system. Various EU programmes are tailored to researching alternative fuels and reduce barrier to market entry (European Commission, 2012). For example the EU project "HORIZON 2020" promotes smart, green and integrated alternatives to improving vehicle efficiency, developing new generations of low or zero emission vehicles, and promoting alternative fuel systems. However, given the complexity of $CO_2$ reduction, no single solution is sufficient (Fig. 81). Instead, the EU looks at a combination of policy initiatives and research innovations to achieve the challenging targets for emission reduction (European Commission, 2012).

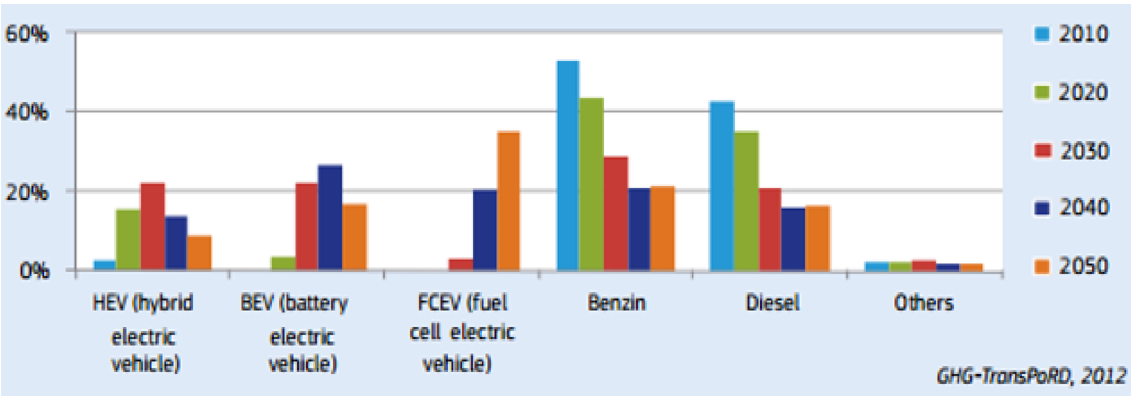



*Figure 81: Movement to alternative fuel in the EU (European Commission, 2012)*

This influenced the majority of players in the market as they incorporate sustainable thinking into their decision making and social responsibility into their business structure. Therefore, any model or framework built to aid companies must incorporeal sustainable thinking to help present the company with a holistic approach that will not only aid its business framework but its sustainable decision making as well. In order to implement change on a macro and micro level, all decision and strategy making models should include a sustainability feature (Britoa *et at*., 2008). Hence, this study looks at the sustainability issues facing automotive companies with regards to their supply chain and logistics, by creating a decision making tree complementary to the diagnostic features of the interactive MDM. This will help businesses select the best suited supply chain strategy for their needs and implement it by incorporating sustainable thinking using the developed sustainable decision making tree. To develop the sustainable decision making tree, this research will use the data provided by JLR $CO_2$ emission report to analyse the sustainability for their mode of transport for each market. This will help establish a profile on which the decision making tree can be built to provide a step by set guide on sustainable thinking and decision making. The creation of this sustainable decision making model is based on the suggestion given by the interview panel during this study's testing with JLR. The decision making model is based on the data given by JLR to generate recommendations for better sustainable distribution methods, yet can be applied to the general automotive industry. The data given by JLR focuses on their European market of the countries they mostly export to and the relative $CO_2$ emission generated from that trade.

## 6.5 Analysing the Sustainability of Automobile Distribution

The calculations for the $CO_2$ were provided by JLR and included the emissions from the "Port of exit to entry" and to the dealer. From the data provided, this study found that due to JLR having a centralised distribution and a push system, it mostly uses sea shipments and road transportation. Table 38, illustrates the different modes of freight transport with their relative CO2 as well as their pros and cons and why they may be favoured. Table 38, helped JLR understand the different variations of CO2 emission in relation to the distance they want to cover and the volumes exported to their markets, as well as the favoured mode of transport. For each market/country JLR has various distribution methods. Some markets are from port of entry to exit and so only have sea shipments, while others need transhipments, requiring shipping and road deliveries. Some of the markets have a good rail network and therefore would have a sea shipment, road and rail distribution system.

*Table 38: Comparing different modes of transport (Source: author)*

| Mode | Total CO2/ mile | Total CO2 Tonnage | Pro | Con | Favoured |
|---|---|---|---|---|---|
| Sea Shipments | 520.49 | 11,928 | More volume, distance and economies of scale | Slow, delays and weather influences | Favoured for long distance large volumes Sustainable with slow steaming if priority allows / alternative fuel |
| Road Movement | 10.36263568 | 5,148 | Fast, reliable, less delays | Low volume, higher cost and low Economies of scale | Favoured for short distance low volume Sustainable with alternative fuel choices |
| Train Movements | 0.104779326 | 234 | Fast, reliable, medium economies of scale, lowest traffic or weather and driver influences | Lower volumes than shipping, higher than cars. Medium economies of scale. Higher cost than shipping. | Favoured for medium sized volume and medium distance Most Sustainable with electric trains |

The sustainability research analyses the breakdown of the different modes for each market with the $CO_2$ emission per mile and the total $CO_2$ tonnage for a one journey destination from port of exit to the designated port of entry or dealer/customer. The sustainability research conducted at JLR is divided into two segments, “Sustainability of a single mode” and “Sustainability of a multi-mode”.

### Sustainability of a single mode

Generically when JLR uses a single mode to distribute to its markets then it emits less $CO_2$ as ships benefit from economies of scale with the vast distance they travel and the volume of cargo they carry (Table. 39). The table shows that all the one mode of distribution are from port of exit to entry. The light green highlights indicate that the $CO_2$ levels are relatively low considering other exported areas.

*Table 39: Single mode non-dealer low $CO_2$ emissions (Source: author)*

| Country | Mode | Total CO2/Mile | Total CO2 |
|---|---|---|---|
| FINLAND- Turku | | 28.36 | 39.49 |
| NORWAY- Brevik | | 33.64 | 14.74 |
| DENMARK- Esbjerg | | 41.77 | 7.66 |
| SWEDEN- Goteborg | | 24.82 | 19.89 |
| ICELAND- Reykjavik | | 238.61 | 4.90 |
| CYPRUS- Limassol | | 53.22 | 56.93 |
| GREECE- Piraeus | | 50.78 | 51.59 |

Meanwhile, some markets/countries that are exported to from port of exit to entry via a single mode, have relatively higher $CO_2$ emissions. This could be due to frequency or distance (e.g. logistic position of port). The dark green indicate that $CO_2$ is low but approaching medium range, while the red highlight indicates the emission is considered high (Table. 40).

*Table 40: Single mode non-dealer medium to high $CO_2$ emission (Source: author)*

| Country | Mode | Total CO2/ Mile | Total CO2 Tonnes |
|---|---|---|---|
| PORTUGAL | | 8.52 | 105.64 |
| TURKEY- Derince | | 15.99 | 185.76 |
| MALTA- Valletta | | 18.24 | 116.50 |
| RUSSIA | | 0.34 | 3886.61 |

## Sustainability of multi-mode

In using multi-mode of transport, results vary depending on the volume carried by trucks and frequency or distance of the shipments. The multi-mode commonly used by JLR are sea shipments and truck. A market that requires multi-mode distribution usually do so because the vehicles are being delivered to the dealer rather than just from the port of exit to entry, hence the use of road freight. The freight transported to Belgium and Netherlands emit low approaching medium $CO_2$ levels, due to volume and frequency of freight (Table. 41). Meanwhile, France is considered a medium range market as there are two dealer centres where the freight has to be delivered. Similarly, the $CO_2$ emission is high for Germany, Italy and Spain as the freight delivered dealers are located at a distance from the port of entry. Italy has the most $CO_2$ due to the distance of the dealer relative to the port and the volume transported by truck, while Spain comes second. Meanwhile, Germany is the lowest of the high range $CO_2$ emissions, as the port of entry is well-connected, has efficient road transportation and one of the dealers is relatively close to the port, however, the other dealer is much further. Therefore, although the total $CO_2$ per mile is lowest at 0.61, the distance and volume of freight being transported by truck to the other dealer plays a major role (Table. 41).

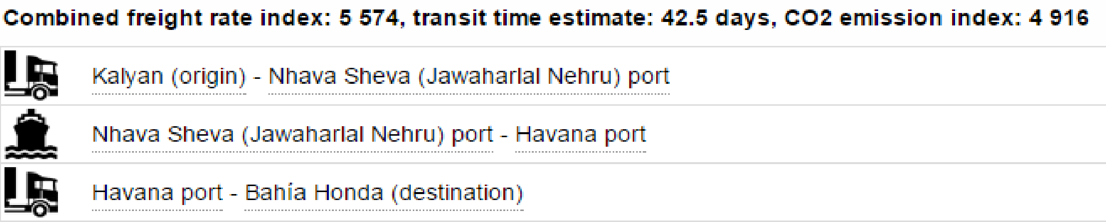
*Table 41: Multi-mode to dealer medium to high $CO_2$ emissions (Source: author)*

| Country | Mode | Total CO2/Mile | Total CO2 Tonnes |
|---|---|---|---|
| FRANCE - Le Havre |  | 1.22 | 872.6 |
| GERMANY - Cuxhaven |  | 0.61 | 1698.93 |
| ITALY – Livorno + Salerno |  | 4.01 | 5150.13 |
| NETHERLANDS- Vlissingen |  | 2.13 | 320.602 |
| SPAIN- Valencia |  | 1.34 | 2398.21 |
| BELGIUM - Vlissingen |  | 1.20 | 379.124 |

### 6.5.1 Multi-mode Options

Several other automotive companies have taken different approaches to $CO_2$ measurement. For example, Ford Motor Company is considering looking at the $CO_2$ levels emitted from sources they do not directly own or control such as supplier plants, contracted transport, and waste disposal (Ford Motor Company, 2014). However, keeping the $CO_2$ levels within range is the responsibility of the delivery agency. If the supplier delivers, then they are responsible; this helps the automotive companies avoid having to make estimations for situations over which they have no direct control (Britoa *et at.*, 2008). For example, when a carrier fails to distribute the freight due to weather conditions, strikes or system failure, the carrier would find an alternative mode, e.g. if a rail company had weather issues or a strike, they may choose trucks as an alternative mode, despite the addition and $CO_2$ emissions. This transfer is recorded in the suitability data and is accounted for by the carrier not the automotive company (Britoa *et at.*, 2008). Therefore, it is difficult to use the sustainability data to compare suppliers and delivery performance, as different companies make different assumptions and will define their supply chains in different ways. However, when automotive companies can acquire all the data, then they can create a $CO_2$ emission database which will help the automation company incorporate it into a website to be used as a tool to calculate the best route with the least $CO_2$ emissions and less lead-time. For example, Honda has released the $CO_2$ emissions of its freight transport for websites to use to compare distribution and different modes. Honda has provided its data to the general public to show their ability to recalculate their roots in order to reduce lead-time and $CO_2$ emission (Honda Motor Company, 2015).

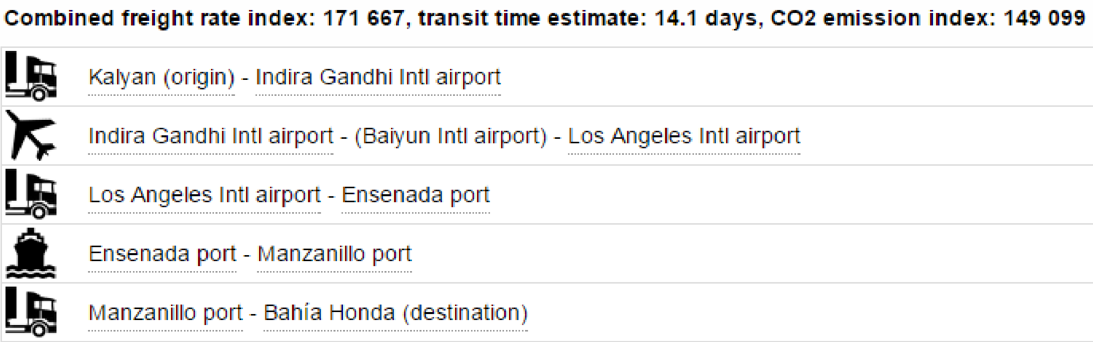
The information shown in Fig. 82, illustrates the logistics route for a batch of Honda vehicles being transported from Kalyan, India to Bahía Honda, Cuba. With the chosen multi-modes the lead-time is 42.5 days from port of exit to port of entry by using truck and sea shipment.



| Combined freight rate index: 5 574, transit time estimate: 42.5 days, CO2 emission index: 4 916 |
|---|
| Kalyan (origin) - Nhava Sheva (Jawaharlal Nehru) port |
| Nhava Sheva (Jawaharlal Nehru) port - Havana port |
| Havana port - Bahía Honda (destination) |

*Figure 82: Truck and sea shipment from Kalyan to Havana (Cargorouter, 2014)*

Meanwhile, when an air freight option is added the lead-time is reduced by more than 50%. However, the $CO_2$ increases significantly due to the introduction of air freight (Fig. 83).



| Combined freight rate index: 171 667, transit time estimate: 14.1 days, CO2 emission index: 149 099 |
|---|
| Kalyan (origin) - Indira Gandhi Intl airport |
| Indira Gandhi Intl airport - (Baiyun Intl airport) - Los Angeles Intl airport |
| Los Angeles Intl airport - Ensenada port |
| Ensenada port - Manzanillo port |
| Manzanillo port - Bahía Honda (destination) |

*Figure 83: Truck, air freight and sea shipment, Kalyan to Havana (Cargorouter, 2014)*

In acquiring all the sustainability data from their suppliers and delivery carriers, Honda can provide databases showing a variety of strategic solutions. Even though data driven metrics can help in driving strategic planning, reducing emissions and implementing more efficient transport networks, not all automotive companies can acquire sensitive data from their suppliers, carriers, or dealers.

In comparing the different $CO_2$ emissions from UK freight transportation, Fig. 84, shows that rail freight is the most efficient and produces the least $CO_2$ emissions whether they have diesel or electric locomotives (McKinnon, 2004). However, in using trains, more volume can be transported and it requires less handling, hence less lead-time. In addition to having fewer drivers and the low $CO_2$ emission, this indicates that trains are considered a favourable mode of freight transport (Fig. 84).

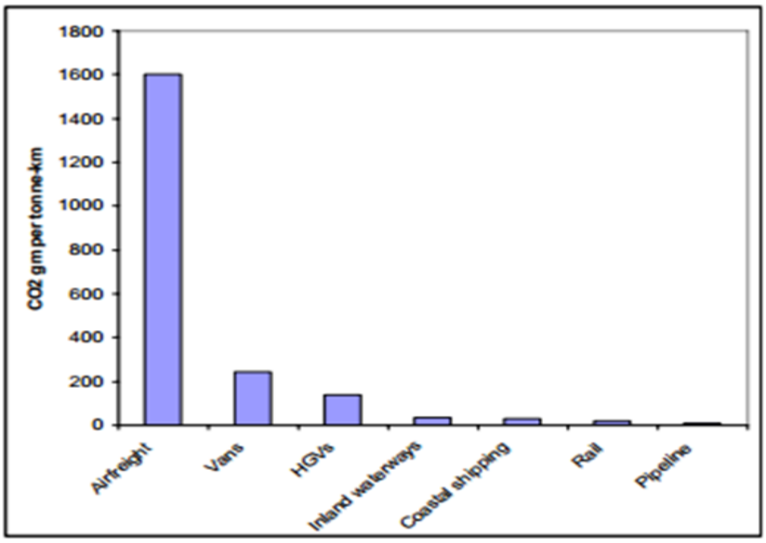



*Figure 84: Comparison of $CO_2$ per tonne-km for UK domestic freight (Mckinnon, 2004)*

This study used the sustainability data by JLR to create tables comparing the different modes of distribution and their relative $CO_2$ in the targeted market. The tables helped create the decision tree model which complimented the MDM tool. The tables, sustainable decision tree and the interactive MDM tool helped JLR understand where their issues lie, in order to formulate methods of mitigation, and plan the thought process of reducing their emissions when applying a recommended strategy by the interactive MDM.

## 6.6 Constructing the Sustainability Decision Making Model

The data from JLR helped establish a profile on which the sustainable decision tree can be built. Due to companies requiring a holistic model that incorporates sustainable thinking, the decision tree will aim to complement the MDM in making it a holistic model that incorporates a sustainable decision making guide to help companies diagnose the best suited supply chain for their market and the means to apply it sustainably. However, before an automotive company uses the decision making tree it must first understand the following: which emissions should be measured? What freight should be included in the emissions calculations? Would freight volume matter in the case of trains and road modes? Are there any shipments between sub suppliers in the case of parts or half finished goods that need re-location? Do packaging deliveries in the case of the cargo need to be covered or contained, or are there no cover/packaging requirements? (E.g. currently the car industry is moving towards transporting covered vehicles to ensure the vehicles do not encounter any damage especially with rising rates of vandalism on train routes). Other issues include, repositioning the goods from one plant to the other, and if transhipment or intra-model is required. Also, accounting for any externalities that would affect the transportation and invoke a strategic change. All these factors must be accounted for when a company uses the sustainable decision tree model. This sustainable decision making tree is created based on the data made available by JLR during the testing phase of the interactive MDM model. It was created as a complementary tool to help automotive companies' ingrain sustainable thinking when using the MDM model. The sustainable decision tree is a generic model that helps sustainable thinking, as it includes a step by step thought process that can be tailored to any company.

### Step One

The company looks at the markets with which it is trading and the request or certification of environmental standards. Once the requirements are made clear, the automotive company can then create mode comparison tables by using their own $CO_2$ data (such as the ones created in the previous section), which will help them understand the different $CO_2$ emissions from each mode and what distribution methods they are using to reach their market and the amount of $CO_2$ tonnage produced from plant to port of entry to port of exit and/or to the warehouse (Fig. 85).

### Step Two

Secondly, companies look at what vehicles are lined as high priority, tagged as VIP or considered a normal priority (Fig. 85). This stage helps the company asses which batch to put through fast distribution routes; for example in JLR, the VIP vehicles are distributed via a process called “Special Moves” where air freight is used for fast delivery, while high priority vehicles that are not VIP, go through sea shipments, trucks and trains. Meanwhile, vehicles that have less priority are considered for slow-steam sea shipments and/or trains.

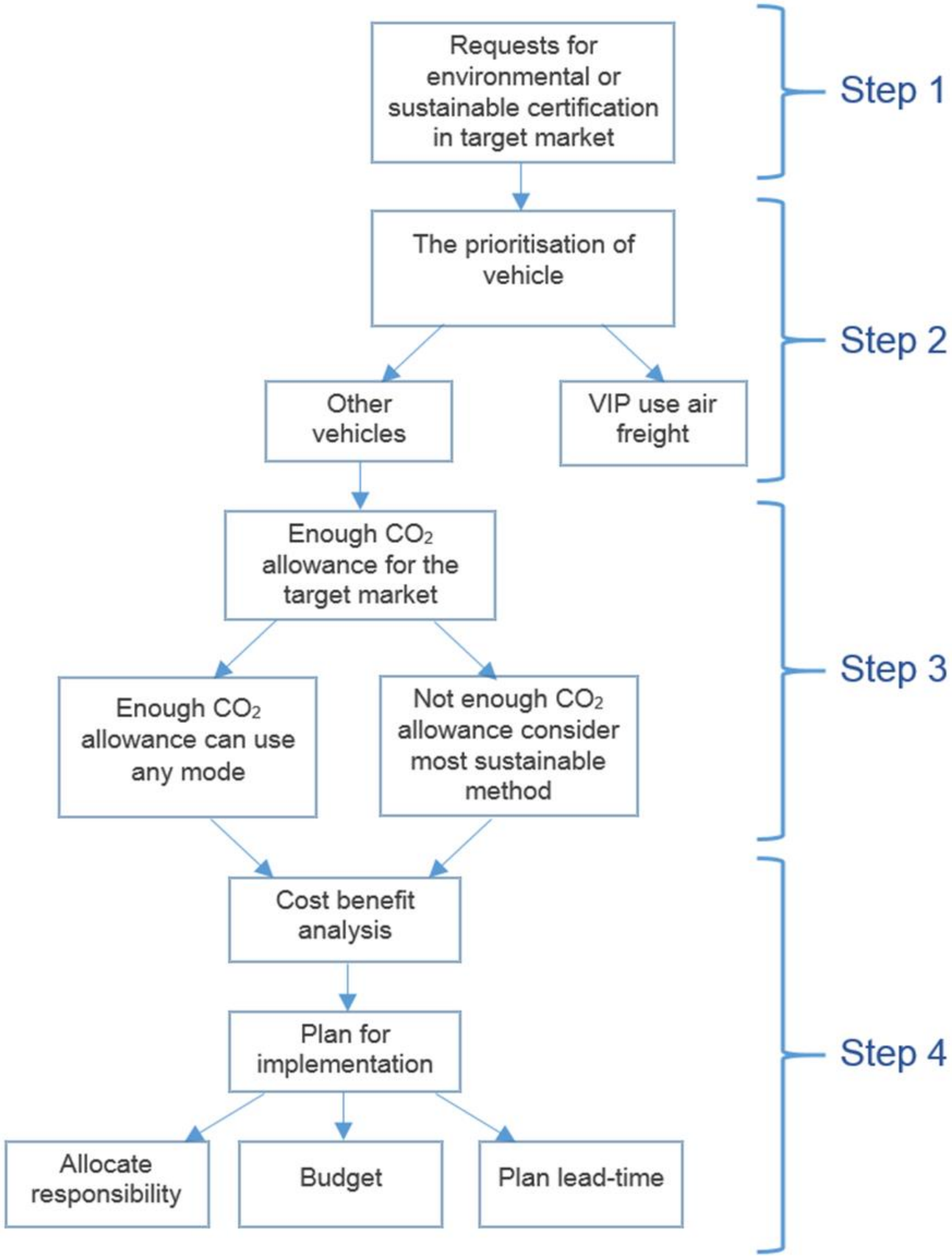



*Figure 85: Sustainability decision making tree (Source: author)*

## Step Three

Thirdly, the automotive company considers the amount of $CO_2$ allowance for each market, and compares it with the amount of $CO_2$ they can afford to give for each distribution strategy (Fig. 85). If the $CO_2$ allowance is low, then options like slow steaming are considered along with electric trains if the distribution is to dealer-customer. If the automotive company has enough $CO_2$ allowance, then it can use normal sea shipments and trucks for tricky routes or trains. With the data given by JLR a map was drawn to highlight the $CO_2$ of each country/market (Fig. 86). An automotive company can create such a map to help visualise the countries where the $CO_2$ is highest, and establish the reasons why, in order to mitigate them.

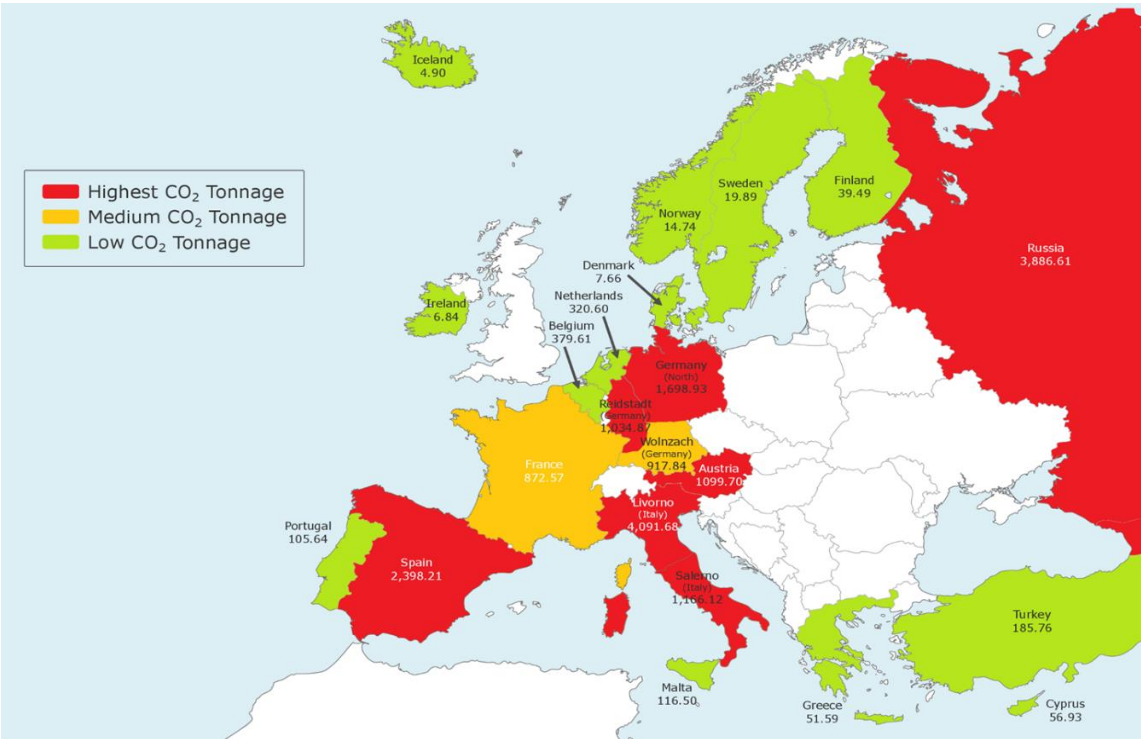



*Figure 86: $CO_2$ map of markets (Source: author)*

## Step Four

Finally, analysing the cost benefit to identify what distribution strategy the company can afford for each market. When identified, the automotive company can then designate the budget, allocate responsibility and plan the scheduling/lead-time. However, the automotive company must account for any vehicle recalls (as the $CO_2$ of the return journey is the company's responsibility), in addition to any special handling as they prove costly as well as emitting high $CO_2$ (Fig. 85).

## 6.7 Conclusion of Discussion

The sustainability project conducted at JLR resulted in the development of the decision making tree that would complement the interactive MDM and help decision makers implement the recommended strategy and identify the means to implement them sustainably. The sustainability project illustrated that other automotive companies have many more manufacturing plants due to their de-centralised structure which emits CO2 in various locations, in contrast to JLR which has a centralised production. Moreover, other automotive companies have much higher volumes so their road and train freight distribution emits high levels of CO2, while JLR has fewer volumes exported due it being a premium good (Wee and Wu, 2009; Ford Motor Company, 2014). Therefore, JLR emits fewer CO2 emissions compared to other automotive companies, however its distribution strategies need to undertake improvements to move from road freight to rail and sea shipments. Overall, JLR found the sustainable decision making model useful in deciding which mode fits with which market/country with regards to the prioritisation of the vehicles. In addition, the recommendation to use rail for the in-house freight distribution has partially helped JLR to re-strategise its distribution from its plant to port of exit.

The interactive MDM and the sustainable decision tree complement each other and provide a holistic approach to help companies diagnose the most suitable supply chain for their market and incorporate sustainable thinking into their framework. The testing has validated the interactive MDM as a useful tool that would further aid strategic planning in designing new supply chain and logistics strategies to reduce lead-time, and planning a better robust business structure that can adapt to changes. Both the MDM and the sustainable decision making tree were put on a web-based software to be used in unison by companies.

# Chapter 7

## Contributions and Further Research

*"Problems cannot be solved at the same level of awareness that created them."* – Albert Einstein

The hypothesis that SMEs and corporations are facing challenges in determining the best suitable supply chain strategy for every node of their business framework has been identified by the literature review, theoretical framework and testing. In order to mitigate the issues of diagnosing their position in the market and choosing a suitable supply chain strategy for their business structure, this research objective was to first identify all the supply chain strategies developed and allocate them into "Eras". The allocation into Eras has been done by determining the emerging definitions arising in each era, and highlighting the issues faced by companies' through the evolution of supply chains. This was achieved throughout the theoretical framework which helped create the conceptual framework that will help achieve the aim of this research, which is incorporating the relevant strategies from each era into a Multi-Dimensional Matrix (MDM). The aim has been accomplished as the interactive MDM was created and tested in its capability to help SMEs and organisations identify and allocate their strategy in accordance with their speciality and market. Furthermore, the testing helped provide knowledge on the interactive MDM's capability to help businesses shorten their lead-time by choosing a suitable strategy for the tested node; in addition, to help them understand which node can add value and reduce costs, as the MDM acts as a diagnostic tool that can generate recommendations as well as options for the company to choose from. Moreover, the interactive MDM has proven to have sufficient capabilities to survive in a digitalised era, as this study indicated by the interactive MDM capacity to be tailored by companies adding variables and truth functions to create a model that is unique to their business structure and framework. This research also accomplished its aim of providing a sustainable decision tree that is complementary to the interactive MDM and helps companies incorporate sustainable decision making, whilst choosing the best supply chain strategy diagnosed to them by the interactive MDM.

## 7.1 Research Contribution

This research proved the usefulness of the interactive MDM and the sustainable decision tree, as tested by a major international vehicle manufacturer (JLR). This research has several contributions, firstly it provided an overview of how supply chains and logistics have developed through time, the evolving definitions of both concepts and the strategies created to counter the issues companies have faced. This was shown as Eras which highlighted the overlap between each evolution, the expansion of the concept and the new developments. This provided an outline for future research to use the historical time-scale to further understand the development of the logistics and supply chain concept that can be used as an established base upon which they can further build on. The contribution of the historical time-scale to business, is to offer an open source of strategies and definitions which they can use to develop their own models that can be incorporated into their business structure.

Secondly, this research established several variable functions from the literature to be used in the Hybrid Fuzzy Delphi in order to measure the issues faced by companies and establish the most suited strategy. Additionally, this study put forward a new concept of measuring time by using the JIT system and the Lean strategy. The variable functions, the JIT Lean concept and its use in the Hybrid Fuzzy Delphi provide academics as well as business the tools and method by which they can select the most relevant variables to measure an issue and develop their own conclusions or model to be applied for their specific requirements. This provides a concise summary of variables that can be used to further aid research and business in the development of models to measure their performance.

Thirdly, the development of the interactive MDM contributed to academic research in providing a methodological framework to illustrate the development of an interactive model which can be used by researchers in the creation of their own models. Furthermore the interactive MDM provides a tested platform that illustrates the issues companies' face, as well as a tool which they can use to mitigate these issues. The interactive MDM provides a blueprint that can be further developed and tailored by the addition of further variable functions to suit the needs of the user.

Lastly, this research's contribution in creating a complimentary sustainable decision making model is to provide insight into the importance of integrating sustainability into a business framework. This can be further developed by researchers and businesses to be fully incorporated into the interactive MDM, creating a holistic platform suitable to their requirements that is able to diagnose the best suitable and sustainable strategy for the user.

These contributions provide an outline that can be taken further by researchers and business to be advanced into sophisticated tools that can help diagnose and identify strategies more accurately by being tailored to the company using it. This research contribution is to help SMEs and organisations understand their supply chain framework better and diagnose the nodes that require improvement by the use of the interactive MDM. This research also ensured that the interactive MDM not only recommends strategies but options and the ability to insert more variables if the user wishes. This resulted in the interactive MDM becoming a useful tool that would further aid strategic planning, designing or improving supply chain and logistics operations by reducing lead-time and help companies develop a robust business structure that can adapt to change.

## 7.2 Further Research

Further research can be conducted to give the interactive MDM reasoning capability by learning from errors. The interactive MDM tool can be improved to synergise human-like reasoning such as learning capability by including heuristic learning and neural networks (Burney and Mahmood, 2006). Furthermore, the interactive MDM can be developed to face external influences; such as political external issues. The extent of these influences can be examined using game theory and the study of strategic decision making to minimise these influences on the proposed recommendations given by the MDM. Heuristic learning enables the addition of more variables into the interactive MDM model, which will give it a wider outlook on recommending the best supply chain and logistics strategy. Adding game theory, heuristic learning and Neural networks to the interactive MDM, will provide a synergy of methods that can establish whether the recommended strategy of the MDM will be accepted and applied by the majority of business or suppliers in order for them to be better off, or whether some will refuse to cooperate in the hope of gaining more by acting independently and thus affecting the overall welfare of the industries.

Game theory's ideology is that people and organisations act in their best interest, yet this behaviour can be predicted (Fox, 2006). Adding equations of game theory into the interactive MDM will allow companies to analyse their supplie's desired goal, their flexibility, their attention to the problem, and their influence (Summer, 1994). The game theory equations will not only allow the interactive MDM to recommend options but will also determine their likely course of action and evaluate their ability to influence others as it predicts the course of events by the help of heuristic learning. If a human mediator is not available, or distrusted, the heretic learning and game theory equations can offer reliable strategic solutions (Maskin and Tirole, 1990). The use of game theory will give the interactive MDM the capability to analyse human behaviour, which is important for strategic prediction (Lange et al, 1990).

Game theory has had a deep impact in on the theory of industrial organisation. According to Fudenberg and Tirole (1987) game theory forces economists to clearly specify the strategic variables, the timing of the variables and the information structure of the firm. Thus, game theory can be used for further research to identify the influences placed on the experts' opinions, as it allows the researcher to learn as much from constructing the model as from solving it; because in construction, one is led to examine the available realistic options (Fox, 2006). The drawback is the freedom given by game theory as the modeller can choose any variables with no constraints. This drawback can be a positive in the field of supply chain, as without constraints there would be more room for adaption and tailoring to the organisation's needs and the market requirements (Fudenberg and Tirole, 1987). The further research can draw conclusions from using game theory with the help of Table 42, which illustrates the advantages and disadvantages of the method.

*Table 42: Pros and Cons of Game Theory (Source: author)*

| Pros. of Game Theory | Cons. of Game Theory |
|---|---|
| 1. A prime tool for modelling and designing automated decision-making processes in interactive environments. The automation of strategic choices enhances the need for these choices to be made efficiently, and to be robust against abuse. Game theory addresses these requirements (Foss, 1999). | 1. Branches of game theory differ in their assumptions. The right branch and assumption must be chosen accurately and in relation to the objective of the question researched. A central assumption in many variants of game theory is that players are rational. This rationality assumption can be relaxed, in different branches of game theory (Foss, 1999). |
| 2. As a mathematical tool for decision-makers, the strength is its capability to provide structure to strategic problems (Foss, 1999). | 2. Getting an accurate prediction, the parameter of the equation has to be simplified (Foss, 1999) |

The use of heuristic learning and neural networks as a hybrid method helps classify the prioritisation of a recommended strategy and the feasible path an organisation can take (Bakheet, 1995). This can be done by establishing which recommendation and course of action is classified as standard or high risk. This suggests that neural networks can be used as means to identify which supply chain strategy companies should incorporate from the MDM model, as it can highlight which strategy has the most risk associated with it, and with heuristic learning, the MDM can learn to improve future recommendations. To help further research draw conclusions on adapting a hybrid system into the MDM mode; Table 43, has been drawn to illustrate advantages and disadvantages of heuristic learning and neural network.

*Table 43: Pros and Cons of hybrid intelligent systems (Source: author)*

| Technology | Pros. | Cons. |
|---|---|---|
| **Neural networks** | 1. Is a computational structure with learning and generalisation capabilities (Rosenblatt, 1959)?<br>2. Conceptually, it stores knowledge acquired by learning with known samples (Shapiro, 2002).<br>3. Operationally, it uses a set of samples that consist of input and output relationships to create learning algorithms that perform optimisation (Widrow and Hoff 1960).<br>4. Has the advantage of adaption, learning and approximation (Werbos 1974). | 1. Relatively slow convergence speed (Rosenblatt, 1959).<br>2. The negative attribute of unforeseen problems or difficulties arising from the use of complex strategies especially when using complex mathematical formulas requiring a computer. This results from lack of transparency in a model or strategy (Shapiro, 2002). |
| **Genetic algorithms in this project its referred to as "Heuristic Learning"** | 1. Suitable to perform randomised global search, as each fitness value and its function is evaluated on the basis of its performance. By using a genetic algorithm the best value is evolved into the next generation value with better functioning solutions (Holland, 1975).<br>2. Has the advantage of random systematic search and derivative-free optimisation (Holland, ibid). | 1. It is difficult to tune the values in accordance with the function's performance (Holland, 1975).<br>2. It has no convergence criterion. The ideal convergence criterion for a genetic algorithm would guarantee each and every parameter converge independently (Beasley et al.1993). Which is demanding and result in too much iteration, hence relaxed convergence criteria are usually employed. |

In conclusion this research analyses the development of supply chains through time from the 1940s to the present.  This study looked at the factories of the future and their focus on mass customisation with the use of various technologies such as: clever software, web-based services, novel materials, automation, new technology (for example three-dimensional printing) and a range of processes aimed at tailoring each product precisely to each customer's taste. With the challenging economic climate and the increasing competitive pressures, this research established era six and seven with the aim to create an interactive web-based MDM which SMEs and organisations can incorporate and a complementary sustainable decision making tree that integrates sustainable thinking into a business framework. These models were tested with a major international automobile company (JLR), yet can be tailored to any business structure to provide them with their unique diagnosed solutions and sustainable approach for each node at their supply chain. In addition, the interactive MDM can be improved further by combining the advances in information technology to enable fast and reliable communication among different nodes as well as stages in a supply chain, by the use of neural networks, heuristic learning and game theory. The further research can improve the interactive web-based MDM into a cyber-network that links the whole supply chain together as well as calculates or compares the organisation's supply chain with its competitors. This will help various industries including those with automated products and facilities to unify their supply chain and mitigate human error.

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# Appendices

# Appendix A: Panel Contact Details

- *Some names are not included due to data protection confidentiality, as requested by the participants themselves, which complies with the Delphi study, as it protects participants' anonymity.*

| Contact Name | Institution | Expertise |
|---|---|---|
| Dr. Federico D'Amico | Hull University Business School | EDF Energy: Innovative transport and deployment systems |
| Prof. Jahangir Akhtar | Birmingham City University | Senior Lecturer: Procurement and Operations Management |
| Dr. Emel Aktas | Cranfield University | Senior Lecturer: Logistics and Supply Chain Management |
| Dr. Graeme Heron | Newcastle University | Lecturer: Operations Management |
| Dr. Richard Oloruntoba | Newcastle University | Senior Lecturer: Logistics and Supply Chain Management |
| Prof. Dong-Wook Song | World Maritime University | Senior Lecturer: Maritime logistics |
| CEO. Nick Gazzard | Incept Consulting | Supply chain costing |
| Dr. Elizabeth Jackson | University of London/ Royal Veterinary College | Senior Lecturer: Business / Livestock supply chains |
| Prof. David Menachof | Hull University Business School | Senior Lecturer: Global Logistics and Supply Chain Management |
| Prof. Tomas Choi | Arizona State University | Senior Lecturer: Supply chain design and network structures |
| William Packer | Lexmark International Technology Switzerland | Logistics Procurement Manager |
| CEO. Clive Kessell | Coastalwise Shipping and Logistics | Maritime Shipping and Logistics |
| Dr. Tim Germann | University of St.Gallen | Lecturer: Logistics Management |
| Dr Adrian Davis | Information Security Forum | Global supply chains: Principal Research Analyst |
| Dr Aristides Matopoulos | Aston University | Senior Lecturer: Logistics and Supply Chain Management |
| Dr Yi Wang | University of Manchester | Lecturer: Supply Chain Management |

| | | |
|---|---|---|
| Dr. Khalil Al-kanaani | University of Aalborg | Senior Consultant in Logistics and Supply Chain Management |
| Prof. Thierry Vanelslander | University of Antwerp | Transport and Regional Economics |
| Prof. Neil Towers | Heriot-Watt University | Supply Chain Management |
| Dr. Rachel Mason-Jones | University South of Wales | International logistics and Supply Chan Management |
| Dr. Kayvan Lavassani | North Carolina Central University | Senior Lecturer: Supply chain and Economics |
| Prof. Judith Whipple | Michigan State University | Supply Chain Management |
| Dr. Nevan Wright | Auckland University of Technology | Operations/supply chain/logistics |
| Dr. Iain Reid | University of Liverpool | Agility of supply chains for SMEs |
| Dr. Jim Monaghan | Harper Adams University | Systems and their role in the supply chain |
| Kurt Radtke | Boart Longyear | Supply Chain Project Manager |
| Alastair Charatan | SIG Distribution | Supply Chain Director |
| Mark Petty | Commercial at Leyton UK | Supply chain cost optimisation, RandD Management and Financing |
| Natalie Wilmot | Sheffield Hallam University | Senior Lecturer: International Business |
| Igor Davydenko | TNO Sustainable Transport and Logistics | Consultant Freight Transport and Logistics |
| Susanna Whawell | Auxilium Management | Managing Director: supply chain benchmarking |
| Alex Gullen | Eagle Shipping International | Senior Claims Handler; setting the supply chain's KPIs |
| Dr. Jane Eastham | Harper Adams University | Senior lecturer: Food marketing and supply chain management |
| Daryl Chesney | The Chartered Institute of Logistics and Transport (CILT[UK]) | Business Development Manager |
| Lisa Paris | Summit Selling Systems | Director of Operations |
| Damon Hill | Anglers Choice Marine | Shipping and Receiving |

| | | |
|---|---|---|
| Michael Sedor | Optum | Regional Account Manager |
| Phill Matos | Smith Sorensen Nutraceuticals | Procurement manager |
| Jennifer Welton | University of Pittsburgh | Manager of corporate relations |
| Phill Matos | EAP | Expediting manager |
| Paul James | Private consultancy | Web-based modelling for optimising and benchmarking supply chains |
| Bart Nissen | Power Tools LLC | Logistics modelling and benchmarking manager |
| Khalid Al-sadigi | SABIC- Diversified manufacturing of industrial polymers | Supply chain consultant |
| Gideon Hillman | Hillman consulting | Supply chain consultant |
| Ishmael Othman | Agricultural municipality | Chief of agricultural supply chain |
| Andrea Chiarini | Chiarini and Associates | Director of Operations Management |
| Anonymous | Independent distributor | Logistics coordinator |
| Anonymous | CFT- Transportation and Logistics company | Logistics market leader |
| Anonymous | Owner of a small business - SME | Supply chain and logistics specialist |
| Anonymous | Toyota | Supply chain procurement specialist |
| Anonymous | Toyota | Quality control |
| Anonymous | Health sector | Medical equipment distribution |
| Anonymous | Mercy Health | Medical equipment distribution |
| Anonymous | Omega Healthcare | Medical equipment distribution |
| Anonymous | Owner of a small company - SME | Supply chain consultant |
| Anonymous | Wall-Mart | Procurement |

| | | |
|---|---|---|
| Anonymous | Wall-Mart | Procurement |
| Anonymous | Web service marketing provider | Director of Procurement |
| Anonymous | MTB INC. | Production safety / High-end sports equipment |
| Anonymous | Owner of a small business - SME | Logistics coordinator |
| Anonymous | ICAP Shipping | Financial advisor and procurement specialist |
| Anonymous | ICAP Shipping | Logistics coordinator |
| Anonymous | ICAP Shipping | Specialises in ERP and APS systems |
| Anonymous | Harris Corp. | Quality control |
| Anonymous | Carrier company for specialist goods | Operation specialist |
| Anonymous | Owner of a small interior design company- SME | Supply Chain and operations Director |
| Anonymous | Conover Inc. | Procurement specialist |
| Anonymous | Chas. S. Ashley and Sons | Cargo insurance manager |
| Anonymous | Chas. S. Ashley and Sons | Financial advisor and procurement specialist |
| Anonymous | Helios management and technology consultancy | Operations specialist |
| Anonymous | Manufacturing sector | Quality control |
| Anonymous | GB Rail-freight | Logistics operations manager |
| Anonymous | Energy sector | Sustainable supply chain analyst |
| Anonymous | Interior design company | Lean systems analyst |
| Anonymous | Landscaping and building supplies | Procurement specialist |
| Anonymous | CLdN – ro-ro Agencies Carrier company for specialist goods | Automotive, Logistics and Solutions manager |

| | | |
|---|---|---|
| Anonymous | Woolf Aircraft, Inc. fabrication pipeline manufacturer | Operations specialist |
| Anonymous | El Camino College | Lecturer: Economics and corporate strategy |
| Anonymous | UPS carrier | Distribution specialist |
| Anonymous | GAC- Logistics carrier company | Logistics operations manager |
| Anonymous | Manufacturing interior products | Operations specialists |
| Anonymous | Delancey Art Galleries Dealers | Supply chain operation |
| Anonymous | IKEA | Strategy and planning specialist |
| Anonymous | Industrial manufacturing | Logistics modelling specialist |
| Anonymous | Manufacturing building supplies | Distribution and material handling specialist |
| Anonymous | Aerospace | Expediting and procurement manager |
| Anonymous | A-S-I Anglo Spanish Imports | Distribution coordinator |
| Anonymous | Supplier of building material and construction-SME | Director of operations |
| Anonymous | Maritime sector | Shipping manager |
| Anonymous | CC. Johnson and Malhotra Co. | Material planning and distribution consultant |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Strategic planning supervisor of the EU distribution team** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Operations specialist of the EU distribution team** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Senior logistics co-ordinator of the EU distribution team** |

| | | |
|---|---|---|
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Distribution strategic planning Specialist** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Logistics co-ordinator Specialist** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **EU Distribution Operations Manager** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Manger of the EU distribution team and the strategic planning division** |
| **Anonymous** | **JLR - EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles** | **Head of Global Material Planning and Logistics Department** |

- *The Fuzzy Delphi panel consists of 90 experts. However, the semi-structured interview panel is not part of the Fuzzy Delphi, in order to avoid biased judgments. The semi-structured interview panel consists of 8 experts from JLR's EU Distribution Team, Planning and Strategy division of Outbound Finished Vehicles.*

# Appendix B: Era Definitions

| Era 1: Definitions |
| --- |
| Supply chains requires traditional separate material functions to report to an executive responsibility to coordinate the entire material process and to require joint relationships with suppliers for multiple tiers. Supply chains is a concept, whose primary objective is to integrate and manage the sourcing, flow, and materials' controlling using the systems perspective across multiple functions and multiple tiers of suppliers. Business relation and coordinating material's flow are the essence of supply chain (Monczka *et al*., 1998). |
| Supply chain management deals with the flow of materials from suppliers through end users. Supply chain was created as an approach to control the flow of raw material from the start point of suppliers to the end point of consumer consumption, by dealing with the planning and control of the materials flow from suppliers to end users (Jones and Riley, 1985). |
| Supply chain management is an integrative philosophy to achieve the flow of a distribution channel from supplier to the ultimate user. Supply chains manages the flow of goods from the suppliers to consumers (Cooper et al., 1997). |
| Supply chains organises the purchasing of raw materials and goods, as well as ensures quality control standard are in place and establishes business long-term and short-term relationships with suppliers and consumers (Shukla et al., 2011). |
| Supply chains create different links from the start of the raw material handling to the end selling point to consumers (Scott and Westbrook, 1991). |
| A network of entities that starts with the suppliers' suppliers and ends with the customers' custom the production and delivery of goods and services. Supply chains creates a network that combines the first suppliers of raw materials and second suppliers (i.e. manufacturing) and ends with the retailers and the delivery processes of goods or services (Lee, and Ng, 1997). |

| Era 2: Definitions |
|---|
| A set of firms that pass materials forwards. Supply chain is forward integration which passes materials in one direction from suppliers to consumers. Supply chain integration aims at creating long-term agreements by establishing trust and commitment to share demand and sales data in an attempt to forecast possible logistic changes. (La Londe and Masters, 1994). |
| Supply chain management is the network of facilities that produce raw materials, transform them into intermediate goods and then final products to be delivered through a distribution system. Supply chains are an integrated network of different suppliers from raw material providers to manufacturers to retailers who supply the market through a distribution system and thus satisfy consumer needs (Lee and Billington, 1995). |
| Supply chains is the alignment of firms that bring services or products to the market and finally to the consumer. Firms utilise their suppliers' processes, from original source of raw materials, through the various firms network of manufacturing and distribution (Lambert *et al*., 1998). |
| The integration of the processes, systems and organisations that control the movement of goods from the supplier to a satisfied customer without waste. Therefore, it improves the efficiency of the processing systems which organise and control the flow of goods. Supply chains integrate upstream and downstream processes to create a value chain which offers a high quality goods or value and services with less supply chain operation cost. (Shukla et al., 2011). |
| Using inter-organisational systems in supply chain practice such as EDI (Electronic Data Integration) and elimination of excess stock levels by postponing customisation toward the end of the supply chain. Integrating systems such as EDI that speeds data exchange between companies and within the internal framework of a firm, in order to mitigate stock waste as a result of delays in supplying customers (Kotzab, 2003). |

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| Six elements of supply chain practice (using factor analysis): supply chain integration, information sharing, supply chain characteristics, customer service management, geographical proximity and Just In Time (JIT) capability. By implicating these elements, a more efficient supply chain system can be established that mitigates delays and provide customer orientated products whilst reducing stock levels (Cooper and Ellram, 1993). |
| Supply chain management covers the flow of goods from supplier through manufacturer and distributor to the end-user. A supply chain integrates three main chains (manufacturer, distributer and user). By passing materials forward in a network of facilities, alignment of nodes, to interconnect strategically in long-term agreement. Integrating upstream and downstream, will integrate various functional areas within an-organisation, eliminating excess stock and enhance information sharing, customer service, geographical proximity and JIT capability (Novak and Simco, 1991). |

| Era 3: Definitions |
|---|
| Supply chain is viewed as a single process, where responsibility for various segments is not fragmented, it depends on, strategic decision making of a shared objective of overall costs and market share. It calls for a different perspective on inventories where a new approach is required to integration rather than interface (Houlihan, 1988). |
| Supply chain is crucial to globalisation as it connects the organisations through upstream and downstream processes within a marketing area regardless of their different activities to increase the value of the product or service to consumers worldwide (Christopher, 1999). |
| Networks of manufacturing and distribution sites that procure raw materials, transform them into intermediate and finished products, and distribute them to customers. Creating a globalise supply chain with multi-national suppliers from raw materials to finished goods and finally to be distributed to the consumer (Lee and Billington, 1995). |

| |
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| Supply chains aims at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to release management resources for developing meaningful, long-term relationship. In the global economy companies are faced with extra competition in developing new products, therefore the information exchanged based on market needs is crucial in determining the most suitable supply chain by combining manufacturing processes with management resources in order to develop long-term relationships (Berry *et al.,* 1994). |
| The functions within and outside a company that enable value chain to make and provide products to the customer. Global supply chains are faced with challenges to add value to the end products distributed to the consumer (Cox, 1996). |
| Supply chain practice includes supplier partnership, outsourcing, cycle time compression, continuous process flow and information sharing. Global supply chains require the outsourcing of business services to second-hand partners multi-national, resulting in the need to improve information flows. Global supply chains aim at reducing supplier cost by developing long-term relationships and involving expert teams to measure the buyer-supplier relationship (Chen and Paulraj, 2004). |
| A supply chain must incorporate the complex nature of the global market and include all the processes that are linked with the product development to fulfil a customer's request (Chopra and Meindl, 2007). |

| **Era 4: Definitions** |
|---|
| Specialist supply chain is to synchronise the requirements of the customer with the flow of materials from suppliers to effect a balance between what are often seen as conflicting goals of high customer service, low inventory management and low unit cost (Stevens, 1989). |
| Specialisation links each element of manufacturing and supply process from raw materials to end user. Specialised supply chains tailor their manufacturing processes and choice of materials to encompass the |

| |
|---|
| regulations of the boundaries the organisation is dealing with. Specialised integrates customer satisfaction with value chain in order to provide specialised goods to the end consumer (Lummus and Vokurka, 1999). |
| Specialised supply chains collaborate between the intra-elements of a company and the entra-elemants such as trading partners in order to optimise efficiency (Tan et al., 1999). |
| Integration activities take place among a network of facilities that procure Raw material, transform them into intermediate goods and then final products and deliver them to customers through a distribution system. Specialised supply chain divided their facility in order to incorporate specialised intermediate goods to produce specialised products to their consumers (Lee and Billington, 1995). |
| Specialised supply chains actively manage channels of procurement and distribution, adding value along product flow from original raw materials to final customer. Specialised supply chain management coordinates the channels of acquiring goods or services and their distribution to ensure specialised materials and methods of manufacturing are used in order to add value to the specialised products for their consumers (Cavinato, 1992). |
| There are seven elements of specialist supply chain practice: agreed vision and goals, information sharing, risk and award sharing, cooperation, process integration, long-term relationship and agreed supply chain leadership (Min and Mentzer, 2004). |

| Era 5: Definitions |
|---|
| The integrating of the globalisation within a supply chain will aim to create a network of specialised global products with a global specialised network of supply. This is initiated by creating long term relationships and trust between companies and suppliers. The systemic, strategic coordination of the traditional business functions within the supply chain, improves the long-term performance of the individual companies and the supply chain as a whole (Mentzer *et al*., 2001). |

| |
|---|
| A globalised and specialised network of supply chain requires a sophisticated network of information flows to reduce the occurrence of error in product development due to the mishandling of information from different parts of the world (Handfield and Nichols, 2004). |
| Supply chains are networks of facilities and distribution options performing procurement of materials that transform into finished products, then distributed to customers. A specialised globalised chain aims at providing an agile method of production and distribution as demand shift are fast in the global market (Ganeshan and Harrison, 1995). |
| Supply chain is a system that constituent parts of material suppliers, production facilities, distribution services, customers linked together via the feed forward flow of materials and the feedback flow information. Globalised and specialised supply chain incorporate an upstream and down-stream flow of information that helps coordinate the flow of raw materials, production and delivery of goods in a fast shifting global market (Towill *et al*., 1992). |

# Appendix C: Cover Letter

Dear [24] ,

I am a PhD student at Plymouth University, United Kingdom; currently researching supply chain strategy and efficiency. I'm conducting a Multi-dimensional Matrix that helps diagnose the best Lean, Agile and Leagile strategy for supply chains. I found your details from ………………………. Your knowledge and expertise in …………………………… is of extreme importance to my research. You're ………and/or ……….. insight will help me identify the benefits of my research in practice, as the Multi-dimensional supply chain matrix aims to help consultants assess the location of the company's supply chain strategies in the market, in relation to what the market actually requires. This project is supervised under Prof. Michael Roe and titled "Development of an optimised, interactive Multi-dimensional model for supply chain management". The data collection is done via gathering expert for a Fuzzy-Delphi. Which requires a minimum of two rounds, hence your commitment, feedback and advice is vital to my research.

*This first stage, requires a general answer. Please complete the provided questionnaire in the following link………………...*

*The second stage, requires the selection of a supply chain for a chosen good or commodity. Any feedback or advice, will help identify the amendments for the third Fuzzy Delphi round and the benefits of my research in practice. Please complete the provided questionnaire in the following link………………...*

Please answer all the questions and write your details at the designated box. The questionnaire will require a maximum of …….. minutes to complete. All the information is strictly confidential. At the end of the PhD there will be a list of contributors to the thesis, if you wish your name to be included, please send a confirmation email. If you would like a summary copy of this study please state so. The data collected will provide useful information regarding supply chain strategies.

Thank you for your valuable time.

Sincerely,

[24] This is a cover letter sample of what was sent to the participants for both Fuzzy Delphi rounds.

# Appendix D: Pilot Fuzzy Delphi

## survey- cost analysis

SME's [50-250 Employees, ≤ £10m-50m turnover, ≤ £10m-43m balance sheet total] and multinational corporation (MNC) which manufactures products or source commodities domestically or internationally to be sold at a local or international market, excluding service providers. - "Please answer the statements with regards to the four dimensions of supply chain strategies (BSC, Lean, Leagile and Agile)".

* Required

**If a company's supply chain cost is 0-10% of the revenue then it is** *

- Low cost
- Medium cost
- High cost

**If a company 's supply chain cost is 20% of the revenue then it is** *

- Low cost
- Medium cost
- High cost

**If a company 's supply chain cost is 30% of the revenue then it is** *

- Low cost
- Medium Cost
- High Cost

**If a company 's supply chain cost is 40% of the revenue then it is** *

- Low cost
- Medium cost
- High cost

**If a company 's supply chain cost is 50% of the revenue then it is** *

- Low cost
- Medium cost
- High cost

**If a company 's supply chain cost is 60% of the revenue then it is** *

- Low cost
- Medium cost
- High cost

## survey- Lean analysis

If a company's supply chain is 0-10% JIT then it is *

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 20% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 30% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 40% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 50% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 60% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 70% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 80% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 90% JIT then it is

- Low Lean
- Medium Lean
- High Lean

Please write your name and email *

# Appendix E: Formula of Pilot Fuzzy Delphi

*(An example of the formulas used in the interlinked survey)*

## Cost Function Formulas

| Value | | | =arrayformula('Form Responses'!B1:T1) | If a company 's supply chain cost is 20% of the revenue then it is | If a company 's supply chain cost is 30% of the revenue then it is | If a company 's supply chain cost is 40% of the revenue then it is | If a company 's supply chain cost is 50% of the revenue then it is | If a company 's supply chain cost is 60% of the revenue then it is |
|---|---|---|---|---|---|---|---|---|
| | | | =if(D4>D5,if(D4>D6,B8),<br>if(D5>D6,B9,if(D6=0, "null", B10))) | =if(E4>E5,if(E4>E6,B8),<br>if(E5>E6,B9,if(E6=0, "null", B10))) | =if(F4>F5,if(F4>F6,B8),<br>if(F5>F6,B9,if(F6=0, "null", B10))) | =if(G4>G5,if(G4>G6,B8),<br>if(G5>G6,B9,if(G6=0, "null", B10))) | =if(H4>H5,if(H4>H6,B8),<br>if(H5>H6,B9,if(H6=0, "null", B10))) | =if(I4>I5,if(I4>I6,B8),<br>if(I5>I6,B9,if(I6=0, "null", B10))) |
| %Response | % Low Cost<br>% Medium Cost<br>% High Cost | | =(D8/B12)*100<br>=(D9/B12)*100<br>=(D10/B12)*100 | =(E8/B12)*100<br>=(E9/B12)*100<br>=(E10/B12)*100 | =(F8/B12)*100<br>=(F9/B12)*100<br>=(F10/B12)*100 | =(G8/B12)*100<br>=(G9/B12)*100<br>=(G10/B12)*100 | =(H8/B12)*100<br>=(H9/B12)*100<br>=(H10/B12)*100 | =(I8/B12)*100<br>=(I9/B12)*100<br>=(I10/B12)*100 |
| Response count | Low Cost<br>Medium Cost<br>High Cost | | =countif(D12:D200, "Low cost")<br>=countif(D12:D200, "medium cost")<br>=countif(D12:D200, "high cost") | =countif(E12:E200, "Low cost")<br>=countif(E12:E20, "medium cost")<br>=countif(E12:E200, "high cost") | =countif(F12:F200, "Low cost")<br>=countif(F12:F200, "medium cost")<br>=countif(F12:F200, "high cost") | =countif(G12:G200, "Low cost")<br>=countif(G12:G200, "medium cost")<br>=countif(G12:G200, "high cost") | =countif(H12:H200, "Low cost")<br>=countif(H12:H200, "medium cost")<br>=countif(H12:H200, "high cost") | =countif(I12:I200, "Low cost")<br>=countif(I12:I200, "medium cost")<br>=countif(I12:I200, "high cost") |
| Sum of responses | =ArrayFormula(iferror(counta(t(D12:D94)))) | =arrayformula ('Form Responses'!A2:T227) | low cost | Low cost | Medium Cost | High cost | High cost | High cost |

## Lean Function Formulas

| | If a company's supply chain is 10% JIT then it is | If a company's supply chain is 20% JIT then it is | If a company's supply chain is 30% JIT then it is | If a company's supply chain is 40% JIT then it is | If a company's supply chain is 50% JIT then it is | If a company's supply chain is 60% JIT then it is | If a company's supply chain is 70% JIT then it is | If a company's supply chain is 80% JIT then it is | If a company's supply chain is 90% JIT then it is |
|---|---|---|---|---|---|---|---|---|---|
| | =if(M4>M5,if(M4>M6,L8),<br>if(M5>M6,L9,if(M6=0, "null",L10))) | =if(N4>N5,if(N4>N6,L8),<br>if(N5>N6,L9,if(N6=0, "null",L10))) | =if(O4>O5,if(O4>O6,L8),<br>if(O5>O6,L9,if(O6=0, "null",L10))) | =if(P4>P5,if(P4>P6,L8),<br>if(P5>P6,L9,if(P6=0, "null",L10))) | =if(Q4>Q5,if(Q4>Q6,L8),<br>if(Q5>Q6,L9,if(Q6=0, "null",L10))) | =if(R4>R5,if(R4>R6,L8),<br>if(R5>R6,L9,if(R6=0, "null",L10))) | =if(S4>S5,if(S4>S6,L8),<br>if(S5>S6,L9,if(S6=0, "null",L10))) | =if(T4>T5,if(T4>T6,L8,if(T5>T6,L9,if<br>"null",L10)))) | =if(U4>U5,if(U4>U6,L8,<br>if(U5>U6,L9,if(U6=0, "null",L10)))) |
| % Low Lean<br>% Medium Lean<br>% High Lean | =(M8/B12)*100<br>=(M9/B12)*100<br>=(M10/B12)*100 | =(N8/B12)*100<br>=(N9/B12)*100<br>=(N10/B12)*100 | =(O8/B12)*100<br>=(O9/B12)*100<br>=(O10/B12)*100 | =(P8/B12)*100<br>=(P9/B12)*100<br>=(P10/B12)*100 | =(Q8/B12)*100<br>=(Q9/B12)*100<br>=(Q10/B12)*100 | =(R8/B12)*100<br>=(R9/B12)*100<br>=(R10/B12)*100 | =(S8/B12)*100<br>=(S9/B12)*100<br>=(S10/B12)*100 | =(T8/B12)*100<br>=(T9/B12)*100<br>=(T10/B12)*100 | =(U8/B12)*100<br>=(U9/B12)*100<br>=(U10/B12)*100 |
| Low Lean<br>Medium Lean<br>High Lean | =countif(M12:M200, "Low Lean")<br>=countif(M12:M200, "Medium Lean")<br>=countif(M12:M200, "High Lean") | =countif(N12:N200, "Low Lean")<br>=countif(N12:N200, "Medium Lean")<br>=countif(N12:N200, "High Lean") | =countif(O12:O200, "Low Lean")<br>=countif(O12:O200, "Medium Lean")<br>=countif(O12:O200, "High Lean") | =countif(P12:P200, "Low Lean")<br>=countif(P12:P200, "Medium Lean")<br>=countif(P12:P99, "High Lean") | =countif(Q12:Q200, "Low Lean")<br>=countif(Q12:Q200, "Medium Lean")<br>=countif(Q12:Q200, "High Lean") | =countif(R12:R200, "Low Lean")<br>=countif(R12:R200, "Medium Lean")<br>=countif(R12:R200, "High Lean") | =countif(S12:S200, "Low Lean")<br>=countif(S12:S200, "Medium Lean")<br>=countif(S12:S200, "High Lean") | =countif(T12:T200, "Low Lean")<br>=countif(T12:T200, "Medium Lean")<br>=countif(T12:T200, "High Lean") | =countif(U12:U200, "Low Lean")<br>=countif(U12:U200, "Medium Lean")<br>=countif(U12:U200, "High Lean") |

# Appendix F: Pilot Fuzzy Delphi Report

*(A sample of the responses for the pilot fuzzy Delphi)*

## Cost Function Responses

| Value | | If a company's supply chain cost is 10% of the revenue then it is | If a company 's supply chain cost is 20% of the revenue then it is | If a company 's supply chain cost is 30% of the revenue then it is | If a company 's supply chain cost is 40% of the revenue then it is | If a company 's supply chain cost is 50% of the revenue then it is | If a company 's supply chain cost is 60% of the revenue then it is |
|---|---|---|---|---|---|---|---|
| | | Low Cost | Low Cost | Medium Cost | High Cost | High Cost | High Cost |
| %Response | % Low Cost | 132.5301205 | 84.3373494 | 18.07228916 | 2.409638554 | 1.204819277 | 1.204819277 |
| | % Medium Cost | 26.5060241 | 7.228915663 | 101.2048193 | 75.90361446 | 27.71084337 | 13.25301205 |
| | % High Cost | 3.614457831 | 18.07228916 | 43.37349398 | 84.3373494 | 133.7349398 | 148.1927711 |
| Response count | Low Cost | 110 | 70 | 15 | 2 | 1 | 1 |
| | Medium Cost | 22 | 6 | 84 | 63 | 23 | 11 |
| | High Cost | 3 | 15 | 36 | 70 | 111 | 123 |
| Sum of responses | 83 | | | | | | |
| | 6/7/2013 8:25:44 | Low Cost | Low cost | Medium Cost | High Cost | High Cost | High Cost |
| | 6/7/2013 8:26:00 | Medium Cost | Medium Cost | High Cost | High Cost | High Cost | High Cost |
| | 6/7/2013 8:26:13 | Medium Cost | Medium Cost | High Cost | High Cost | High cost | High Cost |
| | 6/7/2013 8:26:32 | Low Cost | Medium Cost | Medium Cost | High Cost | High cost | High Cost |
| | 6/7/2013 17:28:47 | Low Cost | Low Cost | Medium Cost | Medium cost | High cost | High Cost |
| | 6/13/2013 16:28:50 | Low cost | Medium cost | Medium Cost | High cost | High cost | High Cost |
| | 6/13/2013 17:24:10 | Low cost | Low Cost | Medium Cost | Medium cost | High cost | High Cost |
| | 6/26/2013 22:04:29 | Medium Cost | Medium Cost | Medium Cost | Medium cost | Medium cost | Medium Cost |
| | 6/26/2013 23:44:03 | Medium Cost | Medium Cost | Medium Cost | Medium cost | Medium cost | Medium Cost |
| | 6/27/2013 0:14:18 | Low cost | Low Cost | Medium Cost | Medium cost | High cost | High cost |
| | 6/27/2013 0:18:28 | Low cost | Low Cost | Low Cost | Medium cost | Medium cost | High cost |
| | 6/27/2013 0:19:06 | Low cost | Low Cost | Medium Cost | Medium cost | Medium cost | Medium Cost |
| | 6/27/2013 0:19:54 | Low cost | Medium Cost | Medium Cost | Medium cost | High cost | High cost |
| | 6/27/2013 0:20:48 | Low cost | Low Cost | Low Cost | Low Cost | Medium cost | Medium cost |
| | 10/15/2013 14:56:24 | Low cost | Medium Cost | High Cost | High cost | High cost | High cost |
| | 10/15/2013 18:05:25 | Low cost | Low Cost | Medium Cost | Medium cost | High cost | High cost |
| | 10/16/2013 16:38:21 | Low cost | Low Cost | Medium Cost | High cost | High cost | High cost |
| | 10/17/2013 17:16:30 | Low cost | Medium Cost | Medium Cost | High cost | High cost | High cost |
| | 10/18/2013 15:50:36 | Low cost | Low cost | Low cost | Medium cost | Medium cost | High cost |
| | 10/21/2013 9:04:01 | Medium Cost | High cost | High Cost | High cost | High cost | High cost |
| | 10/22/2013 14:58:14 | Medium Cost | High cost | High Cost | High cost | High cost | High cost |
| | 10/23/2013 15:58:04 | Low cost | Low cost | Medium Cost | Medium cost | High cost | High cost |
| | 10/28/2013 12:31:42 | Low cost | Low cost | Low cost | Medium cost | Medium cost | High cost |
| | 10/28/2013 23:15:50 | Low cost | Low cost | Medium Cost | High cost | High cost | High cost |
| | 10/29/2013 14:02:50 | Low cost | Medium Cost | Medium Cost | High cost | High cost | High cost |
| | 10/30/2013 8:49:58 | Low cost | Low cost | Medium Cost | Medium cost | High cost | High cost |
| | 11/1/2013 0:49:19 | Low cost | Low cost | Medium Cost | High cost | High cost | High cost |
| | 11/3/2013 18:25:03 | Medium Cost | High cost | High Cost | High cost | High cost | High cost |
| | 11/4/2013 9:22:11 | Low cost | Low cost | Medium Cost | Medium cost | High cost | High cost |
| | 11/4/2013 12:51:45 | Low cost | Low cost | Medium Cost | Medium cost | High cost | High cost |
| | 11/4/2013 13:26:18 | Low cost | Medium Cost | High Cost | High cost | High cost | High cost |
| | 11/5/2013 13:48:34 | Low cost | Low cost | Medium Cost | Medium cost | High cost | High cost |
| | 11/8/2013 8:43:04 | Low cost | Low cost | Medium Cost | High cost | High cost | High cost |
| | 11/8/2013 14:54:03 | Medium cost | High cost | High Cost | High cost | High cost | High cost |
| | 11/11/2013 10:40:56 | Low cost | Medium cost | Medium Cost | High cost | High cost | High cost |
| | 11/12/2013 18:33:33 | Low cost | Medium cost | Medium Cost | High cost | High cost | High cost |
| | 11/13/2013 14:13:15 | Medium cost | High cost | High Cost | High cost | High cost | High cost |
| | 11/13/2013 16:25:36 | High cost | High cost | High Cost | Low cost | Low cost | Low cost |
| | 11/13/2013 22:25:15 | Low cost | Medium cost | Medium Cost | High cost | High cost | High cost |
| | 11/14/2013 5:39:22 | Medium cost | High cost | High Cost | High cost | High cost | High cost |
| | 11/14/2013 20:11:34 | Low cost | Low cost | Low cost | Medium Cost | Medium Cost | Medium Cost |
| | 11/17/2013 3:33:21 | Low cost | Low cost | Low cost | Medium Cost | High cost | High cost |

# Lean Function Responses

| | If a company's supply chain is 10% JIT then it is | If a company's supply chain is 20% JIT then it is | If a company's supply chain is 30% JIT then it is | If a company's supply chain is 40% JIT then it is | If a company's supply chain is 50% JIT then it is | If a company's supply chain is 60% JIT then it is | If a company's supply chain is 70% JIT then it is | If a company's supply chain is 80% JIT then it is | If a company's supply chain is 90% JIT then it is |
|---|---|---|---|---|---|---|---|---|---|
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | FALSE | High Lean |
| % Low Lean | 138.5542169 | 119.2771084 | 53.01204819 | 19.27710843 | 13.25301205 | 8.43373494 | 7.228915663 | 7.228915663 | 6.024096386 |
| % Medium Lean | 10.84337349 | 25.30120482 | 85.54216867 | 102.4096386 | 66.26506024 | 48.19277108 | 24.09638554 | 8.43373494 | 2.409638554 |
| % High Lean | 3.614457831 | 6.024096386 | 12.04819277 | 16.86746988 | 71.08433735 | 92.77108434 | 116.8674699 | 133.7349398 | 142.1686747 |
| Low Lean | 115 | 99 | 44 | 16 | 11 | 7 | 6 | 6 | 5 |
| Medium Lean | 9 | 21 | 71 | 85 | 55 | 40 | 20 | 7 | 2 |
| High Lean | 3 | 5 | 10 | 14 | 59 | 77 | 97 | 111 | 118 |
| | Medium Lean | Medium Lean | Medium Lean | Medium Lean | | | | | |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | | High Lean |
| | High Lean | High Lean | High Lean | Medium Lean | Medium Lean | Medium Lean | Low Lean | Low Lean | Low Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | | | | | | | | |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | High Lean | High Lean | High Lean | Medium Lean | Medium Lean | Medium Lean | Low Lean | Low Lean | Low Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | | Low Lean | High Lean | High Lean | High Lean | High Lean |
| | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | | | | | | | | | |
| | High Lean | High Lean | Medium Lean | Medium Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | | | Medium Lean | Medium Lean | | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | Low Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | Low Lean | Low Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Low Lean | Medium Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean |
| | Low Lean | Low Lean | Medium Lean | Medium Lean | High Lean | High Lean | High Lean | High Lean | High Lean |

# Appendix G: Round One Fuzzy Delphi

- *The Fuzzy Delphi was conduct using the survey tool Qualtrics*

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**Thank you for participating**

**This questionnaire will require a Maximum of Fifteen to twenty Minutes to complete. All the information is strictly confidential.**

This research aims at helping companies identify the best supply chain strategy for their commodity and market. there are four strategies: **Lean, Agile, Leagile and Basic supply chain.**
**Cost:** is calculated from the stage of manufacturing (cost of production) to end-customer. The end-customer varies between different companies from end-retail customer, distribution centers or end-wholesaler. Please chose the supply chain of your own products and what you considered as an end-customer. The supply chain "Cost" consist of producing a product, logistics distribution and delivery to the end-customer, including the cost of lead-times during that process.

**JIT Lean:** the more a supply chain strategy moves towards leanness, by eliminated waste and reducing lead-time, the more lean it becomes as defined by the JIT system, as time equals leanness measured by the JIT system.

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**These retail companies are:** SME's [50-250 Employees, ≤ £10m-50m turnover, ≤ £10m-43m balance sheet total] and multinational corporation (MNC) which manufactures products or source commodities domestically or internationally to be sold at a local or international market, excluding service providers. - "Please answer the statements with regards to the four dimensions of supply chain strategies (BSC, Lean, Leagile and Agile)".

If a company's supply chain cost is 0-9% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 10-19% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 20-29% of the revenue then it is

- Low Cost
- Medium Cost
- High cost

If a company's supply chain cost is 30-39% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 40-49% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 50- > 59% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

In this project, Leanness is measured by JIT, for example : If a company is 20% JIT (20% lean), then there are 80% delays.

If a company's supply chain is 0-9% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 10-19% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 20-29% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 30-39% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 40-49% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 50-59% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 60-69% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 70-79% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 80-89% JIT then it is
- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 90-99% JIT then it is
- Low Lean
- Medium Lean
- High Lean

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**Measuring Resource Performance:** Total cost = Distribution cost + Manufacturing Cost + Inventory cost (opportunity cost + service cost = cost held up as finished goods in transit) (Beamon,1999).

A) *Delivery strategy:* There are three types of deliveries according to Gunasekaran et al (2001), delivery to request, delivery to commit date and order fill lead time.

If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a supply chain delivery cost is calculated by "Delivery to Commit Date", then the supply chain is operating under:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If the supply chain delivery cost is calculated by "Order Fill Lead Time", then the supply chain is operating under:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

B) *Manufacturing cost:* is the cost of Raw Materials, Inventory, Work in Process Inventory, and Finished Goods Inventory.

If a company manufactures an innovative product, demand is unpredictable, then a responsive supply chain is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a company manufactures a functional product with a predictable demand, then an efficient supply chain is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a company manufactures an innovative functional product or a functional innovative product, then the supply chain is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

C) *Distribution strategy: part of integrated Manufacturing as the material flow is viewed from three aspects as a whole; strategic, tactical and operational (Stevens, 2007).*

If a supply chain focuses its material flow to be strategic, then its supply chain distribution system is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a supply chain focuses on its material flow to be tactical, then its supply chain distribution system is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a supply chain focuses its material flow to be operational, then its supply chain distribution system is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

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**Measuring Output:** output is measured by the number of items produced, the time required to produce a particular item and/or set of items and customer satisfaction which is measured by the number of on time deliveries and less led-time between order and corresponding delivery.

A) *Customer satisfaction:* Good flexibility and response to customer needs, good customer service and response to customer queries as well as post transaction customer service, such as problems arising from warranty claims. Less customers complaining about product features or quality, delays or shipping errors (Beamon,1999).

**Customer order path:** Is the path that orders travel by, where time is spent in non-value adding activities, such as paper work, checking, which can be eliminated by using JIT an EDI (Gunasekaran et al, 2001).

**If a supply chain focuses on customer satisfaction in the retail industry, then response time or customer order path must be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**Manufacturing lead time:** is the total amount of time required to produce an item or batch (Beamon,1999).

**If a supply chain focuses on customer satisfaction in the retail industry, then manufacturing lead time should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**Shipping errors:** number of incorrect shipments (Beamon,1999).

**If a supply chain focuses on customer satisfaction in the retail industry, then shipping errors must be:**

Please write the percentage that you think is most accurate

[0] 0-20% Error [0] 21-40% Error [0] 41-60% Error [0] 61% + Error

**Customer service :** is the combined effect of all functions along the supply chain. To provide a higher service level will require higher costs (Stevens, 2007).

**If a supply chain aims to deliver high customer service, then it would require:**

Please write the percentage that you think is most accurate

[0] 0-30% of the total supply chain cost [0] 31-50% of the total supply chain cost
[0] 51-70% of the total supply chain cost [0] 71% +of the total supply chain cost

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**Measuring Product Demand:** by looking at the (1) End-user requirement, or (2) substitute product, or (3) competing product; then assessing the total volume of a product or service that would be bought by a consumer group where the location, time period and marketing effort are defined.

A) ***Life Cycle:*** it has 4 clearly defined stages (Introduction Stage, Growth Stage, Maturity Stage and Decline Stage).

**If a supply chain is focused on innovative products, then it requires Flexible Manufacturing System (FMS) and Computer Integrated Manufacturing (CIM), commonly used in:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**If the supply chain is focused on functional products, then the most suitable strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**If a supply chain is focused on High-end products, then its strategy should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

B) ***High-end products:*** A product that is one of the most expensive or advanced in a company's product range, or in the market as a whole.

**If a supply chain is focused on high-end mass customisation, then its approach should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- **Self-customised goods:** enable the customer to change the product at any time to suit their own preferences (Alford et al, 2000).

**If a company's supply chain is focused on self-customised goods, then its approach is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a company pushes variety of goods into the market then its supply chain manufacturing approach is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Collaborative customisation: is tailored to a specific partnership (Alford et al, 2000).

**If a company focuses its manufacturing on collaborative customisation, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Adaptive customisation: enables the user to customise the product to their requirements (Alford et al, 2000).

**If a company's manufacturing is based on adaptive customisation, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Cosmetic customizer: presents the product differently to each customer, whether through packaging or similar changes in distribution or services (Alford et al, 2000).

**If a company's manufacturing is using cosmetic customiser, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Transparent customiser's: provide unique products or services in a standard form to each customer, without the customer's knowledge that the product or service is customised (Alford et al, 2000).

**If a company's manufacturing is using Transparent customiser, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

***Please provide feedback***

***Please Insert you're first name-***
***It will be much appreciated.***
All names will remain strictly confidential

**Please insert the name of the sector you work in (e.g. University name  or the company's name) And your Job title-**
All information will remain strictly confidential

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# Appendix H: Round Two Fuzzy Delphi

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**Thank you for participating**

**This questionnaire will require a Maximum of Fifteen to twenty Minutes to complete. All the information is strictly confidential.**

This research aims at helping companies identify the best supply chain strategy for their commodity and market. there are four strategies:

**Lean:** Lean focuses on the elimination of waste with a bias towards "pulling" goods through the system based on demand.
**Agile:** Focus is on flexible, efficient response to unique customer demand.
**Leagile**: A hybrid of Lean and Agile: Using make-to-stock/Lean strategies for high volume, stable demand products, and make-to-order/Agile for customised, innovative and innovative functional products. Has flexible production capacity to meet surges in demand or unexpected requirements. Uses postponement strategies, where "platform" products are made to forecast, and then final assembly and configuration done upon final customer order
**Basic supply chain:** basic or daily products that require a reliable chain plan, source, make and deliver (from in-house manufacturing or outsourcing to retail)

**Cost:** is calculated from the stage of manufacturing (cost of production) to end-customer. The end-customer varies between different companies from end-retail customer, distribution centers or end-wholesaler.
Please chose the supply chain of your own products and what you considered as an end-customer.
The supply chain "Cost" consist of producing a product (raw materials, equipment or machinery operations at the manufacturing node), logistics distribution (from resource or component plants to manufacturing and the overall supply chain), and delivery to the end-customer (delivering the commodity from plant to warehouse, retailer, wholesaler or consumer), including the cost of lead-times during that process. The cost excludes overall gain from gross profit, labour, premises or equipment hire, it is only the estimated cost being invested in creating the product, its supply chain and logistics

**JIT Lean:** the more a supply chain strategy moves towards leanness, by eliminated waste and reducing lead-time, the more lean it becomes as defined by the JIT system, as time equals leanness measured by the JIT system.

**The supply chain definition used in this Delphi:**

According to Fisher (1997), the supply chain converts raw materials into parts, components and eventually finished goods, then transports all of them from one point of the supply chain to the next. The specific supply chain point analysed in this study is from manufacturing to retail. This study focuses on the retail industry (e.g textile and automobiles), excluding food, jewellery, pharmaceutical, electronic devices, watches, telecommunication services and white goods.

## Part One:

This part of the questionnaire requires a generic answer regarding what constitutes "high cost" for a company that wishes to transfer its goods from the "Manufacturing" node to the "Retail" node. As well as what constitutes "high lean", which is the minimal delays in shipment and product delivery to the customer.

## Section One:

**Cost analysis:**

These retail companies are:
SME's [50-250 Employees, ≤ £10m-50m turnover, ≤ £10m-43m balance sheet total] and multinational corporation (MNC) which manufactures products or source commodities domestically or internationally to be sold at a local or international market, excluding service providers. - "Please answer the statements with regards to the four dimensions of supply chain strategies (BSC, Lean, Leagile and Agile)".

If a company's supply chain cost is 0-8% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 9-18% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 19-28% of the revenue then it is

- Low Cost
- Medium Cost
- High cost

If a company's supply chain cost is 29-38% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 39-48% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

If a company's supply chain cost is 49-58% of the revenue then it is

- Low Cost
- Medium Cost
- High Cost

*JIT - "Just In Time"* : Is a Japanese production strategy created by Toyota that strives to improve a business' return on investment by reducing inventory and associated carrying costs. JIT relies on signals or "Kanban" between different points, which tell production when to make the next part (Kootanaee, et al. 2013).

In this study, Leanness is measured by JIT Lean, for example : If a company is 20% JIT Lean (20% Leanness), then there is 80% delays.

If a company's supply chain is 0-8% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 9-18% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 19-28% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 29-38% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 39-48% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 49-58% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 59-68% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 69-78% JIT then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 79-88% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

If a company's supply chain is 89-98% JIT Lean then it is

- Low Lean
- Medium Lean
- High Lean

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**Part Two:**

This second stage requires a general answer regarding the retail industry of consumable goods, the main focus of the supply chain is between the manufacturing to the retail. In this study only delivery, distribution, manufacturing, product demand and output are measured and used as an example to formulate the multi-dimensional matrix. The output in this research is measured by customer satisfaction. Specific attention will be placed on high-end products due to their unpredictable nature and their extreme fluctuating demand (e.g. high-end mountain bikes, men suits, women's ball gowns and wedding dresses).

**Section One:**

**Measuring Resource Performance:** Total cost = Distribution cost + Manufacturing Cost + Inventory cost (opportunity cost + service cost = cost held up as finished goods in transit) (Beamon,1999).

**A)** ***Delivery strategy***: consists of various cost elements to develop the appropriate trade-offs in the delivery system that can be applied as a basis for planning a supply chain end delivery strategy from manufacturing to customer, in addition to re-assess the distribution system, so that overall cost effectiveness can be achieved (Beamon,1999).

**There are three types of distributions according to Gunasekaran et al (2001), delivery to request, delivery to commit date and order fill lead time.**

**To classify the response time between order and corresponding delivery:**

**If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If a supply chain delivery cost is calculated by "Delivery to Commit Date", then the supply chain is operating under:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

If the supply chain delivery cost is calculated by "Order Fill Lead Time", then the supply chain is operating under:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**B)** ***Manufacturing cost:*** is the cost of direct material, direct labor, and manufacturing overheads in the fabrication, assembly, and testing of an end item. This includes the utilization of three inventory accounts: Raw Materials, Inventory, Work in Process Inventory, and Finished Goods Inventory.

- According to Fisher (1997), if a company produces an innovative product, its demand is very unpredictable and in need of a responsive supply chain.

**If a company manufactures an innovative product, demand is unpredictable, then a responsive supply chain is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- According to Fisher (1997), a functional product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in need of an efficient supply chain.

**If a company manufactures a functional product with a predictable demand, then an efficient supply chain is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- According to Fisher (1997), an innovative functional product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as toothpaste.

**If a company manufactures an innovative functional product or a functional innovative product, then the supply chain is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**C)** ***Distribution Strategy:*** integrating manufacturing by developing an integrated supply chain, the material flow must be viewed from three aspects as a whole; strategic, tactical and operational (Stevens, 2007).

- **Strategic distribution system:** objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location of its key facilities. The competitive aspect is integrating its manufacturing and distribution with that strategy (Stevens, 2007).

**If a supply chain focuses its material flow to be strategic, then its supply chain distribution system is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- **Tactical distribution system:** creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining the tools, approaches, resources necessary to manage and provide the information infrastructure for the supply chain by using (MRP, DRP, JIT) (Stevens, 2007).

[1] MRP- Material Resource Planning.

[2] DRP- Distribution Resource Planning.

**If a supply chain focuses on its material flow to be tactical, then its supply chain distribution system is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**Operational distribution system:** concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately in terms of supplier performance, inventory investment, service level, throughput* efficiency and cost (Stevens, 2007).

[*] Throughput: is the rate of *successful* message delivery over a communication channel

**If a supply chain focuses its material flow to be operational, then its supply chain distribution system is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

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## Section Two:

<u>Measuring Output:</u> output is measured by the number of items produced, the time required to produce a particular item and/or set of items and customer satisfaction which is measured by the number of on time deliveries and less led-time between order and corresponding delivery.

A) *Customer satisfaction:* Good flexibility and response to customer needs, good customer service and response to customer queries as well as post transaction customer service, such as problems arising from warranty claims. Less customers complaining about product features or quality, delays or shipping errors (Beamon,1999).

<u>Customer order path:</u> Is the path that orders travel by, where time is spent in non-value adding activities, such as paper work, checking, which can be eliminated by using JIT an EDI (Gunasekaran et al, 2001).

**If a supply chain focuses on customer satisfaction in the retail industry, then response time or customer order path must be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

<u>Manufacturing lead time</u>: is the total amount of time required to produce an item or batch (Beamon,1999).

**If a supply chain focuses on customer satisfaction in the retail industry, then manufacturing lead time should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

<u>Shipping errors:</u> number of incorrect shipments (Beamon,1999).

**If a supply chain focuses on customer satisfaction in the retail industry, then shipping errors must be:**

Please write the percentage that you think is most accurate

[0] 0-20% Error [0] 21-40% Error [0] 41-60% Error [0] 61% + Error

- Customer service is the combined effect of all functions along the supply chain. To provide a higher service level will require higher costs (Stevens, 2007).

**If a supply chain aims to deliver high customer service, then it would require:**

- Please write the percentage that you think is most accurate

[0] 0-30% of the total supply chain cost [0] 31-50% of the total supply chain cost
[0] 51-70% of the total supply chain cost [0] 71% +of the total supply chain cost

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**Section Three:**

<u>Measuring Product Demand:</u> by looking at the (1) End-user requirement, or (2) substitute product, or (3) competing product; then assessing the total volume of a product or service that would be bought by a consumer group where the location, time period and marketing effort are defined.

**A)** ***Life Cycle:*** The product life cycle has 4 very clearly defined stages (Introduction Stage, Growth Stage, Maturity Stage and Decline Stage), each with its own characteristics that mean different things for business that are trying to manage the life cycle of their particular products.

- **Innovative products carry risk as the product has a short life cycle due to unpredictable demand, requiring a flexible supply chain with- Flexible Manufacturing System (FMS) and Computer Integrated Manufacturing (CIM) (Fisher, 1997).**

**If a supply chain is focused on innovative products, then it requires Flexible Manufacturing System (FMS) and Computer Integrated Manufacturing (CIM), commonly used in:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- **Functional products have a longer life cycle of more than 2 years with an average margin forecast error of 10% (Fisher, 1997).**

**If the supply chain is focused on functional products, then the most suitable strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- **High-end products have a fluctuating demand, to counter this uncertainty Fisher (1997) suggested a blend of three strategies- reducing uncertainty by identifying and analysing new sources of data, avoiding uncertainty by cutting lead times and incorporating flexibility and hedging against uncertainty with buffets of inventory or excess capacity**

**If a supply chain is focused on High-end products, then its strategy should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**B)** *Customisation:* a make-to-order lean pull system

- Self-customised goods: enable the customer to change the product at any time to suit their own preferences (Alford et al, 2000).

**If a company's supply chain is focused on self-customised goods, then its approach is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

***High-end products:*** A product that is one of the most expensive or advanced in a company's product range, or in the market as a whole.

**If a supply chain is focused on high-end mass customisation, then its approach should be:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Manufactures that involve their customers in a dialogue to identify their needs and establish their requirements are using collaborative customisation, which is specifically tailored to that specific partnership (Alford et al, 2000).

**If a company focuses its manufacturing on collaborative customisation, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Adaptive customisation enables the user to customise the product to their requirements (Alford et al, 2000).

**If a company's manufacturing is based on adaptive customisation, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- The cosmetic customizer presents the product differently to each customer, whether through packaging or similar changes in distribution or services (Alford et al, 2000).

**If a company's manufacturing is using cosmetic customiser, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

- Transparent customiser's provide unique products or services in a standard form to each customer, without the customer's knowledge that the product or service is customised (Alford et al, 2000).

**If a company's manufacturing is using Transparent customiser, then its supply chain strategy is:**

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

**C)** ***Push system:*** a company makes-to-stock and maintains inventory level

- **According to Alford et al (2000), when a company pushes variety of goods into the market in hope that customers will find what they want.**

If a company pushes variety of goods into the market then its supply chain manufacturing approach is:

○ Lean ○ Agile ○ Leagile ○ Basic supply chain strategies

***Please provide feedback***

***Please Insert you're first name-***
***It will be much appreciated.***
All names will remain strictly confidential

**Please insert the name of the sector you work in (e.g. University name or the company's name) And your Job title-**
All information will remain strictly confidential

# Appendix I: Qualtrics Consensus

## Part One:

### Cost Percentage

Q5. If a company's supply chain cost is 0-8% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 78 | 87% |
| 2 | Medium Cost | | 9 | 10% |
| 3 | High Cost | | 3 | 3% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.17 |
| Variance | 0.21 |
| Standard Deviation | 0.46 |
| Total Responses | 90 |

Q6. If a company's supply chain cost is 9-18% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 53 | 59% |
| 2 | Medium Cost | | 29 | 32% |
| 3 | High Cost | | 8 | 9% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.50 |
| Variance | 0.43 |
| Standard Deviation | 0.66 |
| Total Responses | 90 |

Q7. If a company's supply chain cost is 19-28% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 19 | 21% |
| 2 | Medium Cost | | 52 | 58% |
| 3 | High cost | | 19 | 21% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.00 |
| Variance | 0.43 |
| Standard Deviation | 0.65 |
| Total Responses | 90 |

Q8. If a company's supply chain cost is 29-38% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 1 | 1% |
| 2 | Medium Cost | | 55 | 61% |
| 3 | High Cost | | 34 | 38% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.37 |
| Variance | 0.26 |
| Standard Deviation | 0.51 |
| Total Responses | 90 |

Q9. If a company's supply chain cost is 39-48% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 2 | 2% |
| 2 | Medium Cost | | 22 | 24% |
| 3 | High Cost | | 66 | 73% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.71 |
| Variance | 0.25 |
| Standard Deviation | 0.50 |
| Total Responses | 90 |

Q10. If a company's supply chain cost is 49-58% of the revenue then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Cost | | 3 | 3% |
| 2 | Medium Cost | | 11 | 12% |
| 3 | High Cost | | 76 | 84% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.81 |
| Variance | 0.22 |
| Standard Deviation | 0.47 |
| Total Responses | 90 |

## JIT Lean percentage

**Q12.** If a company's supply chain is 0-8% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 73 | 81% |
| 2 | Medium Lean | | 6 | 7% |
| 3 | High Lean | | 11 | 12% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.31 |
| Variance | 0.46 |
| Standard Deviation | 0.68 |
| Total Responses | 90 |

**Q13.** If a company's supply chain is 9-18% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 68 | 76% |
| 2 | Medium Lean | | 11 | 12% |
| 3 | High Lean | | 11 | 12% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.37 |
| Variance | 0.48 |
| Standard Deviation | 0.69 |
| Total Responses | 90 |

## Q14. If a company's supply chain is 19-28% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 38 | 42% |
| 2 | Medium Lean | | 46 | 51% |
| 3 | High Lean | | 6 | 7% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.64 |
| Variance | 0.37 |
| Standard Deviation | 0.61 |
| Total Responses | 90 |

## Q15. If a company's supply chain is 29-38% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 17 | 19% |
| 2 | Medium Lean | | 57 | 63% |
| 3 | High Lean | | 16 | 18% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 1.99 |
| Variance | 0.37 |
| Standard Deviation | 0.61 |
| Total Responses | 90 |

## Q16. If a company's supply chain is 39-48% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 13 | 14% |
| 2 | Medium Lean | | 39 | 43% |
| 3 | High Lean | | 38 | 42% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.28 |
| Variance | 0.50 |
| Standard Deviation | 0.70 |
| Total Responses | 90 |

## Q17. If a company's supply chain is 49-58% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 11 | 12% |
| 2 | Medium Lean | | 35 | 39% |
| 3 | High Lean | | 44 | 49% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.37 |
| Variance | 0.48 |
| Standard Deviation | 0.69 |
| Total Responses | 90 |

Q18. If a company's supply chain is 59-68% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 11 | 12% |
| 2 | Medium Lean | | 14 | 16% |
| 3 | High Lean | | 65 | 72% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.60 |
| Variance | 0.49 |
| Standard Deviation | 0.70 |
| Total Responses | 90 |

Q19. If a company's supply chain is 69-78% JIT then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 13 | 14% |
| 2 | Medium Lean | | 8 | 9% |
| 3 | High Lean | | 69 | 77% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.62 |
| Variance | 0.53 |
| Standard Deviation | 0.73 |
| Total Responses | 90 |

## Q20. If a company's supply chain is 79-88% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 11 | 12% |
| 2 | Medium Lean | | 3 | 3% |
| 3 | High Lean | | 76 | 84% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.72 |
| Variance | 0.45 |
| Standard Deviation | 0.67 |
| Total Responses | 90 |

## Q20. If a company's supply chain is 89-98% JIT Lean then it is

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Low Lean | | 11 | 12% |
| 2 | Medium Lean | | 3 | 3% |
| 3 | High Lean | | 76 | 84% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 3 |
| Mean | 2.72 |
| Variance | 0.45 |
| Standard Deviation | 0.67 |
| Total Responses | 90 |

# Part Two:

## Section One

### *Delivery strategies*

Q24. If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 24 | 27% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 8 | 9% |
| 4 | Basic supply chain strategies | | 33 | 37% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.56 |
| Variance | 1.53 |
| Standard Deviation | 1.24 |
| Total Responses | 90 |

Q25. If a supply chain delivery cost is calculated by "Delivery to Commit Date", then the supply chain is operating under:

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 18 | 20% |
| 2 | Agile | | 33 | 37% |
| 3 | Leagile | | 18 | 20% |
| 4 | Basic supply chain strategies | | 21 | 23% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.47 |
| Variance | 1.13 |
| Standard Deviation | 1.06 |
| Total Responses | 90 |

Q26. If the supply chain delivery cost is calculated by "Order Fill Lead Time", then the supply chain is operating under:

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 19 | 21% |
| 2 | Agile | | 20 | 22% |
| 3 | Leagile | | 21 | 23% |
| 4 | Basic supply chain strategies | | 30 | 33% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.69 |
| Variance | 1.32 |
| Standard Deviation | 1.15 |
| Total Responses | 90 |

Q39. Manufacturing lead time: is the total amount of time required to produce an item or batch (Beamon,1999). If a supply chain focuses on customer satisfaction in the retail industry, then manufactur...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 14 | 16% |
| 2 | Agile | | 35 | 39% |
| 3 | Leagile | | 21 | 23% |
| 4 | Basic supply chain strategies | | 20 | 22% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.52 |
| Variance | 1.02 |
| Standard Deviation | 1.01 |
| Total Responses | 90 |

## Section Two

### *Distribution strategies*

**Q32.** Strategic distribution system: objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location o...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 22 | 24% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 18 | 20% |
| 4 | Basic supply chain strategies | | 25 | 28% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.51 |
| Variance | 1.31 |
| Standard Deviation | 1.14 |
| Total Responses | 90 |

**Q33.** Tactical distribution system: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 16 | 18% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 25 | 28% |
| 4 | Basic supply chain strategies | | 24 | 27% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.63 |
| Variance | 1.13 |
| Standard Deviation | 1.06 |
| Total Responses | 90 |

Q34. Operational distribution system: concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately in terms of supplier per...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 13 | 14% |
| 2 | Agile | | 18 | 20% |
| 3 | Leagile | | 26 | 29% |
| 4 | Basic supply chain strategies | | 33 | 37% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.88 |
| Variance | 1.14 |
| Standard Deviation | 1.07 |
| Total Responses | 90 |

## *Product design*

Q28. According to Fisher (1997), if a company produces an innovative product, its demand is very unpredictable and in need of a responsive supply chain. If a company manufactures an innov...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 9 | 10% |
| 2 | Agile | | 43 | 48% |
| 3 | Leagile | | 19 | 21% |
| 4 | Basic supply chain strategies | | 19 | 21% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.53 |
| Variance | 0.88 |
| Standard Deviation | 0.94 |
| Total Responses | 90 |

## Q29. According to Fisher (1997), a functional product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in need of an efficient...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 21 | 23% |
| 2 | Agile | | 17 | 19% |
| 3 | Leagile | | 14 | 16% |
| 4 | Basic supply chain strategies | | 38 | 42% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.77 |
| Variance | 1.51 |
| Standard Deviation | 1.23 |
| Total Responses | 90 |

## Q30. According to Fisher (1997), an innovative functional product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as too...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 20 | 22% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 26 | 29% |
| 4 | Basic supply chain strategies | | 19 | 21% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.49 |
| Variance | 1.13 |
| Standard Deviation | 1.06 |
| Total Responses | 90 |

## Section Three

### *Demand approach*

**Q47.** High-end products have a fluctuating demand, to counter this uncertainty Fisher (1997) suggested a blend of three strategies- reducing uncertainty by identifying and analysing new sources of dat...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 15 | 17% |
| 2 | Agile | | 22 | 24% |
| 3 | Leagile | | 41 | 46% |
| 4 | Basic supply chain strategies | | 12 | 13% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.56 |
| Variance | 0.86 |
| Standard Deviation | 0.93 |
| Total Responses | 90 |

**Q49.** If a supply chain is focused on high-end mass customisation, then its approach should be:

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 22 | 24% |
| 2 | Agile | | 26 | 29% |
| 3 | Leagile | | 24 | 27% |
| 4 | Basic supply chain strategies | | 18 | 20% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.42 |
| Variance | 1.15 |
| Standard Deviation | 1.07 |
| Total Responses | 90 |

## Q50. B) Customisation: a make-to-order lean pull system Self-customised goods: enable the customer t...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 17 | 19% |
| 2 | Agile | | 25 | 28% |
| 3 | Leagile | | 36 | 40% |
| 4 | Basic supply chain strategies | | 12 | 13% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.48 |
| Variance | 0.90 |
| Standard Deviation | 0.95 |
| Total Responses | 90 |

## Q51. C) Push system: a company makes-to-stock and maintains inventory level According to Alford et a...

| # | Answer | | Response | % |
|---|---|---|---|---|
| 1 | Lean | | 9 | 10% |
| 2 | Agile | | 22 | 24% |
| 3 | Leagile | | 24 | 27% |
| 4 | Basic supply chain strategies | | 35 | 39% |
| | Total | | 90 | 100% |

| Statistic | Value |
|---|---|
| Min Value | 1 |
| Max Value | 4 |
| Mean | 2.94 |
| Variance | 1.04 |
| Standard Deviation | 1.02 |
| Total Responses | 90 |

# Appendix J: SPSS Frequency Tables

## Cost variables

**If a company's supply chain cost is 0-8% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Cost | 79 | 87.8 |
| | Medium Cost | 9 | 10.0 |
| | High Cost | 2 | 2.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 9-18% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Cost | 54 | 60.0 |
| | Medium Cost | 30 | 33.3 |
| | High Cost | 6 | 6.7 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 19-28% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Cost | 17 | 18.9 |
| | Medium Cost | 55 | 61.1 |
| | High cost | 18 | 20.0 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 29-38% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Medium ... | 51 | 56.7 |
| | High Cost | 39 | 43.3 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 39-48% of the revenue then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Medium ... | 21 | 23.3 |
| | High Cost | 69 | 76.7 |
| | Total | 90 | 100.0 |

**If a company's supply chain cost is 49-58% of the revenue then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Medium Cost | 10 | 11.1 |
| | High Cost | 80 | 88.9 |
| | Total | 90 | 100.0 |

## JIT Lean variables

**If a company's supply chain is 0-8% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 84 | 93.3 |
| | Medium ... | 4 | 4.4 |
| | High Lean | 2 | 2.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 9-18% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 76 | 84.4 |
| | Medium ... | 12 | 13.3 |
| | High Lean | 2 | 2.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 19-28% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 39 | 43.3 |
| | Medium ... | 47 | 52.2 |
| | High Lean | 4 | 4.4 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 29-38% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 15 | 16.7 |
| | Medium ... | 57 | 63.3 |
| | High Lean | 18 | 20.0 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 39-48% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 5 | 5.6 |
| | Medium ... | 40 | 44.4 |
| | High Lean | 45 | 50.0 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 49-58% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 3 | 3.3 |
| | Medium ... | 33 | 36.7 |
| | High Lean | 54 | 60.0 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 59-68% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 4 | 4.4 |
| | Medium ... | 12 | 13.3 |
| | High Lean | 74 | 82.2 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 69-78% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 3 | 3.3 |
| | Medium ... | 5 | 5.6 |
| | High Lean | 82 | 91.1 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 79-88% JIT then it is**

| | | Frequenc... | Valid ... |
|---|---|---|---|
| Valid | Low Lean | 2 | 2.2 |
| | High ... | 88 | 97.8 |
| | Total | 90 | 100.0 |

**If a company's supply chain is 89-98% JIT then it is**

| | | Frequency | Valid Percent |
|---|---|---|---|
| Valid | Low Lean | 2 | 2.2 |
| | High Lean | 88 | 97.8 |
| | Total | 90 | 100.0 |

## Logistics variable group

### Distribution strategy

**Strategic distribution system: objective is expressed in terms of responsiveness, lower cost and product availability. The shape the supply chain takes is determined by the strategic location o...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 22 | 24.4 | 24.4 | 24.4 |
| | Agile | 25 | 27.8 | 27.8 | 52.2 |
| | Leagile | 18 | 20.0 | 20.0 | 72.2 |
| | Basic supply chain strategies | 25 | 27.8 | 27.8 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**Tactical distribution system: creates the means by which objectives can be realised by providing balance for each function in the supply chain (e.g. inventory capacity, service, and determining...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 16 | 17.8 | 17.8 | 17.8 |
| | Agile | 25 | 27.8 | 27.8 | 45.6 |
| | Leagile | 25 | 27.8 | 27.8 | 73.3 |
| | Basic supply chain strategies | 24 | 26.7 | 26.7 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**Operational distribution system: concerned with the efficiency of operations by ensuring the detailed procedures of systems and appropriate controls are measured accurately in terms of supplier per...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 13 | 14.4 | 14.4 | 14.4 |
| | Agile | 18 | 20.0 | 20.0 | 34.4 |
| | Leagile | 26 | 28.9 | 28.9 | 63.3 |
| | Basic supply chain strategies | 33 | 36.7 | 36.7 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

## Delivery strategy

**If a supply chain delivery cost is calculated by "Delivery to Request", then the supply chain is operating under:**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 24 | 26.7 | 26.7 | 26.7 |
| | Agile | 25 | 27.8 | 27.8 | 54.4 |
| | Leagile | 8 | 8.9 | 8.9 | 63.3 |
| | Basic supply chain strategies | 33 | 36.7 | 36.7 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**If a supply chain delivery cost is calculated by "Delivery to Commit Date", then the supply chain is operating under:**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 18 | 20.0 | 20.0 | 20.0 |
| | Agile | 33 | 36.7 | 36.7 | 56.7 |
| | Leagile | 18 | 20.0 | 20.0 | 76.7 |
| | Basic supply chain strategies | 21 | 23.3 | 23.3 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**If the supply chain delivery cost is calculated by "Order Fill Lead Time", then the supply chain is operating under:**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 19 | 21.1 | 21.1 | 21.1 |
| | Agile | 20 | 22.2 | 22.2 | 43.3 |
| | Leagile | 21 | 23.3 | 23.3 | 66.7 |
| | Basic supply chain strategies | 30 | 33.3 | 33.3 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

## Manufacturing lead-time

**Manufacturing lead time: is the total amount of time required to produce an item or batch (Beamon,1999). If a supply chain focuses on customer satisfaction in the retail industry, then manufactur...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 14 | 15.6 | 15.6 | 15.6 |
| | Agile | 35 | 38.9 | 38.9 | 54.4 |
| | Leagile | 21 | 23.3 | 23.3 | 77.8 |
| | Basic supply chain strategies | 20 | 22.2 | 22.2 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

## Supply chain variable group

## Product design

**According to Fisher (1997), a functional product is a product that people buy in a wide range of retail outlets that satisfy basic needs and has a predictable demand and in need of an efficient...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 21 | 23.3 | 23.3 | 23.3 |
| | Agile | 17 | 18.9 | 18.9 | 42.2 |
| | Leagile | 14 | 15.6 | 15.6 | 57.8 |
| | Basic supply chain strategies | 38 | 42.2 | 42.2 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**According to Fisher (1997), if a company produces an innovative product, its demand is very unpredictable and in need of a responsive supply chain. If a company manufactures an innov...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 9 | 10.0 | 10.0 | 10.0 |
| | Agile | 43 | 47.8 | 47.8 | 57.8 |
| | Leagile | 19 | 21.1 | 21.1 | 78.9 |
| | Basic supply chain strategies | 19 | 21.1 | 21.1 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**According to Fisher (1997), an innovative functional product is demonstrated by the automobile industry and a functional innovative product is demonstrated by daily consumable goods such as too...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 20 | 22.2 | 22.2 | 22.2 |
| | Agile | 25 | 27.8 | 27.8 | 50.0 |
| | Leagile | 26 | 28.9 | 28.9 | 78.9 |
| | Basic supply chain strategies | 19 | 21.1 | 21.1 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

## Demand approach

**If a supply chain is focused on high-end mass customisation, then its approach should be:**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 22 | 24.4 | 24.4 | 24.4 |
| | Agile | 26 | 28.9 | 28.9 | 53.3 |
| | Leagile | 24 | 26.7 | 26.7 | 80.0 |
| | Basic supply chain strategies | 18 | 20.0 | 20.0 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

**Self-customised goods: enable the customer to change the product at any time to suit their own preferences (Alford et al, 2000). If a company's supply chain is focused on self-customised go...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 17 | 18.9 | 18.9 | 18.9 |
| | Agile | 25 | 27.8 | 27.8 | 46.7 |
| | Leagile | 36 | 40.0 | 40.0 | 86.7 |
| | Basic supply chain strategies | 12 | 13.3 | 13.3 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

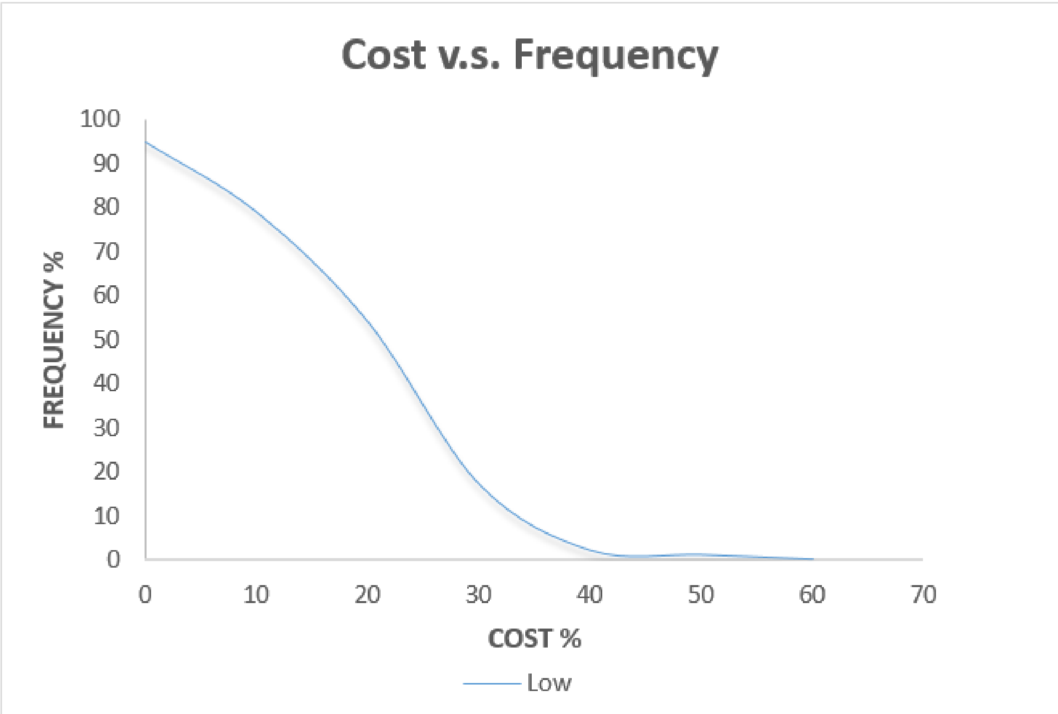
**According to Alford et al (2000), when a company pushes variety of goods into the market in hope that customers will find what they want. If a company pushes variety of goods into the m...**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Lean | 9 | 10.0 | 10.0 | 10.0 |
| | Agile | 22 | 24.4 | 24.4 | 34.4 |
| | Leagile | 24 | 26.7 | 26.7 | 61.1 |
| | Basic supply chain strategies | 35 | 38.9 | 38.9 | 100.0 |
| | Total | 90 | 100.0 | 100.0 | |

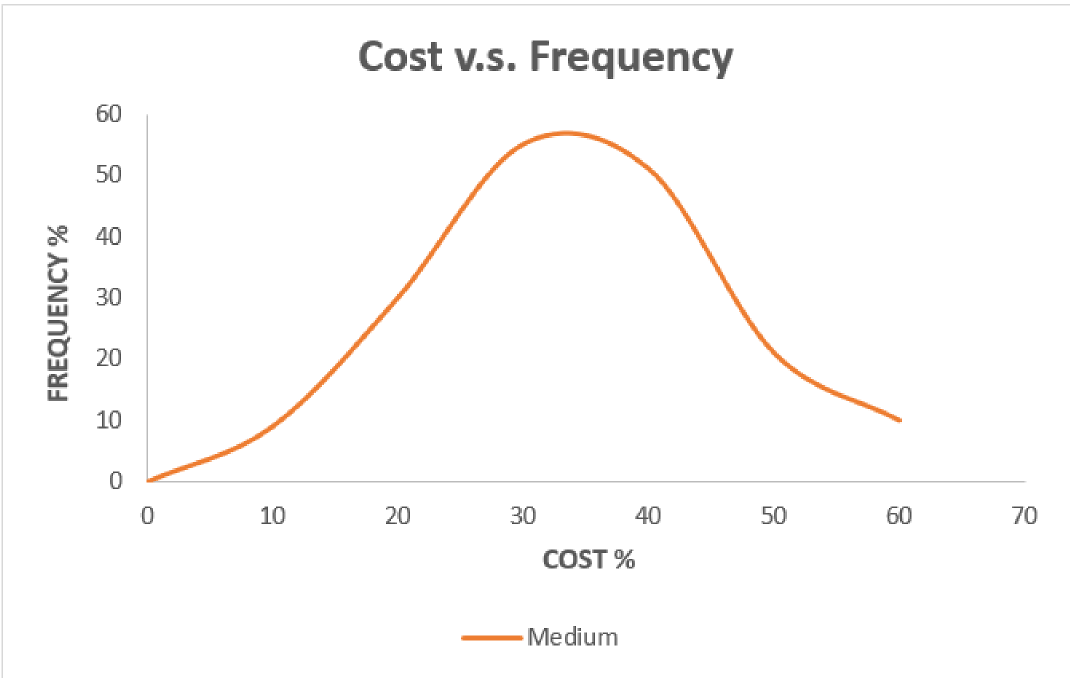
# Appendix K: Cost and JIT Lean Graphs

## Cost variable graph

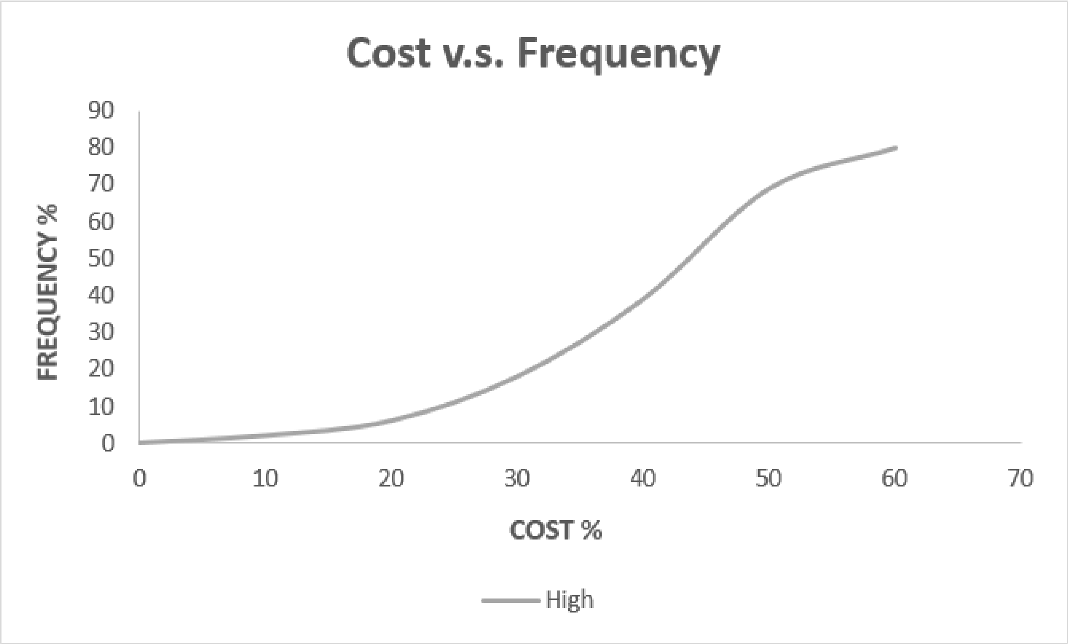
### Low cost trend



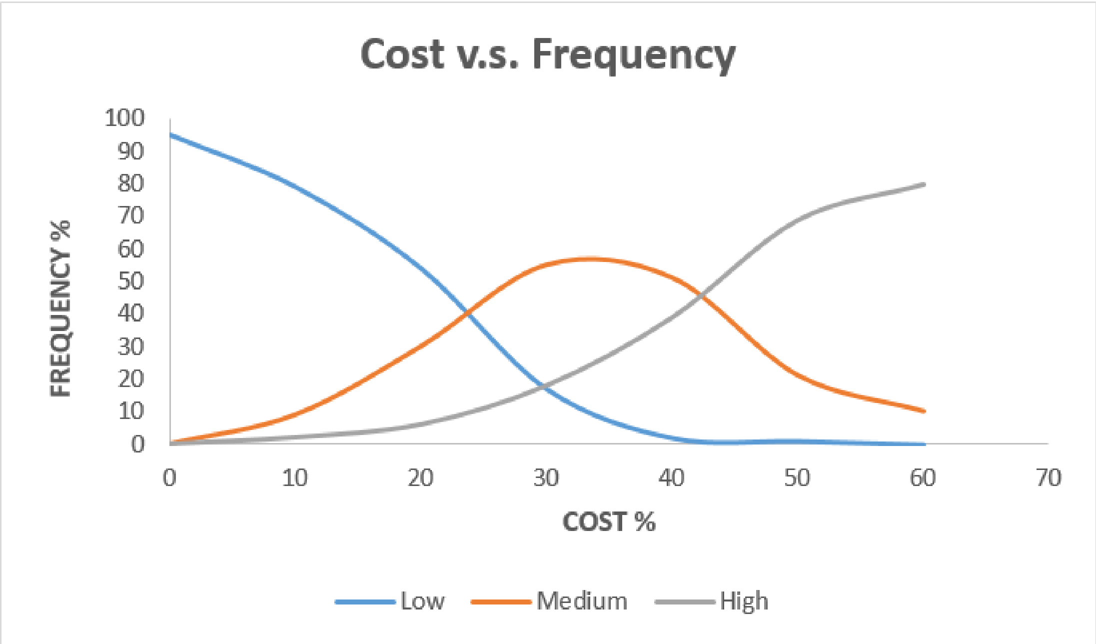

### Medium cost trend



## High cost trend

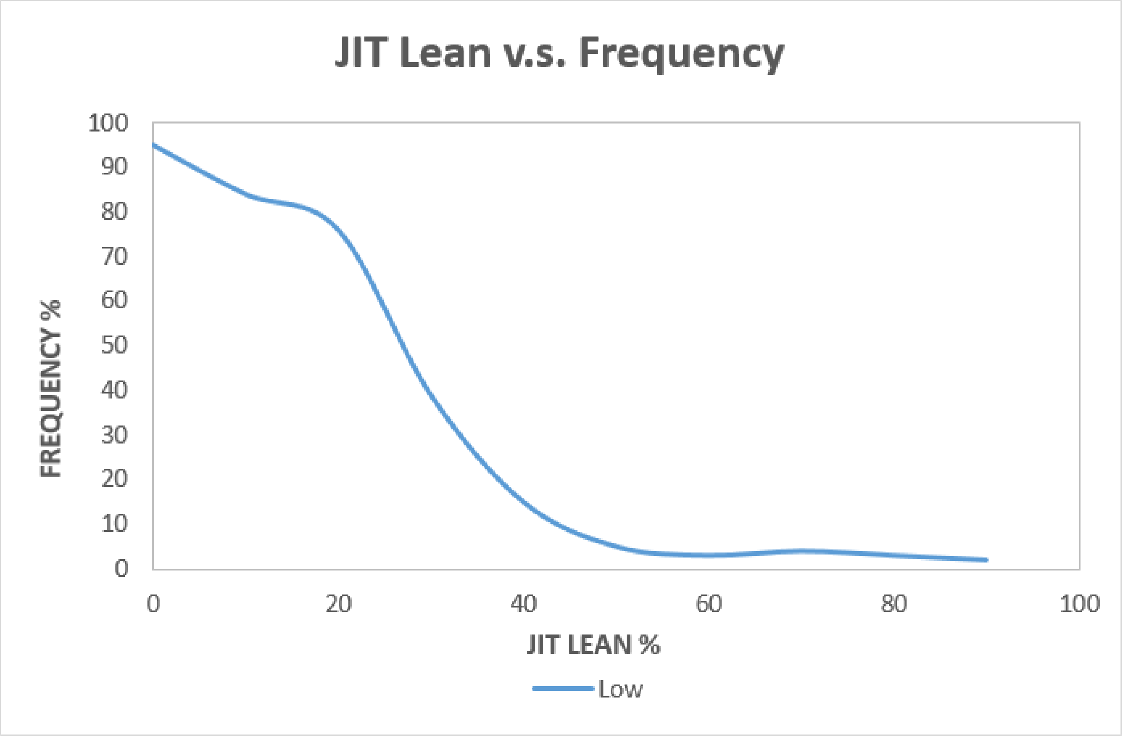



## Low, Medium and High cost trends

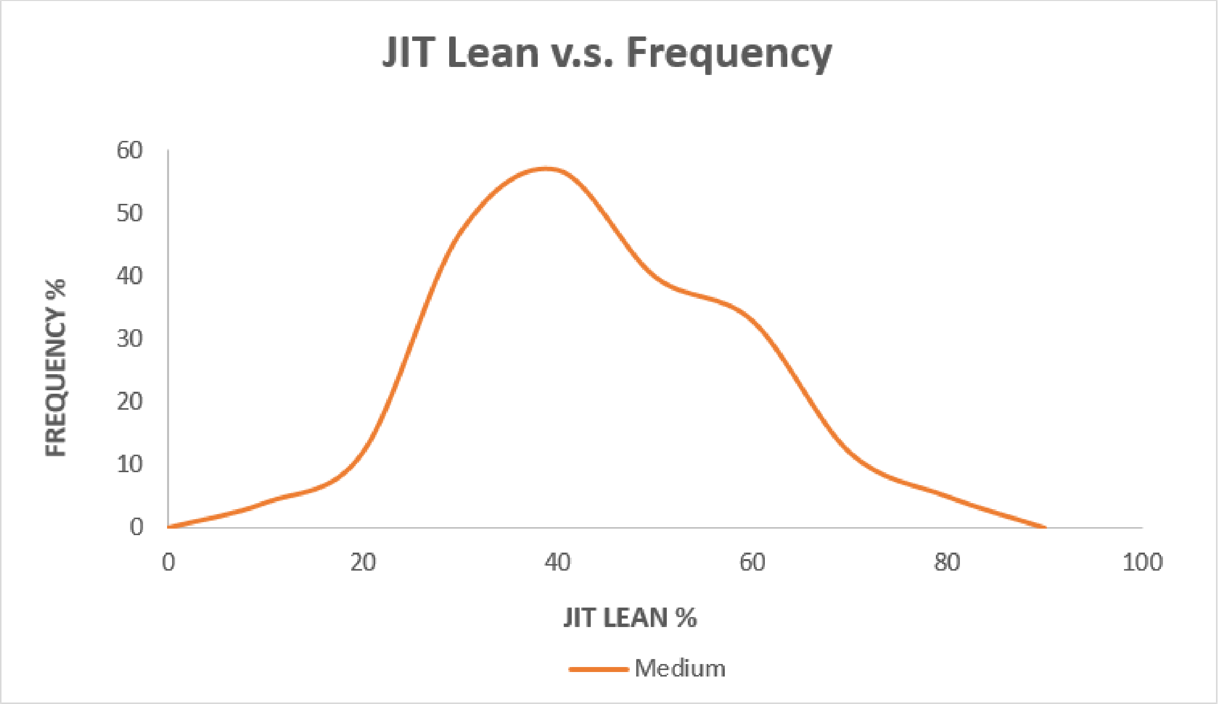


## JIT Lean variable graph

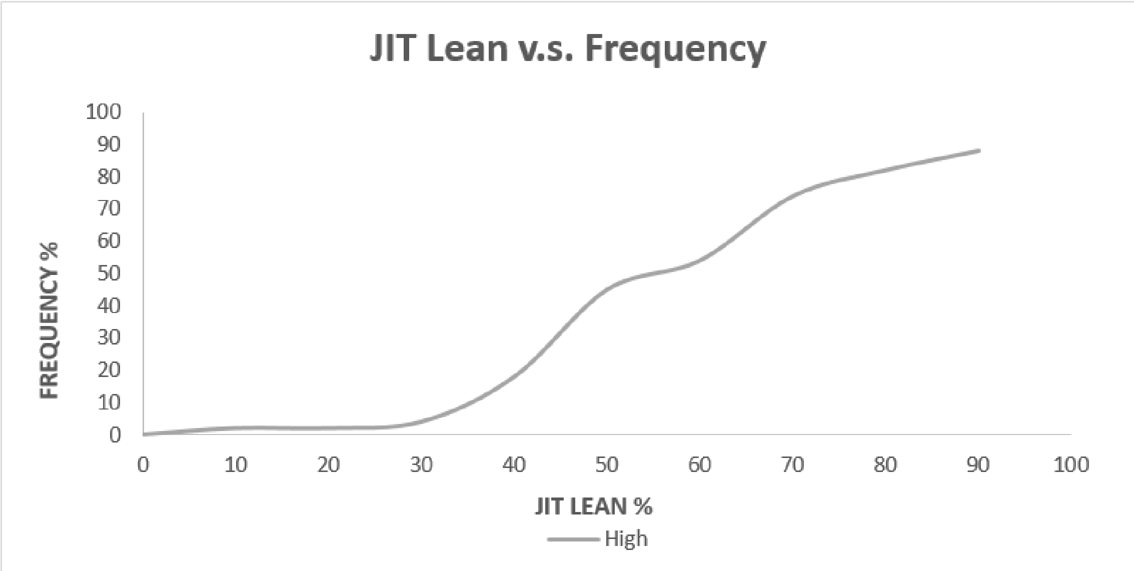
### Low JIT Lean trend



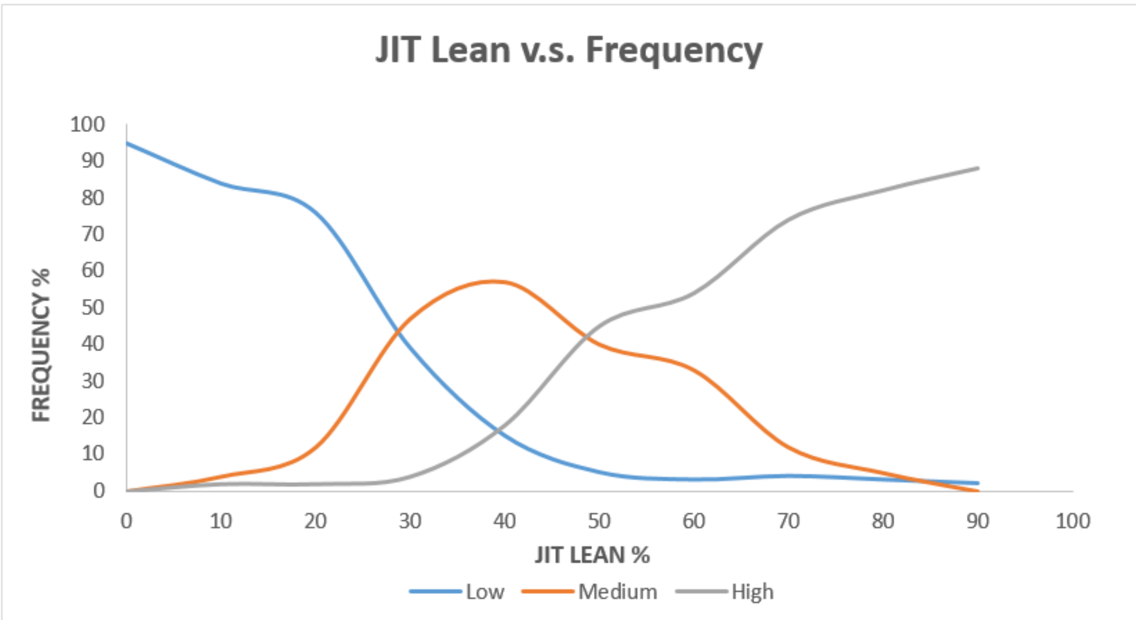

### Medium JIT Lean trend



## High JIT Lean trend




## Low, Medium and High JIT trends



# Appendix L: Scatter Diagrams vs. Cost

| Abbreviations | | | |
|---|---|---|---|
| **1** | **Lean** supply chain strategy | **L** | **Low** |
| **2** | **Agile** supply chain strategy | **M** | **Medium** |
| **3** | **Leagile** supply chain strategy | **H** | **High** |
| **4** | **Basic** supply chain strategy | | |

## Logistics Variables

### Distribution Strategy and Cost

**Distribution Strategies v.s Cost**

| | | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operational Distribution | 4 | 30 | 4 | | 21 | 11 | 1 | 7 | 20 | 6 | | 20 | 13 | | 7 | 26 | | 3 | 30 |
| | 3 | 25 | | 1 | 20 | 5 | 1 | 5 | 18 | 3 | | 18 | 8 | | 7 | 19 | | 3 | 23 |
| | 2 | 15 | 3 | | 8 | 8 | 2 | 3 | 10 | 5 | | 9 | 9 | | 5 | 13 | | 2 | 16 |
| | 1 | 9 | 3 | 1 | 5 | 6 | 2 | 2 | 7 | 4 | | 4 | 9 | | 2 | 11 | | 2 | 11 |
| Tactical Distribution | 4 | 19 | 4 | 1 | 13 | 8 | 3 | 4 | 14 | 6 | | 15 | 9 | | 6 | 18 | | 3 | 21 |
| | 3 | 24 | 1 | | 19 | 6 | | 3 | 19 | 3 | | 15 | 10 | | 4 | 21 | | 3 | 22 |
| | 2 | 20 | 4 | 1 | 12 | 10 | 3 | 6 | 13 | 6 | | 12 | 13 | | 7 | 18 | | 2 | 23 |
| | 1 | 16 | | | 10 | 6 | | 4 | 9 | 3 | | 9 | 7 | | 4 | 12 | | 2 | 14 |
| Strategic Distribution | 4 | 21 | 4 | | 19 | 4 | 2 | 9 | 12 | 4 | | 17 | 8 | | 10 | 15 | | 6 | 19 |
| | 3 | 18 | | | 9 | 9 | | 3 | 11 | 4 | | 10 | 8 | | 4 | 14 | | 1 | 17 |
| | 2 | 19 | 4 | 2 | 12 | 9 | 4 | 1 | 17 | 7 | | 10 | 15 | | 2 | 23 | | 1 | 24 |
| | 1 | 21 | 1 | | 14 | 8 | | 4 | 15 | 3 | | 14 | 8 | | 5 | 17 | | 2 | 20 |

**Cost %**

## Delivery Strategy and Cost

**Delivery Strategies v.s Cost**

| Strategy | Level | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Order Fill Lead Time | 4 | 25 | 3 | 2 | 18 | 8 | 4 | 5 | 17 | 8 | | 16 | 14 | | 6 | 24 | | 3 | 27 |
| | 3 | 20 | 1 | | 11 | 10 | | 4 | 13 | 4 | | 11 | 10 | | 5 | 16 | | | 21 |
| | 2 | 16 | 4 | | 11 | 7 | 2 | 5 | 12 | 3 | | 12 | 8 | | 5 | 15 | | 3 | 17 |
| | 1 | 18 | 1 | | 14 | 5 | | 3 | 13 | 3 | | 17 | 7 | | 5 | 14 | | 4 | 15 |
| Delivery to Committed | 4 | 18 | 2 | 1 | 13 | 5 | 3 | 5 | 12 | 4 | | 11 | 10 | | 6 | 15 | | 5 | 16 |
| | 3 | 17 | 1 | | 10 | 8 | | | 14 | 4 | | 10 | 8 | | | 18 | | | 18 |
| | 2 | 28 | 5 | | 18 | 13 | 2 | 2 | 21 | 8 | | 15 | 18 | | 5 | 28 | | | 33 |
| | 1 | 16 | 1 | 1 | 13 | 4 | 1 | 8 | 8 | 2 | | 15 | 3 | | 10 | 8 | | 5 | 13 |
| Delivery to Request | 4 | 30 | 3 | | 22 | 9 | 2 | 6 | 23 | 4 | | 23 | 10 | | 7 | 26 | | 5 | 28 |
| | 3 | 6 | 2 | | 5 | 3 | | | 6 | 2 | | 1 | 7 | | | 8 | | | 8 |
| | 2 | 20 | 4 | 1 | 16 | 6 | 3 | 5 | 14 | 6 | | 16 | 9 | | 7 | 18 | | 3 | 22 |
| | 1 | 23 | | 1 | 11 | 12 | 1 | 6 | 12 | 6 | | 11 | 13 | | 7 | 17 | | 2 | 22 |

**Cost %**

## Manufacturing Lead-Time and Cost

**Manufacturing Lead Time v.s Cost**

| Manufacturing Lead Time | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 14 | 4 | 2 | 8 | 8 | 4 | | 14 | 6 | | 9 | 11 | | 1 | 19 | | | 20 |
| 3 | 19 | 2 | | 16 | 4 | 1 | 3 | 14 | 4 | | 13 | 8 | | 4 | 17 | | 4 | 17 |
| 2 | 34 | 1 | | 22 | 13 | | 10 | 22 | 3 | | 22 | 13 | | 11 | 24 | | 3 | 32 |
| 1 | 12 | 2 | | 8 | 5 | 1 | 4 | 5 | 5 | | 7 | 7 | | 5 | 9 | | 3 | 11 |

Cost %

## Supply Chain Variables

## Product Design and Cost

**Product Design v.s Cost**

| Product Design | | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Innovative Functional | 4 | 15 | 3 | 1 | 10 | 6 | 3 | 1 | 12 | 6 | | 8 | 11 | | 2 | 17 | | 1 | 18 |
| | 3 | 25 | 1 | | 20 | 6 | | 9 | 15 | 2 | | 20 | 6 | | 11 | 15 | | 5 | 21 |
| | 2 | 21 | 4 | | 13 | 10 | 2 | 5 | 14 | 6 | | 13 | 12 | | 5 | 20 | | 2 | 23 |
| | 1 | 18 | 1 | 1 | 11 | 8 | 1 | 2 | 14 | 4 | | 10 | 10 | | 3 | 17 | | 2 | 18 |
| Functional Product | 4 | 35 | 3 | | 23 | 13 | 2 | 3 | 28 | 7 | | 19 | 19 | | 4 | 34 | | 1 | 37 |
| | 3 | 12 | 2 | | 7 | 7 | | 2 | 10 | 2 | | 7 | 7 | | 3 | 11 | | 2 | 12 |
| | 2 | 14 | 3 | | 9 | 6 | 2 | 4 | 9 | 4 | | 11 | 6 | | 6 | 11 | | 3 | 14 |
| | 1 | 18 | 1 | 2 | 15 | 4 | 2 | 8 | 8 | 5 | | 17 | 7 | | 8 | 13 | | 4 | 17 |
| Innovative Product | 4 | 18 | 1 | | 9 | 9 | 1 | 2 | 13 | 4 | | 7 | 12 | | 2 | 17 | | | 19 |
| | 3 | 17 | 2 | | 11 | 8 | | 2 | 14 | 3 | | 10 | 9 | | 4 | 15 | | 4 | 15 |
| | 2 | 35 | 6 | 2 | 28 | 10 | 5 | 10 | 23 | 10 | | 27 | 16 | | 11 | 32 | | 6 | 37 |
| | 1 | 9 | | | 6 | 3 | | 3 | 5 | 1 | | 7 | 2 | | 4 | 5 | | | 9 |

Cost %

## Demand Approach and Cost

**Demand Approach v.s Cost**

| Demand Approach | | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Push System | 4 | 30 | 4 | 1 | 23 | 8 | 4 | 9 | 17 | 9 | | 21 | 14 | | 11 | 24 | | 5 | 30 |
| | 3 | 21 | 2 | 1 | 14 | 8 | 2 | 2 | 19 | 3 | | 12 | 12 | | 3 | 21 | | 2 | 22 |
| | 2 | 21 | 1 | | 12 | 10 | | 3 | 15 | 4 | | 13 | 9 | | 4 | 18 | | 2 | 20 |
| | 1 | 7 | 2 | | 5 | 4 | | 3 | 4 | 2 | | 5 | 4 | | 3 | 6 | | 1 | 8 |
| Self Customised | 4 | 10 | 2 | | 4 | 7 | 1 | | 8 | 4 | | 4 | 8 | | 1 | 11 | | 1 | 11 |
| | 3 | 33 | 2 | 1 | 23 | 11 | 2 | 7 | 23 | 6 | | 21 | 15 | | 9 | 27 | | 5 | 31 |
| | 2 | 20 | 4 | 1 | 18 | 4 | 3 | 7 | 14 | 4 | | 17 | 8 | | 8 | 17 | | 4 | 21 |
| | 1 | 16 | 1 | | 9 | 8 | | 3 | 10 | 4 | | 9 | 8 | | 3 | 14 | | | 17 |
| High End Strategy | 4 | 15 | 3 | | 8 | 9 | 4 | 3 | 10 | 5 | | 9 | 9 | | 4 | 14 | | | 18 |
| | 3 | 22 | 2 | | 17 | 6 | 1 | 8 | 12 | 4 | | 17 | 7 | | 9 | 15 | | 5 | 19 |
| | 2 | 22 | 3 | 1 | 15 | 9 | 2 | 5 | 16 | 5 | | 14 | 12 | | 6 | 20 | | 4 | 22 |
| | 1 | 20 | 1 | 1 | 14 | 6 | 2 | 1 | 17 | 4 | | 11 | 11 | | 2 | 20 | | 1 | 21 |

**Cost %**

# Appendix M: Scatter Diagrams vs. JIT Lean

## Logistics Variable

### Distribution Strategy and JIT Lean

**Distribution Strategies v.s JIT Lean**

| | | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| Operational Distribution | 4 | 33 | | | 29 | 4 | | 15 | 17 | 1 | 6 | 20 | 7 | 1 | 16 | 15 | 2 | 12 | 19 | 1 | 3 | 29 | 1 | 1 | 31 | | | 33 |
| | 3 | 26 | | | 24 | 2 | | 12 | 13 | 1 | 5 | 19 | 2 | 1 | 12 | 13 | | 10 | 16 | | 4 | 22 | | 1 | 25 | | | 26 |
| | 2 | 13 | 3 | 2 | 12 | 4 | 1 | 8 | 9 | 1 | 2 | 11 | 5 | | 10 | 8 | | 8 | 10 | 2 | 3 | 13 | 2 | 1 | 15 | 2 | | 16 |
| | 1 | 12 | 1 | | 11 | 2 | | 4 | 8 | 1 | 2 | 7 | 4 | 2 | 2 | 9 | 1 | 3 | 9 | 1 | 2 | 10 | | 2 | 11 | | | 13 |
| Tactical Distribution | 4 | 24 | | | 22 | 2 | | 11 | 12 | 1 | 7 | 11 | 6 | 3 | 8 | 13 | 2 | 8 | 14 | 2 | 4 | 18 | 1 | 2 | 21 | | | 24 |
| | 3 | 24 | | 1 | 22 | 2 | 1 | 8 | 17 | 1 | 1 | 22 | 2 | | 13 | 12 | | 9 | 16 | 1 | 3 | 21 | 1 | 2 | 22 | 1 | | 24 |
| | 2 | 21 | 3 | 1 | 18 | 6 | 1 | 13 | 10 | 1 | 4 | 16 | 5 | 2 | 11 | 12 | 1 | 10 | 14 | 1 | 4 | 20 | 1 | 1 | 23 | 1 | | 24 |
| | 1 | 15 | 1 | | 14 | 2 | | 7 | 8 | 1 | 3 | 8 | 5 | | 8 | 8 | | 6 | 10 | | 1 | 15 | | | 16 | | | 16 |
| Strategic Distribution | 4 | 15 | | | 25 | | | 13 | 12 | | 6 | 15 | 4 | 1 | 12 | 12 | 1 | 11 | 13 | 1 | 4 | 20 | 1 | | 24 | | | 25 |
| | 3 | 18 | | | 14 | 4 | | 15 | 12 | 1 | 3 | 9 | 6 | 1 | 7 | 10 | 1 | 3 | 14 | 1 | 1 | 16 | | 2 | 16 | | | 18 |
| | 2 | 21 | 3 | 2 | 21 | 3 | 1 | 10 | 14 | 1 | 2 | 19 | 4 | 1 | 9 | 15 | | 10 | 15 | 1 | 3 | 21 | 1 | 1 | 23 | 1 | | 24 |
| | 1 | 20 | 1 | 1 | 16 | 5 | 1 | 11 | 9 | 2 | 4 | 14 | 4 | 2 | 12 | 8 | 1 | 9 | 12 | 1 | 4 | 17 | 1 | 2 | 19 | 1 | | 21 |

**JIT Lean %**

## Delivery Strategy and JIT Lean

**Delivery Strategies v.s JIT Lean**

Order Fill Lead Time

| Level | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H | 61-70% L | 61-70% M | 61-70% H | 71-80% L | 71-80% M | 71-80% H | 81- > 90% L | 81- > 90% M | 81- > 90% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 29 | 1 | | 27 | 3 | | 15 | 15 | | 3 | 5 | 2 | 5 | 13 | 12 | 3 | 13 | 14 | 2 | 7 | 21 | 1 | 3 | 26 | | | 30 |
| 3 | 20 | 1 | | 17 | 4 | | 5 | 15 | 1 | | 4 | 2 | | 7 | 14 | | 4 | 17 | | 2 | 19 | | | 21 | | | 21 |
| 2 | 18 | 1 | 2 | 18 | 1 | 2 | 11 | 8 | 1 | 2 | 8 | | | 11 | 9 | | 8 | 12 | 1 | 1 | 18 | 1 | | 19 | 1 | | 19 |
| 1 | 17 | 1 | 1 | 14 | 4 | 1 | 8 | 9 | 2 | | 6 | 1 | | 9 | 10 | | 8 | 11 | 1 | 2 | 16 | 1 | 2 | 16 | 1 | | 18 |

Delivery to Committed

| Level | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H | 61-70% L | 61-70% M | 61-70% H | 71-80% L | 71-80% M | 71-80% H | 81- > 90% L | 81- > 90% M | 81- > 90% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 21 | | | 20 | 1 | | 11 | 10 | | | 6 | 3 | 1 | 10 | 10 | 1 | 9 | 11 | 1 | 2 | 18 | 1 | | 20 | | | 21 |
| 3 | 15 | 3 | 3 | 12 | 5 | 3 | 3 | 13 | 2 | 2 | 3 | 2 | | 5 | 13 | | 5 | 13 | 1 | | 17 | 1 | | 17 | 1 | | 17 |
| 2 | 31 | 1 | 1 | 28 | 4 | 1 | 13 | 19 | 1 | 1 | 10 | | 2 | 14 | 17 | 2 | 9 | 22 | 2 | 4 | 27 | 1 | 2 | 30 | 1 | | 32 |
| 1 | 17 | 1 | | 16 | 2 | | 12 | 5 | 1 | 2 | 4 | | 2 | 11 | 5 | | 10 | 8 | | 6 | 12 | | 3 | 15 | | | 18 |

Delivery to Request

| Level | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H | 61-70% L | 61-70% M | 61-70% H | 71-80% L | 71-80% M | 71-80% H | 81- > 90% L | 81- > 90% M | 81- > 90% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 32 | | 1 | 29 | 3 | 2 | 14 | 17 | 2 | 5 | 23 | 5 | 1 | 16 | 16 | 1 | 12 | 20 | 2 | 2 | 29 | 2 | | 31 | 1 | | 32 |
| 3 | 7 | 1 | | 7 | 1 | | 3 | 5 | | 2 | 3 | 3 | 1 | 1 | 6 | 1 | 1 | 6 | 1 | 1 | 6 | | 1 | 7 | | | 8 |
| 2 | 21 | 3 | 1 | 20 | 4 | 1 | 13 | 11 | 1 | 4 | 17 | 4 | 2 | 12 | 11 | | 12 | 13 | 1 | 4 | 20 | 1 | 2 | 22 | 1 | | 24 |
| 1 | 24 | | | 20 | 4 | | 9 | 14 | 1 | 4 | 14 | 6 | 1 | 11 | 12 | 1 | 8 | 15 | | 5 | 19 | | 2 | 22 | | | 24 |

JIT Lean %

## Manufacturing Lead-Time and JIT Lean

**Manufacturing Lead Time v.s JIT Lean**

Manufacturing Lead Time

| Level | 0-10% L | 0-10% M | 0-10% H | 11-20% L | 11-20% M | 11-20% H | 21-30% L | 21-30% M | 21-30% H | 31-40% L | 31-40% M | 31-40% H | 41-50% L | 41-50% M | 41-50% H | 51-60% L | 51-60% M | 51-60% H | 61-70% L | 61-70% M | 61-70% H | 71-80% L | 71-80% M | 71-80% H | 81- > 90% L | 81- > 90% M | 81- > 90% H |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 18 | 1 | 1 | 17 | 2 | 1 | 9 | 9 | 2 | 3 | 12 | 5 | 2 | 8 | 10 | 1 | 8 | 11 | 2 | 3 | 15 | 2 | 1 | 17 | 1 | | 19 |
| 3 | 20 | 1 | | 18 | 3 | | 6 | 14 | 1 | 1 | 15 | 5 | | 6 | 15 | | 5 | 16 | | 1 | 20 | | | 21 | | | 21 |
| 2 | 35 | | | 31 | 4 | | 19 | 16 | | 9 | 23 | 3 | 3 | 20 | 12 | 2 | 14 | 19 | 1 | 7 | 27 | | 3 | 32 | | | 35 |
| 1 | 11 | 2 | 1 | 10 | 3 | 1 | 5 | 8 | 1 | 2 | 7 | 5 | | 6 | 8 | | 6 | 8 | 1 | 1 | 12 | 1 | 1 | 12 | 1 | | 13 |

JIT Lean %

# Supply Chain Variables

## Product Design and JIT Lean

**Product Design v.s JIT Lean**

| | | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| Innovative Functional | 4 | 19 | | | 17 | 2 | | 6 | 11 | 2 | 4 | 8 | 7 | 2 | 5 | 12 | 1 | 6 | 12 | 1 | 2 | 16 | 1 | 1 | 7 | | | 19 |
| | 3 | 26 | | | 25 | 1 | | 15 | 11 | | 7 | 17 | 2 | 1 | 16 | 9 | | 13 | 13 | | 5 | 21 | | 1 | 25 | | | 26 |
| | 2 | 22 | 3 | | 20 | 5 | | 9 | 15 | 1 | 1 | 17 | 7 | | 12 | 13 | | 7 | 18 | | 3 | 22 | | 1 | 24 | | | 25 |
| | 1 | 17 | 1 | 1 | 14 | 4 | 2 | 9 | 10 | 1 | 3 | 15 | 2 | 2 | 7 | 11 | 2 | 7 | 11 | 3 | 2 | 15 | 2 | 2 | 16 | 2 | | 18 |
| Functional Product | 4 | 37 | | 1 | 32 | 5 | 1 | 13 | 23 | 4 | 3 | 25 | 10 | 3 | 14 | 21 | 2 | 12 | 24 | 3 | 3 | 32 | 2 | 2 | 34 | 1 | | 37 |
| | 3 | 12 | 1 | 1 | 12 | 1 | 1 | 7 | 7 | | 2 | 9 | 3 | 1 | 6 | 7 | 1 | 4 | 9 | 1 | 2 | 11 | 1 | 1 | 12 | 1 | | 13 |
| | 2 | 15 | 2 | | 12 | 5 | | 8 | 7 | 2 | 5 | 9 | 3 | | 8 | 9 | | 6 | 11 | | 2 | 15 | | 1 | 16 | | | 17 |
| | 1 | 20 | 1 | | 20 | 1 | | 11 | 10 | | 5 | 14 | 2 | 1 | 12 | 8 | | 11 | 10 | | 5 | 16 | | 1 | 20 | | | 21 |
| Innovative Product | 4 | 18 | 1 | | 16 | 3 | | 5 | 14 | | 1 | 14 | 4 | 1 | 4 | 14 | 1 | 2 | 16 | 1 | | 18 | 1 | | 18 | | | 19 |
| | 3 | 18 | | 1 | 16 | 2 | 3 | 6 | 12 | 1 | 1 | 13 | 5 | | 8 | 11 | | 7 | 12 | 1 | 3 | 15 | 1 | 1 | 17 | 1 | | 18 |
| | 2 | 39 | 3 | 1 | 36 | 6 | 1 | 22 | 18 | 3 | 9 | 26 | 8 | 3 | 22 | 18 | 2 | 20 | 21 | 2 | 7 | 34 | 1 | 4 | 38 | 1 | | 42 |
| | 1 | 9 | | | 8 | 1 | | 6 | 3 | | 4 | 4 | 1 | 1 | 6 | 2 | | 4 | 5 | | 2 | 7 | | | 9 | | | 9 |

**JIT Lean %**

## Demand Approach and JIT Lean

**Demand Approach v.s JIT Lean**

| Demand Approach | | 0-10% | | | 11-20% | | | 21-30% | | | 31-40% | | | 41-50% | | | 51-60% | | | 61-70% | | | 71-80% | | | 81- > 90% | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H |
| Push System | 4 | 33 | 2 | | 32 | 3 | | 20 | 14 | 1 | 10 | 17 | 8 | 3 | 18 | 14 | 2 | 14 | 19 | 2 | 3 | 30 | 1 | 2 | 32 | | | 35 |
| | 3 | 23 | | 1 | 22 | 1 | 1 | 11 | 13 | | 3 | 18 | 3 | 2 | 11 | 11 | 1 | 11 | 12 | 1 | 6 | 17 | 1 | 2 | 21 | 1 | | 23 |
| | 2 | 20 | 1 | 1 | 15 | 6 | 1 | 5 | 15 | 2 | 2 | 15 | 5 | | 7 | 15 | | 6 | 16 | 1 | 2 | 19 | 1 | 1 | 20 | 1 | | 21 |
| | 1 | 8 | 1 | | 7 | 2 | | 3 | 5 | 1 | | 7 | 2 | | 4 | 5 | | 2 | 7 | | 1 | 8 | | | 9 | | | 9 |
| Self Customised | 4 | 11 | 1 | | 10 | 2 | | 3 | 8 | 1 | 1 | 7 | 4 | 1 | 3 | 8 | 1 | 3 | 8 | 1 | | 11 | 1 | | 11 | | | 12 |
| | 3 | 35 | | 1 | 32 | 3 | 1 | 17 | 17 | 2 | 8 | 22 | 6 | 2 | 18 | 16 | 1 | 15 | 20 | 2 | 5 | 29 | 1 | 3 | 32 | 1 | | 35 |
| | 2 | 22 | 2 | 1 | 21 | 3 | 1 | 15 | 9 | 1 | 5 | 17 | 3 | 2 | 14 | 9 | 1 | 12 | 12 | 1 | 6 | 18 | 1 | 3 | 22 | 1 | | 24 |
| | 1 | 16 | 1 | | 13 | 4 | | 4 | 13 | | 1 | 11 | 5 | | 5 | 12 | | 3 | 14 | | 1 | 16 | | | 17 | | | 17 |
| High End Strategy | 4 | 18 | | | 15 | 3 | | 6 | 11 | 1 | 3 | 11 | 4 | 1 | 7 | 10 | 1 | 4 | 13 | 1 | 3 | 14 | 1 | | 17 | | | 18 |
| | 3 | 23 | 1 | | 21 | 3 | | 12 | 11 | 1 | 5 | 15 | 4 | | 15 | 9 | | 12 | 12 | | 2 | 22 | | | 24 | | | 24 |
| | 2 | 22 | 3 | 1 | 22 | 4 | 1 | 12 | 13 | 1 | 4 | 16 | 6 | 2 | 9 | 15 | 1 | 9 | 16 | 2 | 2 | 22 | 1 | 3 | 22 | 1 | | 25 |
| | 1 | 21 | | 1 | 19 | 2 | 1 | 9 | 12 | 1 | 3 | 15 | 4 | 2 | 9 | 11 | 1 | 8 | 13 | 1 | 5 | 16 | 1 | 2 | 19 | 1 | | 21 |

**JIT Lean %**

# Appendix N: Logistics Strategies Fuzzy Rules (JIT Lean and Cost)

## Distribution Strategy

### Operational strategy

| Distribution Strategy-Operational vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-10 | 0-60 | Legile Strategy | And/Or BSC Strategy | |
| 11-30% | 0-60 | BSC Strategy | Legile Strategy | |
| 31-60 | 0-60 | BSC Strategy | And/Or Legile Strategy | |
| 61- > 90 | 0-60 | BSC Strategy | Legile Strategy | |

### Strategic strategy

| Distribution Strategy-Strategic vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-10 | 0-10 | BSC Strategy | Agile Strategy | |
| | 11-20 | BSC Strategy | Lean Strategy | |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | And/Or Lean Strategy |
| | 31-40 | BSC Strategy | Agile Strategy | And/Or Lean Strategy |
| | 41-60 | BSC Strategy | And/Or Agile Strategy | And/Or Lean Strategy |
| 11-20 % | 0-10 | BSC Strategy | Agile Strategy | |
| | 11-20 | BSC Strategy | Lean Strategy | |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | And/Or Lean Strategy |
| | 31-40 | BSC Strategy | Agile Strategy | And/Or Lean Strategy |
| | 41-60 | BSC Strategy | And/Or Agile Strategy | Lean Strategy |
| 21-30 | 0-20 | BSC Strategy | And/Or Legile Strategy | Agile Strategy |
| | 21-30 | BSC Strategy | And/Or Legile Strategy | Agile Strategy, And/Or Lean Strategy |
| | 31-40 | BSC Strategy | And/Or Legile Strategy | Lean Strategy |
| | 41-60 | BSC Strategy | And/Or Legile Strategy | Agile Strategy, And/Or Lean Strategy |

| | | | | |
|---|---|---|---|---|
| 31-40 | 0-10 | BSC Strategy | And/Or Agile Strategy | |
| | 11-20 | Agile Strategy | And/Or Lean Strategy | |
| | 21-30 | Agile Strategy | Lean Strategy | |
| | 31-40 | BSC Strategy | And/Or Agile Strategy | Lean Strategy |
| | 41-60 | Agile Strategy | Lean Strategy | |
| 41-50 | 0-10 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| | 11-20 | Legile Strategy | And/Or BSC Strategy | Lean Strategy |
| | 21-30 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 31-40 | Lean Strategy | And/Or Legile Strategy | BSC Strategy |
| | 41-50 | Legile Strategy | And/Or BSC Strategy | Agile Strategy, And/Or Lean Strategy |
| | 51-60 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| 51-60 | 0-10 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| | 11-30 | Legile Strategy | And/Or BSC Strategy | Lean Strategy |
| | 31-40 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| | 41-60 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| 61-70 | 0-10 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 11-20 | BSC Strategy | Legile Strategy | And/Or Lean Strategy |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | Legile Strategy, And/Or Lean Strategy |
| | 31-40 | BSC Strategy | Agile Strategy | And/Or Lean Strategy And/Or Legile Strategy |
| | 41-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy, And/Or Lean Strategy |
| 71-80 | 0-20 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| | 31-40 | BSC Strategy | Legile Strategy | |
| | 41-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| 81- > 90 | 0-20 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| | 31-50 | BSC Strategy | Legile Strategy | |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |

## Tactical strategy

| Distribution Strategy-Tactical vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-20 | 0-20 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| | 21-30 | Legile Strategy | And/Or BSC Strategy | |
| | 31-40 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| | 41-50 | Legile Strategy | And/Or BSC Strategy | |
| | 51-60 | Legile Strategy | And/Or BSC Strategy | Agile Strategy |
| 11-30% | 0-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | BSC Strategy | |
| | 31-40 | Legile Strategy | Agile Strategy | And/Or BSC Strategy |
| | 41-50 | Legile Strategy | And/Or BSC Strategy | |
| | 51-60 | Legile Strategy | And/Or Agile Strategy | |
| 31-40 | 0-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | BSC Strategy | |
| | 31-40 | Legile Strategy | Agile Strategy | And/Or BSC Strategy |
| | 41-50 | Legile Strategy | Agile Strategy | |
| | 51-60 | Legile Strategy | And/Or BSC Strategy | |
| 41-50 | 0-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | BSC Strategy | |
| | 31-40 | Legile Strategy | Agile Strategy | And/Or BSC Strategy |
| | 41-60 | Legile Strategy | And/Or BSC Strategy | |
| 51-60 | 0-50 | BSC Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| 61-70 | 0-60 | Agile Strategy | And/Or BSC Strategy | And/Or Legile Strategy |
| 71-80 | 0-30 | Agile Strategy | And/Or Legile Strategy | BSC Strategy |
| | 31-40 | Agile Strategy | And/Or BSC Strategy | And/Or Legile Strategy |
| | 41-50 | Legile Strategy | And/Or Agile Strategy | BSC Strategy |
| | 51-60 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| 81- > 90 | 0-60 | Agile Strategy | And/Or Legile Strategy | And/Or BSC Strategy |

# Delivery Strategy

## Delivery to commit date

| Delivery To Commit Date vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-20 | 0-30, 41-60 | Agile Strategy | BSC Strategy | |
| | 31-40 | Agile Strategy | BSC Strategy | And/Or Lean Strategy |
| 21-30 | 0-30, 41-60 | Agile Strategy | And/Or Legile Strategy | |
| | 31-40 | Lean Strategy | And/Or Legile Strategy | And/Or Agile Strategy |
| 31-60 | 0-30, 41-60 | Agile Strategy | | |
| | 31-40 | Agile Strategy | And/Or Lean Strategy | |
| 61-70 | 0-60 | Agile Strategy | And/Or Legile Strategy | |
| 71-80 | 0-30, 41-60 | Agile Strategy | BSC Strategy | |
| | 31-40 | Agile Strategy | BSC Strategy | And/Or Lean Strategy |
| 81- > 90 | 0-30, 41-60 | Agile Strategy | BSC Strategy | |
| | 31-40 | Agile Strategy | And/Or Lean Strategy | |

## Delivery to request

| Delivery To Request vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-10 | 0-50 | BSC Strategy | And/Or Lean Strategy | |
| | 51-60 | BSC Strategy | And/Or Lean Strategy | And/Or Agile Strategy |
| 11- 60% | 0-10 | BSC Strategy | And/Or Lean Strategy | |
| | 11-50 | BSC Strategy | | |
| | 51-60 | BSC Strategy | And/Or Lean Strategy | And/Or Agile Strategy |
| 61-70 | 0-10 | BSC Strategy | And/Or Lean Strategy | And/Or Agile Strategy |
| | 11-50 | BSC Strategy | And/Or Agile Strategy | |
| | 51-60 | BSC Strategy | And/Or Lean Strategy | And/Or Agile Strategy |
| 71- > 90 | 0-60 | BSC Strategy | And/Or Lean Strategy | And/Or Agile Strategy |

## Order fill lead-time

| Order Fill Lead-Time vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-10 | 0-30, 41-60 | BSC Strategy | And/Or Legile Strategy | |
| | 31-40 | BSC Strategy | And/Or Legile Strategy | And/Or Lean Strategy |
| 11-20 % | 0-10, 41-60 | BSC Strategy | And/Or Legile Strategy | |
| | 11-30 | BSC Strategy | | |
| | 31-40 | BSC Strategy | And/Or Lean Strategy | |
| 21-30 | 0-30, 41-60 | BSC Strategy | And/Or Legile Strategy | |
| | 31-40 | BSC Strategy | And/Or Legile Strategy | And/Or Lean Strategy |
| 31-40 | 0-10 | BSC Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| | 11-30 | BSC Strategy | And/Or Agile Strategy | |
| | 31-40 | Agile Strategy | And/Or Lean Strategy | And/Or BSC Strategy |
| | 41-60 | BSC Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| 41-50 | 0-30, 41-60 | BSC Strategy | And/Or Legile Strategy | |
| | 31-40 | Lean Strategy | And/Or Legile Strategy | And/Or BSC Strategy |
| 51-60 | 0-30 | Legile Strategy | And/Or BSC Strategy | |
| | 31-40 | Legile Strategy | And/Or BSC Strategy | And/Or Lean Strategy |
| | 41- 60 | BSC Strategy | And/Or Legile Strategy | |
| 61- > 90 | 0-30, 41-60 | BSC Strategy | And/Or Legile Strategy | |
| | 31-40 | BSC Strategy | And/Or Lean Strategy | And/Or Legile Strategy |

## Manufacturing Lead-Time

| Manufacturing Lead-Time vs. JIT Lean and Cost variables | | | | |
|---|---|---|---|---|
| IF | → | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-10 | 0-20 | Agile Strategy | Legile Strategy | |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | |
| | 41-50 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 51-60 | Agile Strategy | BSC Strategy | Legile Strategy |
| 11-60% | 0-60 | Agile Strategy | Legile Strategy | |
| 61-70 | 0-40 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 41-60 | Agile Strategy | BSC Strategy | Legile Strategy |
| 71-80 | 0-20 | Agile Strategy | Lean Strategy | Legile Strategy |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or Lean Strategy And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 41- 60 | Agile Strategy | BSC Strategy | And/Or Lean Strategy And/Or Legile Strategy |
| 81- > 90 | 0-20 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 21-30 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| | 31-40 | Agile Strategy | Legile Strategy | BSC Strategy |
| | 41-60 | Agile Strategy | BSC Strategy | Legile Strategy |

# Appendix O: Supply Chain Strategies Fuzzy Rules (JIT Lean and Cost)

## Product Design

### Innovative product

| Innovative Product vs. JIT Lean and Cost variables | | | | |
|---|---|---|---|---|
| IF → | THEN | | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-20 | 0-60 | Agile Strategy | Legile Strategy | And/Or BSC Strategy |
| 21-50 | 0-60 | Agile Strategy | | |
| 51- >90 | 0-60 | Agile Strategy | BSC Strategy | |

### Functional product

| Functional Product vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | THEN | | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-20 | 0-40 | BSC Strategy | Lean Strategy | |
| | 41-50 | BSC Strategy | And/Or Agile Strategy | Lean Strategy |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Lean Strategy And/Or Legile Strategy |
| 21-70 | 0-40 | BSC Strategy | | |
| | 41-50 | BSC Strategy | And/Or Agile Strategy | |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| 71- >90 | 0-40 | BSC Strategy | Lean Strategy | |
| | 41-50 | BSC Strategy | And/Or Agile Strategy | Lean Strategy |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Lean Strategy And/Or Legile Strategy |

### Innovative Functional product

| Innovative Functional vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-20 | 0-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | Agile Strategy | And/Or Lean Strategy |
| | 31-40 | Legile Strategy | Agile Strategy | |
| | 41-60 | Agile Strategy | Legile Strategy | |
| 21-30 | 0-20 | Legile Strategy | And/Or Agile Strategy | |
| | 21-30 | Legile Strategy | Agile Strategy | And/Or Lean Strategy |
| | 31-40 | Legile Strategy | Agile Strategy | |
| | 41-60 | Agile Strategy | Legile Strategy | |
| 31-40 | 0-20 | Legile Strategy | And/Or Agile Strategy | |
| | 21-30 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 31-60 | Agile Strategy | And/Or Legile Strategy | |
| 41-50 | 0-10 | Legile Strategy | Agile Strategy | |
| | 11-20 | Legile Strategy | | |
| | 21-30 | Legile Strategy | Agile Strategy | And/Or Lean Strategy |
| | 31-40 | Legile Strategy | | |
| | 41-60 | Agile Strategy | And/Or Legile Strategy | |
| 51-60 | 0-10 | Legile Strategy | Agile Strategy | |
| | 11-20 | Legile Strategy | | And/Or Lean Strategy |
| | 21-30 | Legile Strategy | Lean Strategy | Strategy |
| | 31-40 | Legile Strategy | | |
| | 41-60 | Legile Strategy | And/Or Agile Strategy | |
| 61-70 | 0-10 | Agile Strategy | And/Or Legile Strategy | |
| | 11-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | Agile Strategy | And/Or Lean Strategy |
| | 31-40 | Legile Strategy | And/Or Agile Strategy | |
| | 41-50 | Agile Strategy | Legile Strategy | |
| | 51-60 | Agile Strategy | And/Or Legile Strategy | |
| 71- >90 | 0-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | Agile Strategy | And/Or Lean Strategy |
| | 31-40 | Legile Strategy | Agile Strategy | |
| | 41-60 | Agile Strategy | Legile Strategy | |

# Demand Approach

## High-end mass customisation

| High End Strategy vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0-10 | 0-10 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 11-20 | Legile Strategy | Agile Strategy | |
| | 21-30 | Legile Strategy | And/Or Lean Strategy | Agile Strategy |
| | 31-40 | Legile Strategy | Agile Strategy | |
| | 41-50 | Legile Strategy | And/Or Lean Strategy | And/Or Agile Strategy |
| | 51-60 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| 11-20% | 0-10 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 11-20 | Agile Strategy | And/Or Legile Strategy | |
| | 21-30 | Agile Strategy | And/Or Lean Strategy | |
| | 31-40 | Legile Strategy | And/Or Agile Strategy | |
| | 41-50 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 51-60 | Agile Strategy | Lean Strategy | And/Or Legile Strategy |
| 21-30 | 0-20 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 21-30 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 31-40 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 41-50 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 51-60 | Agile Strategy | Legile Strategy | And/Or Lean Strategy |
| 31-40 | 0-20 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 21-30 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 31-40 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 41-60 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| 41-50 | 0-20 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 21-30 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 31-40 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 41-50 | Agile Strategy | And/Or Lean Strategy | Legile Strategy |
| | 51-60 | Agile Strategy | Legile Strategy | And/Or Lean Strategy |

| | | | | |
|---|---|---|---|---|
| 51-60 | 0-10 | Agile Strategy | And/Or Lean Strategy | And/Or BSC Strategy |
| | 11-20 | Agile Strategy | And/Or Legile Strategy | And/Or BSC Strategy |
| | 21-30 | Agile Strategy | And/Or Lean Strategy | BSC Strategy |
| | 31-40 | Agile Strategy | And/Or Legile Strategy | And/Or BSC Strategy |
| | 41-50 | Lean Strategy | And/Or Agile Strategy | Legile Strategy, And/Or BSC Strategy |
| | 51-60 | Agile Strategy | Lean Strategy | Legile Strategy, And/Or BSC Strategy |
| 61-70 | 0-10 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 11-20 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 21-30 | Lean Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| | 31-40 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 41-50 | Lean Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| | 51-60 | Agile Strategy | And/Or Lean Strategy | And/Or Legile Strategy |
| 71-80 | 0-10 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 11-20 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 21-30 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 31-40 | Legile Strategy | And/Or Agile Strategy | Lean Strategy |
| | 41-50 | Lean Strategy | And/Or Agile Strategy | And/Or Legile Strategy |
| | 51-60 | Agile Strategy | And/Or Lean Strategy | And/Or Legile Strategy |
| 81- >90 | 0-40 | Agile Strategy | And/Or Legile Strategy | Lean Strategy |
| | 41-60 | Lean Strategy | And/Or Agile Strategy | And/Or Legile Strategy |

## Self-customised

| Self customiser vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| **JIT %** | **Cost %** | **Favoured** | **Option** | **And / Or** |
| 0- >90 | 0-60 | Legile Strategy | Agile Strategy | |

## Push system

| Push System vs. JIT Lean and Cost variable | | | | |
|---|---|---|---|---|
| IF → | | THEN | | |
| JIT % | Cost % | Favoured | Option | And / Or |
| 0-10 | 0-10 | BSC Strategy | Legile Strategy | |
| | 11-20 | BSC Strategy | Legile Strategy | And/Or Lean Strategy |
| | 21-30 | BSC Strategy | Legile Strategy | |
| | 31-40 | BSC Strategy | Legile Strategy | And/Or Lean Strategy |
| | 41-50 | BSC Strategy | Legile Strategy | |
| | 51-60 | BSC Strategy | Legile Strategy | And/Or Lean Strategy, And/Or Agile Strategy |
| 11-20% | 0-20 | BSC Strategy | Legile Strategy | |
| | 21-30 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |
| | 31-50 | BSC Strategy | Legile Strategy | |
| | 51-60 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |
| 21-30 | 0-10 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| | 11-20 | BSC Strategy | Agile Strategy | |
| | 21-30 | BSC Strategy | And/Or Agile Strategy | |
| | 31-40 | BSC Strategy | Agile Strategy | |
| | 41-50 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 51-60 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| 31-40 | 0-60 | BSC Strategy | And/Or Legile Strategy | Agile Strategy |
| 41-50 | 0-10 | BSC Strategy | And/Or Agile Strategy | Legile Strategy |
| | 11-40 | BSC Strategy | Agile Strategy | |
| | 41-50 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 51-60 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |
| 51-60 | 0-10 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 11-40 | BSC Strategy | Agile Strategy | |
| | 41-60 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |
| 61-70 | 0-60 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| 71-80 | 0-10 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 11-60 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |
| 81- >90 | 0-40 | BSC Strategy | Agile Strategy | And/Or Legile Strategy |
| | 41-60 | BSC Strategy | Legile Strategy | And/Or Agile Strategy |

# Appendix P: Logistics Strategies MDM Matrix (JIT and Cost)

| Headings Abbreviations | | | |
|---|---|---|---|
| **MLT** | Manufacturing Lead-Time | **F** | Favoured |
| **OD** | Operational Distribution | **Opt** | Option |
| **TD** | Tactical Distribution | **Cho** | Choice |
| **SD** | Strategic Distribution | | |
| **DOF** | Delivery on Order fill lead-time | | |
| **DTR** | Delivery To Request | | |
| **DTC** | Delivery To Commit Date | | |

| Text Abbreviations | |
|---|---|
| **ASC** | Agile |
| **LeSC** | Legile |
| **BSC** | Basic Supply Chain |
| **LSC** | Lean |

IF ⟶ THEN

| JIT % | COST % | MLT | | | | OD | | TD | | | SD | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Opt | And / Or | Cho | F | Opt | F | Opt | And / Or | F | Opt | And / Or | Cho |
| 81-100 | 0-20 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or LeSC | And/Or BSC | BSC | ASC | And/Or LeSC | |
| | 21-30 | ASC | LeSC | And/Or BSC | | BSC | LeSC | ASC | And/Or LeSC | And/Or BSC | BSC | And/Or ASC | LeSC | |
| | 31-40 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or LeSC | And/Or BSC | BSC | LeSC | | |
| | 41-50 | ASC | BSC | LeSC | | BSC | LeSC | ASC | And/Or LeSC | And/Or BSC | BSC | LeSC | | |
| | 51-60 | ASC | BSC | LeSC | | BSC | LeSC | ASC | And/Or LeSC | And/Or BSC | BSC | And/Or ASC | LeSC | |
| 71-80 | 0-20 | ASC | LSC | LeSC | | BSC | LeSC | ASC | And/Or LeSC | BSC | BSC | ASC | And/Or LeSC | |
| | 21-30 | ASC | LeSC | And/Or LSC | And/Or BSC | BSC | LeSC | ASC | And/Or LeSC | BSC | BSC | And/Or ASC | LeSC | |
| | 31-40 | ASC | LeSC | And/Or BSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | LeSC | | |
| | 41-50 | ASC | BSC | LSC | And/Or LeSC | BSC | LeSC | LeSC | And/Or ASC | BSC | BSC | And/Or ASC | LeSC | |
| | 51-60 | ASC | BSC | LSC | And/Or LeSC | BSC | LeSC | ASC | LeSC | And/Or BSC | BSC | And/Or ASC | LeSC | |
| 61-70 | 0-10 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | ASC | And/Or LeSC | |
| | 11-20 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | LeSC | And/Or LSC | |
| | 21-30 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | And/Or ASC | LeSC | And/Or LSC |
| | 31-40 | ASC | LeSC | BSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | ASC | And/Or LSC | And/Or LeSC |
| | 41-50 | ASC | BSC | LeSC | | BSC | LeSC | LeSC | And/Or BSC | And/Or LeSC | BSC | And/Or ASC | LeSC | And/Or LSC |
| | 51-60 | ASC | BSC | LeSC | | BSC | LeSC | ASC | And/Or BSC | And/Or LeSC | BSC | And/Or ASC | LeSC | And/Or LSC |
| 51-60 | 0-10 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or BSC | ASC | |
| | 11-20 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or BSC | LSC | |
| | 21-30 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or ASC | LSC | |
| | 31-40 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or BSC | ASC | And/Or LSC |
| | 41-50 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or ASC | LSC | |
| | 51-60 | ASC | LeSC | | | BSC | LeSC | BSC | And/Or ASC | And/Or LeSC | LeSC | And/Or ASC | LSC | |
| 41-50 | 0-10 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | | LeSC | And/Or BSC | ASC | |
| | 11-20 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | | LeSC | And/Or BSC | LSC | |
| | 21-30 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | BSC | | LeSC | And/Or ASC | LSC | |
| | 31-40 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | | LSC | And/Or LeSC | BSC | |
| | 41-50 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | And/Or BSC | | LeSC | And/Or BSC | ASC | And/Or LSC |
| | 51-60 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | And/Or BSC | | ASC | And/Or LeSC | LSC | |
| 31-40 | 0-10 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | | BSC | And/Or ASC | | |
| | 11-20 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | | ASC | And/Or LSC | | |
| | 21-30 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | BSC | | ASC | LSC | | |
| | 31-40 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | ASC | And/Or BSC | BSC | And/Or ASC | LSC | |
| | 41-50 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | And/Or BSC | | ASC | LSC | | |
| | 51-60 | ASC | LeSC | | | BSC | And/Or LeSC | LeSC | And/Or BSC | | ASC | LSC | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-30 | 0-10 | ASC | LeSC | | | BSC | LeSC | LeSC | ASC | | BSC | And/Or LeSC | ASC | |
| | 11-20 | ASC | LeSC | | | BSC | LeSC | LeSC | ASC | | BSC | And/Or LeSC | ASC | |
| | 21-30 | ASC | LeSC | | | BSC | LeSC | LeSC | BSC | | BSC | And/Or LeSC | ASC | And/Or LSC |
| | 31-40 | ASC | LeSC | | | BSC | LeSC | LeSC | ASC | And/Or BSC | BSC | And/Or LeSC | LSC | |
| | 41-50 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | | BSC | And/Or LeSC | And/Or ASC | LSC |
| | 51-60 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or ASC | | BSC | And/Or LeSC | And/Or ASC | LSC |
| 11-20 | 0-10 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | ASC | BSC | ASC | | |
| | 11-20 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | ASC | BSC | LSC | | |
| | 21-30 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | | BSC | And/Or ASC | LSC | |
| | 31-40 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | ASC | BSC | ASC | And/Or LSC | |
| | 41-50 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | | BSC | And/Or ASC | LSC | |
| | 51-60 | ASC | LeSC | | | BSC | LeSC | LeSC | And/Or BSC | And/Or ASC | BSC | And/Or ASC | LSC | |
| 0-10 | 0-10 | ASC | LeSC | | | LeSC | And/Or BSC | LeSC | And/Or BSC | ASC | BSC | ASC | | |
| | 11-20 | ASC | LeSC | | | LeSC | And/Or BSC | LeSC | And/Or BSC | ASC | BSC | LSC | | |
| | 21-30 | ASC | LeSC | And/Or BSC | | LeSC | And/Or BSC | LeSC | And/Or BSC | | BSC | And/Or ASC | LSC | |
| | 31-40 | ASC | LeSC | | | LeSC | And/Or BSC | LeSC | And/Or BSC | ASC | BSC | ASC | And/Or LSC | |
| | 41-50 | ASC | LeSC | And/Or BSC | | LeSC | And/Or BSC | LeSC | And/Or BSC | | BSC | And/Or ASC | LSC | |
| | 51-60 | ASC | BSC | LeSC | | LeSC | And/Or BSC | LeSC | And/Or BSC | And/Or ASC | BSC | And/Or ASC | LSC | |

**IF ⟶ THEN**

| JIT % | COST % | DOF | | | DTR | | | DTC | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Opt | And / Or | F | Opt | And / Or | F | Opt | And / Or |
| 81-100 | 0-20 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 21-30 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 31-40 | BSC | And/Or LSC | LeSC | BSC | And/Or LSC | And/Or ASC | ASC | BSC | And/Or LSC |
| | 41-50 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 51-60 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| 71-80 | 0-20 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 21-30 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 31-40 | BSC | And/Or LSC | LeSC | BSC | And/Or LSC | And/Or ASC | ASC | BSC | And/Or LSC |
| | 41-50 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| | 51-60 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| 61-70 | 0-10 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | And/Or LeSC | |
| | 11-20 | BSC | LeSC | | BSC | And/OrASC | | ASC | And/Or LeSC | |
| | 21-30 | BSC | LeSC | | BSC | And/OrASC | | ASC | And/Or LeSC | |
| | 31-40 | BSC | And/Or LSC | LeSC | BSC | And/OrASC | | ASC | And/Or LeSC | |
| | 41-50 | BSC | LeSC | | BSC | And/OrASC | | ASC | And/Or LeSC | |
| | 51-60 | BSC | LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | And/Or LeSC | |
| 51-60 | 0-10 | LeSC | And/Or BSC | | BSC | And/Or LSC | | ASC | | |
| | 11-20 | LeSC | And/Or BSC | | BSC | | | ASC | | |
| | 21-30 | LeSC | And/Or BSC | | BSC | | | ASC | | |
| | 31-40 | LeSC | And/Or BSC | And/Or LSC | BSC | | | ASC | And/Or LSC | |
| | 41-50 | BSC | And/Or LeSC | | BSC | | | ASC | | |
| | 51-60 | BSC | And/Or LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | | |
| 41-50 | 0-10 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | | |
| | 11-20 | BSC | And/Or LeSC | | BSC | | | ASC | | |
| | 21-30 | BSC | And/Or LeSC | | BSC | | | ASC | | |
| | 31-40 | LSC | And/Or LeSC | BSC | BSC | | | ASC | And/Or LSC | |
| | 41-50 | BSC | And/Or LeSC | | BSC | | | ASC | | |
| | 51-60 | BSC | And/Or LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | | |
| 31-40 | 0-10 | BSC | And/Or ASC | LeSC | BSC | And/Or LSC | | ASC | | |
| | 11-20 | BSC | And/Or ASC | | BSC | And/Or LSC | | ASC | | |
| | 21-30 | BSC | And/Or ASC | | BSC | And/Or LSC | | ASC | | |
| | 31-40 | ASC | And/Or LSC | BSC | BSC | And/Or LSC | | ASC | And/Or LSC | |
| | 41-50 | BSC | And/Or ASC | LeSC | BSC | And/Or LSC | | ASC | | |
| | 51-60 | BSC | And/Or ASC | LeSc | BSC | And/Or LSC | And/Or ASC | ASC | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 21-30 | 0-10 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | And/Or LeSC | |
| | 11-20 | BSC | And/Or LeSC | | BSC | | | ASC | And/Or LeSC | |
| | 21-30 | BSC | And/Or LeSC | | BSC | | | ASC | And/Or LeSC | |
| | 31-40 | BSC | And/Or LeSC | LSC | BSC | | | LSC | And/Or ASC | And/Or LeSC |
| | 41-50 | BSC | And/Or LeSC | | BSC | | | ASC | And/Or LeSC | |
| | 51-60 | BSC | And/Or LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | And/Or LeSC | |
| 11-20 | 0-10 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | BSC | |
| | 11-20 | BSC | | | BSC | | | ASC | BSC | |
| | 21-30 | BSC | | | BSC | | | ASC | BSC | |
| | 31-40 | BSC | And/Or LSC | | BSC | | | ASC | BSC | And/Or LSC |
| | 41-50 | BSC | And/Or LeSC | | BSC | | | ASC | BSC | |
| | 51-60 | BSC | And/Or LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |
| 0-10 | 0-10 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | BSC | |
| | 11-20 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | BSC | |
| | 21-30 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | BSC | |
| | 31-40 | BSC | And/Or LSC | And/Or LeSC | BSC | And/Or LSC | | ASC | BSC | And/Or LSC |
| | 41-50 | BSC | And/Or LeSC | | BSC | And/Or LSC | | ASC | BSC | |
| | 51-60 | BSC | And/Or LeSC | | BSC | And/Or LSC | And/Or ASC | ASC | BSC | |

# Appendix Q: Supply Chain Strategies MDM Matrix (JIT and Cost)

| Headings Abbreviations | | | |
|---|---|---|---|
| **SC** | Self Customiser | **F** | Favoured |
| **PS** | Push System | **Opt** | Option |
| **HES** | High End Strategy | **Cho** | Choice |
| **IF** | Innovative Functional | | |
| **FP** | Functional Product | | |
| **IP** | Innovative Product | | |

| Text Abbreviations | |
|---|---|
| **ASC** | Agile |
| **LeSC** | Legile |
| **BSC** | Basic Supply Chain |
| **LSC** | Lean |

**IF ⟶ THEN**

| JIT % | COST % | SC | | PS | | | HES | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **F** | **Opt** | **F** | **Opt** | **And / Or** | **F** | **Opt** | **And / Or** | **Cho** |
| 91-100 | 0-20 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 21-30 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 31-40 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 41-60 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| 81-90 | 0-20 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 21-30 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 31-40 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 41-50 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| 71-80 | 0-10 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 11-20 | LeSC | ASC | BSC | LeSC | And/Or ASC | LeSC | And/Or ASC | LSC | |
| | 21-30 | LeSC | ASC | BSC | LeSC | And/Or ASC | ASC | And/Or LeSC | LSC | |
| | 31-40 | LeSC | ASC | BSC | LeSC | And/Or ASC | LeSC | And/Or ASC | LSC | |
| | 41-50 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | ASC | LSC | And/Or LeSC | |
| 61-70 | 0-10 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LeSC | LSC | |
| | 11-20 | LeSC | ASC | BSC | LeSC | And/Or ASC | LeSC | And/Or ASC | LSC | |
| | 21-30 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| | 31-40 | LeSC | ASC | BSC | LeSC | And/Or ASC | LeSC | And/Or ASC | LSC | |
| | 41-50 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | And/Or LeSC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | ASC | LSC | And/Or LeSC | |
| 51-60 | 0-10 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LSC | LeSC | And/Or BSC |
| | 11-20 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | And/Or BSC |
| | 21-30 | LeSC | ASC | BSC | ASC | | ASC | And/Or LSC | BSC | |
| | 31-40 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | And/Or BSC |
| | 41-50 | LeSC | ASC | BSC | LeSC | And/Or ASC | LSC | And/Or ASC | LeSC | And/Or BSC |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | ASC | LSC | And/Or LeSC | And/Or BSC |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 41-50 | 0-10 | LeSC | ASC | BSC | And/O | LeSC | ASC | And/Or LeSC | LSC | |
| | 11-20 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | |
| | 21-30 | LeSC | ASC | BSC | ASC | | ASC | And/Or LSC | LeSC | |
| | 31-40 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | |
| | 41-50 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LSC | LeSC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | ASC | LeSC | And/Or LSC | |
| 31-40 | 0-20 | LeSC | ASC | BSC | And/O | ASC | ASC | And/Or LeSC | LSC | |
| | 21-30 | LeSC | ASC | BSC | And/O | ASC | ASC | And/Or LSC | LeSC | |
| | 31-40 | LeSC | ASC | BSC | And/O | ASC | ASC | And/Or LeSC | LSC | |
| | 41-50 | LeSC | ASC | BSC | And/O | ASC | ASC | And/Or LSC | LeSC | |
| | 51-60 | LeSc | ASC | BSC | And/O | ASC | ASC | And/Or LSC | LeSC | |
| 21-30 | 0-10 | LeSC | ASC | BSC | And/O | LeSC | ASC | And/Or LeSC | LSC | |
| | 11-20 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | |
| | 21-30 | LeSC | ASC | BSC | ASC | | ASC | And/Or LSC | LeSC | |
| | 31-40 | LeSC | ASC | BSC | ASC | | ASC | And/Or LeSC | LSC | |
| | 41-50 | LeSC | ASC | BSC | ASC | And/Or LeSC | ASC | And/Or LSC | LeSC | |
| | 51-60 | LeSc | ASC | BSC | And/O | LeSC | ASC | LeSC | And/Or LSC | |
| 11-20 | 0-10 | LeSC | ASC | BSC | LeSC | | ASC | And/Or LeSC | LSC | |
| | 11-20 | LeSC | ASC | BSC | LeSC | | ASC | And/Or LeSC | | |
| | 21-30 | LeSC | ASC | BSC | LeSC | And/Or ASC | ASC | And/Or LSC | | |
| | 31-40 | LeSC | ASC | BSC | LeSC | | LeSC | And/Or ASC | | |
| | 41-50 | LeSC | ASC | BSC | LeSC | | ASC | And/Or LSC | LeSC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or ASC | ASC | LSC | And/Or LeSC | |
| 0-10 | 0-10 | LeSC | ASC | BSC | LeSC | | LeSC | And/Or ASC | LSC | |
| | 11-20 | LeSC | ASC | BSC | LeSC | And/Or LSC | LeSC | ASC | | |
| | 21-30 | LeSC | ASC | BSC | LeSC | | LeSC | And/Or LSC | ASC | |
| | 31-40 | LeSC | ASC | BSC | LeSC | And/Or LSC | LeSC | ASC | | |
| | 41-50 | LeSC | ASC | BSC | LeSC | | LeSC | And/Or LSC | And/Or ASC | |
| | 51-60 | LeSc | ASC | BSC | LeSC | And/Or LSC | LeSC | And/Or ASC | LSC | |

**IF → THEN**

| JIT % | COST % | IF | | | | FP | | | | IP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Opt | And / Or | Cho | F | Opt | And / Or | Cho | F | Opt | And / Or |
| 91-100 | 0-20 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | LSC | | | ASC | BSC | |
| | 31-40 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 41-60 | ASC | LeSC | | | BSC | And/O | LSC | | ASC | BSC | |
| 81-90 | 0-20 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | LSC | | | ASC | BSC | |
| | 31-40 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 41-50 | ASC | LeSC | | | BSC | And/O | LSC | | ASC | BSC | |
| | 51-60 | ASC | LeSC | | | BSC | And/O | LSC | And/O | ASC | BSC | |
| 71-80 | 0-10 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 11-20 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | LSC | | | ASC | BSC | |
| | 31-40 | LeSC | ASC | | | BSC | LSC | | | ASC | BSC | |
| | 41-50 | ASC | LeSC | | | BSC | And/O | LSC | | ASC | BSC | |
| | 51-60 | ASC | LeSC | | | BSC | And/O | LSC | And/O | ASC | BSC | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61-70 | 0-10 | ASC | And/Or LeSC | | | BSC | | | | ASC | BSC | |
| | 11-20 | LeSC | ASC | | | BSC | | | | ASC | BSC | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | | | | ASC | BSC | |
| | 31-40 | LeSC | ASC | | | BSC | | | | ASC | BSC | |
| | 41-50 | ASC | LeSC | | | BSC | And/Or ASC | | | ASC | BSC | |
| | 51-60 | ASC | And/Or LeSC | | | BSC | And/O | LeSC | | ASC | BSC | |
| 51-60 | 0-10 | LeSC | ASC | | | BSC | | | | ASC | BSC | |
| | 11-20 | LeSC | | | | BSC | | | | ASC | BSC | |
| | 21-30 | LeSC | LSC | ASC | | BSC | | | | ASC | BSC | |
| | 31-40 | LeSC | | | | BSC | | | | ASC | BSC | |
| | 41-50 | LeSC | And/Or ASC | | | BSC | And/Or ASC | | | ASC | BSC | |
| | 51-60 | LeSC | And/Or ASC | | | BSC | And/O | LeSC | | ASC | BSC | |
| 41-50 | 0-10 | LeSC | ASC | | | BSC | | | | ASC | | |
| | 11-20 | LeSC | | | | BSC | | | | ASC | | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | | | | ASC | | |
| | 31-40 | LeSC | | | | BSC | | | | ASC | | |
| | 41-50 | ASC | And/Or LeSC | | | BSC | And/Or ASC | | | ASC | | |
| | 51-60 | ASC | And/Or LeSC | | | BSC | And/O | LeSC | | ASC | | |
| 31-40 | 0-20 | LeSC | And/Or ASC | | | BSC | | | | ASC | | |
| | 21-30 | ASC | And/O | LSC | | BSC | | | | ASC | | |
| | 31-40 | ASC | And/Or LeSC | | | BSC | | | | ASC | | |
| | 41-50 | ASC | And/Or LeSC | | | BSC | And/Or ASC | | | ASC | | |
| | 51-60 | ASC | And/Or LeSC | | | BSC | And/O | LeSC | | ASC | | |
| 21-30 | 0-10 | LeSC | And/Or ASC | | | BSC | | | | ASC | | |
| | 11-20 | LeSC | And/Or ASC | | | BSC | | | | ASC | | |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | | | | ASC | | |
| | 31-40 | LeSC | ASC | | | BSC | | | | ASC | | |
| | 41-50 | ASC | LeSC | | | BSC | And/Or ASC | | | ASC | | |
| | 51-60 | ASC | LeSC | | | BSC | And/O | LeSC | | ASC | | |
| 11-20 | 0-10 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 11-20 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 21-30 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 31-40 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 41-50 | LeSC | ASC | | | BSC | And/O | LSC | | ASC | LeSC | And/Or BSC |
| | 51-60 | LeSC | ASC | | | BSC | And/O | LSC | And/O | ASC | LeSC | And/Or BSC |
| 0-10 | 0-10 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 11-20 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 21-30 | LeSC | ASC | And/Or LSC | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 31-40 | LeSC | ASC | | | BSC | LSC | | | ASC | LeSC | And/Or BSC |
| | 41-50 | ASC | LeSC | | | BSC | And/O | LSC | | ASC | LeSC | And/Or BSC |
| | 51-60 | ASC | LeSC | | | BSC | And/O | LSC | And/O | ASC | LeSC | And/Or BSC |