

# **Investigation into Re-Shoring UK Manufacturing Using Additive Manufacturing as a Method to Enable Manufacturing Postponement**

**By:**

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Doctoral Thesis

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# **Abstract**

This thesis describes case study research investigation into re-shoring UK manufacturing using Additive Manufacturing as a method to enable manufacturing Postponement. After identifying the gap in the knowledge by conducting a literature review, the author aims to understand the primary motivation behind the re-shoring phenomenon in the UK. The initial investigation is done by targeting the UK based organisations that have been involved in supporting the re-shoring phenomenon. As a result, lack of responsiveness was found to be the key factor behind re-shoring in the UK. This is then followed by an investigation considering this issue from countries to which manufacturing has been offshored in the past, in particular, India. The research studies the factors that influence this decision from Indian industries' perspectives and investigates what the key issues are behind the lack of responsiveness in India. This is whilst India is one of the most attractive offshoring destinations among the other low-cost countries. This introduces the next objective of this research which is to identify a strategy that could help the industries to address such issues. Consequently the concept of Postponement was selected as a strategy and Additive Manufacturing (AM) was identified as a manufacturing method that could enable Postponement. Such a combination can enable companies to shorten their lead-time and be more responsive to their domestic customers. This study also develops a clear picture of re-shoring in the UK and bridges this phenomenon to the new generation of technologies and emerging mega trends. It particularly focuses on AM technologies as an enabling manufacturing method the Industry 4.0. The results obtained from the survey study indicate that there is a positive view towards applicability of AM technologies within the supply chain of the re-shoring companies. The final section of this thesis aims to

provide a series of case studies where AM technologies are used to further enable companies to reduce their lead time and achieve more customisation. It shows that the companies can re-shore their production activities back to the home country by using AM technologies and engage in a local supply chain. Therefore this study adds insight into manufacturing challenges related to re-shoring and provides a potential solution for the companies that are involved in the production of high value added production. The results from this section indicate that the re-shoring companies will be capable of accommodating product changes and process changes. They can also reduce their inventories, production lead-time, and transportation costs, meanwhile increase product customisation.

# Contributions

## Journal Papers

Moradlou, H. and Backhouse, C.J. (2016), "A review of manufacturing re-shoring in the context of customer-focused Postponement strategies", *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, pp. 1–11.

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## Conference Papers

Moradlou, H. and Backhouse, C. (2014), "Re-shoring UK Manufacturing Activities , Supply Chain Management & Postponement Issues", *18th Annual Cambridge International Manufacturing Symposium*, pp. 344–354.

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Moradlou, H. and Backhouse, C. J. (2015). Supply Chain Management Issues in Re-shoring Manufacturing Activities within the context of Postponement Strategies. *International Conference on Industrial Engineering and Operation Management (IEOM), Dubai*

Moradlou, H. and Backhouse, C. J. (2014). Reshoring UK Manufacturing Activities. An Investigation to decision making criteria in respect of Supply Chain Management. *3rd Annual EPSRC Manufacturing the Future Conference, UK*

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**DEDICATED**

**TO MY BELOVED FAMILY**

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## Abbreviations

AM	Additive Manufacturing
AHP	Analytical Hierarchy Process
ATO	Assemble to Order
B2B	Business to Business
B2B2C	Business to Business to Customer
CAD	Computer Aided Design
CEO	Chief Executive Officer
CIT	Coimbatore Institute of Technology
CNC	Computer Numerical Control
CODP	Customer Order Decoupling Point
CPS	Cyber Physical Systems
CQ	Cost & Quality
CQT	Cost, Quality & Time
CRM	Customer Relationship Management
DDM	Direct Digital Manufacturing
EDI	Electric Data Interchange
EEF	Engineering Employers Federation
ETO	Engineering to Order
FDM	Fused Deposition Modelling
HP	Hewlett-Packard
IP	Intellectual Property
IT	Information Technology

JIT	Just In Time
JLR	Jaguar and Land Rover
MAS	Manufacturing Advisory Service
MDF	Manufacturing Demonstration Facility
MNC	Multinational Cooperation
MRP	Material Requirement Planning
MTO	Make to Order
NBIC	National Bicycle Industry Company
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
POS	Point of Sale
PTO	Purchasing to Order
PTO	Packaging to Order
PwC	PricewaterhouseCoopers
RP	Rapid Prototyping
SD	Standard Deviation
SLS	Selective Laser Sintering
SME	Small and Medium Enterprises
STO	Ship to Order
TCG	TATA Consultancy Group
TCS	TATA Consultancy Service
UKTI	UK Trade and Investment
USA	United States of America
UTK	University of Tennessee Knoxville

# Chapter 1, Introduction

## 1.1 Overview

Considering today's rapidly shifting global competitive conditions, the manufacturing location decision has become an extremely challenging task for the companies (Tate et al., 2014). For more than half a century offshoring has been a common practice among the industries who are seeking to reduce their costs and increase their efficiency (Martinez-Mora and Merino, 2014). Offshoring is defined as the transfer of business processes and activities to foreign locations (Lewin and Volberda, 2011). The intensified offshoring decisions have dramatically transformed the global manufacturing landscape. However while companies continue to globally expand their manufacturing activities, there is evidence indicating different purposes for doing so (Louis et al., 2015). According to Fine (2013) during recent years, "the big names at the end of the chain have come to realise that the lowest price can mean highest risk – and highest risk can mean high total costs". Hence the advantages of the relocation to low-cost countries solely with the purpose of cost reduction have been diminishing in some industries (Louis et al., 2015). This has led companies to perform rigorous risk analysis considering total cost and to take the supply chain perspectives into account when making manufacturing location decisions. They no longer rely solely on cost aspects of the production (Ellram, 2013). However according to Bals et al. (2015), while offshoring strategy may remain beneficial in some industries, for others it might cause an increase in delivery times, significant capital tied up in safety stock, and open up the company to uncontrollable quality issues.



Having considered the discrepancy between the initially estimated cost of offshoring and those actually incurred from the unexpected costs, it is evident that there are tendencies on reversing the offshoring strategy (Ellram, 2013; Gray et al., 2013). As a result, in recent years, there has been a decline in offshoring (Bals et al., 2015) and it is evident that some multinational companies have decided to re-shore parts of their manufacturing activities to their home countries (Bailey and De Propris, 2014). According to Gray et al. (2013) re-shoring is defined as ‘moving manufacturing back to the country of its parent company’.

Re-shoring manufacturing has been receiving significant attention in recent years (PwC, 2014a; Sirkin et al., 2012). Companies have begun to establish a better understanding of total cost and base their manufacturing location decisions on supply chain issue and strategic factors rather than simply relying on unit part cost. A survey study conducted among 319 American companies’ shows that 40% of the companies perceived a trend towards re-shoring to the US in their industries (Tate et al., 2014). For instance by re-shoring their supply chain, Wal-Mart can substantially improve the overall supply chain efficiency by partnering with the local suppliers where greater transparency can be achieved (Shih, 2014). This is by enhanced reaction to the upcoming changes and disruptions in the supplies and demand (Bailey and De Propris, 2014).

It is evident both in the literature and media that industries and jobs that are returning to the developed countries will be different to the ones that were previously offshored, that is, mainly labour-intensive activities (Bailey and De Propris, 2014; Bals et al., 2015; Fine, 2013). According to Shih (2014) when it comes to rebuilding the supplier ecosystem “The long-term development of capabilities becomes far more important than short-term haggling over price”. Therefore as companies face a diverse and uncertain environment, it is essential to be able to cope with the flexibility in operation strategy required to meet the customer demand (Sánchez and Pérez, 2005). The following section discusses the existing gap in the literature which provides the basis for development of the research questions.

## 1.2 Gap in the knowledge

After conducting a literature review it was evident that the academic research on re-shoring topic is scarce (Fratocchi et al., 2013; Kinkel and Maloca, 2009; Bailey and De Propris, 2014; Ellram, 2013). As discussed in Chapter 2, much is written on the policy side of the re-shoring phenomenon which provides a detailed insight into the government related challenges (Bailey and De Propris, 2014; Ellram, 2013). Despite the significance of this phenomenon to manufacturing, the supply chain literature has focused predominantly on the macro economic analysis, while the literature on the operational aspects of re-shoring is relatively sparse. This raises the question which aims to understand the manufacturing challenges related to the re-shoring in the UK. Having identified this gap, this study aims to investigate the manufacturing side of this phenomenon.

Meanwhile as manufacturing industries are witnessing an unprecedented increase in global competition on cost and quality, there is a significant desire towards more customisation and shorter time to market that require novel production strategies (Brettel et al., 2014). PA Manufacturing Group claim that quality and costs issues are unlikely to be the reason for the long-term repatriation of production from low cost countries (Lawrence, 2015). Instead it is believed that the only way for a long lasting and sustainable re-shoring strategy is fundamental transformation of the current industrial production (Lawrence and Vasak, 2014). Hence the new generation of manufacturing activities are required to adopt modern technologies such as AM, intelligent robotics, big data and internet of things, by which industries will ensure their competitive position in the market (Bechtold et al. 2014; Lawrence 2015).

This emphasises the significance of integrating the new generation of technologies within manufacturing activities that are being re-shored. In addition to reviewing the operational motivations behind the re-shoring phenomenon, it is essential to investigate the relationship between re-shoring phenomenon and the emerging trends in the context of supply chain management. Therefore the current literature has failed to identify potential technologies which can help re-shoring phenomenon and does not provide a comprehensive view on the outcomes.

### **1.3 Research Aims**

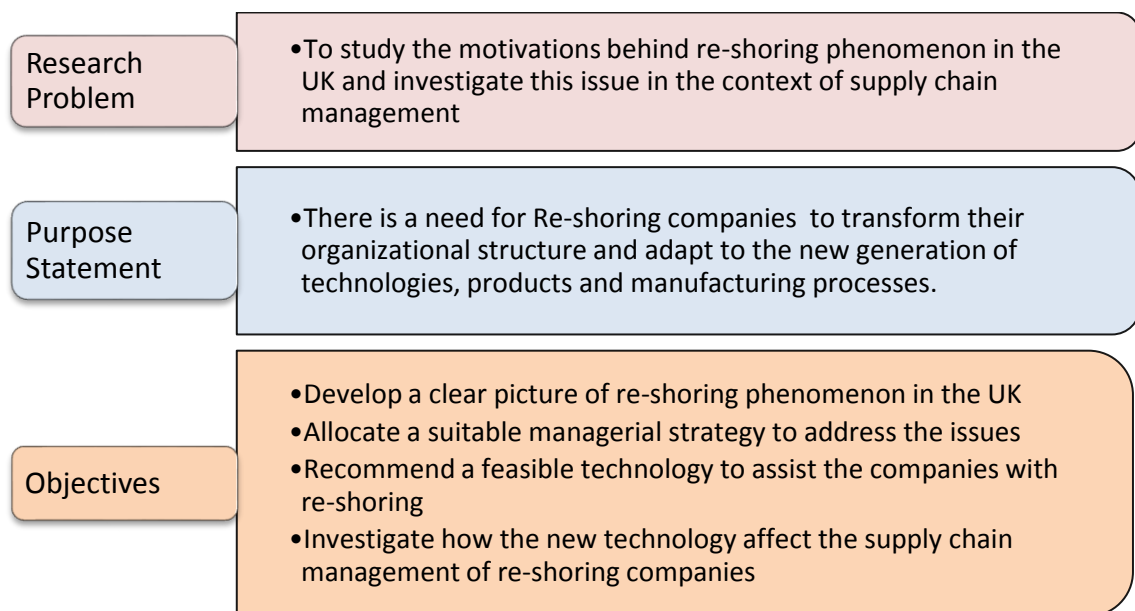
This study aims to investigate the relationship between re-shoring phenomenon and the new generation of technologies, particularly Additive Manufacturing (AM) technologies in the context of supply chain management. The objectives in this research study can be divided into two parts. The purpose of the first part is to understand the re-shoring phenomenon in the UK and identify the primary reason that leads to bringing the production back. This part focuses on the key factor that affects the companies to make manufacturing location decision. Having identified the primary motivation behind re-shoring, a potential manufacturing strategy is required to address the manufacturing challenges related to the relocation. This introduces the second objective in this research.

There is an urgent need for the local suppliers to support the industries who are repatriating their production activities to the home countries otherwise these industries would face what Shih (2014) calls a hollowed-out supply base. According to Louis et al. (2015) a number of recent studies suggest that manufacturing may be entering a new era of flux that will influence the configuration of production around the world. The introduction of new technologies such as Additive Manufacturing (AM), intelligent robotics, big data and internet of things, can create a new potentials for transformation of traditional production methods and lead to a new configuration in global manufacturing pattern (Louis et al., 2015). Therefore the second section of Chapter 4 focuses on the future mega-trends and new generation of technologies and aims to bridge the new trend to the re-shoring phenomenon in the UK. As a result concept of Postponement is studied as a potential solution to meet the customer demand. In order to identify a technology that enables the Postponement strategy, AM technologies were studied. It should be noted that the focus in this research study is the managerial implication of AM in supply chain management.

### **1.4 Research question and objectives**

Every research begins with the attempt to answer certain research problems and it requires careful formulation of research questions. The type of a research question can determine whether the research is calling for quantitative or qualitative approaches (Robson, 2011). Therefore it is essential to construct preliminary research questions at early stages of the research procedure to determine the direction that the researcher needs to follow. For

instance identification of research questions allows researchers to allocate the correct target sample for the research and only collect the precise and relevant information to the questions (Graziano and Raulin, 2007; Huberman and Miles, 2002). In this study the research questions have gone through several iterations whilst identifying the main issues with re-shoring the supply chain to the UK. Then the final research questions were developed accordingly and research direction was consolidated. The reason behind gradual development of final research questions was because of insufficient available literature on the re-shoring phenomenon in the UK at the time of starting this study and other academic works being at their infancy. Although Graziano & Raulin (2007) believe that one of the ways to develop the research questions is to base the questions on knowledge that can be found in the literature and in similar studies, an alternative way is to use the researchers' previous knowledge and background on the topic (Graziano and Raulin, 2007). As the study was progressed, further information about the phenomenon was continuously gathered through various interviews, conferences and national manufacturing debates which led to a careful formulation of research questions. Figure 1-1 presents the research problems, purpose statement and the objectives relevant to this study.



**Figure 1-1, Research problem, Purpose statement and the research objectives**

The research enquiry firstly starts by identifying the research problem that the researchers seek to address. Hence as part of this study, the initial step was to identify the real world problem that the manufacturing industries were facing in the UK. In this scenario the research problem was set to identify the primary motivations behind re-shoring phenomenon in the UK and to investigate this issue in the context of supply chain management. The research problem was then narrowed down to establish the purpose statement. With re-shoring phenomenon gaining momentum in the UK, the need for transformation of organisational structure and supply chain configuration from a more globally spread to a more concise supply network, is inevitable. A number of reasons have driven companies to come to this decision. One of the main reasons behind this transformation is the adoption of new generation of technologies, products and manufacturing processes. This is repeatedly evident in various reports by consultancy firms (EEF, 2014a; PwC, 2014a; RBR, 2014; TATA Consultancy Service, 2013b). By attaining the purpose statement, a set of objectives can be developed. Despite having a number of statistical results about the scale of re-shoring decisions in the UK and the potential reasons behind it, an accurate picture of this phenomenon remains unclear. Thus the first objective was to develop a better understanding about re-shoring as a manufacturing location decision. Once this was completed, a link between the shortcomings in the supply chain and a manufacturing managerial strategy was identified (Postponement strategies). Having considered the new generation of technologies, Additive Manufacturing was selected as a method that can be potentially implemented to support further Postponement strategies. The final objective was to assess the sustainability of Postponement concept through AM. According to the above objectives and aforementioned gap in the re-shoring literature, five research questions were developed, presented as follows:

- 1) What is the main reason behind re-shoring phenomenon in the context of supply chain?

Having looked at the available literature and the government reports, various factors have been listed as main motivations for the company managers to repatriate manufacturing activities. However this list appears to be different from one report to another. Therefore the first research question is due to inadequacy of available information about re-shoring movement in the UK and it aims to identify the main reason.

2) What are the links between Postponement and re-shoring (Mega-Trends)?

Today's manufacturing environment is witnessing a significant advancement as the new technologies emerge. However these technologies have wide range of applications in industry, one thing that they have in common is the potential to shorten the production lead time and improve the response time to customer demand. Since lack of responsiveness was found to be playing a major role for manufacturing location decision in the UK, this questions aims to identify the link between re-shoring and the Postponement strategy which has been proven to enhance production responsiveness.

3) Is there a positive relationship between Postponement and re-shoring?

Once the link between re-shoring and Postponement strategy has been clarified, further work is required to determine the nature of this relationship. Due to the need of the re-shoring companies for responsive supply chain in the UK, the third question focuses on to study this link which ultimately could allow companies to be able to respond quickly to unpredictable customer demands.

4) Is there a positive relationship between AM and re-shoring?

The next part of this research is to investigate Additive Manufacturing technology as a type of Postponement strategy (engineering to order) that can decrease production response time. Hence the fourth question is designed to examine the relationship between AM and re-shoring trend and to see whether AM can be implemented as a mean to further facilitate re-shoring decisions in the UK by using local suppliers.

5) How does AM influence the supply chain structure in the UK?

The final research question attempts to further study the relationship identified in question number four. Therefore it requires detailed investigation on the influences of Postponement strategy and utilisation of AM technology on the configuration of supply chain in the UK. Note that each of the aforementioned research questions will be answered using different data collection methods.

## 1.5 Scope and Boundaries

This section provides the scope and the boundaries, which have been taken into account while conducting this research study. This is to narrow down the areas under investigation to assist the researcher to draw a better conclusion from the data collections and analysis. The following points emphasises the scope of this research.

1. This study only focuses on high value added product where short lead-time, customisations and fast time to market are important. Therefore it does not consider the commodity type products where the cost still plays the key role in selection of manufacturing location and suppliers.
2. The majority of the companies investigated are directly/indirectly related to the automotive sector. This is in the case of the interviews in India, survey study conducted in the UK and the two case studies in the US. It is important to note that the findings can differ from industry to industry.
3. The Chapter 4 of this thesis only investigates the Indian industry's perspectives. Hence the results only provide a viewpoint which may differ from another country.
4. This study only focuses on AM technologies as a type of Postponement strategy and its impacts on re-shoring in the UK. Therefore this research does not investigate the other aspects of Industry 4.0 such as the intelligent robotics, big data and Internet of things. The logic behind this decision is the significant potentials related to AM applications and the on-going research on this subject. Meanwhile the author's previous knowledge about AM technologies is another contributor to the decision process.
5. The Chapter 5 of this thesis conducts a preliminary investigation using survey questionnaire to investigate this phenomenon and new generation of technologies in a larger scale. For the purpose of this study only companies who are related to AM technologies are contacted.

## **1.6 Overview of the thesis**

As shown in Figure 1-2, this study is presented in eight chapters including an introductory chapter. Chapter 2 aims to perform an in-depth literature review on the subject of re-shoring. It begins with an overview of the current literature and moves into investigating the motivation behind this phenomenon around the world. It also identifies different types of re-shoring strategies. Once this is achieved, an introduction to the new generation of technologies and Industry 4.0 is presented. It then outlines an extensive review of literature on the concept of Postponement. It provides a background on the application of Postponement and introduces different types of Postponement strategies. This is then followed by a brief introduction of AM technologies and the advantages and disadvantages of this manufacturing method. Hence Chapter 2 aims to identify the gap in the knowledge and provides the foundation which this research is based on.

Chapter 3 provides an account on the methodology adopted in this research. It presents a clear logic for the flow of activities taken in the research inquiry. The research approach is discussed and the research questions are developed. This chapter also explains different data collection methodologies that are employed addressing each individual question and the data analysis adopted.

Chapter 4 aims to identify the primary motivation behind re-shoring phenomenon in the context of supply chain management. The findings are included followed by a discussion of the results. Once this is done, data collected in India is presented. The data collection is performed over the author's two-month visit at Coimbatore Institute of Technology (CIT), India. This chapter delivers the list of the factors that affect the responsiveness of the Indian companies towards the customer demand in the UK. As a result two propositions are developed that require further investigation.

Chapter 5 provides a wider picture on the re-shoring phenomenon in the UK. It presents the results obtained after conducting a preliminary survey questionnaire in the UK. The target samples are the companies that are directly or indirectly involved in using AM or the supply of the raw materials used in these technologies. As a result 50 companies participated in this survey providing generalisable findings about the connection between re-shoring and new generation of technologies.



Chapter 6 aims to investigate re-shoring decision by conducting a case study in the UK. In order to do so a case study was identified where the company has been involved in offshoring and re-shoring decisions and in addition it utilises AM technologies in their production line. This provides an in-depth view on the factors affecting the company's manufacturing location decision.

Chapter 7 is an in-depth study on the impacts of AM technologies on re-shoring. This is achieved by conducting two case studies in the US where re-shoring phenomenon has been practiced for the last 6 years. The case studies provide a detailed scenario where AM is used in a large scale to manufacture functional products meanwhile the companies work with the local suppliers in the US. The data collection is done over the author's two-month visit at the University of Tennessee Knoxville, US.

In Chapter 8, the nature of the contributions is summarised. It concludes the work done in this research and describes how the research questions were addressed. It also identifies the limitations of this research study and recommends future research directions.

In addition Figure 1-3 shows the publications achieved from each chapter of this thesis.

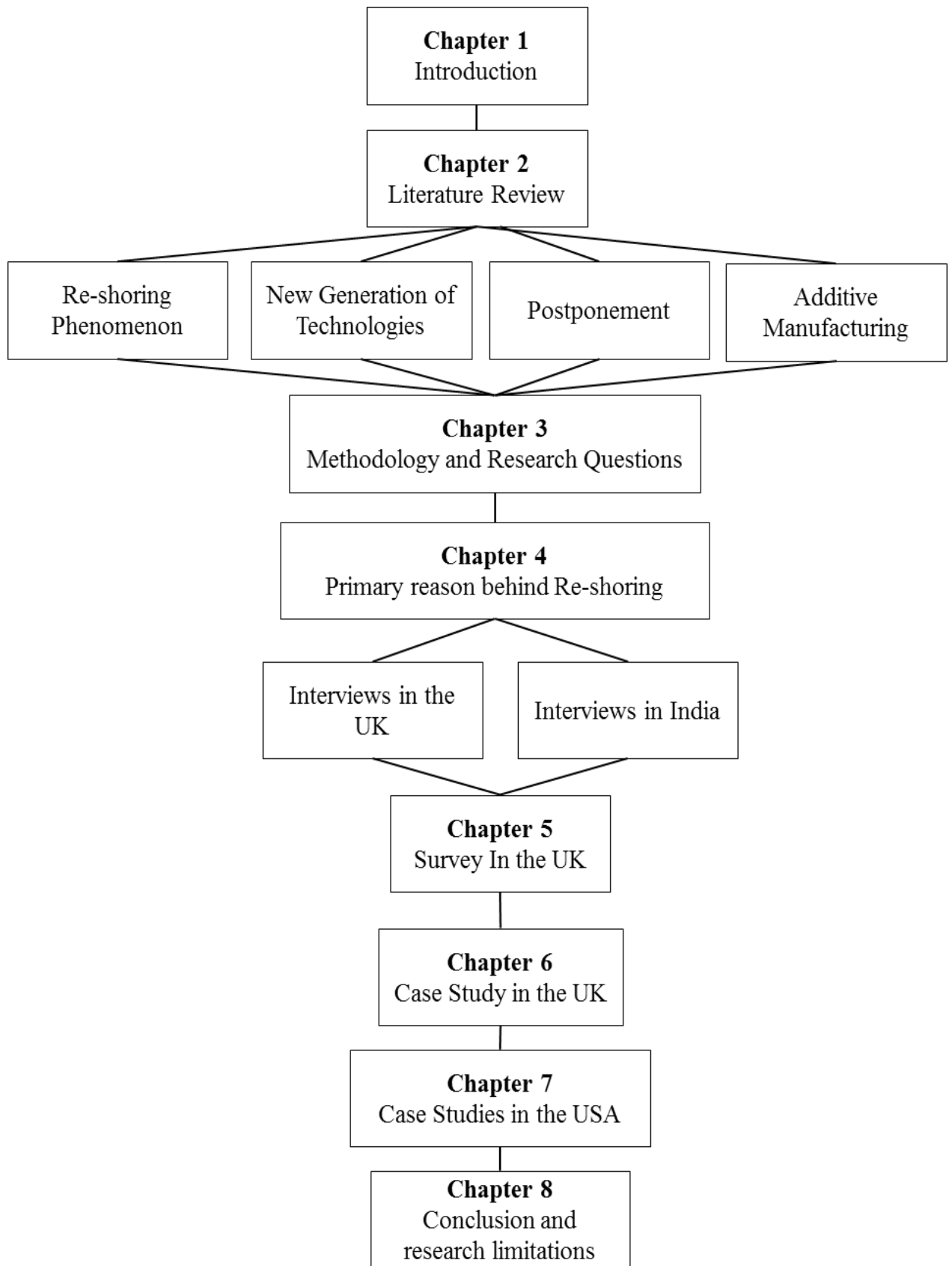


Figure 1-2, Thesis Structure

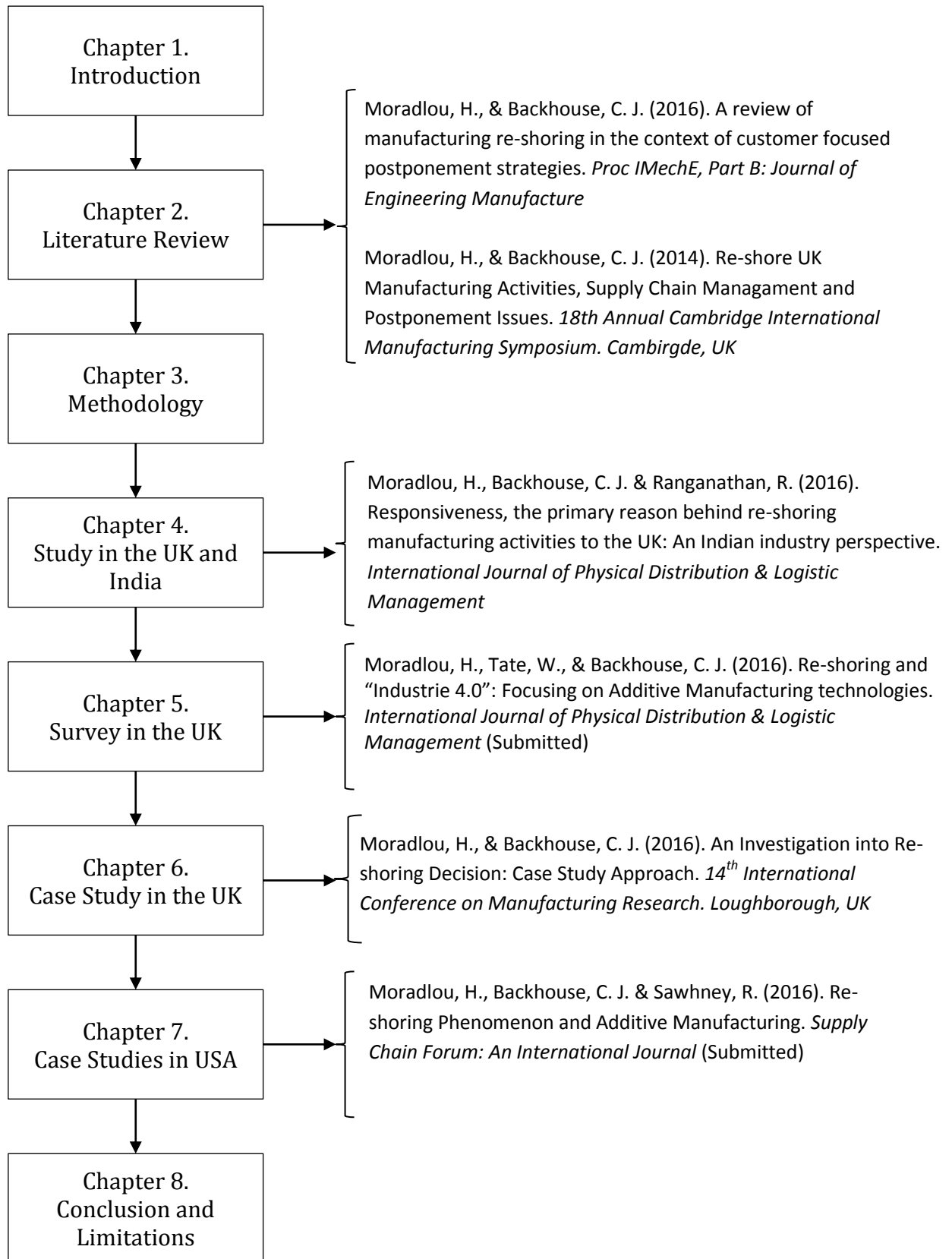


Figure 1-3, Research Publications

## **Chapter 2. Literature Review**

### **(Re-shoring and Offshoring, New generation of technologies, Postponement and Additive Manufacturing)**

#### **2.1 Overview**

The purpose of this chapter is to provide a foundation for the thesis based on the literature available on the subject of re-shoring. It provides an insight to the gap in the current literature and identifies the areas where further research is required. This section of the thesis can be divided into two subsections. The primary concentration of the first subsection is to explore the re-shoring phenomenon in the UK and study the reasons behind re-shoring manufacturing activities and the issues related to the supply chain management. It begins with an intensive review on the nature of re-shoring by comparing the existing definitions and explores different types of re-shoring strategies. It then moves into identifying the reasons that drive re-shoring decisions. In addition it classifies the motivations behind re-shoring into two main categories of expected and unexpected costs.

The second section of this chapter focuses on the future mega-trends and new generation of technologies, in other words the Industry 4.0 which is the fourth industrial revolution (Bechtold et al., 2014). According to Brettel *et al.* (2014) “the fourth industrial revolution

(Industry 4.0) will be triggered by the internet, which allows communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks”. The following subsection provides a brief literature review on the concept of Postponement and discusses different types of Postponement strategies for the purpose of production responsiveness. By looking at the Postponement literature it identifies 6 types of Postponement as follow, “ship to order, packaging to order, assemble to order, make to order, purchasing to order and engineer to order” (Yang et al., 2005a). It then progresses on to investigating different categories of AM technologies (as a type of Postponement strategy) and their impacts on the supply chain management and re-shoring. It should be noted that AM could be categorised as “Engineer to Order” type of Postponement (described in section 2.8.1) since the products are manufactured once the customer order has been fully received. This section also presents the pros and cons related to AM technologies in making prototypes as well as functional products. All the research analysis parameters in this thesis are determined first in this chapter along with a review of the literature relating to the re-shoring and AM technologies. Once the literature review was completed, the gap in the existing knowledge was identified which determines the bases of this research. Using the outcome of this chapter, “Chapter 3” discusses the research questions and the methodologies required in addressing them.

## **2.2 Introduction**

In today’s internationalised world, manufacturing enterprises are obliged to operate within far more complicated and longer supply chains than in the past. Businesses are forced to structure their supply chain around global configurations to remain competitive in a dynamic market (Bechtold et al., 2014). By doing so they can access cheap labour, raw materials, larger market as well as take advantage of the incentives offered by the host governments for foreign investments (Manuj and Mentzer, 2008). Consequently, the trend for expanding and contracting across the globe has become popular across all industries with the aim of ultimately reducing the production costs and gaining competitive advantage (Crinò, 2009). This involves strategic planning in terms of sourcing from locations that offer the lowest procurement rates, moving manufacturing and assembly to the low-cost countries and finally marketing in regions that have the highest potential customer demands (AlHashim, 1980).

Western industries started to shift their production to the low-cost countries, that is, Eastern Europe and Asia, in the 1990s, as an activity which is commonly known as ‘offshoring’ (Crinò, 2009). This trend began by moving the low-skilled jobs such as simple assembly processes for high-volume commodity-type products to the developing countries. However, with the help of communication technologies and easier access to educational channels, these developing countries are now capable of providing a far more sophisticated labour force. Consequently this is one of the reasons behind the dramatic decrease in manufacturing jobs in some of the developed countries such as United States, Germany, France and United Kingdom (Herath and Kishore, 2009).

However according to Fine (2013) during the recent years “the big names at the end of the chain have come to realise that the lowest price can mean highest risk – and highest risk can mean high total costs”. Therefore, when it comes to manufacturing location decisions, industries have begun to pay more attention to unexpected factors such as the supply chain reliability issues and strategic factors rather than simply considering unit part cost (Fratocchi et al., 2014; Tate, 2014). Additionally, the issue of brand reputation and the risk to companies of being exposed in the transparent global supply chains imposes greater ethical and long-term manufacturing location decisions (Ellram, 2013). Having considered the discrepancy between the initially estimated cost of offshoring and those actually incurred from the unexpected costs, it is evident that there are tendencies for companies to reverse offshoring strategies and re-shore their manufacturing activities (Gray et al., 2013). Companies have performed rigorous risk by analysis considering total cost and taking supply chain perspectives into account when making manufacturing location decisions. They no longer rely solely on cost aspects of the production (Ellram, 2013). Nonetheless, it is essential for the company to perform an in-depth research to identify the risks associated with their location decision as well as outsourcing and insourcing strategies.

It is evident both in the literature and in the media that the industries and jobs that are returning to the developed countries will be different to the labour-intensive activities that were previously offshored (Fine, 2013; RBR, 2014). Due to these changes it is believed that the only way for a long lasting and a sustainable re-shoring strategy is fundamental transformation of the current industrial production. In a report written by Tata Consultancy Service (TCS), these transformations are called “Reinvented Manufacturing” (TATA Consultancy Service, 2013a). Meanwhile PA Manufacturing Group claim that quality and costs issues are unlikely to be the primary reason for the long-term repatriation of

production from low cost countries (Lawrence and Vasak, 2014). Seven mega-trends were identified by Tata Consulting Service (TCS) as result in order to present a new direction to manufacturing industries (TATA Consultancy Service, 2013a). Note that the term “seven mega-trend” was coined by TCS. These mega-trends are as follows:

1. ‘Consumerisation’ of manufacturing – from B2B to B2B2C;
2. Virtualisation and Digitisation for all – global collaboration from product design to customer service;
3. Supply chain network economy for better management of B2C aspiration;
4. Complexity reduction and Modularisation of business;
5. Product design, material science and sustainability;
6. Next-gen technology – hybrid crossover solutions;
7. Evolution of the manufacturing model.

The new mega trends also emphasise the significance of integrating the new generation of technologies within manufacturing activities that are being re-shored. This study aims to investigate the relationship between re-shoring phenomenon and the new generation of technologies, particularly AM technologies in the context of supply chain management.

In the early stages of this study, the concept of Postponement was identified to offer a wide range of benefits that can ultimately align the companies that have re-shored and are operating in volatile business environments, with these mega-trends. Postponement essentially refers to delaying activities (as to the form and/or place of goods) until the latest possible point in time (Yang et al., 2004a). Thus this chapter also aims to determine from the literature the feasibility of a manufacturing strategy, Postponement, as a possible solution for the companies to adjust and cope with the volatile customer demands and new generation of technologies towards more responsive production and customisable products.

In this research an exploratory literature review has been conducted to provide a better understanding of the term re-shoring which is commonly used in the media, industrial

reports and academic literature. However due to immaturity of the concept various names have been dedicated to this strategy such as “on-shoring”, “back-shoring”, “home-shoring”, “re-distributed manufacturing” and “repatriating manufacturing” (Fratocchi et al., 2013). This chapter also discusses the significance of re-shoring to the UK economy starting with a brief explanation of the governmental incentives for the companies that are planning to re-shore their production activities back to the UK. This is then followed by a discussion of the concept of re-shoring. In this section various types of re-shoring are introduced and the areas in which re-shoring is applicable are stated. After that the main motivations behind re-shoring are discussed. This includes the expected and unexpected costs.

The final part discusses the nature of new generation of technologies coming back to the developed countries also known as Industry 4.0. This study focuses on the AM technologies as a type of Postponement strategy, which can also be considered as an enabler of new generation of technologies.



## 2.3 Offshoring

Offshoring is a term widely used in the industry to refer to a strategy in which parts of, or entire manufacturing facilities are moved to a foreign location that would allow them to serve the global demand as well as meeting the local requirements. However the term offshoring is commonly associated with outsourcing strategy (Metters and Verma, 2008). Whereas it should be noted that offshoring and outsourcing are two separate concepts (Davis et al., 2006). Outsourcing describes the allocation of jobs and processes to an external party irrespective to the location of the supplier. Therefore the supplier could be located in the home country or overseas. On the other hand offshoring refers relocation of jobs to a foreign location (Olsen, 2006). The concept of offshoring has been a common practice in manufacturing and service industries (Amiti and Wei, 2005) to the point where even the Small and Medium Enterprises (SMEs) now have engaged in the international market (Roza et al., 2011). According to TPI (2007), European companies have aggressively shifted their manufacturing facilities to the low-cost countries making Asia the world's biggest location for offshoring.

The growing interest in offshoring strategies has led to an increase in the number of studies performed to better understand how offshoring can be used to create value in the supply chain (Kedia and Mukherjee, 2009). Consequently there has been number of definitions associated with the offshoring concept throughout the years. For instance in one of the recent studies Kumar et al. (2009) define offshoring as “transferring or sharing management control and/or decision making of a business function to a supplier in a different country, which entails a degree of two-way information exchange, coordination and trust between the overseas supplier and its client”. However this perspective does not address the scenario in which the parent company owns the entire facilities in a foreign location. For instance scholars such as Kedia and Mukherjee, (2009) take this into account and define offshoring as relocation of a firm's business functions to overseas locations as a result of advancement in information and communication technologies.

These definitions include concepts that can be described as the internal and external offshoring. The internal offshoring essentially means to establish production facilities or subsidiaries in a foreign location that is under the firm's full control, in other words “captive offshoring”. On the other hand external offshoring is when an independent

foreign supplier is in charge of the business function, which is also called “offshore outsourcing” (Kedia and Mukherjee, 2009).

Despite the scale of offshoring strategies being implemented every year, the results reported shows lower success rate than what was expected (Herath and Kishore, 2009). This has ultimately led to numerous studies on investigation of offshoring-outsourcing risk management. Some of the examples of these studies are Kumar et al. (2009) where areas such as transaction, financial, value, socio-economic, country risks are studied. Another example is by Herath & Kishore (2009) where the offshoring risks are categories in four different categories. These are Strategic Decision Challenges, Vendor Selection Challenges, Vendor Management Challenges and Technology Challenges. Thun & Hoenig (2011) also study the offshoring risks by assessing the vulnerability of supply chains in general and identifying the key drivers of supply chain risks.

The contribution of offshoring to the complexity of operational processes across the country as well as the reduction in manufacturing jobs has stimulated various opinions for overcoming the problems caused by it. The suggestions can be classified into four groups (Atkinson, 2004). First one is to “ignore and do nothing” which considers offshoring not as a challenge for the country’s economy. Secondly to “reject and protect” for promotion of anti-globalisation and penalisation of offshoring. Next one is “subsidise and hand-out” in order to cut tax and support the industries to compete with their competitors in low-cost countries. Last but not least “adapt and innovate” to increase firm’s productivity and agility (Atkinson, 2004).

In addition, offshoring strategy has faced number of challenges over the past years. According to Crinò (2009) over the last two decades there have been various protests by the opponents of globalisation, against offshoring and other types of foreign activities employed by the multinational companies. The purpose of these protests was to convince the government to impose stricter policies that would limit the company’s international activities due to their negative influence on the economic fortunes of domestic employees (Crinò, 2009). The next section is an introduction to re-shoring strategies which appears to be the reverse approach to the offshoring decision.

## **2.4 Re-shoring or Back-shoring**

Recently companies have begun to establish a better understanding of the total cost of production and base their manufacturing location decisions on supply chain issue and strategic factors rather than simply relying on piece part production costs (Ellram, 2013). For this reason the decision on reversing the previous offshoring strategy has gained substantial momentum. However, despite the significance of this phenomenon, the supply chain literature has not received sufficient attention by the academics (Ellram, 2013). Therefore due to the immaturity of the concept, several names have been dedicated in the existing literature such as “on-shoring”, “back-shoring”, “home-shoring”, “re-distributed manufacturing” and “repatriating manufacturing” (Fratocchi et al., 2013; Kinkel and Maloca, 2009).

It is evident in the literature that reversing offshoring decisions is not a new phenomenon. There are a number of studies performed under different titles such as “de-internationalisation” and “international divestment”. The term “de-internationalisation”, was first introduced by Welch & Luostarinen (1988). Benito & Welch (1997) define de-internationalisation as any activities, voluntary or compulsory, that decreases a company’s engagement in present cross-border activities. The analysis in this study was carried out from three theoretical perspectives: economic, strategic management and internationalisation management. There are number of other scholars that have also contributed to the concept of de-internationalisation in terms of establishment of conceptual framework and classification of various de-internationalisation modes (Calof and Beamish, 1995; Turcan et al., 2010). On the other hand the concept of international divestment defines the reduction of level of ownership in company’s direct foreign investment regardless of decision voluntariness (Boddewyn, 1979). However these concepts, de-internationalisation and international divestment, are lacking some of the key features of re-shoring phenomenon such as outsourced production. Another factor that these studies do not particularly demonstrate is the relocation of the facilities to the home country.

One of the most recent studies that investigate the offshoring reverse decision was conducted by Gray et al. (2013). In this American-based study, the term re-shoring was used where the major emphasis was on the location decision and their consequences on manufacturing companies. According to Gray et al. (2013) “Re-shoring, as such, is

fundamentally concerned with where the manufacturing activities are to be performed, independent of who is performing the manufacturing activities in question – a location decision only as opposed to a decision regarding location and ownership”. Moreover in the same study after establishing a better definition of the re-shoring phenomenon, Gray et al. (2013) have emphasised that the re-shoring should be assessed as a reversion of a prior offshoring strategy rather than in isolation. Another study, using the term re-shoring, was undertaken by Ellram et al. (2013) where re-shoring is defined as “moving manufacturing back to the country of its parent company”. This study likewise uses the data from a survey among American companies to explore the reasons that influence the organisation’s manufacturing location decision in the United States (US). In order to establish better understanding of the location assessment, the factors influencing these decisions according to various regions were investigated. The results obtained from this study state that the importance of supply chain characteristics varies according to different regions across the globe. However, it is important to note that the findings in this study only focus on the wholly owned manufacturing facilities in foreign locations and do not address the scenarios such as re-shoring products that were previously outsourced to other foreign suppliers.

The term back-shoring is an alternative name which is frequently used in the recent literature to refer to re-shoring phenomenon. Kinkel & Maloca (2009) are among the scholars that have made major contributions to this concept. According to Kinkel & Maloca (2009), back-shoring is defined as a process of returning full or part of the production from fully owned facilities in foreign locations or a foreign supplier to the company’s domestic site. Unlike studies performed by other researchers, in this analysis, Kinkel & Maloca (2009) claim “Back-shoring activities are predominantly short-term correction of prior misjudgement in offshoring decisions rather than long-term adjustment to changing conditions at the foreign location”. This study was carried out based on the data obtained from German Manufacturing Survey 2006 (Fraunhofer Institute of System and Innovation Research). However, one element that has not been mentioned in this German study is the voluntariness of the back-shoring decision. For this reason, the study completed by Fraticchi et al., (2014), which used the term back-reshoring, proposes a unified and operative definition. According to this study Back-reshoring is “a voluntary corporate strategy regarding the home country’s partial or total relocation of (in-sourced or out-sourced) production to serve the local, regional or global demand”.

In order to identify the main features of re-shoring phenomenon, Fratocchi et al. (2014) have used a comparative analysis of the re-shoring definition found in the existing literature. As a result of this study, three main characteristics of re-shoring concept were found. First, it is a decision to reverse a previous decision to offshore facilities. Second, re-shoring can comprise only partial repatriation and does not imply closure of the entire production facilities in the offshored location. Third, re-shoring decision determines the relocation of the facilities back to the home country regardless of the ownership mode (insourcing and outsourcing) (Fratocchi et al., 2014). Table 2-1 summarises the different concepts available on re-shoring or similar topics and shows the differences between them.

<b>Concept</b>	<b>Definition</b>	<b>Differences</b>
<b>Back-reshoring</b>	A voluntary corporate strategy regarding the home country's partial or total relocation of (in-sourced or out-sourced) production to serve the local, regional or global demand (Fratocchi et al., 2015)	The study fully covers voluntariness on the back-reshoring decisions
<b>Re-shoring</b>	Brining manufacturing back to the country of parent company (Ellram, 2013; Gray et al., 2013)	The study does not address the voluntariness of the back-shoring decisions
<b>Back-shoring</b>	Repatriation of parts of production from own manufacturing facilities as well as a foreign supplier to the home country (Kinkel & Maloca 2009)	The study does not address the voluntariness of the back-shoring decisions
<b>De-internationalisation</b>	A voluntary or forced decision to reduce the companies engagement in manufacturing activities in a foreign location (Benito and Welch, 1997)	The study does not specify the repatriation back to the home country. It also does not talk about insourcing and outsourcing
<b>International divestment</b>	A voluntary or involuntary reduction in the percentage of ownership in companies direct investment (Boddewyn, 1979)	The study does not specify the repatriation back to the home country. It also does not talk about insourcing and outsourcing

**Table 2-1, Different concepts of re-shoring and comparison**

### **2.4.1 Types of re-shoring**

As it was mentioned in the previous section, the re-shoring phenomenon can happen independent to the facility ownership. This includes both insourced and outsourced production. Therefore, manufacturing re-shoring can be considered from company boundaries (insourcing and outsourcing) and geographical boundaries (home country and foreign country) perspectives (See Figure 2-1) (Gray et al., 2013). As a result, four possible re-shoring strategies can be identified. These four strategies are different from each other, but they share the element of location decision. These scenarios are listed below:

- In-house re-shoring, where companies supply their domestic market by repatriating the entirety or part of their wholly owned manufacturing facilities from the foreign country to wholly owned facilities in the UK.
- Re-shoring for outsourcing, where companies supply their domestic market by shifting the manufacturing activities from wholly owned manufacturing facilities from the offshored location to a UK-based supplier.
- Re-shoring for insourcing, where companies supply their domestic market by changing the companies' sourcing strategy from offshored suppliers to wholly owned manufacturing facilities in the UK.
- Outsourced re-shoring, where companies supply their domestic market by converting their supply mode from offshored suppliers to UK-based suppliers. (Gray et al., 2013)

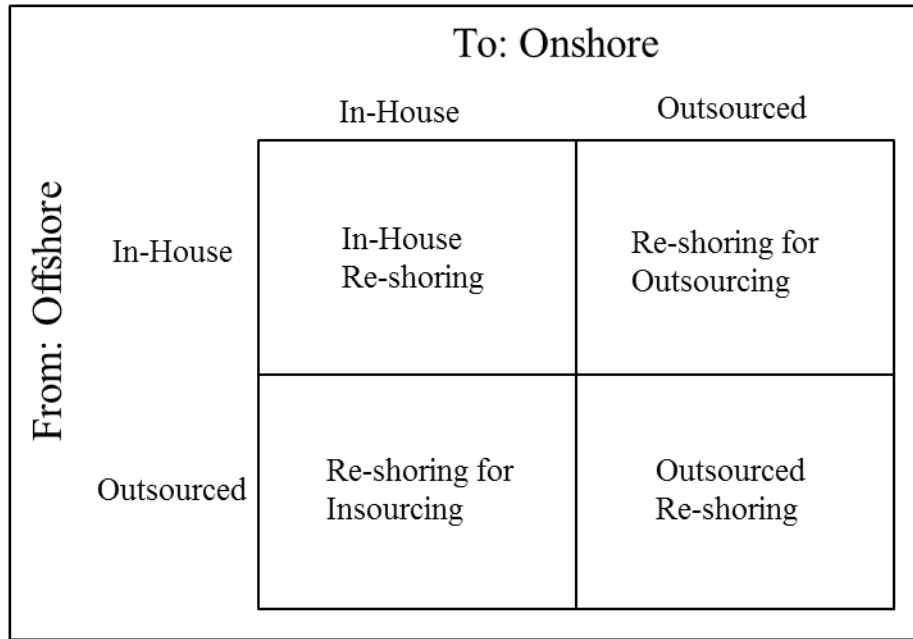


Figure 2-1, Re-shoring Options (Gray et al. 2013)

#### 2.4.2 Predicted Industries for re-shoring

Despite the popularity of the re-shoring, this strategy can only be economically justified in number of manufacturing industries (McMeekin and McMackin, 2012). The areas in which the re-shoring movement is happening in the UK is still under investigation (Cranfield University, 2015; EEF, 2014a). However according to the UK Automotive Council (2015), automotive industries have the highest potentials to repatriate the suppliers from low cost countries by identifying the fact that the UK is now capable of manufacturing 80% of the automotive parts in the country.

According to the study done by the Sirkin et al. (2012) at Boston Consulting Group, there are a number of tipping point industries in the US where re-shoring manufacturing is more likely to occur. The prediction is made according to the volume of the trade between US and Asian suppliers and rise in the cost of production in China. These industries are as follow:

- Transportation equipment (e.g. automotive, aircraft parts, motorbikes,)
- Electrical equipment's and appliance (e.g. refrigerators, dishwashers, microwaves)
- Computer industries and electronics
- Machinery (e.g. air conditioner, heaters, office equipment, agricultural tools)

- Furniture industry (e.g. high end clothing, home furnishing)
- Fabricated metals, rubber and plastics (e.g. plumping fixtures, pots and pans, tires, bottles) (Sirkin et al., 2012).

### **2.4.3 Motivations for re-shoring**

According to Leibl et al., (2009), most offshoring decisions are taken without evaluating a clear picture of total costs versus total benefits. This leaves the companies with the problem of facing various costs also mentioned as ‘hidden costs’ by various scholars (Ellram, 2013; Leibl et al., 2011). In this section, the main motivations behind the re-shoring decisions are discussed. Figure 2-2 illustrates the main motivations behind the re-shoring decisions and identifies hidden costs. After a comprehensive literature review, the costs were classified into two main categories, namely, the expected and unexpected costs (Cranfield University, 2015; EEF, 2014b; Ellram, 2013; Fratocchi et al., 2013, 2014; Gray et al., 2013, 2011; Kinkel, 2012; Leibl et al., 2011). The diagram captures the variety of elements studied in the re-shoring literature and provides a big picture of the costs that determine the success or failure of a manufacturing location decision.

However according to the study done by Leibl et al., (2011), the significance of these costs influencing the re-shoring decisions, varies according to different countries. For instance in recent years, ongoing studies have been performed to investigate the feasibility of the re-shoring strategy within the UK. Based on the latest Manufacturing Advisory Service Barometer, the costs, quality and reducing delivery time were recognised to be the main three reasons respectively, driving the re-shoring decisions in the UK (MAS, 2014). Nonetheless the factors for the French companies appear to be different to that of the UK. According to Bellego, (2014) the most important factors for the French industries were the transport and operational costs followed by the quality and lack of internal competence. In addition this study divides the re-shoring movement into three types namely, tactical re-shoring, home re-shoring and development re-shoring and identifies different motivations for each type of re-shoring.

In this section, it is aimed to identify the factors that can be applied for the majority of the companies regardless of where the companies are based. The diagram below (Figure 2-2) illustrates different examples of expected and unexpected costs. The left hand side shows



the expected costs which are possible to predict and the right side indicates the unexpected costs which are more challenging to estimate prior to the relocation. The middle section represents the costs that can be calculated but are not entirely under the control of the companies. These factors appear to be influenced by government decisions and socio-political issues such as exchange rates, environmental legislations, fluctuations in the fuel price and coordination costs. The following section contains a brief description of some of the offshoring costs mentioned in Figure 2-2.

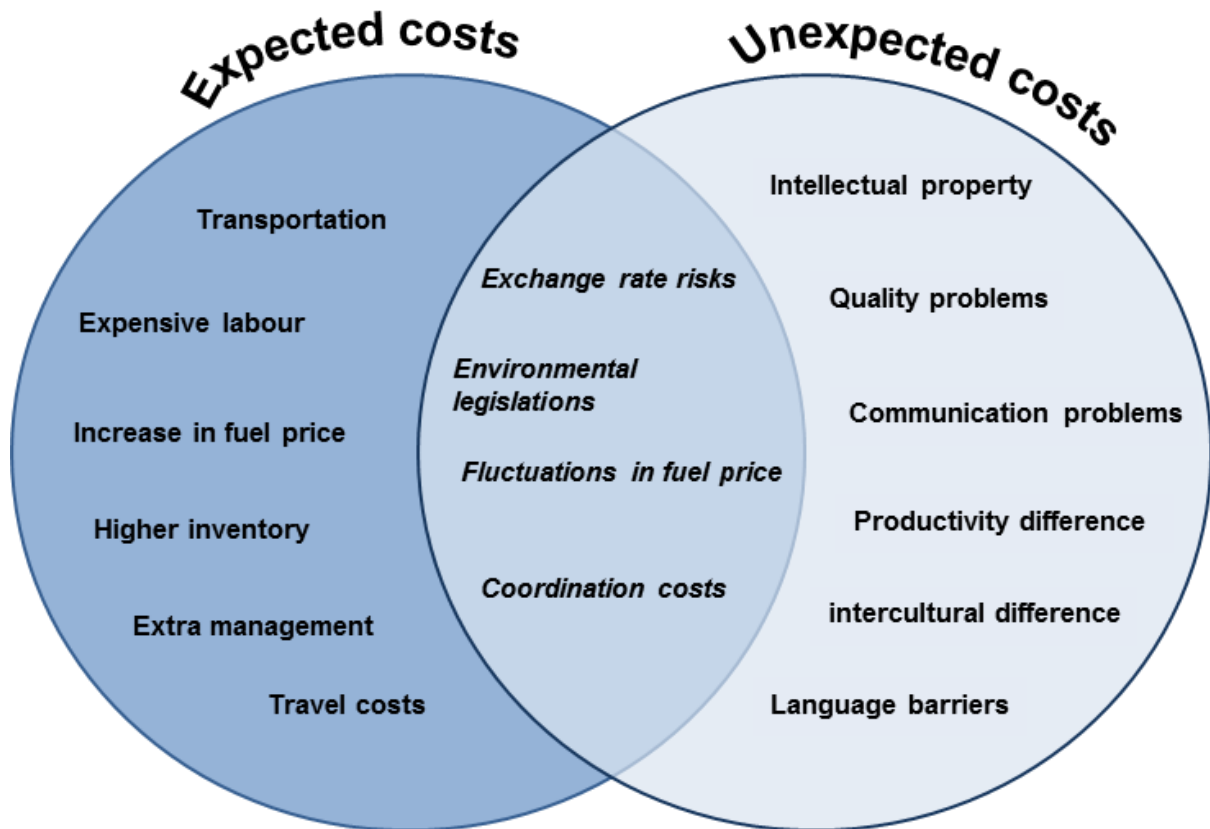


Figure 2-2, Expected and Unexpected costs

#### 2.4.3.1 Expected Costs

The left-hand side shows the factors that are distinctive to any relocation strategy and the companies can have an approximation of the costs associated with them. In other words, companies are capable of picturing these costs prior to the relocation to a foreign location. Noteworthy direct factors imposing a change on the offshoring trend are transportation costs and volatile fuel prices (Venables and Behar, 2010). These factors made the transportation cost more important relative to other costs such as inventory, production and facility fix costs (Simchi-Levi, 2011). Moreover, with the adoption of slow steaming

practices for the shipping industry, to reduce the fuel oil costs, the global supply chain slowed down considerably making re-shoring a more attractive strategy (Tate et al. 2014; Hull 2005). For instance according to Solomon (2012) transit time from Shanghai to the West Coast in the US has gone from 15 to 17 days, and to the East Coast it has increased from 29 to 36 days. The longer the supply chains become, the transfer of goods get slower and therefore ultimately it leads to an increase in the capital required as well as the risk of failing the on-time delivery. Clearly in 2015, the reduction in the oil price will again change the impact of this factor; however, it is too early to see the effect of this on re-shoring decisions. On the other hand, the reinforcement on the environmentally concerned legislations, specifically on the carbon emission, has placed an unprecedented pressure on the transportations costs (Ellram, 2013).

Another potential cost is the dramatic increase in the labour cost in the low-wage countries. This is considered to be the next important factor influencing offshoring decisions. Wage rate differential between the western countries and countries in far-east Asia was one of the critical drivers for the offshoring decisions. However, this gap is gradually decreasing as the wages are rising due to the higher expectations of labour and continuous strikes due to lack of attention to working conditions (Kianian et al., 2015). According to Nakayama et al. (2014) the difference between the labour cost in the city of Shanghai and other major cities in China was 30% cheaper than the labour cost in the US. However this gap has been decreasing dramatically in the recent years. One example of significant increase in labour costs occurred in Honda, which led to 47% increase in wages of Chinese employees in 2010 (Tavasolli, 2013). Furthermore according to Fishman (2012), the difference between the labour productivity ratio in western countries and Asia is another contributor that supports re-shoring strategy.

Meanwhile the unexpected travelling requirements can impose substantial costs on the company during the transition stage when the program managers, team leaders and the business owners need to be frequently present at the offshore location (Kianian et al., 2015). In this early stage, the experienced members of the organisation are required to be travelling to the low cost country to provide sufficient amount of training to the less experienced workers on the site (Leibl et al., 2009).

#### **2.4.3.2 Unexpected Costs**

The second category consists of the expenses that are not easy to quantify and require rigorous risk analysis. These costs appear to be challenging to predict prior to the relocation to foreign location (Leibl et al., 2011). These costs normally play a very important role in manufacturing location decisions but companies will often not learn about them before starting to offshore (Gray et al., 2013) and also are listed among the motives behind the re-shoring decisions (Cranfield University, 2015; EEF, 2014a).

The first major issue is the inconsistency in the quality of the products. According to the survey carried out by Engineering Employers Federation (EEF, 2014a), quality appears to be the predominant reason for the competitive advantage in the UK therefore, maintaining the high quality is considered to be the primary goal. In addition, the study performed by Gray et al. (2011) shows this by identifying the difficulties in controlling the factors that can potentially affect quality of the products when being involved in offshore manufacturing. It also indicates the absence of accessible measures for the quality of products that are consistent across geographic regions. The next common problem associated with offshoring is the miscommunications. This can be seen in terms of misunderstood requirements, design mistakes and problems with the phone systems and language barrier that can cause frustrations during the calls. Nevertheless this can be considered as one of the main reasons for quality issues.

Offshoring can also reduce a company's flexibility of the production in addressing the issues related to the fast changes in the market conditions. By locating the manufacturing facilities closer to the end customer, quicker responses to the changes can be ensured due to shorter supply chains and better understanding of the market (Gray et al., 2013). This also enhances the capability of the company to recover in the case of any disruption in the supply chain (Fishman, 2012). Offshoring can also increase the lead-time when last minute changes are required in the product design.

In addition, the problems caused by the time differences between the countries can be eliminated by re-shoring since the major part of the supply chain is located in one geographical location. For instance the time difference between US (Washington DC) and China (Beijing) is 12 hours causing delays in communications during the office hours. Another significant drawbacks related to moving the business abroad, is the protection of sensitive information. Despite of having laws to protect the Intellectual Properties (IP) in

countries such as China, the confidential data about innovative and new products are still vulnerable being exposed in a foreign market (Ellram et al., 2013). Study completed by Wang (2004) shows that “in the 25 countries with the highest software piracy rates, China stands in second place among the offenders, with a software piracy rate of 92% in 2001”. Furthermore Tate (2014) backs this up by giving an example of an Indian employee in a reputable software company deciding to transfer some of the key information to her personal email account and disappear without being charged guilty in India.

Another contributor to the unquantifiable costs is the cultural differences between the targeted country and the home country. These differences appear to be greater in Eastern Asian countries (Zimmerman, 2013). Examples include diverse attitude on the product quality as well as the value perceived. Cultural differences can also influence the view towards product IP within the governments as Zimmerman (2013) states “Reviewing the history of intellectual property (IP) in China it is clear that Chinese political culture did not lend itself to the concept of IP ownership”. In addition to these, different countries adopt different approaches on the communications and negotiations (Leibl et al., 2009).

Having identified a series of expected and unexpected costs, the companies can take the necessary actions to minimise or eliminate the potential offshoring risks. According to the case studies completed in the UK and US, by employing re-shoring strategies, a wide range of hidden costs can be reduced (EEF, 2014a; Reshoring Initiative, 2015). The case study completed by EEF, Martin Rubber Company was one of the examples of businesses that witnessed the difficulty in sourcing from low-labour-cost countries. This company is involved in providing design and development service to the customers who were using overseas suppliers in China. Nevertheless, Martin Rubber Company is seeing a steady flow of companies looking for the UK suppliers to counteract offshore production characterised by long lead times, inconsistency product quality and communication break-down with the foreign suppliers (EEF, 2014a).

The Figure 2-3 illustrates some of the potential benefits that can be achieved by re-shoring the production activities to the home country. This Figure is based on the literature review and the case studies illustrated by the EEF (2014a) and Reshoring Initiative (2015). It should be noted that the diagram below only represent the benefits associated with the supply, demand and operations. However re-shoring also offers other advantages such as creation of jobs in the home country, reduced political uncertainties, access to the

governmental incentives and also tax benefits. In addition Figure 2-4 illustrates the overall picture showing the effect of re-shoring from time perspectives that is required to take the product from factory to market (Bishop, 2011).

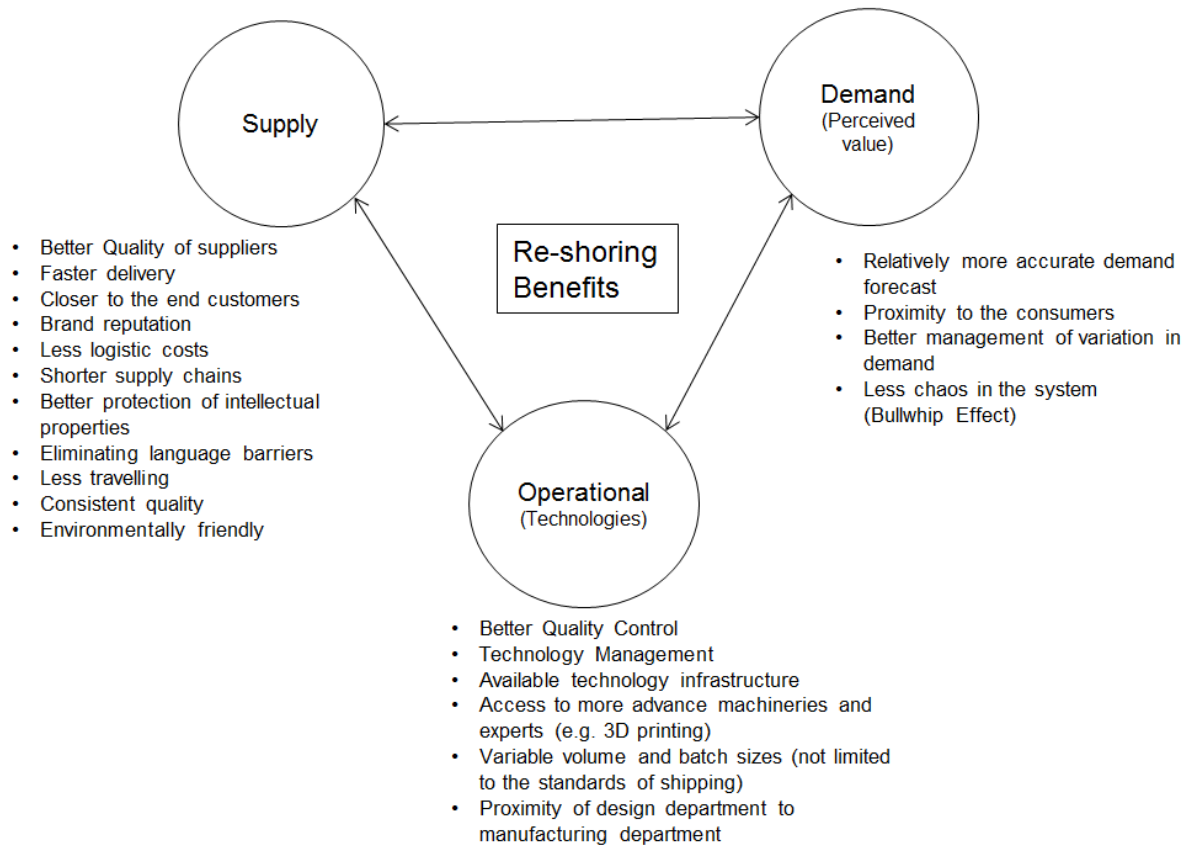


Figure 2-3, Re-shoring benefits from Supply, Demand and Operational perspectives

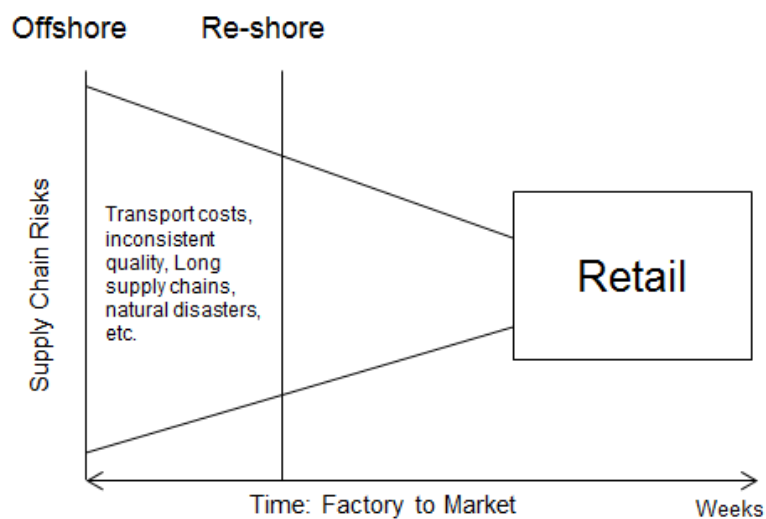


Figure 2-4, Effect of re-shoring strategy on product delivery time from factory to market (Bishop 2011)

Having mentioned the potential advantages of implementing re-shoring decision in terms of demand, supply and operation, there are also some shortcomings that the companies might face when going back to the parent (host) country. The following is a brief explanation of each shortcoming.

- **Hollow-out supply chain.** This is considered to be the main problem that the re-shoring companies would face when they repatriate their manufacturing activities back to their countries. Once the companies decide to move their production activities overseas they are required replacing the suppliers from a domestic supplier to a foreign supplier. This can gradually shift all the suppliers overseas and ultimately decrease the supplying capability of the country. In other words lose the suppliers that were previously used to supply the parts and component to the OEMs (Shih 2014).
- **Shortage of skills.** This is another problem that the companies need to consider when making relocation plan. The repatriation of manufacturing activities requires further recruitment of skilled workers in the parent company. Having considered the shift of manufacturing job to the low cost countries, the demand for skilled manufacturing manpower has also shrunk. This can indicate that the size of available workforce in developed countries such as the UK has been reduced over the time since the start of offshoring strategies (Bailey and De Propris, 2014).
- **Shortage of material and other resources.** One of the factors behind offshoring strategies was to access to source of raw materials in countries such as China and India. Hence the repatriation of manufacturing activities can be influenced by the shortage of raw materials and minerals in western countries. Therefore in order to procure the required materials overseas suppliers must be still used which can ultimately lead to higher costs for the company.
- **Available market.** It should be noted that this study focuses on the companies that re-shore their production in order to serve the domestic demand or similarly a closer market. Therefore re-shoring is most likely to be less beneficial for

companies that still want to be present in the overseas market (Bailey and De Propriis, 2014).

## **2.5 UK government incentives**

In order for the UK government to adopt an integrated vision to support the re-shoring movement in terms of policymaking, energy cost and supply of skills, “Re-shore UK” was established. This was launched in 2014 by collaboration between the UK Trade and Investment (UKTI) and the Manufacturing Advisory Service (MAS) resulting in a one-stop-shop service to help industries to return their production back to the UK (GOV.UK Press release, 2014). Re-shore UK was aimed at supporting the UK SME’s to be globally competitive and be a suitable substitute for the foreign suppliers. Additionally it would provide essential services for the selection of appropriate location as well as recommending individuals to assist the companies when advice was required. According to the UKTI, one in six companies has repatriated parts of their production back to the UK since 2011 (EEF, 2014a; GOV.UK Press release, 2014) however the types of the industries and the sizes have not been specified. The re-shoring has resulted in the creation of 1,500 manufacturing jobs in the UK. The number of jobs returning home appears to be insignificant in comparison with the ones which were offshored previously, but it is crucial to inform the businesses, Small and Medium Enterprises (SMEs) as well as Multinational Cooperation (MNC), about the key factors that drive re-shoring and other location decisions. When it comes to decision making for the manufacturing locations, criteria can change over the time. This can be seen as the companies have begun to establish a better understanding of the total cost and base their manufacturing location decisions on supply chain issue and strategic factors rather than simply relying on cost (Ellram, 2013).

Such schemes are not confined to the UK. Re-shoring Initiative is an American organisation, which was first established in 2010 that aims to bring back jobs to the United States. This organisation puts the main emphasise on the localisation of manufacturing activities in the US. It provides training for the suppliers in the US to effectively meet the requirement to satisfy domestic demand. As a result this organisation aims to introduce the benefits of bringing back the manufacturing activities and start producing in the US. In order to do so, it has created a total cost of ownership estimator (Reshoring Initiative, 2016) which helps the manufacturers to determine a company’s profit and loss impact of the

manufacturing location decision (re-shoring and offshoring). It has also been used as a model to develop an online platform in the UK where the British manufacturers can calculate their total cost of ownership in the case of re-shoring to the UK (Cranfield University, 2015).

## **2.6 Nature of new technologies**

As manufacturing industries are witnessing an unprecedented increase in global competition on cost and quality, there is a significant desire towards more customisation and shorter time to market that necessarily require novel production strategies (Brettel et al., 2014). Hence there is a need towards more integrated networks of businesses where they share their core competencies (RBR, 2014). In today's world, manufacturing industry is experiencing a significant change in the business ecosystem as a result of ever-increasing complexity in customer behaviour, technological development as well as competitive environment (TATA Consultancy Service, 2013b). However PA Manufacturing Group claim that quality and costs issues are unlikely to be the reason for the long-term repatriation of production from low cost countries (Lawrence and Vasak, 2014). Instead it is believed that the only way for a long lasting and sustainable re-shoring strategy is fundamental transformation of the current industrial production. In other words, it will not be economically feasible to repatriate the same manufacturing tasks, such as labour and energy intensive activities, that were previously offshored.

A new generation of manufacturing activities are required to adopt modern technologies such as AM, intelligent robotics, big data and internet of things, by which industries will ensure their competitive position in the market (Bechtold et al. 2014; Lawrence 2015). It is believed that "Upcoming industrial revolution will be triggered by the internet, which allows communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks" (Brettel et al., 2014). This is also called the fourth industrial revolution (Industry 4.0) in which virtualisation, decentralisation and network building will change the manufacturing landscape.

One of the major focuses in the concept of Industry 4.0 is the personalisation of the product by moving from mass production towards mass customisation in order to address the ever-changing customer expectations. By doing so, industry can achieve higher product



variety while keeping production volume low. It is also aimed at reducing the time to market and have a more flexible production by employing new technologies and materials. Modern manufacturing organisations should collaborate from all around the world to cope with the dramatic changes in the market (Soo et al., 2002).

Physically distributed manufacturing architecture and teams is another enabler for reinvention of manufacturing that combines organisations from different locations and allows them to contribute their main capabilities into the business (Stevenson and Spring, 2007). The temporary alliance of these businesses can be managed by utilisation of systems that integrate all the organisations involved in the business. In order to develop such environments virtual enterprise can be utilised. The virtual enterprise is the collaborative network of businesses that share their core competencies in order to pursue a mutual goal, which is to respond to business opportunities (Backhouse and Burns, 1999). For instance, in such collaboration, one organisation takes the responsibility of product design whilst the other provides the manufacturing data supports. In order to develop a virtual enterprise and distributed manufacturing architecture, it is vital for the business to establish an appropriate partnership with the involving partners to ensure the fastest response to the market changes (Bechtold et al., 2014). The establishment of the rapid partnership is based on the partner's delivery capabilities, the quality of the products, infrastructure and the level of their dependability to IT. The key objectives of forming a rapid partnership would be to integrate the technical knowledge as well as marketing skills in order to remain competitive against other manufacturing organisations (Gunasekaran, 1998).

According to the PA Manufacturing Group the reinvention of manufacturing will provide new business opportunities and models for the home based local manufacturer. Among these new technological opportunities, big data, intelligent robots, 3D printing and self-assembly nano-machines and utilisation of new materials such as nanotechnologies, cyber materials and green plastics were mentioned (Lawrence and Vasak, 2014).

Meanwhile another study conducted by Tata Consultancy Group (TCG) states that the future of manufacturing needs to be aligned with seven mega trends in order to address problems caused by the evolving technological landscape. These mega trends are as follow:

- Consumerisation of manufacturing. In other words shifting the focus from Business-to-Business (B2B) to Business-to-Business-to-Consumer (B2B2C). This

involves establishment of customer-centric business system using interactive websites, digital marketing channels, Point-of-Sale (POS) systems, e-commerce.

- **Virtualisation and Digitisation.** This comprises utilisation of software to simulate, visualise, and virtualise the product behaviour and performance under virtual scenarios. Hence it enables the companies to achieve more products testing iteration in a shorter time resulting in a quicker time-to-market. The Cloud technologies can be considered as one of the way to initiate such collaborations.
- **Connected Supply Chain.** A network of interrelated supply chain that can also provide high visibility from suppliers to distributors. This would allow the companies to develop an agile production plan and maintain minimum inventory.
- **Complexity Reduction and Modularisation of Business.** Modularisation can be applied in various aspects of the business, products as well as processes. For instance by adopting standardisation and harmonisation, companies can ensure component economies of scale since similar components across product families will be used which also facilitates product updating. Moreover it increases the product variety and also reduces the order lead-time due to fewer components.
- **Product Design, Material Science and Sustainability.** This trend investigates the application of the new generation of materials with higher performances, lower costs and environmentally friendly. Moreover, companies are also obliged to consider the carbon footprint from supply perspective by intelligent sourcing and shortening the supply chains.
- **Next Gen Technology.** This includes the utilisation of embedded electronics, telematics, mobility, telecom services, and conventional engineering systems.
- **Evolution of the manufacturing model.** This indicates the requirement for a shift from large centralised companies to a network of smaller Modularised businesses that offer their core competencies and are closer to the end customers (TATA Consultancy Service, 2013a).

As a result of these mega-trends mentioned above, business processes should be transformed in order to adapt to the new technological changes and organisational policies, meanwhile the people are expected to cope and perform differently to these transformations. The following section introduces a strategy, which can potentially address some of the mega-trends recommended by the Tata Consultancy Group. It consists of a literature review on the concept of Postponement and different types of Postponement applications within industries.

## **2.7 Postponement in the context of re-shoring**

Once the relocation for the manufacturing activities has taken place, companies are required to develop an effective management strategy for their new supply chain layout that can creatively integrate and perform the logistics and production activities (Pagh and Cooper, 1998). Meanwhile, customers demanding for higher levels of product customisations have put the manufacturing industries under substantial pressure for having to deal with shorter product lifecycles. This requires an accurate planning and product demand forecast. However as the time passes this task is becoming more difficult and risky due to process complexity. To address such difficulties in production and minimise the uncertainties in demand, a supply chain strategy called Postponement is being widely used (Yang and Burns, 2003). Postponement was initially viewed, in marketing literature, as a strategy to reduce the risk and uncertainty costs associated with the differentiation (form, place, and time) of goods (Alderson, 2006). According to Yang & Burns (2003) “Postponement centres around delaying activities in the supply chain until real information about the markets are available”. This strategy can be applied in product design, process design and supply chain management (Van Hoek et al., 1999). Postponement enables the companies to identify the components that can be potentially modularised and standardised, but meanwhile can allocate the parties to their best-suited tasks. Furthermore it determines when and where the inventories are required and also indicated what components should be manufactured according to the forecast (Yang and Burns, 2003).

There are numerous studies presented which investigate different aspects of Postponement both in business and marketing as well as production management literature where earlier studies can date back to 1950 (Alderson, 1950). The reasons for the popularity of Postponement as a growing strategy in industry has been studied by academics such as Bowersox and Morash, 1989; Feitzinger and Lee, 1997; Van Hoek, 1998; Yang et al.,

2004a; Zinn and Bowersox, 1988. These studies mainly identify where, when and how to implement the Postponement strategy (Yang et al., 2005a). Table 2-2 represents a list of scholars that have made a contribution to the concept of Postponement. The left hand side shows the name of the scholar and the right hand side shows the type of Postponements that have been identified.

Bucklin (1965) and Shapiro (1984) are also among the scholars who extended the concept of Postponement investigating the speculation-Postponement applied to the distribution channels. Speculation-Postponement divides the supply chain into two parts, downstream and upstream. The speculation essentially refers to employing push approach where customer demand is needed hence it requires a demand forecast. Whereas Postponement utilises the pull system by allowing the penetration of customer specifications in product design and production process phases (Bucklin, 1965; Shapiro, 1984).

<b>Literature</b>	<b>Classification</b>
(Zinn and Bowersox, 1988)	Labeling Postponement, packing Postponement, assembling Postponement, manufacturing Postponement and time Postponement
(Bowersox and Morash, 1989)	Time Postponement, place Postponement, manufacturing/form Postponement
(Lee, 1998)	Full Postponement, logistics Postponement and form Postponement
(Pagh and Cooper, 1998)	Full speculation, logistics Postponement, manufacturing Postponement and full Postponement
(Brown et al., 2000)	Product Postponement and process Postponement
(Waller et al., 2000)	Upstream Postponement, downstream Postponement, product Postponement and place (distribution) Postponement
(Yang and Burns, 2003)	Engineering-to-order, buy-to-order, MTO, assemble-to-order, MTS, ship-to-stock and make-to-forecast
(Yang et al., 2004b)	Product development Postponement, purchasing Postponement, production Postponement and logistics Postponement

**Table 2-2, Classification of Postponement strategy** (Yeung et al., 2007)

Yang et al. (2004b) summarise the reasons behind implementation of Postponement into following bullet points:

- Shorter product life cycles,
- Increase in product variation,
- Access to the advanced technological facilities,
- Educated customer with higher expectations,
- Shorter delivery times,
- Better information and communication systems using e-commerce and
- Focus shift to overall supply chain management (Yang et al., 2004a).

To achieve these objectives, Postponement imposes modifications in supply chain that can manage, reduce or completely eliminate the impact of uncertainties in customer specifications (Davis, 1993). For instance Wadhwa et al. (2006) claim that the concept of Postponement can be applied both to internal as well as external supply chain through a collaborative strategy. According to Mason-Jones & Towill (1998) uncertainties related to the supply chain can fall into four categories namely supply side, process side, control side and demand side.

Figure 2-5 illustrates how Postponement is related to the seven-mega trends and re-shoring. It also shows the main areas that AM and Postponement can be implemented. As shown in the diagram, the challenges associated with the re-shoring phenomenon can be divided into business side and the manufacturing side. The business challenges can comprise factors such as policies, tax, tariffs and government incentives (Bailey and De Propriis, 2014). However this study does not aim to investigate the business oriented challenges related to re-shoring. On the other hand there are manufacturing challenges that require fundamental transformation of business operations (Fine, 2013; Lawrence and Vasak, 2014). According to Slack et al. (2013), to assess the organisation's operational performances, three aspects namely supply, operation and demand need to be taken into account in manufacturing activities.

Numerous studies have indicated the necessity for the modern manufacturing to adopt exponentially growing technologies (Bechtold et al. 2014; Deloitte 2014; Dujin et al. 2014). The operational aspect of manufacturing is directly linked to the aforementioned mega-trends. Meanwhile the concept of Postponement can be considered as a strategy

where the operational challenges can be connected to the demand side of manufacturing. In other words Postponement strategy (Particularly AM technologies) can incorporate all the seven megatrends identified by TATA Consultancy Service.

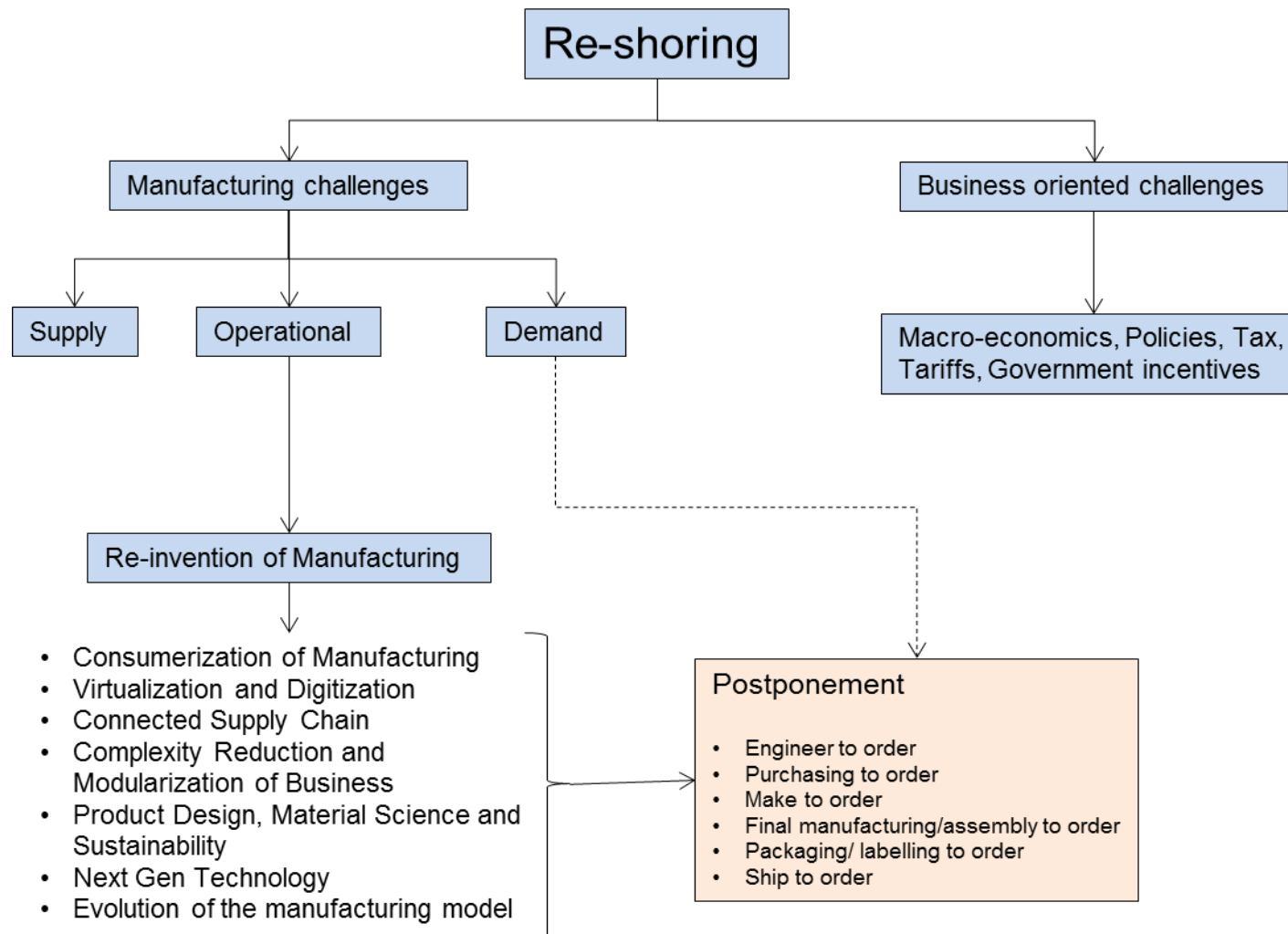


Figure 2-5, Connections between Postponement and re-shoring

### 2.7.1 Types of Postponement

Postponement strategies can be used in various forms. Figure 2-6 illustrates the application of the Postponement by the means of Customer Order Decoupling Point (CODP), which is shown by the dotted line. By having looked at this diagram it can be concluded that Postponement can be applied along the entire supply chain using CODP. According to Hilletofth (2009) “CODP, known as the order penetration point, is the point at which the customer orders (demand) penetrate the supply chain”. In other words the forecast-driven production is substituted by the order-driven activities (Hilletofth, 2009).

Figure 2-6 illustrates the various leagile (lean-agile) supply chain methodologies based on Postponement of the CODP upstream in the supply chain in which the lean supply chain should be converted into an agile supply chain. It should be noted that the lean supply chains primarily focus in reducing the wastes across the entire supply chain including inventory and lead-time and are suitable for markets where demand is high and relatively stable. Whereas on the other hand, the agile supply chains intends to increase the flexibility of the production to rapidly respond to the changes in the market (Christopher, 2000). Therefore according to Christopher (1998), Postponement can take advantage of globalised and centralised activities upstream the supply chain that reduces the production costs. Meanwhile localise and decentralise the downstream activities to reduce lead-time and meet the customer demand (Christopher, 1998). Hence it is suitable for the volatile markets with high variety of demand. According to Feitzinger & Lee (1997) and van Hoek (1998), Postponement can be implemented through product architecture and production processes. This can be achieved by standardisation and Modularisation of the designs. According to Yang et al. (2005) there are six types of Postponement as follow:

- Engineering to Order: Product is designed and manufactured based on customer order (e.g. Additive Manufacturing)
- Purchasing to Order: Product is produced to customer order, but no parts/materials are stored in the inventory
- Make to Order: Product is made from inventoried parts or raw materials according to the customer' request
- Assemble to Order: Base products are initially produced and stored and then assembled at the customer order



- Packaging to Order: Packaging operations are kept and done until a customer order is received
- Ship to Order: Finished good is not shipped until a customer order is fully received

Despite having a well-established literature available, the application of Postponement strategies are not as much as it is expected (Battezzati and Magnani, 2000; Yang and Burns, 2003). Therefore it is evident that the application of the Postponement is expected to increase within the industries (Yang et al. 2004b).

According to Feitzinger & Lee (1997) and Sigronelli & Heskett (1984), Postponement has been widely applied in the computer and garment industries. In the study done by Wadhwa et al. (2006), the Postponement strategy in respect to automotive manufacturing has been investigated since this sector implemented progressive product differentiation over several stages. Every stage in the process requires forecasting, therefore any inaccuracy in forecasting can be cumulative and lead to significant inventory level. Studies indicate that over 75 percent of the sample automotive companies that have utilised Postponement in their production have confirmed it benefits and considered their implementation a success. In addition 91 percent of respondents have experienced substantial improvements in customer satisfaction and inventory costs. Meanwhile as it was mentioned in the “Potential Industries for Re-shoring” section of this report automotive industries is considered to be one of the areas where re-shoring is currently happening. Therefore this indicates the importance in applying Postponement techniques in the automotive industries that are heading back to the developed countries such as the UK.

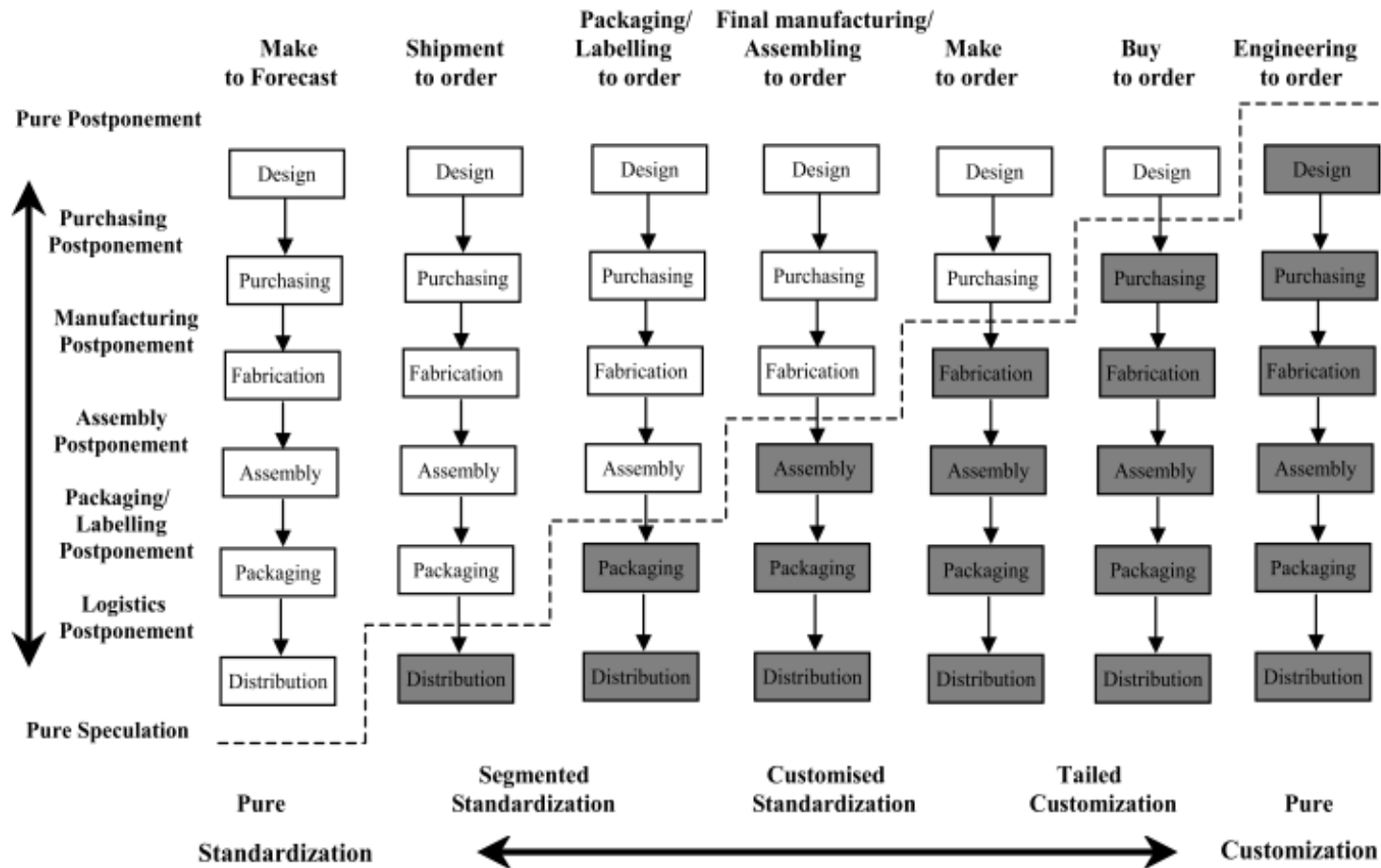


Figure 2-6, Variation of Customer Order Decoupling Point in the Supply Chain, adapted from (Lampel and Mintzberg, 1996)

### 2.7.2 Additive Manufacturing (AM)

One of the new technologies which is thought to revolutionise the manufacturing industries, is the AM technology (Berman, 2012). Hopkinson & Dickens (2001) defines AM as a manufacturing process in which a part is made from a 3D model data by adding layer on layer, as opposed to traditional subtractive manufacturing method. Therefore this technology allows receiving the customer order prior to taking any action for the production. Considering the Figure 2-7 in the previous section, such technology can shift the CODP or in other words order penetration point, to the downstream in the supply chain making pure Postponement a possible strategy. Therefore the use of AM can facilitate the Postponement strategy since it allows the company to delay the production until the real data about customer demand is available and achieve pure customisation (Van Hoek, 2001). Considering the work done by Yang *et al.* (2004), AM can be seen as a Postponement concept known as Engineering To Order (ETO) in which product is designed and produced based on customer order. Hence AM increases the ability of the companies to be more responsive through Postponement strategy.

According to number of studies, AM technologies can be seen as one of the enablers of the “Industry 4.0” (Bechtold *et al.*, 2014; Deloitte, 2014; Dujin *et al.*, 2014). Likewise Holmström & Partanen (2014) claim that AM is the best known technology that enables digital manufacturing that supports innovation. One way to be more responsive to customer demand is by adopting AM approach or more commonly known as 3D printing (Eyers and Potter, 2015). Numerous studies have been published presenting the advantages and disadvantages of using AM (Holmström *et al.* 2010; Mellor *et al.* 2014; Berman 2013; Bak 2003; Walter *et al.* 2004; Holmstrom *et al.* 2016) whereas this research studies the supply chain perspectives of AM and focuses on the applicability of the AM technologies in the supply chain management of re-shoring companies. It is believed that re-shoring can provide a platform to utilise the new generation of technologies such as Additive Manufacturing (AM), intelligent robotics, big data and Internet of things.

It should be noted that the advancement of AM technologies has gone a long way since it first started. With over 20 years of history, AM initially started as a technology that was mostly applied for the fabrication of conceptual and functional prototypes, also known as Rapid Prototyping (RP). Hence the prototypes were mainly used in product development

stage of the lifecycle to communicate and inspect the tools, making several physical models in short time directly from digital files (STL files) enabling to shorten the production development steps (Mellor et al., 2014). But the improvement has not stopped ever since producing rough physical prototypes of final products (Huang *et al.* 2013; Khajavi et al., 2014). For instance three of the parameters that have experienced a considerable advancements are the range of material that can be used in AM, the speed of the processes and built volume (Bak, 2003). As a result, AM is increasingly used in end products and making functional components. The introduction of AM as a technology that can manufacture end-products will transform the traditional supply chain. Tuck *et al.* (2007) state that “the use of AM will have particular impact on supply chain management paradigms such as lean and agile and has particular strategic fit with mass customisation”. Hence AM is known to be one of the potential enablers of mass customisation.

In recent years the industries have been increasingly witnessing the evolution of AM methods as production technologies. This technology has reached a suitable precision and quality necessary to be used to manufacture the final functional parts for special applications (Khajavi et al., 2014). The AM methods are being used to manufacture functional parts in several industries (Huang *et al.* 2013; Bak 2003). For instance one of the applications of AM is in the aerospace industries. According to Holmström *et al.* (2010) Boeing F18 military jets uses number of parts which are manufactured by AM technology called Selective Laser Sintering (SLS) machines (see section 2.7.2.1 for further explanation of the technology). Similarly AM is also being used in tool making industry which allows the development of tools in a short time and with a more flexibility in the design (Hänninen, 2001). This in turn indicates the importance of the AM in end-product market. These are just two examples of a growing range of applications within all manufacturing sectors. According to the Royal Academy of Engineering (2013) the timeline for the development of AM technologies indicating the past, present and the future potentials, can be shown as follow (see Table 2-3).

Year	Capability
<b>1988-1994</b>	Rapid Prototyping
<b>1994</b>	Rapid Casting
<b>1995</b>	Rapid Tooling
<b>2001</b>	AM for Automotive
<b>2004</b>	Aerospace (Polymer)
<b>2005</b>	Medical (polymer jigs and guides)
<b>2009</b>	Medical implants (metals)
<b>2011</b>	Aerospace (Metals)
<b>2013-2016</b>	Nano-manufacturing
<b>2013–2017</b>	Architecture
<b>2013-2018</b>	Biomedical Implants
<b>2013-2022</b>	In Situ Bio-manufacturing
<b>2013-2032</b>	Full Body Organs

Table 2-3, AM development timeline (Royal Academy of Engineering 2013)

### 2.7.2.1 Different types of AM

There are currently a range of AM processes being used in multiple industry subsectors, including motor vehicles, aerospace, machinery, electronics, and medical products. The following is a short explanation of the seven standard methods (Thomas and Gilvert, 2014). It should be noted that this study does not aim to investigate each AM process in detail, rather it seeks to identify the impact of these technologies on the supply chain management.

1. Binder Jetting: This process utilises liquid bonding agent deposited using an inkjet-print head to join powder materials in a powder bed.
2. Directed Energy Deposition: This process uses thermal energy, typically from a laser, to fuse materials by melting them whilst they are deposited.
3. Material Extrusion: These machines extrude material, typically a thermoplastic filament, through a nozzle onto a platform that can move in horizontal and vertical directions.
4. Material Jetting: This process utilises a moving inkjet-print head in order to deposit material across a build area.

5. Powder Bed Fusion (Selective Laser Sintering): In this method powder in a powder bed is selectively fused using thermal energy of a laser or electron beam.
6. Sheet Lamination: In this method three-dimensional objects are produced by bonding sheets of materials.
7. Vat Photopolymerisation (Stereolithography systems): In this method, a liquid photopolymer are selectively cured in a vat using light.

The recent progress in applications for direct part manufacture, or Rapid Manufacturing, has directed the research effort focusing on discovering new processes and materials. There are now a wide range of materials that can be used in AM. Some of the examples are as follow: Polymers and polymer blends, Composites, Metals, Graded/hybrid metals, Ceramics, Investment casting patterns, Sand molds and cores, and Paper (Thomas and Gilvert, 2014).

#### **2.7.2.2 Advantages and disadvantages of using AM**

AM has been recognised as having several theoretical benefits for the supply chain and product manufacturing (Hopkinson and Dickens, 2001). Study done by Holmström et al., (2010) highlights a number of advantages of using AM over the conventional manufacturing methods. The following are some examples:

- No requirement for tooling which ultimately results in significant reduction in production time and expense.
- Economically feasible to manufacture small product batches.
- Capability of accommodating design changes
- Optimisation of the product design for function (for example Optimised cooling channels).
- Allowing economical custom products (batch of one).
- Reduction in waste related to the material
- Shortening the supply chain and the production lead-time
- Reduction in inventory
- Design freedom and pure customisation

Meanwhile according to Royal Academy of Engineering, (2013), despite the clear benefits that AM offer, there are some limitations in the current technologies and lack of

supportive framework. The followings are some of the challenges related to implementation of AM technologies:

- Limited range of material available in comparison to conventional manufacturing
- Absence of energy-reducing economies of scale in AM comparing to the traditional methods of manufacturing
- Significant cost currently associated with the purchase of the machines and the feed stocks
- Limitations in producing high volume products
- Low speed in production (e.g. slow material deposition rate)
- Infringing the intellectual property right

## **2.8 Summary**

Re-shoring manufacturing activities has drawn the attention of academics in recent years. As mass production has shifted to the low-cost countries, European and US companies are obliged to rapidly switch towards low volume production of more innovative, customised and sustainable products with high added value. This indicates the necessity for transformation of the supply chain required to support the re-shoring companies to the UK. As a result of the literature review conducted in this study, it appears that the companies with high sales fluctuation, short product life cycles and product differentiation are more likely to repatriate their manufacturing activities back to the UK. This is due to requirement for shorter lead times in production and product delivery. This chapter adds insight into the manufacturing challenges related to the re-shoring decisions and identifies the potential manufacturing strategy to support this phenomenon. It also identifies different type of re-shoring decisions namely; In-house re-shoring, Re-shoring for outsourcing, Re-shoring for insourcing and Outsourced re-shoring.

After looking at the future mega trends emerging in the manufacturing environment, it was found that the companies have to be able to align themselves to ensure a sustainable re-shoring movement. The companies are required to take into account the Consumerisation of manufacturing, Virtualisation and Digitisation, Connected Supply Chain, Complexity Reduction and Modularisation of Business, Product Design, Material Science and Sustainability, Next Gen Technology, Evolution of the manufacturing model. As a result the concept of Postponement was selected to be the enabler for the aforementioned factors.

This also allows the companies to reduce their lead time and be responsive towards the customer demand. By considering the new generation of technologies, one way to do so is to employ AM technologies for the high value added products.

Consequently the literature review conducted in this chapter allows the author to identify the gap in the literature and develop the research idea. In the literature much is written on the policy side of the re-shoring phenomenon which provides a detailed insight on the government related challenges. However the challenges related to the manufacturing side are not considered in detail. This raises the question of; what are the manufacturing challenges related to the re-shoring in the UK? This question is answered by looking at the new technologies such as AM and investigating how this can shorten the supply chain in the UK. The next chapter discusses the research questions in detail and allocates different methodologies to address each research question.



## **Chapter 3, Research Design**

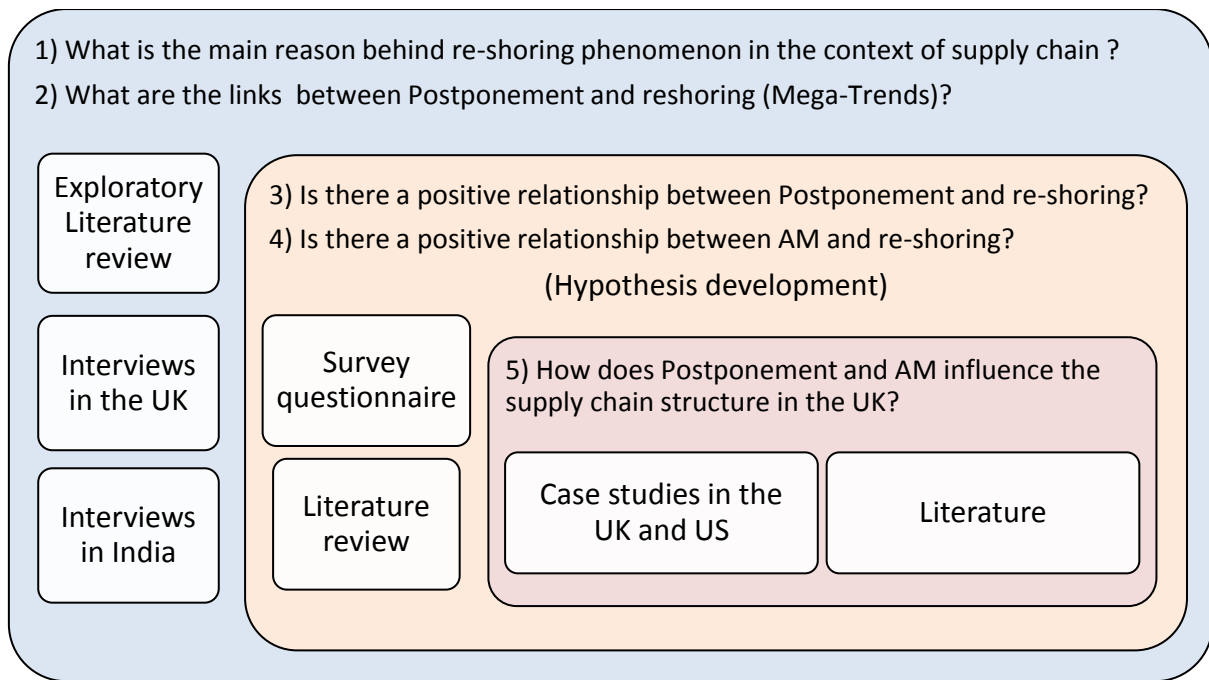
### **3.1 Overview**

In the previous chapter, an extensive literature review was conducted mainly in the following areas: offshoring and re-shoring strategies, new generation of technologies (re-invention of manufacturing), Postponement strategy as well as Additive Manufacturing. This chapter is structured to show the logical journey on selecting the appropriate research tools to accomplish the research objectives and clearly presents the flow of activities completed for research inquiry. The chapter comprise various sections that will guide the reader step by step through the decisions made for data collection method. The first part of this study is to identify the factors driving the re-shoring movement in the UK which has a descriptive nature. A descriptive study intends to provide a better explanation to complicated issues associated with re-shoring and make them more understandable for the readers (Punch, 2000). Hence the literature review was conducted in Chapter 2 to investigate the gap in the knowledge on re-shoring strategies and ultimately develop the research questions and hypothesis. By doing so, the research novelty and the applicability of its contribution can be justified. There are number of different methods that can be employed to fulfil the objectives of this study and to prove the acceptability of its

hypothesis. Alternatively they can be used in conjunction with each other for further validation of the results and complementation of one another. To select these research methodologies, firstly this study provides a brief introduction to the research questions. Once the research objectives are clarified and the research questions are developed, the general issues on the research design are discussed. After that an introduction to different data collection methods is included and pros and cons are discussed in details. Rationale for using qualitative and quantitative data analysis processes is included and the suitability of the selected methodology is further justified.

### **3.2 Research design**

This research aims to investigate the issues related to the supply chain management aspects of re-shoring manufacturing activities back to the UK. The best strategy was to begin with establishing a detailed understanding of the problem by conducting a comprehensive literature review as included in “Chapter 2”. In this chapter the relevant materials for identification of the research gap are collected, organised and summarised. Literature review is an essential element in research studies which identifies whether other researchers have asked similar questions in their studies and what the outcomes are. Once the research problem was identified and overall framework was constructed, some additional research questions were developed and new set of objectives were brought forward that would contribute to the body of knowledge. This section aims to introduce the research methodology adopted for the aforementioned research questions. Following the theoretical study of the research methodologies used in supply chain research, Figure 3-1 presents the research methodologies that have been allocated for each research questions. As it is shown, the first two questions will be addressed by adoption of qualitative approach whereas the third and fourth questions require larger sample size therefore a quantitative approach will be employed. Finally for question five, case study approach will be implemented. Further justifications of these decisions and logical sequence of activities are included later in this chapter.



**Figure 3-1, Research questions and proposed data collection methods**

Allocation of different methodologies for each research question indicates that this study uses mix methods approach in which quantitative and qualitative methods are utilised in the same research project. However there are number of scholars that believe, qualitative and qualitative are two distinct paradigms that are incompatible (Guba, 1987; Sale et al., 2002). For instance with regards to mixed method, Sale et al. (2002) state that “Because the two paradigms do not study the same phenomena, quantitative and qualitative methods cannot be combined for cross-validation or triangulation purposes. However, they can be combined for complementary purposes”. Whereas Gueulette et al. (1999) have studied 300 randomly chosen papers who claim to have used qualitative approach and have discovered that 40 percent of this population have used qualitative as well as quantitative methodologies in their studies. In other words, restricting the research study to only qualitative or quantitative methodologies can be extremely limiting (Onwuegbuzie and Leech, 2005). In the period between 1950s to 1970s positivist quantitative paradigm was the dominant research methodology among the scholars. However this changed in 1970s to 1990s as qualitative interpretivism research paradigm was established as a viable alternative. It was only after 1990s that mixed method emerged to be more commonly used in the research (Robson, 2011). Scholars such as Tashakkori & Teddlie (2003) have explained the distinctive nature of the mixed methods and its advantages. One of the

advantages of multi strategy research designs is the ability to generate a more complete and comprehensive outcome for the topic under investigation. It allows researchers to address wider range of research problems without having the limitations of single method approach. Hence in attempting to study complex phenomena, each strategy can address and contribute certain perspectives (Robson, 2011). The following section introduces the qualitative and quantitative research.

### **3.3 Qualitative research**

Traditionally scholars have adopted quantitative approach such as statistical analysis and surveys to investigate issues related to the supply chain management (Golicic and Davis, 2012; Sachan and Datta, 2005). However in recent time, qualitative research has received more attention by the European researchers (Taylor & Taylor 2009; Spens & Kovács 2006; Tachizawa & Thomsen 2007; Koste et al. 2004). It is evident from the literature that since 1980 the number of scholars employing empirical studies within operations management studies has increased significantly (Rungtusanatham et al., 2003). One of the reasons behind this is because of academics have begun to realise that the mathematical methods, in isolation, can not sufficiently capture and explain the entire scope of operations management (Swamidass, 1991). According to Dabbs (1982) “the notion of quality is essential to the nature of things. On the other hand quantity is elementally an amount of something”. This study has also found that there is a lack of qualitative studies on manufacturing side of re-shoring phenomenon as the current literature appears to address issues related to business policies (Bailey and De Propriis, 2014; Tate, 2014). Due to the immaturity of the subject within the academic context and limited practical application of re-shoring in industrial level, an in-depth approach is required from a selected population of interviewees that allows an access to reliable information and gather the required data for developing hypotheses. According to Golicic & Davis (2012) in situations where the phenomenon of interest is new, dynamic and complex and a detailed description of the problem is required, qualitative research is the preferred method. This clearly represents the problem under investigation in this research study. Hence qualitative approach was selected to begin the problem identification.

### **3.3.1 Research traditions in qualitative studies**

Robson (2011) believes that the qualitative research has the characteristics of a flexible research design which can adopt the three most common design traditions, namely case studies, ethnographic studies and grounded theory studies. The case study approach normally involves focusing on one case. The target can be a person, a group or an entire organisation depending on the purpose of the study. One of the characteristics of the case study approach is that the researchers can employ multiple methods to collect data. It should be noted that qualitative and quantitative methods can be implemented simultaneously (Robson, 2011). Further discussion on case studies is given in the “case study” section of this chapter. An alternative approach to inquiry in qualitative research is ethnographic studies. According to Greetz (1973), in ethnography people are investigated during a certain time period in their own natural environment so the researcher can capture detailed information about the subject. The purpose for this kind of studies is to provide a “thick description” of events or cultures that are little known (Greetz, 1973). Therefore it requires an insiders’ perspectives. Once the target population is studied in their natural setting the focus is on the most frequently occurring behaviours and events to develop a better understanding of their significance (Robson, 2011). The next widely used qualitative approach is the grounded theory studies. Grounded theory mainly aims to generate or discover theories through analysis of data (Corbin and Strauss, 2008). It is defined as a systematic methodology that is used in social science for a systematic research. It involves collection of data that can be coded and created into concepts. These concepts are then categorised to generate the basis of a new theory (Corbin and Strauss, 2008). According to Robson (2011) grounded theory is unlike the traditional model of research in which the researchers first collect data and then start analysing them but instead it is used when attempting to solve a complex problem. It should be noted that there are also several other traditions available that are used for addressing specific types of questions which are not discussed in this section, e.g. Narrative research, Biographical and life story, Phenomenological research and Hermeneutics (Robson, 2011).

In qualitative method, a number of methods are used to capture the required information. The most common technique is in-depth interviews. This can be achieved by individual interviews (one-to-one) or group interviews (focus group), which are often conducted in an informal way and involve conversation and discussion instead of question and answer type

data collection. An alternative method would be through direct observation. Capturing the required information can be achieved by regularly visiting the location or being involved in a project that contains the relevant data. It is also possible to take advantages of photos and videos that include sufficient information. Last but not least is the data collection by using the written data that already exists and does not need to be collected from scratch. This data may exist in the form of the transcripts of conversations, annual reports, websites, books and magazine (Creswell, 2003). The following section provides further explanation of qualitative data collection methods.

### **3.3.2 Interviews**

This method of data collection is widely used in social science and more recently in operations management (Saunders et al., 2009). One of the advantages that this method offers is the capability of generating in-depth and complex textual descriptions about the subject of study. This method best suits the situations in which intangible factors are under investigation. According to Bryman (1988) “The most fundamental characteristic of qualitative research is its express commitment to viewing events, action, norms, values, etc. from the perspective of the people who are being studied”. Interviews can vary in the degree to which they are structured. The researchers can use structured, semi-structured and unstructured interviews (Creswell, 2003). It should be noted that the semi-structure and unstructured interviews are the most commonly used methods in flexible designs (Robson, 2011). Therefore throughout the first phase of this study semi-structured interviews were used. In such interview approach, the researcher uses the interview guide that consists of the order for the questions and a checklist that needs to be met. However the wording and the number of questions can vary according to different situations and the knowledge of interviewee on the subject (Robson, 2011). Hence semi-structured interviews were used to refine the research question and develop hypothesis that can be validated using quantitative approach later in this study. These interviews are used to create a reliable research instrument (Survey Questionnaire) explained in the next chapter. In order to do so it is essential to identify the interviewees who are willing to provide the required information.

### **3.3.3 Target organisation**

In order to get an accurate idea of re-shoring phenomenon, reliable sources of information had to be identified. Following the literature review and theoretical studies, the research problem was further consolidated through interviewing several other organisations. The target firms include:

1. Jaguar and Land Rover as a British OEM in the automotive sector,
2. UK Trade and Investment (UKTI) and Engineering Employers Federation (EEF) as governmental organisations,
3. TATA Consultancy Service (TCS) and Manufacturing Advisory Service (MAS) as examples of two consulting groups that have been closely involved in consulting re-shoring projects in the UK, and
4. Cranfield University as an educational organisation.

This provided the opportunity to talk to the experts in this field and draw a complete picture of the issues faced in the industries. These interviews were carried out mainly direct, face to face and by telephone and Skype. The results obtained from these preliminary interviews were then used to develop another set of questions that can target companies in offshore locations e.g. China and India.

After consideration of a potential destination (a low cost country) for data collection, India was selected for further data collections. In order to gain access to sites and the individuals in India, an Indian university (Coimbatore Institute of Technology) was first contacted for a possible exchange program for the period of two month. As a result 11 interviews were performed during this period. Every interview was audio recorded with the permission of the interviewee and the key notes were taken during the interview. The rationale behind the development of interview questions and the content of the interview guide is further discussed in Chapter 4.

### 3.4 Quantitative support

The quantitative research is defined as a process where scholars gather data from participants in their working environment, normally by asking questions through survey questionnaires or interviews schedule in person (Neuman, 2007). Aliaga & Gunderson (2000) define quantitative research as “explaining phenomena by collecting numerical data that are analysed using mathematically based methods (in particular statistics)”. Surveys are one of the most widely used approaches to collect evaluation information (Taylor-Powell and Hermann, 2000). This technique is a systematic and standardised method of collecting data directly from people. This type of study can examine the attitudes, behaviours, and experiences of people according to set of variables (Graziano and Raulin, 2007). One of the major advantages of this methodology is the ability of accessing to a large amount of data, which can then be used to assess the population of interest. Hence there is no limitation on the number of targeted people (Taylor-Powell and Hermann, 2000). This method is considered to be a good combination with the other data collection methodologies since the surveys are not able to capture all sorts of information. In such scenarios other techniques such as direct observations, use of existing data, records and documentation, test abilities and case studies can be utilised as a complimenting approach. Therefore studies can begin with qualitative methods and then later develop into quantitative (Bryman, 1988). There is a distinct tradition in the social science literature that emphasises on using multiple research methods (Jick, 1979). This was evident by introduction of triangulation concept. According to Denzin (1978) Triangulation is "the combination of methodologies in the study of the same phenomenon". Hence it provides diverse viewpoints on the topic of interest. There are various types of triangulation research methods, namely data triangulation, investigator triangulation, theoretical triangulation and methodological triangulation (Denzin, 1978; Guion, 2002). The data triangulation is achieved through using multiple sampling strategies that allows access to data from different times and social situations. Investigator triangulation differs from other triangulation methods in which it requires more than one researcher working on the data collection and interpretation. The next one is theoretical triangulation which involves number of professional perspectives to translate a single set of collected data. Therefore in this method participation of other evaluators from different disciplines is possible (Denzin, 1978). The last approach is the methodological triangulation which appears to be the most



common among the other methods (Guion, 2002). This method involves utilisation of multiple methods including quantitative and qualitative inquiries. However it requires more resources and time for analysing the data from each individual method. Yin (2009) also points out that the triangulation can be used in case study approach by using more than one source of information. By doing so, the reliability and validity of the research can be improved considerably. However Flick (1992) believes that the validity of the research outcome is not improved by the methodological triangulation and similarly theoretical triangulation would not address the problem with bias judgement.

### **3.4.1 Surveys**

For the purpose of this investigation the first set of interviews is followed by conducting a survey. Recently the validity of the research is becoming a more and more important element in qualitative research (Flick, 1992). Typically survey questionnaires target large number of organisations while enquiring relatively low level of details than interview approach (Taylor-Powell and Hermann, 2000). The study done by Bourque & Fielder (1995) suggests that surveys are best used when the objectives of the investigation is clearly defined and is not complex. However due to the characteristics of quantitative research in lacking flexibility, it is important to conduct a pilot study beforehand in order to reduce the errors and finalise the questionnaire. For the purpose of this study the data obtained in the first phase of data collection phase will be further examined by targeting a larger sample size and generating reliable outcomes. Surveys can have different formats. It can be sent through the post, email or be on-line self-administered (Robson, 2011).

Using surveys in research can have positive and negative points. One of the advantages of using surveys is the ability to get access to many sources of information with minimal cost (Neuman, 2007). It should be noted that the surveys are widely known by people therefore it makes them easy to understand. It does not take a long time to complete one questionnaire since it does not involve much writings. This makes it a suitable approach to target the company managers who may not devote time for other methods such as face to face interviews. Using surveys can also provide large amount of data in a short period of time that makes it convenient to finish the study on-time. High amounts of data standardisation, is another advantage of using surveys (Robson, 2011). Due to the large

number of organisations and their geographical dispersion interview approach was not selected for this part of the data collection. This is in line with what Wass and Wells (1994) suggest that if the number of targeted companies exceed 30, then it is more convenient and efficient to conduct survey questionnaire using mail than interviews. In addition similar studies have been done in the past and it is evident in the Postponement literature that survey questionnaire can be applied to provide statistical generalisation and is a suitable for exploratory research on Postponement concept (Van Hoek, 1998; Jyh-Shen Chiou et al., 2002). Similarly Yang (2004) claims that the use of surveys on the concept of Postponement has increased in recent years.

One of the disadvantages of using surveys is the possibility of getting low response rates. Therefore it is difficult to assess whether the sample size is representative for the phenomenon under investigation (Taylor-Powell and Hermann, 2000). Furthermore ambiguous questions and poorly designed questionnaire can ultimately weaken the results obtained (Rungtusanatham et al., 2003). To ensure designing a reliable questionnaire, a series of actions were executed which are explained in detail in Chapter 5. Another shortcoming in using survey is that it constraints the respondent to fixed answers which does not apply to qualitative approach and conducting in-depth interviews.

### **3.4.2 Hypothesis development**

After completing the first phase of the research, a more generalisable data needs to be gathered to validate the initial findings and to access to a larger data source. It is required to investigate the relationship between re-shoring, Postponement and Additive Manufacturing. For this purpose three hypotheses were developed to test the two of the research questions and explore the nature of the phenomenon. The following is the recall of research question number three and four:

- Is there a positive relationship between Postponement and re-shoring? (the third research question)
- Is there a positive relationship between AM and re-shoring? (the fourth research question)

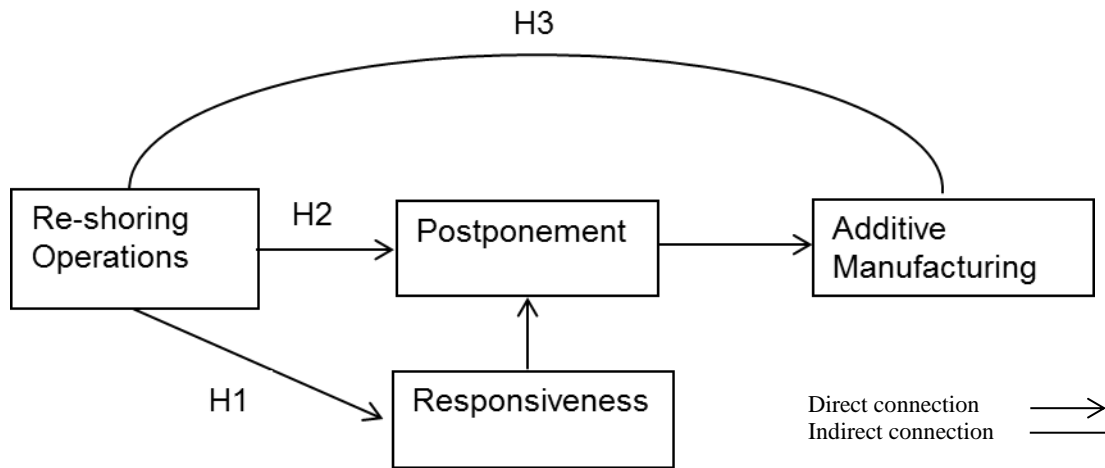


Figure 3-2, Hypothesis development

**Hypothesis 1:** Supply Chain responsiveness is a key factor behind re-shoring manufacturing activities to the UK.

**Hypothesis 2:** There is a positive relationship between re-shoring manufacturing activities and Postponement strategy.

**Hypothesis 3:** There is a positive relationship between Additive Manufacturing (as a type of Postponement strategy) and re-shoring strategy.

The above diagram (Figure 3-2) illustrates the logic that links the re-shoring phenomenon to the concept of Postponement and AM. As mentioned before, one of the objectives of this study was to provide a clear picture of the re-shoring strategies in the UK. This was partly achieved through series of interviews in the UK. However in order to validate the findings it was necessary to examine the outcome in a larger scale. The result indicated that being responsive to the customer demand is the primary factor that is considered in manufacturing location decision in the UK. Therefore the first hypothesis was developed to examine and emphasises that there is a strong link between being responsiveness and repatriation of manufacturing activities back to the UK. Hence the first hypothesis aims to provide evidence which shows that shorter lead time, proximity to end customers, and being responsive to customer demand are among the top priorities that company managers consider when re-shore their manufacturing activities to the UK.

Since at present little research in the literature has been directed to address the manufacturing challenges associated with the re-shoring phenomenon, the third research question, “Is there a positive relationship between concept of Postponement and re-shoring strategy?” was designed. The nature of the principle research questions helped to develop the second and third hypothesis and therefore defines the instrument used. In order to answer this research question, the hypothesis number 2 was developed. This is also aligned with the findings in the study done by Yang (2004). He suggests that “Across most industry sectors, there is a distinct trend towards increasingly employing Postponement, especially in the practice of international business, where companies have to simultaneously target local responsiveness, global efficiency and worldwide learning” (Yang, 2004). Hence it aims to identify the common elements between re-shoring and the benefits that Postponement concept can offer. As illustrated in Figure 3-2, responsiveness is the gateway in which Postponement strategy can be linked to re-shoring in the UK.

Last but not least, the hypothesis number 3 was generated to address the fourth research question. As discussed in the “Chapter 2” section of this thesis, as the new technologies such as Additive Manufacturing, cloud manufacturing, intelligent robotic and big data emerge; companies are required to undergo a significant transformation in their organisational structure and are prepare to adopt new manufacturing processes and product designs (Hanifan et al., 2014; Lawrence, 2015; TATA Consultancy Service, 2013b). According to the preliminary literature study, the application of AM can be considered as a type of Postponement strategy in which products are engineered in response to customer order. In other words the entire manufacturing process is postponed until accurate information about the product is available. Hence AM was chosen as an example of new generation of technologies which can be considered as a feasible solution for localisation of manufacturing activities in the UK. Hypothesis number 3 was generated to examine the applicability of AM technologies in re-shoring and determine how it can help companies to be more responsive. This investigation involves determining how AM technologies will affect the current supply chain structure. Note that in this survey, only those activities closely associated with the customer order may be worth considering toward Postponement and AM. In order to achieve the aforementioned objectives a careful questionnaire design is required.

### **3.4.3 Questionnaire design**

As discussed previously qualitative research designs can incorporate quantitative approaches for data collection (Robson, 2011). In this study questionnaire approach was identified to be a suitable methodology to help build statistical generalisations on the extent to which companies believe AM can be implemented as a solution for further reduction of response time. In this scenario the questionnaire was found to be the best possible means of interacting with the respondent and to collect a large database of information (Gillham, 2000). Meanwhile in order to design a reliable questionnaire, similar studies in the literature were identified and used as a guideline (Ranganathan, 2007; Skipworth, 2003; Yang, 2004). However this study differs in which as it targets specific companies that are involved in using and supplying AM products and manufacturing high end product with variable demand.

Questionnaires enable the researcher to access geographically dispersed source of information and to save the travel cost/ time. However it is essential to target the right industrial sector which can provide accurate information about the re-shoring phenomenon. It is found that the most issues associated with the analysis stage of the questionnaire approach can be tracked back to the accuracy of the questionnaire design (Dillman, 2007). For this reason a pilot study was conducted through several emails and participation in events such as the National Manufacturing Debate at Cranfield University 2015. While carrying out the pilot study, the participants were asked to provide feedback regarding the questionnaire structure. Series of meetings was also planned with expert academics in the field to gain further thoughts on the questionnaire design.

The questionnaire is used firstly to demonstrate the relationship between re-shoring and Postponement and secondly between re-shoring and AM. Such data could be used to clarify the modifications required in the supply chain design to accommodate AM technologies. In addition to this, it allows to study the feasibility of using these technologies in high value added production in upcoming years. It is important to note that the information provided by the respondent depends on the clarity of their understanding of the subject and the questions. Therefore it is aimed to provide a comprehensive picture of overall subject and individual questions by reducing the ambiguity in the questionnaire.

#### **3.4.4 Identifying respondents**

Once the questionnaire is developed, the targeted respondents for this study were identified and discussed in this section. Looking into the non-response to survey, three types of non-response were identified (Saunders et al., 2009). The first category is the ones that simply refuse to complete the survey and provide any information. The second group include the participants who are unable to answer the questions. For instance it consists of people who do not have enough information regarding the subject under investigation and it is not relevant to their expertise. The last group are the targeted respondents to whom the questionnaire does not reach. Hence it is essential to have update addresses of all individual. A poor sample selection can ultimately result in a low response rate.

The sample size was determined based on addressing the information requirement for the research and the cost and the time. Sample size for this study was chosen according to the requirement for conducting the statistical analysis. However Dillman (2007) believes that there are not certain rules which dictate the optimum sample size for a survey. Due to the unique characteristics of this survey study, careful thinking is required to identify the organisations that have been involved in dealing with the oversea suppliers and are currently operating in an uncertain market where AM technologies are utilised. Therefore the applications of AM technologies should be also viable in their production processes. This imposes a challenge in finding a suitable sample size that can incorporate all these three factors in it.

#### **3.4.5 Response rate**

One of the key concerns with conducting a mail questionnaire is the low response rate that ultimately increases the non-response bias (Paxson, 1992). If a low response rate is achieved in a survey, it reduces the generalisability of its outcome (Wilson, 1999). According to Jolliffe (1986), the non-response or unit non-response is the result of target informant refusing to provide information and take place in the survey. This can ultimately appear in the form of inaccuracy in the survey results. However there are various available methods to test the non-response bias (Jolliffe, 1986; Whitehead et al., 1992). One of these methods is to compare the extent to which the early responses and late responses differ from each other. While conducting a survey it is essential to ensure that the right respondents are targeted who are interested in the subject of study. The importance of the

research can in turn create motivation for the respondent to respond to the emails and provide their thoughts on the matter.

According to the literature there are various approaches that the researcher can use in order to improve the response rate (Dillman, 2007). One of the most widely used methods is to provide a clear explanation of the importance of the research and its objectives and to emphasise the significance of the contributions made by respondents. Other methods such as showing positive regard, offering incentives/rewards, following up by contacting them multiple times and constructing short and respond-friendly questionnaire (Dillman 2007; Creswell 2003). The following factors are the methods used to increase the response rate, while being mindful of the constraints imposed by the nature of this research:

1. Generally offering incentives in a survey study can significantly increase the response rate but it should be noted that this survey is a part of PhD study. Due to this reason it is not feasible or permissible to dedicate any financial incentives to the respondents. Instead the respondents were offered some non-monetary incentives. As the initial emails were sent out, the respondents were promised to receive the summary of this research and its outcomes which aims to provide a better insight into re-shoring phenomenon in the UK. To increase the response rate and add to the importance of this research study, a cover letter was also included in the email which clarifies the purpose of this study. It also emphasises on the academic as well as managerial value of the survey.
2. According to the literature all the follow-up techniques can be helpful to increase the response rate. However in the case of physical distribution, follow up can increase the overall costs. In this research study, in the cases where email questionnaire were sent, two to three reminders were sent via emails. In some instances the follow-ups indicate the amount of dedication that the researcher has put into the study and shows how important it is that people participate in this investigation. According to Dillman, (2007), in order to get a satisfactory response rate the first reminder should be sent off approximately two weeks from the initial email. This is to remind them for filling out the questionnaire if they have not done by that time. To do this, several methods such as reminder letter or email and telephone calls can be used. The third follow up can be done after four weeks from

the initial contact. This was done as a replacement attachment with covering letter to those who have not completed the survey.

3. Since this questionnaire asks the respondent about the manufacturing location decision as well as strategies such as AM, used in the production plan, it could be essential to reassure them about the confidentiality of their answers. Therefore in this study the participant were promised that their names and organisation detail will remain anonymous. This is also applied to the companies interviewed in India in the first phase of this research.
4. In order to design an attractive questionnaire, it is important to give the questionnaire a short and meaningful title. The questionnaire itself should also be kept concise so it can be filled in a short time. According to Dillman et al. (1993) this can be the most effective way to maximise the response rate. Factors such as having each section of the questionnaire coloured differently were also considered. The questionnaire also needs to avoid having too many open-ended questions. To do this a ranking approach was used that only requires respondents ticking the required boxes.

In addition to the above considerations, other factors such as mailing the questionnaire midweek to obtain a better response rate was taken into account. There was also no deadline mentioned in the cover letter since the sense of urgency may discourage people to fill the questionnaire.

#### **3.4.6 Reliability and validity**

In every research study, it is essential to indicate that the research outcomes are reliable and valid (Tashakkori and Teddlie, 1998). In this specific scenario where questionnaire has been used to obtain the data, the reliability and validity need to be presented. According to Miles & Humberman (1994) reliability is the extent to which the outcomes of the research study can be repeatedly tested and be consistent when using different respondents. The validity is defined by Litwin (1995) as a the capability of the instrument or the question to really measure the phenomenon or what it is required to measure.



Kirk & Miller (1986) suggest that there are three types of reliability in quantitative approach. The first type is the degree to which the data measurement will remain consistence as the experiment or the measurement is repeated. The second category emphasises on the stability of the outcomes as the time passes. And the final group relates to the consistency of the measurement within a given time period (Golafshani, 2003; Kirk and Miller, 1986). Meanwhile according to Yin (2009), researchers need to focus on construct validity, internal validity, external validity and reliability. Construct validity can be seen as identification of suitable operational measures to the phenomenon under investigation. On the other hand the internal validity looks at the adequacy of the chosen items for representing the subject of interest. Lastly the external validity is concerned with the generalisability of the findings and its applicability on the real world.

In terms of ensuring the construct validity, Yin (2009) recommends using multiple data sources. Construct validity can be achieved through conducting a survey questionnaire (Yin, 2009). One of the ways to ensure construct validity is to base the questionnaire on the work that has been previously done by the other researchers and conduct a pilot study (Mason and Bramble, 1989). The researcher may be able to prove that their research instrument is reliable but it is possible that the instrument itself may appear to be not valid (Golafshani, 2003). In order to improve the internal validity it is essential that multiple source of information is deployed and for the external validity it is important to ensure a high response rate by focusing on the appropriate questionnaire design. In Chapter 5 the reliability and the validity of the result is further discussed.

### **3.5 Case Study**

This section gives an introduction to case study approach and also provides rational for using this methodology for the final research question, through comprehensive discussion on its advantages. According to (Yin, 2009) case study is defined as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used”. Case study research designs have been frequently employed in social science disciplines and are continuously being used in organisational and management sciences (Buchanan and Bryman, 2009). In addition to this the case studies have been used to centre on the practical experience of companies in implementing

Postponement (Cooper, 1993; Feitzinger and Lee, 1997; Van Hoek, 1998; Van Hoek et al., 1999). Case studies are mainly used to address the “what”, “how” and “why” types of questions, whereas questions such as “who” and “how many” cannot be addressed using this approach (Yin, 2009). Moreover, this strategy enables the researcher to develop a better insight into a complex and relatively unexplored phenomenon by enabling them to use all types of data collection methods including qualitative, quantitative or both approaches (Yin, 2009).

Case studies are often used to gather data and examine an event or a phenomenon that require explanation and description. It is mostly used when the variables are not easily identifiable and the causes of the behaviour are not known. According to Rowley (2002), case study approaches can be employed by taking three considerations into account. The first one is the types of questions to be addressed. It is evident that the case study approach is suitable to address “why” and “who” types of questions. The second factor is the extent to which the researcher can have access to the variables and behaviour of interest. Case study is a suitable solution for this since it allows direct event observation and interviewing people who are involved in the event of interest. The final consideration is the degree of focus on contemporary as opposed to historical events. The case studies are very helpful if the event of interest is a contemporary event (Yin, 2009). It allows continuous interaction with people involved in the event.

### **3.5.1 Required number of case studies**

Case studies have traditionally been viewed as a somewhat problematic form of enquiry compared to other empirical methods and the most common concern is lack of rigour in the research design (Barratt et al., 2011; Seuring, 2008). Number of scholars believe that the selection of one case study to collect the data about a phenomenon could be sufficient (Merriam, 1988; Mitchell, 1983; Ragin, 1989). However according to Verschuren (2003) using single case study in research can cause several limitations. One of the main drawbacks related to single case study is the lack of generalisability of the findings. Having only one case study to investigate on can also lead to the risk of misjudgement in analysing the outcome whereas by studying multiple cases this issue can be minimised (Voss et al., 2002). It should be noted that the case study approach is not a suitable method to build statistical generalisation due to the small sample sizes (Yin, 2009).

The study done by Voss et al. (2002) suggests that the case selection should be based on the logic of replication or theoretical sampling. The case selection can be based on literal replication and theoretical replication. This study suggests the literal replication when the case is expected to provide the same outcomes found in the previous case or cases. On the other hand the theoretical replication is used when the case is expected to provide contrary outcomes to those already found from previous cases due to availability of specific reasons.

In this research study the author chooses to select more than one case study to gather more data from the industries which can provide reliable representation of the specific phenomenon under investigation. According to (Yin, 2009) using two or more case studies will allow the researchers to produce stronger justifications behind the research findings. Table 3-1 shows the case study choice and the generalisability of their findings.

<b>Choice</b>	<b>Generalisability</b>
Single case study	Limited generalisability
2 to 3 cases	Literal generalisability
More than 3	Theoretical generalisability

**Table 3-1, Case study choice and generalisability**

In total, three case studies are performed to address the final research question in this study. In “Chapter 6”, a case study in the UK is used where semi-structured interview is conducted. Similarly in “Chapter 7” the author investigates two separate cases in the USA and performs thematic analysis for analysing the data gathered. Table 3-2 shows the list of the investigated companies along with the choice justification.

Case	Type of organisation	Reason for selection
<b>Brinsea Ltd (Chapter 6)</b>	Manufacturing	<ul style="list-style-type: none"> <li>• The involvement in the re-shoring decision from China to the UK</li> <li>• Operating in volatile market and competitive environment</li> <li>• Utilisation of AM technologies in the production of certain products</li> <li>• Manufacturing high value added products</li> </ul>
<b>Local Motors (Chapter 7)</b>	Manufacturing	<ul style="list-style-type: none"> <li>• Targeting to bring back suppliers from China closer to the home country</li> <li>• Operating in volatile market</li> <li>• Utilisation of AM technologies in the production of certain products</li> <li>• Manufacturing high value added products</li> <li>• Promoting localisation by using AM technologies</li> </ul>
<b>Manufacturing Demonstration Facilities (MDF) (Chapter 7)</b>	Manufacturing and Research	<ul style="list-style-type: none"> <li>• Expertise in manufacturing functional products using AM technologies</li> <li>• Serving the local demand</li> <li>• Manufacturing high value added products using AM</li> <li>• Operating in volatile market</li> <li>• Research on high scale manufacturing using AM technologies</li> </ul>

Table 3-2, Case study: reasons for selection Case

### **3.5.2 Rigor in case study approach**

Despite the fact that the case study is one of the most important data collection approaches available in operation management, it is often criticised for the lack of rigour in the knowledge it produces (Mitchell, 1983). This is mainly due to the small sample sizes in case study research. Another common stereotype about this approach is that the relevance of its scope is only limited to the case under investigation. In other words case investigation would not have external value and hence it is microscopic (Hamel et al., 1993). However in response to these criticism, Yin (2009) has come up with four steps that can address the problems. Table 3-3 presents the four logical steps that are taken into account in this research to ensure a rigorous and valid research approach. There are external validity test, reliability test, construct validity test and internal validity test.

In the external validity test the researcher should ensure that the findings can be generalised. For instance in survey research the statistical generalisation can be achieved through selecting the sample from a large population (Bryman and Bell, 2007). However in case study research this is achieved by using the replication logic (Yin, 2009). This would require testing the finding in more than one case. Therefore multiple case designs can ensure a higher external validity in comparison to the single research designs (Voss et al., 2002). Multiple case designs normally require two to eight cases as a source of information (Yin, 2009). By selecting more than one case study, the researcher can make a comparison between the cases and extract what is common among them in order to build a theory.

On the other hand the reliability test ensures the degree to which the results are independent of any accidental circumstances in the data collection (Kirk and Miller, 1986). This indicates that the later investigator should be able to obtain the same results and conclusion using the same data collection approach as the previous researcher. Therefore the data collection and analysis should be done whilst biases in a case study is minimised. According to (Rowley, 2002), reliability in case study can be achieved through accurate documentation of methods and record keeping in order to be able to repeat the same procedure for other cases.

The third step is the construct validity. Construct validity essentially means the degree to which the test measures, what it claims to be measuring in the study (Brown, 1996). In order to improve the construct validity in this research, author chooses to use mixed methods (interviews and survey questionnaire) to provide a chain of evidence. Similar findings from various sources of information can be shown as a chain of evidence to strengthen the construct validity. In addition to this, the construct validity can be improved by having the key informant review the draft of case studied.

The final step is the internal validity test. This is the approximate truth about inference regarding cause-effect or causal relationship (Seuring, 2008). According to Yin (2009), the researchers can improve the internal validity by “pattern matching” logic. In other words it is to examine whether the actual data patterns of a case study matches the predicted or proposed patterns. As shown in Table 3-3 this step is mainly taken place in the data analysis part of the research. One of the most widely used methods is the thematic analysis (Stuart et al., 2002) which is also employed in this research.

<b>Tests</b>	<b>Case study tactic</b>	<b>Phase of research in which tactic occurs</b>
<b>External validity</b>	• Use theory in single-case studies	Research design
	• Use replication logic in multi-case studies	Research design
<b>Reliability</b>	• Use case study protocol	Data collection
	• Develop case study database	Data collection
<b>Construct validity</b>	• Use multiple sources of evidence	Data collection
	• Establish chain of evidence	Data collection
	• Have key informants review draft CS report	Composition
<b>Internal validity</b>	• Do pattern-matching	Data analysis
	• Do explanation-building	Data analysis
	• Address rival explanations	Data analysis
	• Use logic models	Data analysis

**Table 3-3, Four steps test for case study research design Case (Yin, 2009)**

### **3.6 Summary**

This chapter presented an extensive account on the distinct research methodology used to investigate the five research questions developed in this study. It begins by providing a rigorous presentation of the flow of actions followed in the research inquiry. The chapter consists of several sections. It highlights the research questions and the objectives of the study to allow a careful selection of the most appropriate research design. Once the research questions are discussed, different data collection methodologies are allocated to each question to gather the required data. For this purpose explanations on qualitative and quantitative research approaches are given. To address the first two research questions, the investigation starts by interviewing companies in the UK which is then followed by another series of interviews in India. Then a preliminary survey questionnaire is distributed to gather data for answering the third and fourth questions. For the final question case studies approach is selected. The case studies are completed in the UK and US.

## **Chapter 4, Responsiveness, the primary reason behind re-shoring manufacturing activities (The UK and India perspectives)**

### **4.1 Overview**

This chapter consists of two sections. The first part aims to understand the primary reason behind re-shoring phenomenon in the UK. This is done by studying the literature and the statistics published in governmental reports and examining the results by performing interviews in the UK. The second section in the chapter is to investigate the re-shoring movement from the perspective of a low cost country. In this case India was selected as a point of data collection. Figure 4-1 illustrates the content of this chapter respectively.

As it is shown in the diagram, a review of current literature and statistics published in government's reports was further enhanced through interviewing six organisations. These organisations include an Indian owned British OEM in the automotive sector, two governmental organisations promoting re-shoring in the UK, two consultancy services that have been closely involved in consulting re-shoring projects in the UK and an educational organisation which hosted the 2015 UK National Manufacturing Debate with the theme of



re-shoring. This provided an informative setting on the areas where the UK supply chain could enhance the supply capabilities in support of re-shoring companies. These interviews, together with the understanding developed from the literature formed the basis for the direction of research developed in this chapter.

India is one of the most important low-cost countries where western supply chains have migrated to. Once the key factors for re-shoring had been identified in the UK, this was then used as a basis for the investigation among Indian industries. Thus the second section in this chapter is to investigate the factors behind re-shoring from an Indian industry perspective. In other words the second part of this chapter focuses on what the shortcomings in the supply chain are in Indian industries that lead to re-shoring in the UK. The data collection for this part was carried out during the author's visit in India and collaboration with Coimbatore Institute of Technology (CIT) in the state of Tamil Nadu, India. The outcome is based on interviews conducted among 11 Indian industries in various sectors. As a result two propositions were developed which should be further studied using quantitative approach. This is to validate the findings and obtain more generalisable results.

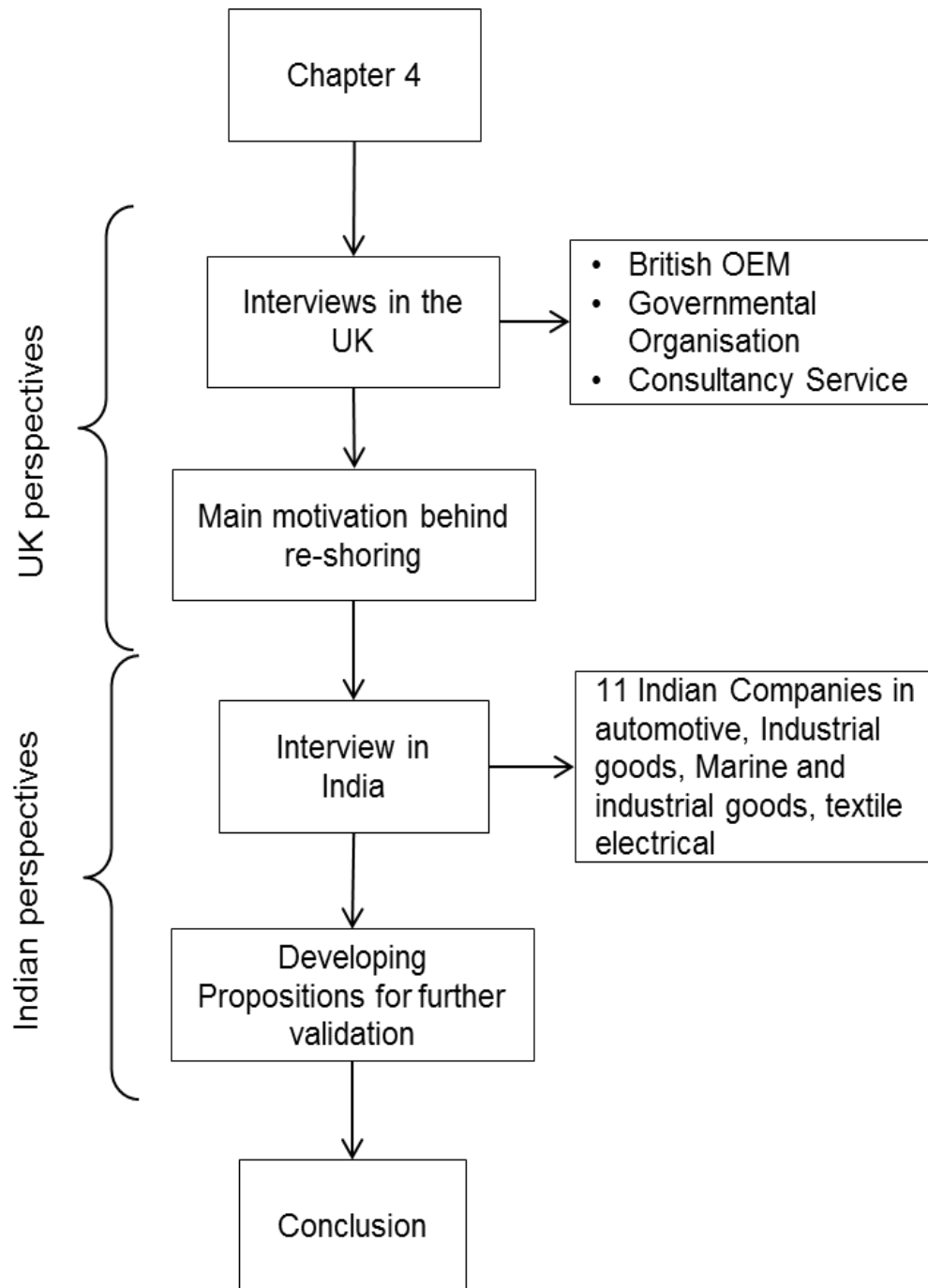


Figure 4-1, Chapter 4 content

## 4.2 Introduction

In today's manufacturing environment location decisions for both OEMs and suppliers are considered to be core to business strategy. Companies are required to have a supply chain and business intelligence strategy designed to make the best total value decision (Tate et al., 2014). For over two decades, developed countries have been offshoring their manufacturing activities to the low cost countries such as China and India (Lewin and Peeters 2006). Initially the migrations of these industries were solely with the purpose of reducing production costs in order to gain competitive advantage. This often overlooked what could be considered secondary level factors such as supply chain reliability issues with respect to time and quality (Fratocchi *et al.* 2014; Harrington 2011; Arlbjørn and Lüthje 2012). Despite the scale of offshoring strategies implemented every year, the reports showed lower success rates than what initially was expected (Herath and Kishore 2009). As a result in recent years, there has been a decline in offshoring (Bals et al., 2013) and it is evident that some multi-national companies have decided to re-shore parts of their manufacturing activities to their home countries (Bailey and De Propriis 2014). According to Koh *et al.* (2007), "the globalisation and intensive world-wide competition along with the technological advancements create an entirely new business environment for the manufacturing organisations". In addition to this, the intensity of the global competition for customer satisfaction has made the customer-supplier relationship management more important than ever before (Choy *et al.* 2003). Tate (2014) suggests that the proximity to the emerging population of customer can be the motive behind the "shoring" decision. These indications have led to emergence of new trend called "re-shoring" in countries such as Germany, France, UK and USA (Bailey and De Propriis 2014; Ellram *et al.* 2013; Fratocchi *et al.* 2013; Kinkel and Maloca 2009; Gray *et al.* 2013).

As mentioned before the re-shoring trend has received considerable attention in the UK with the Prime Minister of the UK calling the UK the "re-shoring nation" at the world economic forum in Davos Switzerland (Groom and Parker 2014). In order for the government to support the new movement in terms of policymaking, energy cost and supply of skills, Re-shore UK was established. This was launched in a collaboration between the UK Trade and Investment (UKTI) and the Manufacturing Advisory Service (MAS) resulting in a one-stop-shop service to help industries to return their production

back to the UK (GOV.UK Press release, 2014). This indicates the significance of re-shoring and how the UK is supporting its industries to bring back their manufacturing activities. According to the report published by Business Birmingham (2013), 41% of the respondent studied in this investigation, has stated that the UK has become a more attractive option for manufacturing companies in comparison with other locations. This is further supported by the UK government report indicating that one in six companies has re-shored parts of their production back to the UK since 2011 (EEF 2014; Gov.UK 2014). However despite the significance of re-shoring in the UK and the momentum in research related to macroeconomic analysis of re-shoring, the literature associated with the operational challenges still remains sparse.

The aim of this chapter is to identify the key driver behind the re-shoring phenomenon in the UK. As explained in “Chapter 2” the motivations can be divided into the expected and unexpected costs associated with the offshoring decision. Once the gap was identified the author chooses to investigate this issue from supply chain management perspectives. It then further investigates this key driver among the Indian industries. An in-depth study is conducted to realise what the factors are behind the shortcoming in the Indian supply chain. The following section presents the company demographics that were used to collect data in the UK and India.

### **4.3 Company demographics**

Scholars have traditionally adopted quantitative approach such as mathematical modelling and surveys to investigate issues related to supply chain management (Golicic and Davis 2012; Sachan and Datta 2005). In recent times, qualitative research has received more attention by European researchers (Taylor and Taylor 2009; Spens and Kovács 2006; Tachizawa and Thomsen 2007; Koste *et al.* 2004). However there still remains a lack of qualitative studies on the manufacturing aspects of the re-shoring phenomenon. Due to the immaturity of the subject within the academic context and limited practical application of re-shoring at the industrial level, it was recognised by the author that an in-depth approach was required, from a selected population of interviewees, to facilitate access to reliable information. Since the underlying dynamic of re-shoring phenomenon in the UK is still not well understood, qualitative research methods were selected to fill the gap in the literature. According to Golicic and Davis (2012) in situations where the phenomenon of interest in

new, dynamic and complex and a detailed description of the problem is required, qualitative research is a preferred method.

For the purpose of this study, semi-structured interviews were conducted in various industries. The investigation started by identifying data sources that were in the forefront of the re-shoring topic in the UK, mainly the study of UK government reports (EEF, 2014a). As a result of this, six organisations in the UK were identified that were at the core of the re-shoring movement. After establishing contacts, six interviews were performed with the purpose of determining the main motivational reasons, from a manufacturing point of view, for UK industries to re-shore their production activities from low labour cost countries back to the UK. These organisations are as follow:

1. UK Trade and Investment (UKTI)
2. Engineering Employees Federation (EEF)
3. Manufacturing Advisory Service (MAS)
4. TATA Consultancy Service (TCS)
5. Jaguar and Land Rover (JLR)
6. Cranfield University

Following the initial investigation in the UK the focus of research was transferred to India. The selected sample for the second part of this investigation consisted of Indian manufacturers who were involved in supplying parts to Europe. The investigation involved focusing on the bottlenecks in the responsiveness of the Indian suppliers. For this purpose the chosen sectors were the industries operating in a high demand uncertainty environment where lead-time plays an important role. Once the target companies were identified, contacts were made through the Coimbatore Institute of Technology. As result 11 interviews were performed in 11 different companies each taking between 1-1:30 hours. The analysis was carried out through manual coding and thematic analysis in order to identify the most repetitive patterns within their operations.

The companies were 1<sup>st</sup> and 2<sup>nd</sup> tier suppliers in mainly automotive, textile, industrial machinery and marine industries. The profile of the companies interviewed is listed in Table 4-1. For this data collection a highly ranked informant was selected who had an in-depth knowledge of supply chain management and issues related to overseas supplies. Each informant was contacted separately prior to the interview date and was provided with the range of questions that needed to be answered. Once they were confident in answering

them, the interview appointments were arranged. The data collection from both UK and India were conducted separately in 2014-2015 and were all in English. The following is the list of the companies interviewed in India. Note that while interviewing the companies it was promised that their input to the research would remain confidential. For this reason companies are labelled as Manufacturing 1, 2 etc. in Table 4-1.

- Autotext
- Craftsman
- ELGI auto
- Flow Link
- Gishnu Gears
- MM gears
- Hella Industries
- Pricol
- Roots
- ELGI Industries
- Suba Plastics

<b>Sector</b>	<b>Firm</b>	<b>Number of employees</b>	<b>Informant position</b>
Automotive	Manufacturer 1	1500	Commercial Officer
	Manufacturer 2	6000	Supply Chain Manager
	Manufacturer 3	150	Managing Director
	Manufacturer 4	120	Managing Director
	Manufacturer 5	80	Managing Director
	Manufacturer 6	200 in one department	Senior Quality Officer
Marine and Industrial goods	Manufacturer 7	3000	Design Manager
	Manufacturer 8	1300	Supply Chain Manager
Electrical	Manufacturer 9	600	Supply Chain manager
Textile	Manufacturer 10	260	Managing Director
Industrial goods	Manufacturer 11	720	Sales and Marketing Manager

**Table 4-1, Firms Profiles**

The following section discusses the ethical considerations associated with qualitative research study.

#### **4.4 Ethical consideration**

According to Graziano & Raulin (2007) once the respondents are identified, every research design needs to consider what observations to make, what the ethical considerations are required and what analytical methodology to employ. Saunders et al. (2009) defines ethic as “the appropriateness of your behaviour in relation to the rights of those who become the subject of your work, or are affected by it”. Normally the ethical considerations are required when the researchers interact with the respondent and visit the data collection sites (Smith et al., 2002). Batchelor & Briggs (1994) believe that the researchers who fail to consider the ethical issues in their studies are those who are being ill-prepared to cope with the uncertain nature of qualitative approach. Generally in qualitative research ethical consideration plays much more important role than in quantitative studies. This is due to the direct interaction (face to face) with the participants (Smith et al., 2002).

When it comes to conducting interview or accessing a site for data collection three concerns may rise (Saunders et al., 2009). The first one is the amount of time required for the access to the site or resources which should normally be kept to a minimum. The second factor to be considered is the sensitivity of the subject. The companies tend to be less cooperative in the case of having negative implications in the firm. For instance, generally companies tend to not admit to any shortcomings in their operations if the purpose of investigation is to study the firm’s performance (Saunders et al., 2009). The third factor is the confidentiality of the data to be gathered. This required the anonymity of the companies or individuals being interviewed.

In this research since the re-shoring can be a sensitive topic for Indian companies, a clear assurance was given to the respondent indicating that this study only aims to provide a better picture on re-shoring phenomenon in the UK and will not affect their businesses. One of the issues with the research ethic is the deception. According to Bryman & Bell (2007) deception occurs when the respondent are not fully introduced with the objectives of the research and are given wrong information instead. For instance this can happen when the researchers pretend to be students to the participants while gathering information for their competitors. Hence it is their right to be fully aware of the research objectives and its implications (Bryman and Bell, 2007). It should be noted that the companies

interviewed in this study were contacted through Coimbatore Institute of Technology (CIT) in India. This further ensures the ethical treatment of the participants.

The next section of this chapter provides the details about the framework of the interviews.

## **4.5 Supply chain responsiveness in the UK**

When interviewing the organisations in the UK, the main objective was to identify the most important supply chain issue that the UK industries experienced when collaborating with Indian suppliers which influenced their decision to re-shore. Table 4-2 provides a summary of the findings from the interviews and presents a series of bullet points to provide an indicative summary of the overall motivations behind re-shoring to the UK.

The primary factor that emerged from the interviews concerned responsiveness. This mainly emphasised lead-time reduction since it appeared repeatedly as one of the top reasons behind re-shoring in each individual interview. However other factors such as quality improvement, logistics cost reduction, customer satisfaction and better communication in the supply chain were among the other reasons behind re-shoring. Findings also showed the proximity to the end customers, faster delivery, and shorter lead times are the vital elements for the businesses serving the domestic market in the UK. This is also aligned with the findings from the report published by EEF (2014) which indicated that 93% of companies felt that as the time passes the responsiveness to customer demand is becoming the major challenge in their businesses. Depending on the demand characteristics, firms competing in a market where customer demands are highly unpredictable need to be more responsive to these changes and to collaborate more closely with other supply chain members.

Comparing the results from this study and the ones in the literature shows great similarities as supply chain responsiveness repeatedly appears among the top motivation behind re-shoring phenomenon. For instance the report published by MAS indicates that the top four reasons for re-shoring are 1) to improve quality, 2) to shorten lead time, 3) to enhance delivery performance and strengthen the supply chain and finally 4) to reduce the labour costs (MAS, 2014). Similarly, more recent survey conducted by Cranfield University (2015) shows that the respondent gave the highest marks to shorter lead time, better supply



service and better customer satisfaction respectively. This indicates that the supply chain responsiveness is a vital factor that causes the repatriation of manufacturing units.

These findings from UK companies also aligned with the literature. It is recognised that companies are no longer competing on an individual bases but require to be fully integrated with their supply chain to fulfil a mutual goal (Lambert and Cooper 2000). The research on supply chain responsiveness has been going on for more than a decade (Holweg 2005; Li *et al.* 2006). Since the early 1990s, companies have come to realise the significance of aligning their business strategies with their upstream and downstream activities (Kumar *et al.*, 2006). It is evident that the capability to react to changes in customer demand is an important determinant of competitive advantage (Squire *et al.*, 2009). The activities between UK manufacturers and Indian suppliers involve purchasing the raw materials, conversion of these materials into a final product and finally delivering the products to the retailers. Holweg (2005) emphasised that as the product lifecycles are shortened manufacturer are facing more challenges to accommodate these changes in their supply chains. As a result the speed to market and flexibility to respond to customer requirements are gaining substantial importance among the British manufacturers.

No	Organisation	Type	Date of Interview	Viewpoint about re-shoring
1	UK Trade and Investment (UKTI)	Governmental Organisation	02.04.2014	<ul style="list-style-type: none"> <li>• Create more jobs in the UK</li> <li>• Serve domestic market</li> <li>• Cut production costs</li> <li>• Use government incentives</li> </ul>
2	Engineering Employees Federation (EEF)	Governmental Organisation	02.04.2014	<ul style="list-style-type: none"> <li>• Improve quality of the output</li> <li>• Reduce product delivery time</li> <li>• Minimise logistic costs</li> </ul>
3	Manufacturing Advisory Service (MAS)	Consultancy	29.07.2015	<ul style="list-style-type: none"> <li>• Reduce costs</li> <li>• Improve quality</li> <li>• Shorten lead-time</li> </ul>
4	TATA Consultancy Service (TCS)	Consultancy	02.06.2015	<ul style="list-style-type: none"> <li>• Be more responsive to the demand</li> <li>• More integrated supply chain</li> <li>• Lower transportation costs</li> </ul>
5	Jaguar and Land Rover (JLR)	Original Equipment Manufacturer	26.11.2014	<ul style="list-style-type: none"> <li>• Lower production costs</li> <li>• Better communication</li> <li>• Shorten lead-time</li> </ul>

6	Cranfield University	Educational Organisation	02.04.2015	<ul style="list-style-type: none"> <li>• <i>Be more responsive to the demand in UK</i></li> <li>• <i>Better supply Service</i></li> <li>• <i>Better customer satisfaction</i></li> <li>• <i>Lower transportation costs</i></li> </ul>
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Table 4-2, Summary of the interviews in the UK

## 4.6 Interview framework for Indian companies

After conducting the literature review on the concept of supply chain responsiveness and the first series of interviews in the UK, the framework for the interviews in India was developed. It focuses on investigating the three factors that were considered to be the key enablers of responsiveness in the companies. These are Information Technology (IT) solutions, manufacturing equipment and human factors. The interview guide was structured around these three factors. The insight gained from the interviews is expressed in Figure 4-2 which indicates that the responsiveness can be achieved by utilisation and integration of these three strongly linked factors. In the context of these three key enablers the Indian companies were interviewed to capture the overall picture of the issue on supply chain and assess their capability for being responsive towards the demand in western countries.

As shown in Figure 4-2, the absence of each factor can result in different types of bottlenecks. This is illustrated as each circle represents one enabler and the combination of them results in responsiveness (the centre of the diagram). The combination of only two circles results in issues which are indicated using italic font in the diagram. For instance the absence of IT can cause poor communication and lack of integration in the supply chain between the suppliers in India and the companies in the UK. Consequently there will be less transparency about the supply and demand possibly leading to lack of information exchange (Catalan and Kotzab, 2003; Squire et al., 2009). Similarly once the companies lack the manufacturing capability, the responsiveness can be influenced in terms of lack of flexibility in addressing any changes in product design or order volume. Additionally it can result in poor quality of products. The next section provides a brief explanation on how these three factors can help companies to be more responsive.

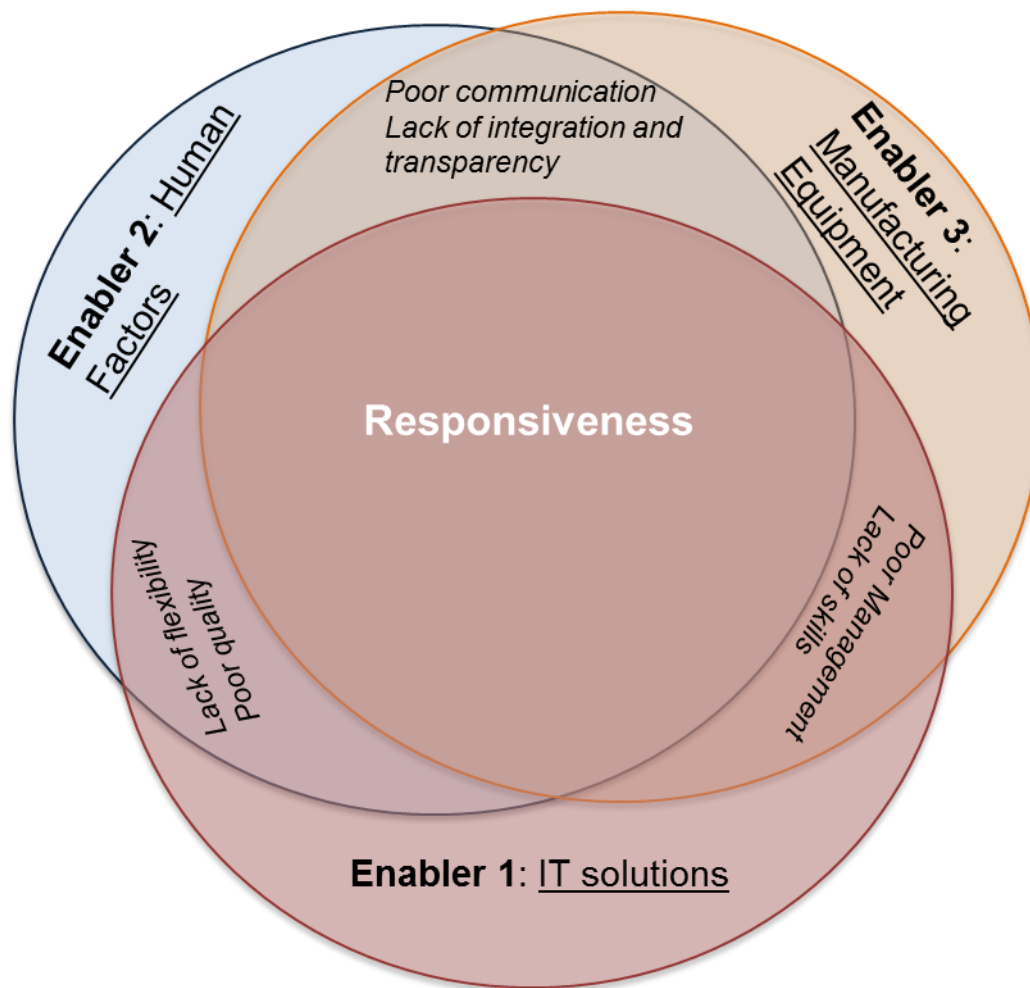


Figure 4-2, Responsiveness Framework

#### 4.6.1 IT solutions

Today the influence of IT solutions on supply chain management is unprecedented. This is evident in the way that the data exchanges among companies are carried out. The linkage between them has been transformed in comparison to how it was done traditionally (Plamer and Griffith 1998; Arlbjörn and Lüthje 2012). IT can be utilised to establish partnerships for more effective and efficient supply chain systems (Choy *et al.* 2003; Waller and Fawcett 2013). The IT solutions can be in various forms ranging from mobile telephone communications and emails to Electronic Data Interchange (EDI), Customer Relationship Management (CRM), intranet and extranet, and direct links-up with suppliers (Quayle 2002). These technologies facilitate the collaborative planning among the suppliers and allows real-time information sharing such as demand forecasts and production schedule for supply chain decision making (Kumar *et al.* 2006). As it is shown

in Figure 4-2, the absence of IT as one of the three enablers of responsiveness can lead to poor communication and lack of integration and transparency. According to Choy *et al.* (2003) “the rapid advance in IT is now deployed not only to improve existing operational effectiveness of a business, but also to build the new capability to meet today’s business environment and complexity”. Once the IT tools are in place the paper transactions are significantly reduced and it also leads to shorter order cycle times and decrease in inventory level (Prajogo and Olhager 2012; Quayle 2002).

#### **4.6.2 Human factors**

According to Kumar *et al.* (2006) the first phase in achieving manufacturing flexibility and becoming more responsive to customer demand relies on the responsibility of the senior management in identifying the specific aspects of responsiveness and focusing on the areas that can improve the competitiveness in terms of product range and speed. The absence of this factor can result in lack of right management support and skilled workforce which can ultimately reduce the company’s responsiveness. Hence human factors can be divided into two parts. The first part is related to the responsibilities of the management team in the company. One of the critical aspects of management strategies towards responsiveness is provision of training and educating the workforce (Backhouse and Burns 1999). Hopp and Oyen (2004) believe that “cross-training can enable shorter lead time quotes and more reliable delivery by reducing the mean and variance of the cycle time (and hence lead time) to produce a product or service”. In other words the adjustment and reconfiguration of the operations to achieve responsive production will only be feasible if there is right culture within which the workforce operates (Duclos *et al.* 2003). Hence training multi-skilled workforce can have a significant influence on the operation performance (Sawhney, 2013). The second part of the human factor is about the availability of the workforce (Duclos *et al.* 2003; Sawhney 2013). This can consist of the shop floor operators with basic skills to engineers and personnel with specific expertise. According to Bailey and De Propriis (2014) lack of skills in the UK is considered to be one of the limitations that the re-shoring companies are currently facing.

### **4.6.3 Manufacturing equipment**

The last factor to be considered is the re-configurability of the manufacturing equipment to meet the customer demand and shorten production lead-time. The manufacturing system can be seen as an enabler to meet the emerging customer trends by reconfiguration of assets and operations (Duclos *et al.* 2003). Mehrabi *et al.* (2000) draw a line between re-configurability and agility of the production in which re-configurability does not deal with the entire organisation and instead it focuses on the production system and objective of manufacturing responsiveness. They suggest that the manufacturing systems should be able to be designed rapidly and be adjustable towards production of new products, at the same time its capacity should be modifiable and allow easy integration of new technologies in order to manufacture variety of products with unpredictable demands (Mehrabi *et al.*, 2000). The flexibility of the machines is defined as the range of operations that a machine can complete without any major modifications in setup and the operation flexibility is the extent to which a part can be manufactured using different processes (Stevenson and Spring 2007).

## **4.7 Responsiveness in Indian industries**

According to ATKearney (2014) report, India still remains the first offshoring destination for westerns companies among the other low cost countries. This indicates that India is still increasingly being considered as an attractive option and plays an important role in manufacturing location decision. According to PwC (2014) “India is one of the most mature global sourcing destination with the widest range of options”. Selecting South India (Tamil Nadu) as a point of data collection offers range of benefits such as its influence in global supply chain. The capital of Tamil Nadu, Chennai is known as the biggest industrial and commercial centre in South India and currently is considered as one of the largest supplier of components to the European automotive sector and British carmakers such as Jaguar and Land Rover (JLR). Hence it provides a platform to establish better understanding of quantity, quality and range of product that are being supplied to the western industries. According to Make in India (2015) the Indian government is currently taking several initiative to further support foreign investment, foster innovation, protect Intellectual Properties (IP) and build best-in-class manufacturing infrastructure.

In the preliminary part of the interviews, the interviewees were first introduced to the concepts of re-shoring and responsiveness and the objectives of the study were clearly defined. The language of some of the questions was simplified in order to make them easier to understand. Having considered the motives behind re-shoring movement in the UK, the companies were first asked about some of the potential reasons for why western companies are repatriating their manufacturing back to their countries. Subsequently a new viewpoint towards the re-shoring strategies can be obtained. The three factors that were mentioned by the respondents were the dramatic increase in the labour and transportation costs and longer delivery time. They believed that this has initiated the steady flow of firm's reorientation of production activities towards west. This is also in line with reasons found in the literature (Ellram, 2013; Fratocchi et al., 2013; Gray et al., 2013). Then the issue on responsiveness and shortening the supply chain was mentioned and discussed.

IT is considered to be an important facilitator for communications and data exchange between Indian firms and their customers in Europe. This was also evident when the majority of the participant claimed that they are investing heavily in IT to enhance their abilities to manage their information and knowledge in the supply chain. However according to Fawcett et al. (2007) the only possible way to utilise IT solutions, is if both parties are willing to share required information whereas without supporting this, large investments in IT can fail. Therefore this requires firms to communicate their strategic supply chain information and not only transactional data e.g. materials or product orders (Fawcett et al., 2007). Such level of communication will require great level of trust between the companies. The risk of intellectual properties being exposed to foreign market has been increasingly taken into account when making offshoring decisions (Casson, 2013; Lewin and Volberda, 2011; Tate et al., 2014). Despite of having laws to protect the intellectual properties in countries such as China and India, the confidential data about innovative and new products are still vulnerable to being stolen (Ellram, 2013; Zimmerman, 2013). An instance was when an Indian employee in a reputable software company decided to transfer some of the key information to her personal email account and disappear (Tate, 2014). However a number of respondents claimed that IP in India is taken more seriously than in China, making India a safer place for manufacturing facilities.

Mainly in large organisations in India sufficient amount of IT facilities were provided in order to facilitate the communications with foreign customers and suppliers around the world. However smaller companies lacked these facilities which ultimately can be a limitation in being a part of bigger supply chains. One of the main bottlenecks in utilisation of IT solutions in India was companies mostly focusing on the technological side of the IT and paying less attention to the organisational culture. This can make the companies unsatisfied with the return on the investment (Soo et al., 2002). Hence this raises the issue on the human factors in the organisations. The participants were asked about their approach for training the workforce and providing education for their staff. According to Davis et al. (2012) “manufacturing workforce with substantially more advanced training and skills will not only be fundamental but will also be the key competitive advantage as dynamic management and operation of demand-driven product profiles increase and as innovation and faster time-to-market for new products becomes a key economic driver”. The results from the data gathered show that in recent time much attention has been given in providing right training and introducing educational channels in Indian companies. All the companies interviewed have claimed to adopt some sort of training for their personnel. This ranges from providing simple shop floor skills such as working with the machining tools, using internal resources to more advanced engineering skills for quality assurance, lean and agile principles, Customer Relation Management (CRM) and technical support for design. Some of the companies had also a close collaboration with their customers in Europe where they would send some of their staff abroad for training purposes every year. These were consistently happening throughout the year. Furthermore, contracts were made with the local universities to provide part time education for the people willing to advance their engineering knowledge. University educations were mainly engineering courses such as mechanical, electrical and chemical engineering.

The education of the workforce and familiarisation with the latest technologies and IT systems also indicates that the implementation time and overall cost of IT will also be reduced by substantial amount as a result of reduction in disruption time and clarification of the long-term benefits (Gaimon et al., 2011). Consequently over a course of time this will create an effective and efficient organisational culture which in turn will affect the working attitude of the workforce. The responsiveness of a firm can also depend on availability of the skilled labour in the case of emergencies. This was also raised as one of

the issues that the Indian manufacturers were facing in recent years. Depending on the geographical location of the firm, the access to working population varies. For instance the availability of engineers in southern part of India is not an issue however conversely there is a shortage of skilled manpower for tasks such as shop floor machining and assembly operations. It should be noted that the big companies capitalise on their strong brand image and international reputation, therefore they face less difficulties in finding skilled workers than Small and Medium Size (SMEs) companies. The reason behind such issues is the level of automation utilised in large manufacturing companies that requires less manual work therefore less skills.

The manufacturing facilities are the next area investigated and has a substantial influence in the ability to shorten the time involved in manufacturing and supply of the product. The selected sample in this research provides diverse production methods (e.g. automated, semi-automated and manual operations). The large companies mainly tend to adopt high level of automation and advanced technologies whereas the small and medium sized companies had greater tendency towards manual/traditional operations. Companies were questioned on the level of automation used in their production line and the future plan for further investments in manufacturing equipment. Due to the globalisation and volatile market, Indian manufacturers are experiencing a significant transformation from traditional and conventional manufacturing to more intelligent and reconfigurable systems. Results indicate that significant attention has been put on rapid adjustment of production capacity due to the fluctuation in the demand market in recent years. Large investments are made on flexible and generic machines to accommodate wider range of products. Therefore it is expected that the Indian companies to have more automated systems with minimum human interactions. This also can increase the speed of production therefore help the companies to be more responsive to customer demand. However Mehrabi et al. (2000) claims that the reconfigurable manufacturing systems do not necessarily require more investment than dedicated transfer lines. This study suggests that reconfigurable manufacturing systems "... will allow adding, removing, or modifying specific process capabilities, controls, software, or machine structure to adjust production capacity in response to changing market demands or technologies" (Mehrabi et al., 2000).



## 4.8 Factors affecting the responsiveness in India

One of the objectives of this chapter is to identify the bottlenecks that prolong the supply of product to western market which has resulted in companies re-shoring production back to their home countries (Fratocchi *et al.* 2013; Gray *et al.* 2013; Fine 2013; Bailey and De Propriis 2014). Figure 4-3 illustrates the top four factors as determined in this research affecting the responsiveness of the Indian companies supplying overseas market. The percentage of each factor represents the proportion of instances that each individual factor was recorded in overall data collection. The percentage indicates the number of companies that mentioned these factors as their operational problem that causes delay in their delivery time. The results obtained from the interviews show that the top three factors influencing the responsiveness of Indian industry beyond the conventional views expressed in the literature. The utilisation of IT and manufacturing equipment were not key determinants in improving the lead-time for the products supplied from India. Instead the logistics and transportation, electricity shortage, excessive paper work and working attitude of the personnel were the main issues respectively. The following is detailed explanation of each of the actual key determining factors identified in the research.

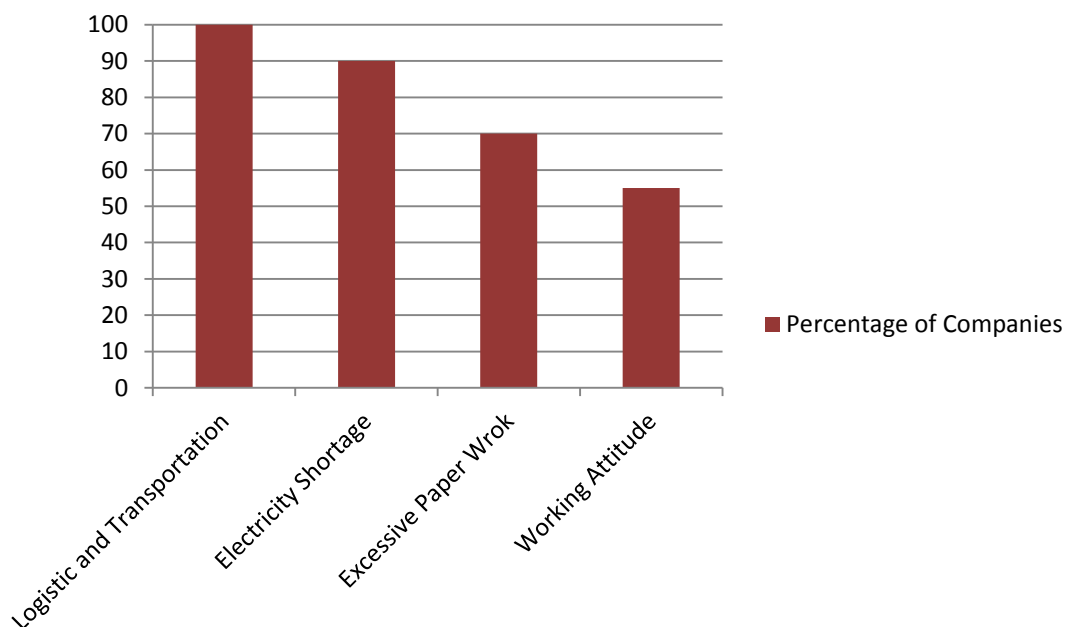


Figure 4-3, Factors affecting the responsiveness of Indian industries

- Logistics and transportation: This takes the biggest portion of the overall lead time to overseas markets and shipment around the globe. On average 4-6 weeks is spent on shipping the products using sea transportation from ports in south India to Europe. Whereas products manufactured in the UK or Europe can save up to two month of transportation time. Additionally, due to the enforcement of the governmental policies towards cleaner transportation using slow-steaming ocean transit, the working capital is tied up in inventory for longer periods. This further prolongs the lead-time imposing pressure on the companies that need to achieve faster delivery for products with short lifecycles. The following quote is an example that shows the viewpoint on transportation issues from India to Europe.

*“Of course the customers are demanding, we currently make some products in 4-5 week and some in 10-12 weeks but on top of that you need to consider the shipping time which is normally 4 weeks for Europe and 7 weeks for North America. So they are demanding shorter lead time and expecting us to have a warehouse and manage the inventory at their own place*

*... sometimes customers demand for faster delivery where we need to re-route and change the port. This is a disadvantage where the people in Europe and North America also have the same lead-time and produce in 4-5 or 10-12 weeks but we in here need to add shipping time and transportation on top of that. That is why we are talking to them about opening a new warehouse and have vendor management inventory in our major customer’s country because we want to have the advantage of what the domestic manufacturers have in US and EU (Manufacturer 11)”*

As clearly pointed out in the above quote, one of the ways to reduce the delivery-time is to have an additional warehouse in the country where the products are marketed. Hence the products are shipped from an in-house location once the order has been placed. However this requires significant amount of investment and resources in the target country leaving this option out of reach for small and medium companies in India. Another issue related to transportation is the limitation on the volume of the goods being shipped. The following quote shows that small and medium companies are obliged to have a certain number of items or volume that can be dispatched using sea transportation.

*“We need to have certain batch size so we can send our products overseas. We don't always produce in a large number so it is difficult to ship them. Actually sometimes when the order is urgent we ship them by airplanes which is a bit costly for us (Manufacturer 5)”*

- Electricity shortage: This is the next factor that has a significant effect on prolonging the production processes. Inconsistent electricity supply was mentioned almost by all the respondents as a problem that they face on a daily basis. However this is except the large companies that have their own power generators in place inside the organisation. Thus in this situation the electricity shortage does not directly affect their production. This factor is not directly under the control of manufacturers and needs to be addressed by the Indian government. However according to Make in India (2015) the government has started paying more attention and is targeting a capacity addition of 88.5 GW during 2012-2017 and 86.4 GW during 2017-2022. In order to address the issues related to the electricity shortage the government is also offering range of incentives for foreign direct investment in generation and transmission of electric energy produced in hydro-electric, coal, lignite, oil and gas based thermal power plants. The following quotes are some examples that were recorded while interviewing.

*“Here in India, we need our governments’ support, for example in our company we suffer from inconsistent electricity supply. There are situations that we need to stop working for 3 hours during the day time (Manufacturer 4)”*

*“We don't have any problem with electricity but it is because we produce our own energy. Some of our suppliers do have this problem and I am sure other smaller companies are struggling with this issue every day. (Manufacturer 1)”*

- Excessive paperwork: This problem consists of the time taken to complete the paperwork required for domestic transportation, handling the logistics and export to Europe. However this issue can, to some extent, be addressed by appropriate implementation of IT and better management but the major bottlenecks are

associated to the government related end of the stream. It is another factor which does not solely depend on the firm and should be addressed by the Indian government.

*“Our work is normally moved from one office to another, sometimes there is a delay for over a week for some unknown reasons and we need to wait while our product delivery is delayed (Manufacturer 5)”*

- Working attitude: Working attitude was also among the top four reasons behind lack of supply responsiveness of Indian suppliers. However this can be the result of insufficient management skills to motivate and engage the workforce in team works towards company's set of clearly defined goals. This is further emphasised in the report published by Phew Research Centre (Pew Research Center, 2014). This study shows that the 38% of Indian workforce believe that it is important (0-10 scale) to work hard to achieve more whereas this figure for USA and UK are 73% and 60% respectively. However the issue with employee's working attitude was more evident in small and medium companies since larger organisations offer more motivations such as incentives, regular training courses, etc.

*“One thing that we normally suffer from is the working attitude. Sometimes they (workforce) tend to do the job in last minute, if there is no pressure from management the orders will not be met until the last week.*

*... also another problem is that we have too many holidays in India and in addition to that workers are asking for more holidays to spend time with their families (Manufacturer 3)”*

*“At the beginning when we started we had a lot of issues with our people (employees) sometimes they were not doing what they were told to do. But we are trying to provide more training and better management to make better (working) culture. In the past we have sent people to Europe so they learn about their working habits and be familiar with how they work. I think this has been a good way for us to train our employees (Manufacturer 9)”*

As a result of the data gathered in this section, Figure 4-4 was developed to illustrate a simplified picture of the supply chain. This diagram demonstrates the engagement of overseas suppliers in supplying products to the companies in the UK who are targeting the domestic market. As shown in the diagram factors such as cost, quality and time are typically considered as main drivers in selecting the suppliers in traditional supply chain (Harland, 1996). The feedback obtained from the customer is then transferred and communicated to the suppliers where the changes in product specifications and order volume are required. Note that this diagram will be further developed in “Chapter 7” to indicate the impacts of Additive Manufacturing (AM) in the supply chain management of re-shoring companies.

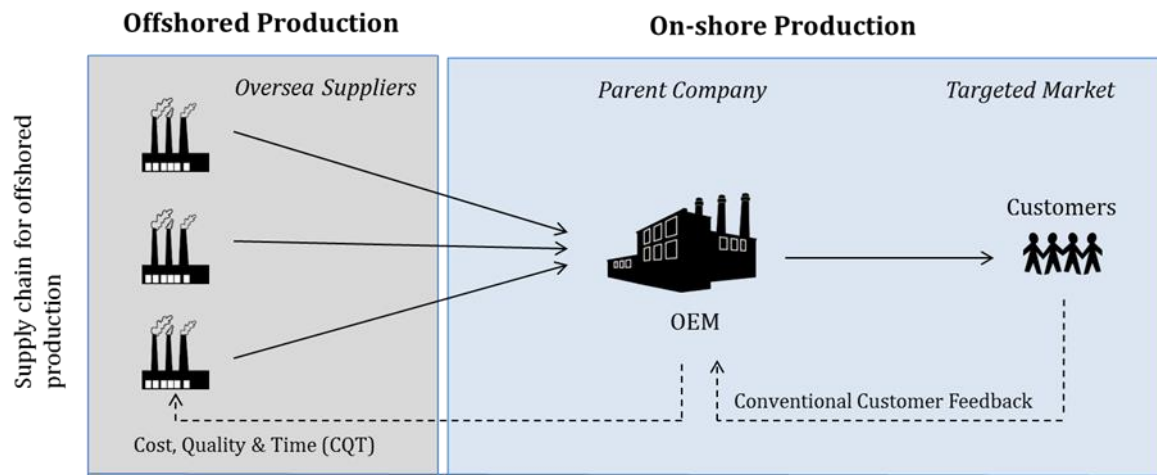


Figure 4-4, Traditional supply chain

## 4.9 Propositions

However according to the literature the companies are more likely to be responsive to the customer demand by better utilisation of IT, advanced manufacturing facilities and better management of human resources (Choy et al., 2003, Hopp & Oyen 2004, Mehrabi et al., 2000). The result obtained in this study indicates that the lack of responsiveness in Indian industry is not strongly related to the insufficient level of IT capability in the organisations. In fact there is substantial effort put into enhancing the communications and data sharing with western companies to facilitate the product development, reduce miscommunications

and ultimately increase the visibility in the supply chain. The main bottlenecks in achieving faster delivery times are mainly out of firms' operational impact and depend on the business environment inside India. Despite the government providing incentives and other helps for Indian industries, this support varies across India and problems such as electricity shortage is widely noted in the state of Tamil Nadu. In accordance with these results we establish the following propositions in the context of supply chain management, which should be analysed in further studies:

P1: Changing production cost differentials between India and UK is not the main reason behind the British manufacturers' re-shoring strategies.

P2: Lack of production responsiveness in India is the main reason behind re-shoring strategies in the UK.

India is still considered to be a low cost country and continuous to be targeted by western multinational companies. Despite the dramatic increase in labour and transportation costs in Asian countries (RSA and Lloyds Banking Group, 2013), India still offers price competitive advantages in comparison with other low cost locations (Make in India, 2015). However lack of supplier responsiveness is challenging Western OEMs who need to meet ever increasing customer requirements. Today customers demanding for higher levels of product customisations have put the manufacturing industries under substantial cost pressures due to having to deal with shorter product lifecycles. Consequently unresponsive supply chains lead to lower customer satisfactions (Yang et al., 2005b). By re-shoring parts of the operations required for producing products with shorter lifecycles and uncertain demand, the innovation and product changes will be much easier managed by shorter supply chains. Since Postponement can potentially delay the activities in the supply chain and differentiation of end product until the real information about the customer demand are available (Yang and Burns 2003). Hence by moving the decoupling point (where the forecast driven production gives way to demand driven production) downstream in the supply chain, the delivery time needs to be shorter which in turn requires a more responsive supply chain (Van Hoek *et al.* 1999; Yang *et al.* 2004). Such strategy also allows to "right-shore" or "Intelli-source" the operations by combining the local knowledge and global network (Fine, 2013; Tate, 2014). In other words both offshoring and re-shoring strategies can be adopted while having in mind that "the lowest

price can mean highest risk and highest risk can mean high total costs” (Fine 2013; Bals *et al* 2015).

The repatriation of manufacturing activities to western countries can be seen as an opportunity to further employ Postponement strategy in the supply chain. Recent studies shows that the job being brought back to western countries are not necessarily the same jobs which previously were offshored due to the advancements in technology resulting in more automated manufacturing and less requirement for manpower (Tate et al., 2014). Hence re-shoring can provide a platform to keep the products in generic state and delay the product differentiation by taking advantage of local suppliers in the UK. The businesses affected by slow supply chain can then improve their responsiveness by postponing their manufacturing activities that serve the domestic market. Despite having a well-established literature available on the concept of Postponement, the applications of this strategy are still at an infancy stage (Van Hoek, 2001; Yang and Burns, 2003).

The findings in this chapter lead the study to the next part of this research which involves investigation of the re-shoring phenomenon in a larger scale by conducting questionnaire where the above propositions can be validated.

#### **4.10 Limitations**

While this study has contributions to the body of knowledge, it also has some limitations in its research methodology and data collection. The findings in this chapter are limited to the companies that were interviewed in the UK and India and the reduced sample size restrains the level of generalisability of the findings. This study can firstly benefit from further in-depth investigation and identification of other factors behind re-shoring. In addition to this further validation is required using quantitative approach and larger sample sizes to include a wider range of industrial sectors. It should be noted that responsiveness was found to be the main reason for re-shoring to UK only in the context of Indian industries. This can be further supported by studying other low cost countries such as China.

## 4.11 Summary

Considering today's volatile business environment, companies are revisiting decisions about their desired manufacturing location. Due to the shift in global competitive conditions, companies have started to establish a better understanding of the total risk/benefit-balance and base their supplier decisions on strategic supply chain issue rather than simply relying on piece part cost analysis. In addition to this, due to the urgent requirement to meet the customer specifications and survive in a dynamic business environment companies are revisiting their manufacturing location decisions. This has resulted in a gradual repatriation of manufacturing back to the UK. Consequently there is an emerging trend in returning the manufacturing activities back to the firms' parent country. However the motivations behind such strategies appear to be inconsistent in the available literature. Two objectives were outlined in this chapter. Firstly it aims to explore and introduce the primary motivation behind the re-shoring strategy in the UK and investigate the factors that influence this decision. Hence it provides a clear viewpoint of the issues related to supply chain management that leads to re-shoring. Secondly it investigates this issue from Indian perspectives. The analysis of this chapter is based on interviews conducted in the UK and India (State of Tamil Nadu) in various industries including automotive, industrial goods, textile, and marine. The findings indicate that re-shoring is the direct result of inadequacy in responsiveness of Indian suppliers. Therefore delivery time plays a vital role in re-shoring decisions. Furthermore highlights four major factors slowing down the supply from India.



# **Chapter 5, Applicability of Additive Manufacturing in re-shoring companies (survey study in the UK)**

## **5.1 Overview**

This chapter aims to answer two of the five research questions that were initially developed in this study and listed on page 53 in Chapter 3. The two questions that are addressed are:

- 3) Is there a positive relationship between Postponement and re-shoring?
- 4) Is there a positive relationship between AM and re-shoring?

In order to do so, a preliminary study using the survey approach was conducted. This chapter provides the details on how the questionnaire instrument was developed at the first place. It is emphasised on designing a concise and comprehensive questionnaire that can be filled across various industrial sectors. A poor questionnaire design can also affect the validity of the findings in the research. Hence a clear guideline was used to develop a

questionnaire in which any misinterpretation is minimised and research objectives are well communicated.

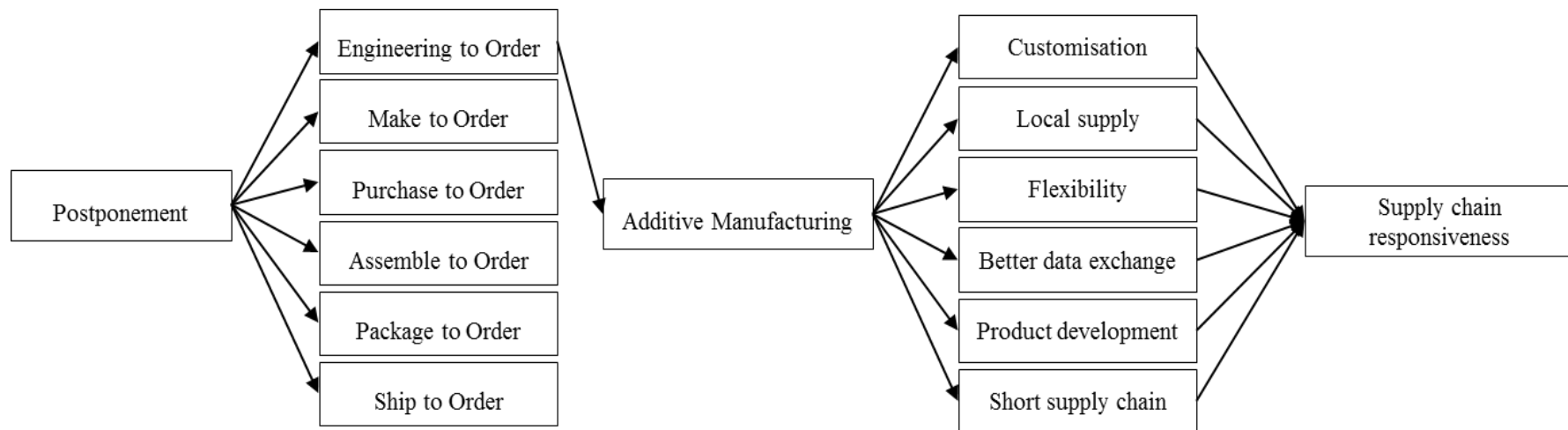
Once the survey questionnaire is developed, target respondents were identified to ensure the maximum effectiveness of their responses. Due to the nature of this study, the respondents had to be selected from industries that manufacture high value added products in an uncertain market. As a result 50 companies participated in this survey study. The results obtained from the questionnaire are presented in bar charts using Likert scale, 1- strongly disagree, 2- somewhat disagree, 3- neither agree nor disagree, 4- somewhat agree, 5- strongly agree. This provides an overall picture of what British Additive Manufacturing (AM) industries think about re-shoring manufacturing activities back to the UK and how AM can contribute to this phenomenon in terms of responsiveness in production. Last but not least a brief discussion is included to explain the possible theoretical outcomes from integrating AM in UK supply chain that will be further discussed in the next chapters and based on conducting three case studies.

## **5.2 Questionnaire structure**

This section presents the details on how the questionnaire was structured to acquire the data necessary for addressing the research questions. As part of the objectives that were defined in this research, three different areas should be included in the questionnaire design, namely re-shoring, Postponement and AM technologies. However to start the questionnaire, series of questions were asked regarding to companies basic information (See Appendix B). For instance the participants were asked about their role in the company, number of employees, gross annual sales, type of business they work for, the industrial sector they operate in and the type of products they manufacture. This can assist to classify the responses received and have a clear understanding of which sectors can benefit the most from application of AM after they re-shore. This is followed by series of questions that will take the participants step by step through the questionnaire.

Figure 5-1 shows the connection between the Postponement strategies and the AM technologies. As discussed in “Chapter 2” the concept of Postponement can be implemented in various forms depending on the availability of the information on the customer demand. As a result AM technologies can be considered as a type of Postponement where the products are engineered according to the customer specifications.

Figure 5-1 also indicates the factors that can be helpful to the companies to address the primary motivation behind the re-shoring manufacturing, which was found in “Chapter 4” of this thesis. It determines the benefits of utilising AM technologies towards having a more responsive supply chain in the UK. The following discusses each section in the questionnaire design.



**Figure 5-1, Relationship between Postponement, Additive Manufacturing and responsiveness**

### **5.2.1 Re-shoring**

Re-shoring phenomenon is still at its infancy in the UK and is not entirely known among the UK manufacturers. Hence it is important that the questionnaire contains a brief introduction of the research project and clarifies its objectives. Once the project is introduced, respondent can start to fill in the questionnaire. The first section in the questionnaire aims to ask the participant's viewpoint on re-shoring movement in the UK. Hence a number of questions are dedicated to finding out the reasons that motivates the industries to repatriate their manufacturing back to the UK. The questionnaire lists number of factors such as speedy delivery to customers, proximity to the end customers, customisation of the products, rapid new product introduction to the marketplace, cost of production and development of new products. However the main focus of the questionnaire is on the factors related to the production responsiveness. Despite having several governmental reports and statistics available on the factors leading to re-shoring and the scale of the phenomenon, none of them are specifically targeting the companies that manufacture high value added products. According to this study high value added manufacturing is one of the main areas in which re-shoring is currently occurring. This is due to the priority of the time to market to the cost of the production. This leads to the next area which is the Postponement concept.

### **5.2.2 Postponement**

As mentioned above this study focuses on the high value added products in which time plays an important role. This is where Postponement strategies can make significant difference in terms of total lead-time reduction. In other words Postponement concept has been repeatedly applied in various industries and has proven to add significant value to the companies in terms of lead-time reduction and increase in product customisation. Hence a section in the questionnaire was used to ask the participants what they think of Postponement strategy as a possible solution to address the long lead-time issue when dealing with overseas suppliers. This investigates the feasibility of applying Postponement concept to keep the products in a generic state and respond faster to customer demand once the order has been put into place. Respondents were asked about their general viewpoint

on applicability of Postponement in the UK and the extent to which UK based suppliers are capable of supporting Postponement strategies for the companies re-shoring.

### **5.2.3 Additive Manufacturing**

The main part of the questionnaire concerns about applicability of AM technologies in companies that are re-shoring back to the UK. This introduces an unstudied area in the re-shoring literature in which the aim is to bridge the re-shoring phenomenon to the new generation of technologies. In this scenario AM technologies was selected as a potential manufacturing method to improve the responsiveness of the UK industries.

Hence the final section in the questionnaire includes a series of questions pointing out the contributions that AM can offer to re-shoring companies. Example of these benefits are using local manufacturers in the UK, reducing miscommunications with the suppliers, faster product development, shortening supply chain, offering more customised products and finally reducing the lead-time.

## **5.3 Demographic of the sample**

In this chapter re-shoring has been studied from the operational aspect, which provides a solution that enhances the re-shoring decisions. The data collection instrument was verified by having series of discussions with experts in this fields e.g. academics and consultants. The outcome was put into test by attending the National Manufacturing Debate 2015 at Cranfield University. It should be noted that the purpose of debate was to investigate re-shoring and its impacts on the UK economy. Further areas such as assessing UK's capability to support re-shoring were discussed. Once some more feedbacks were received, the finalised version of the questionnaire was developed. The analysis used in this chapter is based on the responses from 50 manufacturing companies who utilise AM technologies in their supply chain, either directly or indirectly. This in turn helps to build a statistical generalisation. In order to get the required data, the respondents were accessed through the author's attendance in the conferences, exhibitions and seminars that involved AM application in industry. Therefore this provided the opportunity for selection of the respondents from the participants in various events and engaging in a face-to-face conversation and explaining the objectives of the study. In addition to this, a number of

feedbacks were received when engaged in a conversation with the target respondent. Then the feedbacks were used to alter the questionnaire and develop a more suitable instrument to collect the data.

In order to get the maximum effectiveness from the collected answers, the sample targets the companies who are familiar with the AM technologies and are aware of its applications and impacts on the supply chain management. This consists of the companies that are already involved in using AM processes in their production or require additively produced components in their products. In addition to this the participants were asked about their knowledge on re-shoring phenomenon in the UK. Once the initial clarifications were made the questionnaire was given to those who were adequately familiar with the re-shoring phenomenon and AM technologies.

The distribution of the sample is presented in the following table in respect to company size and the sectors. It also shows the number of respondents from each industrial sector. As illustrated in Table 5-1 the respondents were mainly from “automotive and supplier”, “aerospace” and “machinery equipment” sectors. Demographic data indicated that in terms of employment, the majority of the respondents were small and medium-sized companies. This is because the AM technology is relatively a new manufacturing method and its market is still at its infancy. However this is expected to grow in the up-coming years (Gausemeier et al., 2013). In addition, the majority of the respondents were in top management roles or executive positions which allow accessing more reliable information.

The work on re-shoring strategies has been considerably increasing in recent years which provides insights into why re-shoring is currently happening in developed countries (Bailey and De Propriis, 2014; Ellram, 2013; Fratocchi et al., 2014; Gray et al., 2013; Kinkel and Maloca, 2009; Kinkel, 2012; Tate, 2014). It indicates that despite the significance of this phenomenon to manufacturing, the supply chain literature has focused predominantly on the macro-economic analysis whilst the literature on the operational aspects of re-shoring is relatively sparse.

Sector	Number of employees			
	1-50	50-250	>250	
Automotive and suppliers	13	4	2	
Aerospace	5	1	0	
Machinery equipment	6	3	4	
Others	9	2	1	
<b>Total</b>	33	10	7	50

Table 5-1, Company demographics

## 5.4 Findings

In this section, the results obtained from conducting the questionnaire, are presented. For this purpose series of bar charts were generated each illustrating the outcomes for different questions listed in the questionnaire. The results illustrated are obtained by using Likert scale, 1- Strongly disagree, 2- somewhat disagree, 3- neither agree nor disagree, 4- somewhat agree, 5- strongly agree. In order to recall the research questions developed at the starting point of this study, the Figure 5-2 is shown below. As illustrated in Figure 5-2, research questions, number 3 and 4, will be addressed in this chapter by using survey questionnaire and literature review.



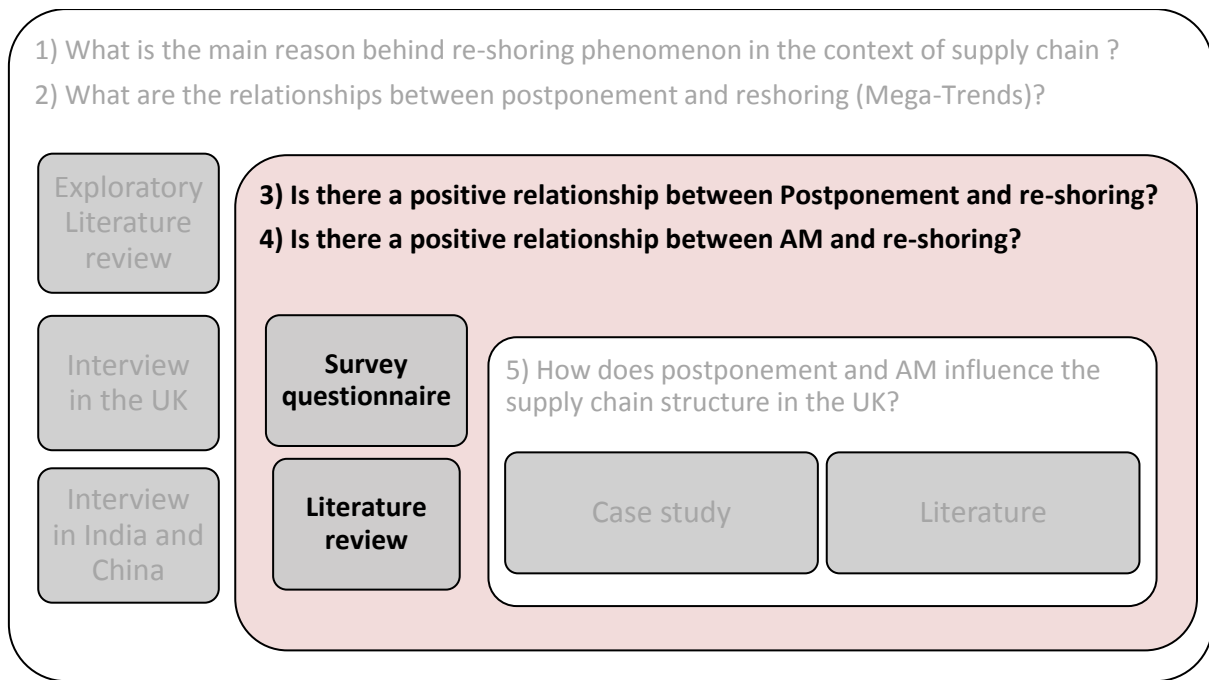


Figure 5-2, Research questions

Note that the questions were developed at the early stage of this research, hence whilst developing them the responsiveness was not yet identified as the primary reason behind re-shoring manufacturing. The term positive relationship in the research questions indicates the possibility of the Postponement strategy and AM technologies to help companies overcome the shortcoming (manufacturing challenges) that has made companies to repatriate their manufacturing to the UK. Therefore to carry out this investigation following three hypotheses were developed that needs to be put into test. The first hypothesis is related to the outcomes of Chapter 4 where responsiveness was determined as a key reason behind re-shoring and examines such claim in a larger scale. The second and third hypotheses are directly related to the third and fourth research questions respectively.

1. Supply chain responsiveness is a key factor behind re-shoring manufacturing activities to the UK.
2. Postponement can help re-shoring manufacturing activities back to the UK by making companies more responsive to the customer demand. (Research question 3)

3. Additive Manufacturing (as a type of Postponement strategy) can help re-shoring manufacturing activities back to the UK by making companies more responsive to the customer demand. (Research question 4)

Figure 5-3 illustrates a flow chart where the main theme of the questionnaire are colour coded. It also presents the questions that are asked from the participant related to each theme so the reader can get a clear picture of the logic used to design the questions and obtained required information.

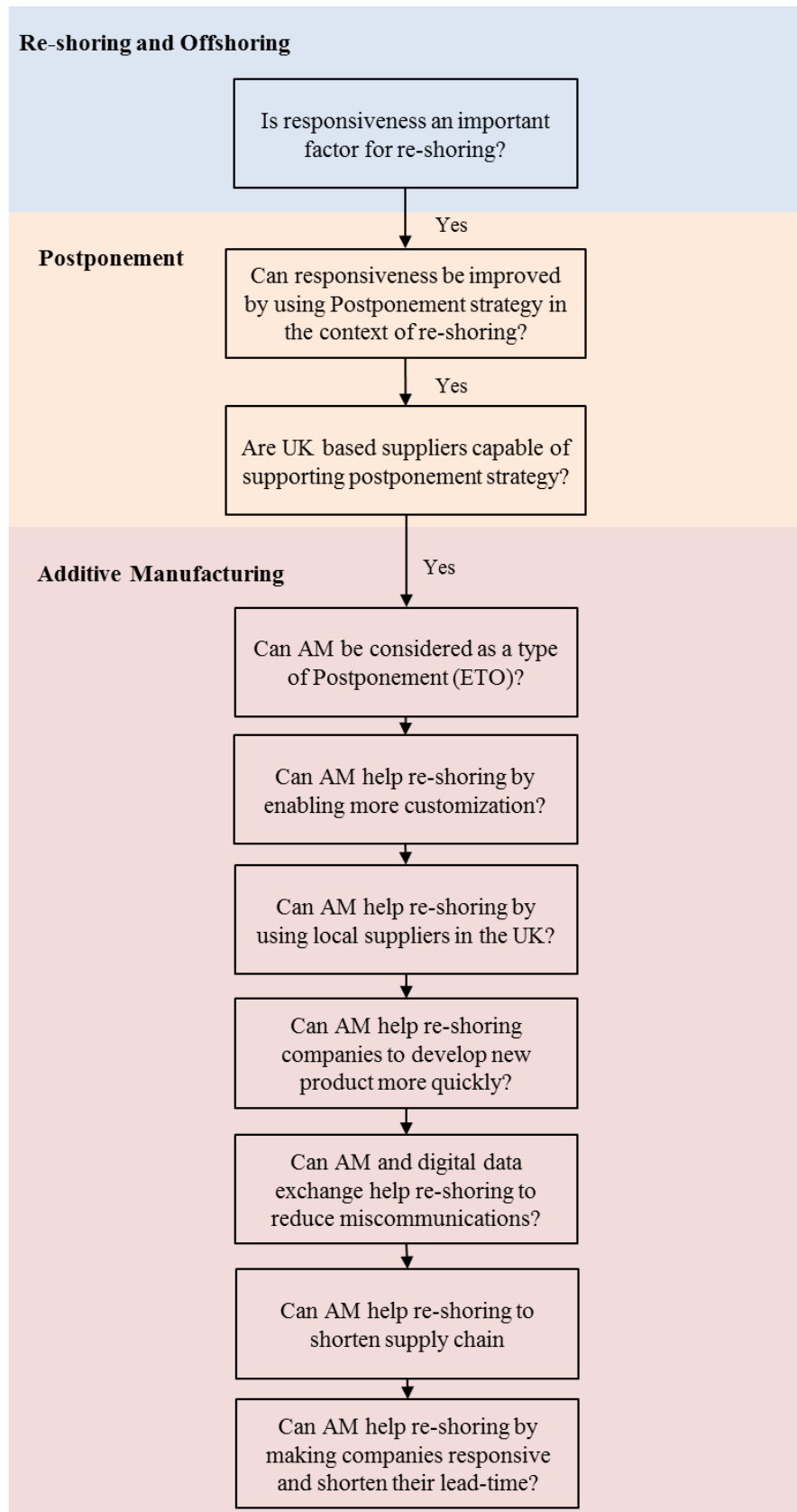
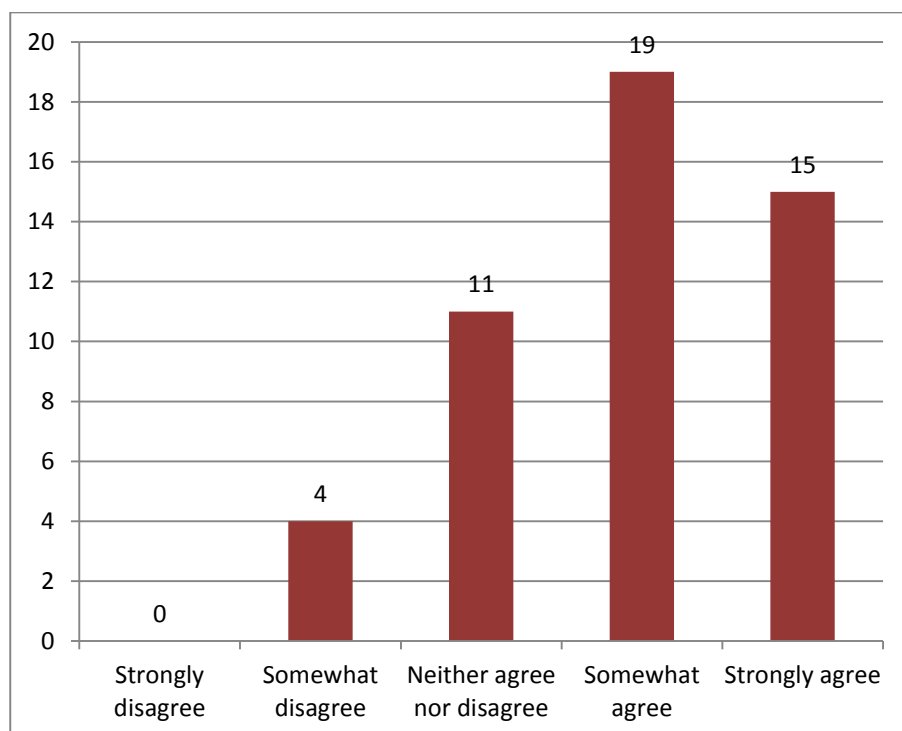


Figure 5-3, logical process for gathering information using questionnaire

The customers demanding for more personalised products and faster deliveries have derived many companies to re-shore their production or parts of their supply chain back to the home country (Cranfield University, 2015). This is where AM technologies can contribute as an enabler of product customisation and production responsiveness (shorter lead-time). Alternatively it can be seen as a Postponement strategy in which entire product is manufactured based on order or some components of the end product is produced. The latter would allow to keep the product in generic state and delay the product differentiation by taking advantage of local suppliers in the UK.

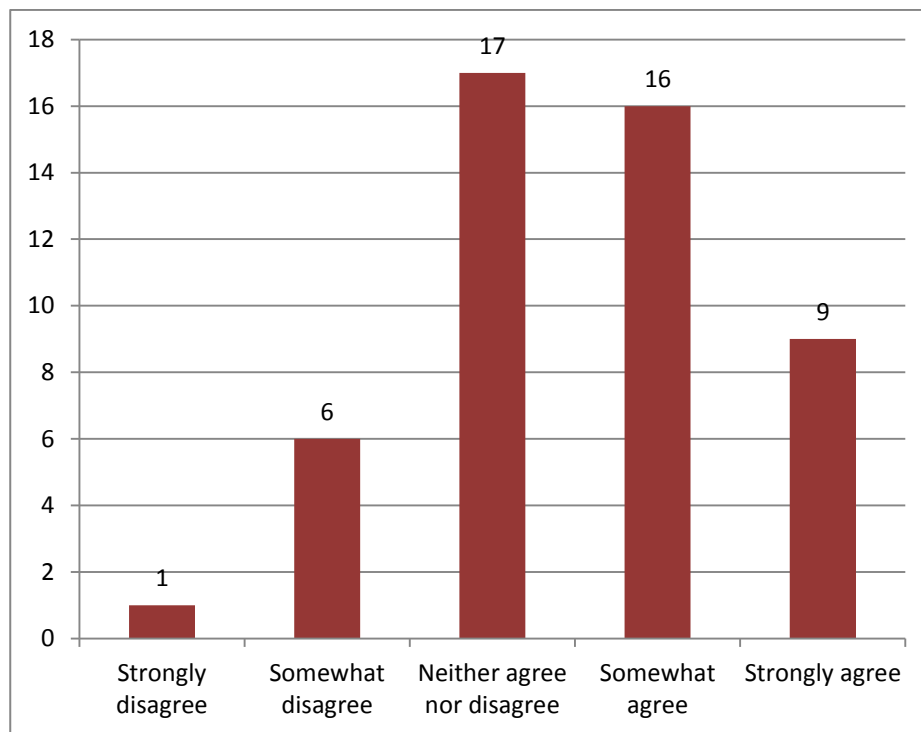
Figure 5-4 illustrates the number of companies that believe responsiveness is the main motivator behind re-shoring strategies. It can be seen that the majority of the respondents tend to see the shorter response time as an important factor to satisfy the demand in the UK and is one of the main motivators for re-shoring. It should be also noted that the results were mainly from companies operating in an uncertain market manufacturing high value added products.



**Figure 5-4, Is responsiveness an Important factor for re-shoring?**

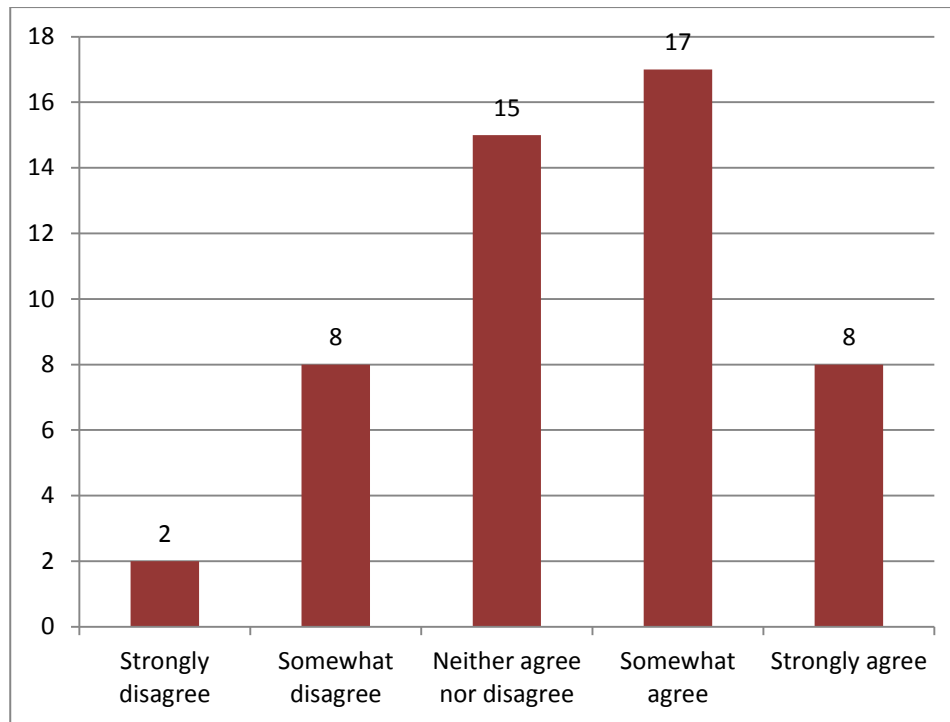
Once the primary reason behind re-shoring is confirmed, a potential solution for operational aspect can be recommended. In this scenario, the concept of Postponement is

determined to offer range of benefits that enable the companies to shorten their lead-time. Postponement enables the companies to identify the components that can be potentially modularised and standardised, meanwhile can allocate the parties to their best-suited tasks. Furthermore it determines when and where the inventories are required and also indicated what components should be manufactured according to the forecast (Yang and Burns, 2003). Figure 5-5 presents the number of companies who agree that Postponement strategy can enhance the company's ability to be more responsive which can ultimately help re-shoring activities. The distribution of the answers illustrates that the majority of the respondents have a positive viewpoint about the implementation of Postponement in re-shoring and its advantages in managing their supply chains.



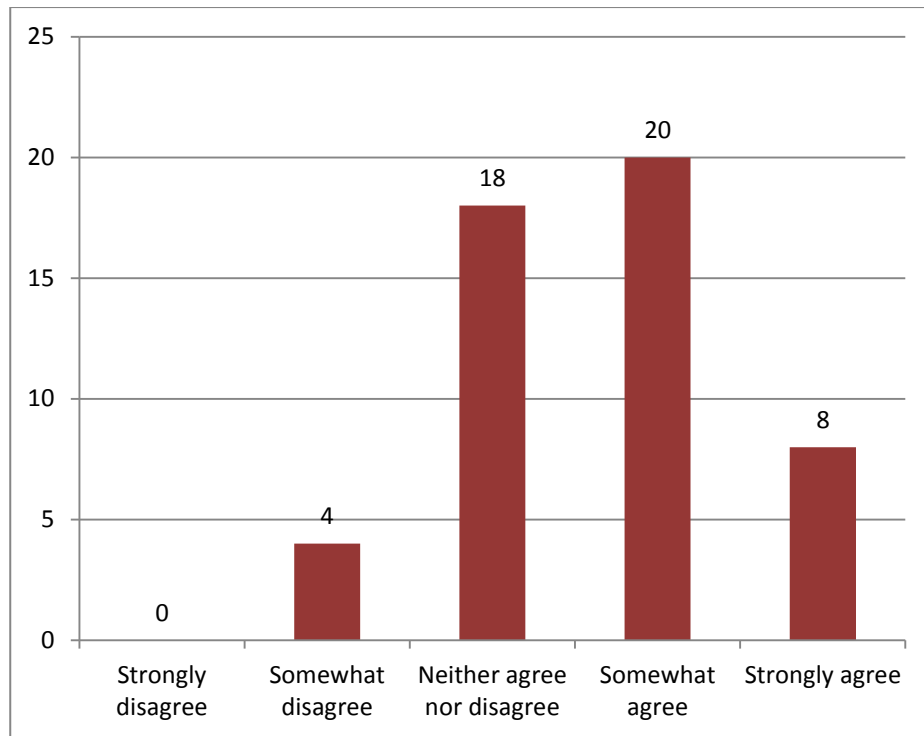
**Figure 5-5, Can Postponement strategy enable re-shoring by making companies responsive?**

In addition to acquiring the general viewpoint about Postponement and its influence on re-shoring, the participants were also asked to provide their thought on the capability of the UK based supply chain to support Postponement strategies in the country. As a result the following chart (Figure 5-6) was obtained which demonstrates that relatively a large number of companies believe, “somewhat agree”, that there is an adequate infrastructure and capability in the UK to support the Postponement strategies. This is in terms of being able to get the products/components delivered within the promised time.



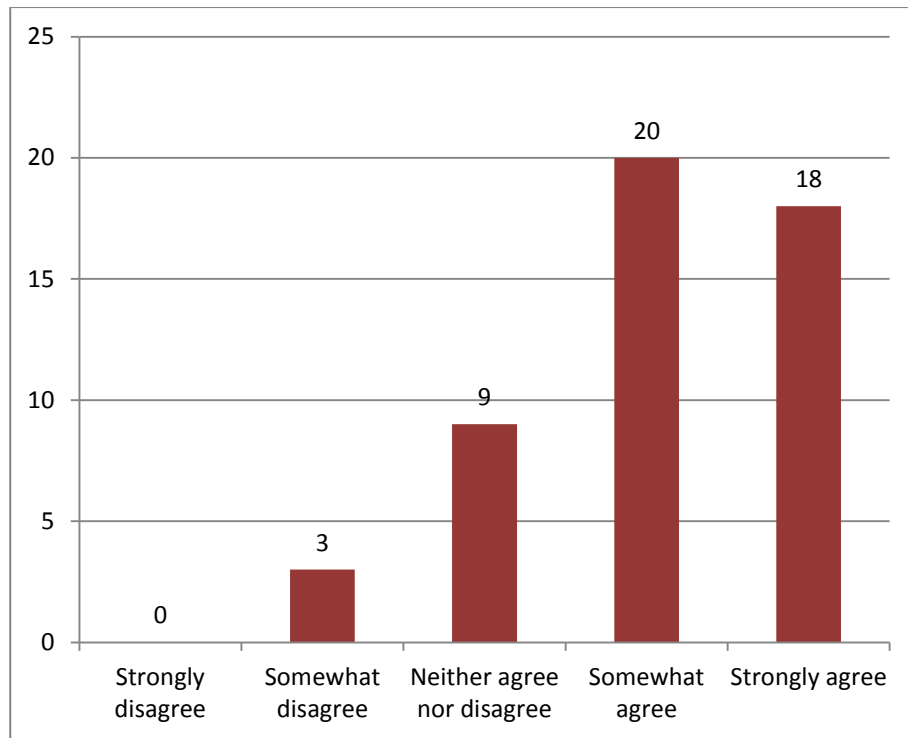
**Figure 5-6, Are UK based suppliers capable of supporting further Postponement strategies in the UK**

Once it is established that Postponement can add value to the UK based supply chain in terms of responsiveness and the supply chain members have the ability to support this strategy, the companies were asked about their viewpoint on whether AM technologies can be considered as a type of Postponement strategy. As previously explained in the literature review section of this thesis, the use of AM can facilitate the Postponement strategy since it allows the company to delay the production until the real data about customer demand is available (Van Hoek, 2001). Considering the work done by Yang et al. (2004), AM can be seen as a Postponement concept known as Engineering To Order (ETO) in which product is designed and produced based on customer order. These shares a common point with AM technologies in which any products made by AM is pulled by a customer order. Therefore no inventory, apart from the raw material in the form of powder or feedstock, is required. Figure 5-7 shows that the extent to which companies see AM as a Postponement strategy.



**Figure 5-7, Can AM be considered as a type of Postponement strategy (ETO)?**

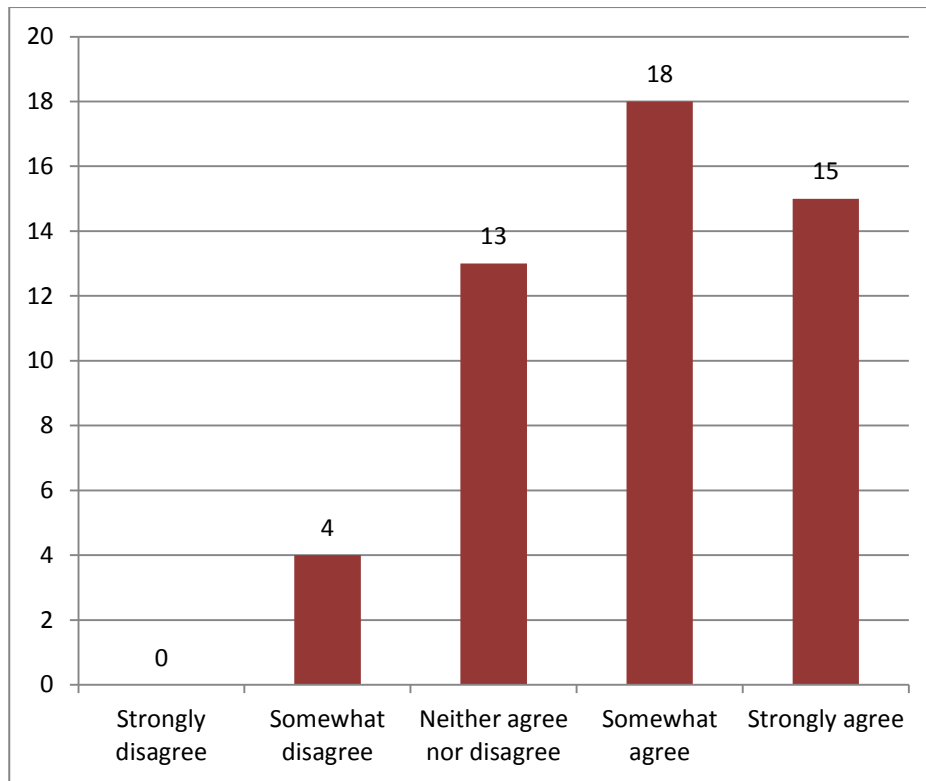
In one hand, one of the most recognisable advantages of AM technologies is in its design freedom and the ability for customisation in the product development stage. On the other hand, one of the key factors that improve the responsiveness of a company is its capability to manufacture customisable products according to the customer demand (Berman, 2012). In other words, the capability of the companies to accommodate any changes in product design and specification and manufacture it within a reasonable time, can significantly reduce the lead-time. Hence customisation is one of the areas that AM can contribute to the re-shoring company. The Figure 5-8 shows what the companies respond to the question emphasising on the customisation aspect of AM technologies.



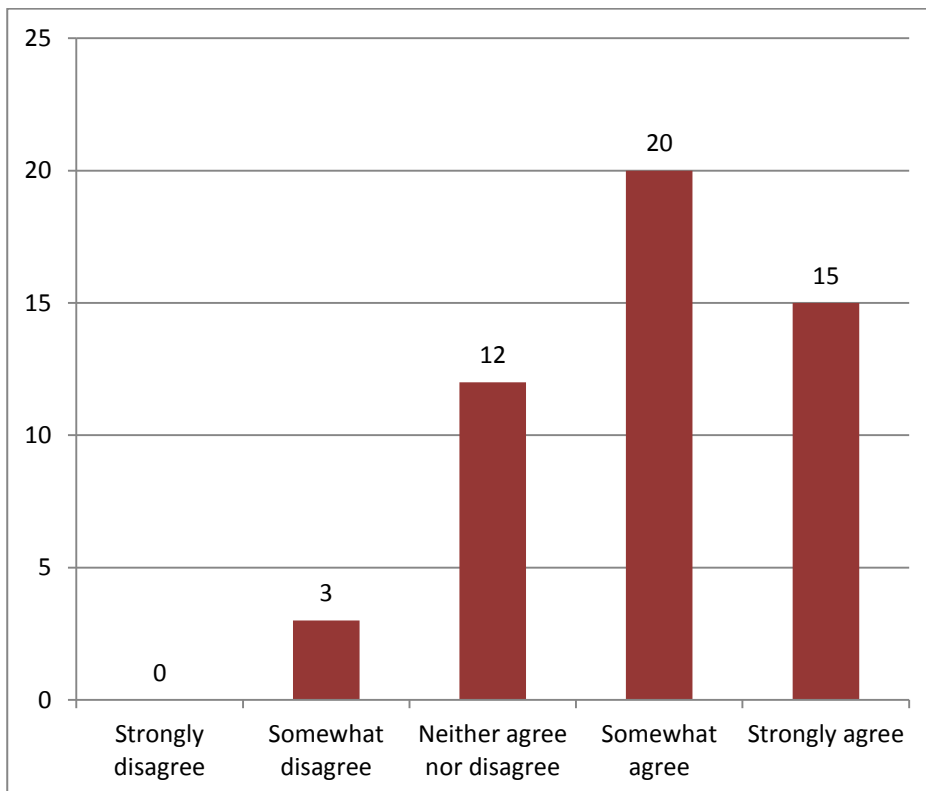
**Figure 5-8, Can AM help re-shoring by helping companies to customise their products according to the customer demand?**

Another advantage of using AM suppliers in the supply chain is the flexibility in their geographical location. The AM can facilitate the engagement of the local suppliers in the UK and their contributions to the UK economy. This is due to the faster supplies in comparison to their overseas competitors. Figure 5-9 shows the degree to which the companies believe that AM can help re-shoring by using local suppliers in the UK. This is followed by a question on the speed of product development in the company. Figure 5-10 shows whether companies think AM can help them to improve product development time. This is either by using AM to manufacture the prototypes or for their end products. Meanwhile in Figure 5-11 the digital communication aspect of AM technologies is questioned. It shows the results on whether the companies see AM as a way to reduce miscommunications in different stages of working with foreign suppliers such as product development stage. It should be noted that miscommunication was one of the reasons behind re-shoring strategies in the UK. This can be improved by using digital data exchange for engineering drawing and product specifications.

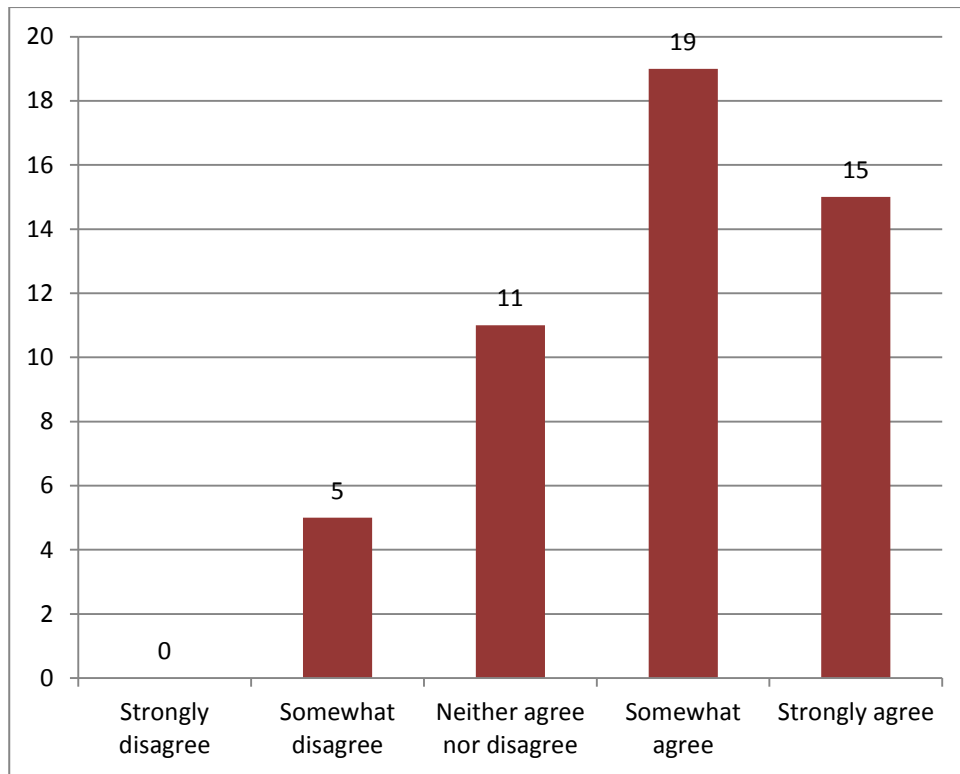




**Figure 5-9, Can AM technologies help re-shoring by using local suppliers in the UK?**

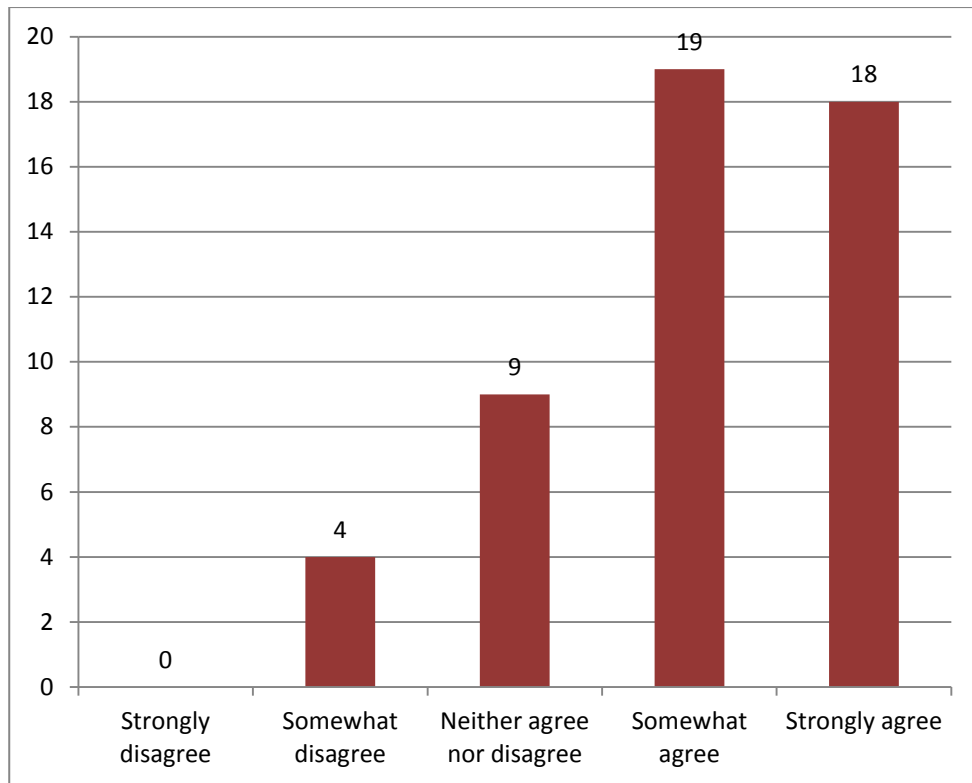


**Figure 5-10, Can AM technologies help re-shoring companies to develop new products more quickly?**

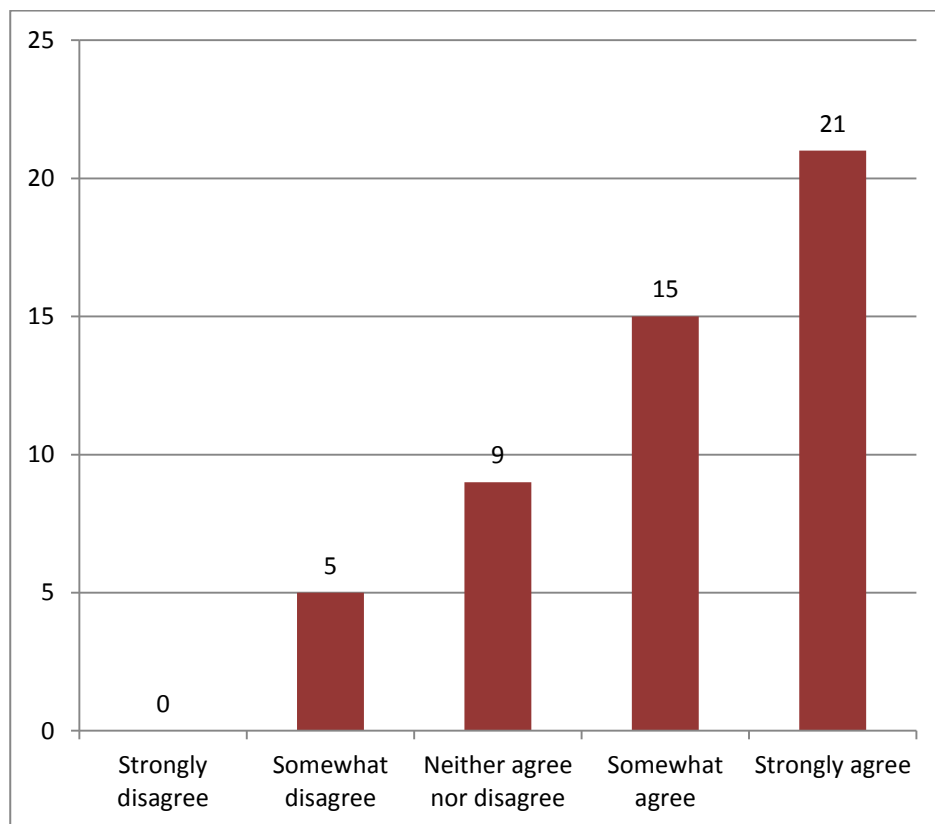


**Figure 5-11, Can AM and digital data exchange help re-shoring by reducing miscommunications with the suppliers?**

One of the main objectives of this study is to investigate the feasibility of using AM technologies as a solution to overcome the problems which lead to re-shoring manufacturing activities back to the UK. The most important operational challenges that the industries are facing at this time is long lead-times (founded in “Chapter 4”) which can be a direct result of long supply chains. This raises the next question where participants are asked whether AM can shorten the supply chain, which can ultimately help re-shoring movement. This is shown in Figure 5-12. Last but not least, the third research question aims to investigate the applicability of AM as a type of Postponement strategy in re-shoring supply chain to enhance the rapid delivery of the products and customisation. Figure 5-13 indicates the significance of companies who see AM as a potential technology that can encourage re-shoring in the UK. The result appears to be in support of this technological solution which bridges the re-shoring to the emerging new generation of technologies and “Industry 4.0”.



**Figure 5-12, Can AM technologies help re-shoring companies to shorten their supply chain?**



**Figure 5-13, Can AM technologies help re-shoring by making companies more responsive and shorten their lead-time?**

## 5.5 Discussion

The question of identifying the key driver behind re-shoring manufacturing activities back to the western countries, is one that has been asked previously in other studies (Bailey & De Propriis 2014; Fraticocchi *et al.* 2014; Ellram *et al.* 2013; Gray *et al.* 2013; Kinkel & Maloca 2009). However, the author chose to ask it again within the context of this study, supply chain perspectives. The findings show similar results to the earlier study in Chapter 4, as much as responsiveness is the primary reason behind re-shoring. Figure 5-14 combines the results noted by the survey respondents in order of frequency for three aforementioned hypotheses. It can be noted that the data is collected using the Likert scale, 1- Strongly disagree, 2- somewhat disagree, 3- neither agree nor disagree, 4- somewhat agree, 5- strongly agree. Hence the results are presented simply in this format.

The respondents were first asked to choose what they thought the primary driver for re-shoring was out of the listed factors. These factors were speedy delivery to customers, proximity to the end customers, customisation of the products, rapid new product introduction to the marketplace, cost of production and development of new products. Note that the listed factors in the questionnaire was based on the review study done by Moradlou & Backhouse (2016). The results significantly support the findings in Chapter 4.

Figure 5-14 also illustrates the extent to which the participants believe re-shoring provides an opportunity for companies to further engage in Postponement strategies to reduce their production lead-times and customise their products. This addresses the third research questions and second hypothesis developed in this chapter.

Finally the respondents were asked to what degree they believe AM technologies can be used in the UK supply chain to support re-shoring activities and address the issue regarding the lack of responsiveness towards the domestic demand. This section also addresses the forth research question.

■ AM technologies help re-shoring by making companies more responsive and shorten their lead-time

■ Re-shoring enables postponement strategies to make companies more responsive

■ Responsiveness is the key factor behind re-shoring to the UK

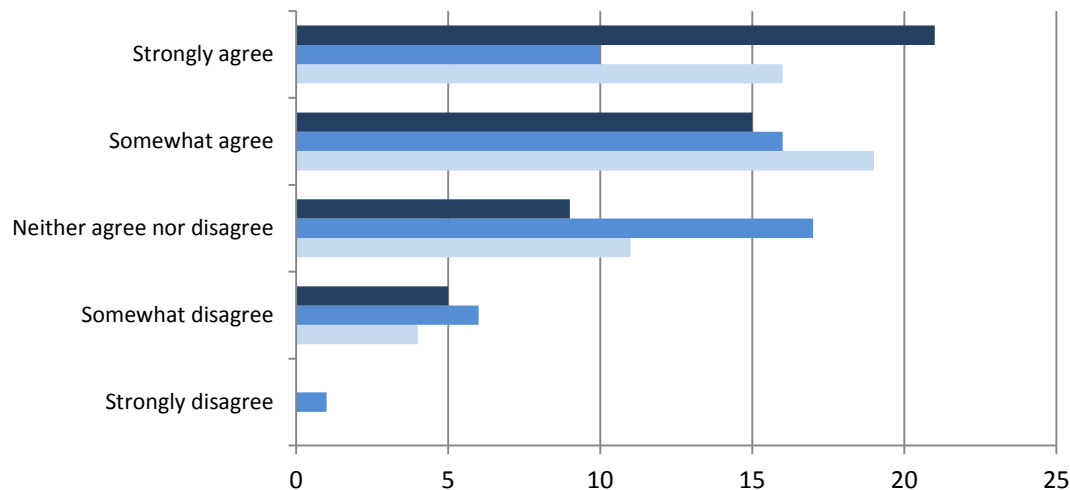


Figure 5-14, Survey questionnaire findings

Once the data was collected, the results were plotted in one bar chart. The three hypothesis developed in this study were all relatively supported. Statistical results such as the means and standard deviations are also demonstrated in Table 5-2. The data collected shows that 70% of the participants in the survey believe that the responsiveness is the main factor behind re-shoring manufacturing to the UK. This is whilst 22% neither agree nor disagree leaving only 8% of the respondent having negative viewpoint about this statement. This is significant evidence that shows UK industries are operating in a fast changing market that requires shorter lead-times. This also indicates that the proposition developed in “Chapter 4” stating: “P1: Changing production cost differentials between India and UK is not the main reason behind the British manufacturers’ re-shoring strategies.” and “P2: Lack of production responsiveness in India is the main reason behind re-shoring strategies in the UK” are valid.

On the other hand, the second hypothesis (third research question) was supported as the 52% of the respondents believed that re-shoring provides a suitable platform for the industries to further implement Postponement strategies in their supply chain.

Meanwhile 34% of the answers were neutral about this. However author believes that the reason behind this could be the lack of knowledge about the Postponement concept or unfamiliarity of the participant with the term Postponement. This leaves only 14% of respondent disagreeing with the benefits that Postponement can offer to support re-shoring.

One of the key areas investigated in this chapter is the applicability of AM in re-shoring companies. The data shows the connection between the manufacturing location decision and the new era of technologies emerging in the developed economies. The final hypothesis (forth research question) in this research is significantly supported as shown in Figure 5-14. The graph shows that 72% of the sample population voted in favour of the value that AM technologies can add into the supply chain performance in the UK. Another 18% also had no particular opinion on this matter hence neither agreed nor disagreed with the statement leaving only small population of 10% disagreeing with the application of AM in re-shoring supply chain.

<b>Hypotheses</b>	<b>Means</b>	<b>SD</b>
Supply chain responsiveness is a key factor behind re-shoring manufacturing activities to the UK.	3.94	0.934
Postponement can help re-shoring manufacturing activities back to UK by making companies more responsive to the customer demand.	3.56	1.013
Additive Manufacturing (as a type of Postponement strategy) can help re-shoring manufacturing activities back to UK by making companies more responsive to the customer demand	4.04	1.009

**Table 5-2, Statistical results for the hypotheses**

Once this was observed the results were further investigated to identify the correlation between the responses. Among these responses, three companies believed that responsiveness is not the main factor for re-shoring and therefore disagreed with the implementation of Postponement concept to reduce the lead time. The same respondents

also disagreed with the application of AM technologies and its benefits on re-shoring. This indicates that these companies did not see responsiveness as an important factor and shortening their lead-time is not their priority in production. One possibility is that these three companies are not operating in an uncertain environment and do not require product variety or customisation. Therefore this indicates that the other positive responses gathered are more clear representatives from the industries that operate in an uncertain environment and require a strategy which improves their responsiveness towards the customer demand.

## **5.6 Summary**

This chapter firstly provides a statistical insight to a primary reason behind the re-shoring activities in the UK. It further studies the connection between the new generations of technologies (Industry 4.0) and re-shoring phenomenon. The author believes that re-shoring provides a great platform to implement the concept of Postponement through AM technologies. This is whilst the responsiveness was found to be one of the most important triggers behind repatriation of production lines to the western countries. AM allows to manufacture the product/part based on the customer order without having to forecast or store any part in the inventory. In addition, it encourages the businesses to work with local suppliers in the UK. The results indicated that AM can help the UK manufacturer to re-shore by utilising AM in their supply chain which ultimately shortens their lead-time. According to the literature it is expected that the influence and importance of the AM to rise and companies to manufacture more functional products using these technologies.

One of the limitations of this chapter is the lack of generalisability of the finding due to a relatively small sample size. Further research is needed to develop a better understanding on the types of the products that can be manufacturing using AM technologies. Field study and case research are also needed to describe how AM does actually influence the supply chain of the re-shoring companies in the UK and what the challenges are along the process.

# **Chapter 6, Investigation into re-shoring decision in the UK (case study Brinsea Product Ltd)**

## **6.1 Overview**

This chapter aims to provide a comprehensive picture on the re-shoring decision by looking closely into a re-shoring case in the UK. The objective is to highlight the issues faced by the company that have resulted in repatriation of manufacturing and the suppliers to the UK. Hence a case study approach was adopted to collect the required data. In order to meet the objectives, Brinsea Product Ltd was selected as a case study. Brinsea is an incubation specialist that manufactures high-end machines for breeding a range of expensive and rare birds that require an innovative and reliable technology due to the sensitivity and the high cost of each egg. This company has brought production back to subcontractors in South Wales from China in 2012. The company also received the governmental support via the Manufacturing Advisor Service (MAS) in terms of finding alternative suppliers that could meet the company standards and customer specification. Therefore the company provides an excellent example of UK based manufacturer facing difficulties in working with foreign suppliers in China and selecting local suppliers in the



UK over overseas suppliers. In addition to this, the company operates within a competitive market where the responsiveness and product development play vital role.

The previous two chapters investigated the primary reasons behind re-shoring manufacturing to the UK and then assessed the potentials for applications of Additive Manufacturing (AM) technologies within the industries respectively. The results indicated that being more responsive to customer demand was the primary reason behind the repatriation of production activities. Meanwhile there was a positive response on the applicability of the AM systems in production processes in order to reduce the lead-time and increase product customisation. This chapter is a brief example of re-shoring phenomenon in the UK where AM technologies are utilised. A general comparison is made between the offshoring and re-shoring decisions in the context of five operations performance factors. These factors are cost, quality, speed, flexibility and dependability. Hence the company's viewpoint on the impact of re-shoring to the aforementioned factors is presented.

## **6.2 Data collection**

Due to the gap in the existing literature, which fails to provide an adequate explanation of the phenomenon under investigation, this study adopts a qualitative approach to collecting data in a systematic manner and provides a detailed overview of re-shoring in the UK. The case study approach was selected as a method to gather the required data through conducting semi-structured interviews. As a result Brinsea Product Ltd was selected and contacted to arrange the interview. Prior to the appointment the questionnaire was sent to the company via email in order to familiarise the interviewee with the questions that would be asked during the interview. In order to ensure collection of reliable information the CEO of the company was interviewed.

To conduct the interview, a comprehensive framework was developed which is further explained later in this chapter. The interview was performed and it was accompanied by a factory visit and explanation of manufacturing processes. According to Seuring (2008) "If the research process is carried out in a structured way and is well documented then case study research will continue to allow the in-depth analysis of contemporary phenomena".

Hence the data were documented in detail and was then analysed using thematic analysis. As a result the data is compared and presented in the form of a Table 6-1. According to Taylor & Bogdan (1984), the following are the three steps were taken for the data analysis.

1. The objectives of the research should be revised along with the interview transcriptions in order to determine general theoretical topics which can help to generate a coding framework for the interview transcripts. Note that the coding framework is a set of words (in this case the operations performance factors) or topics that are carefully chosen to represent a general meaning of what has been said in the interviews segments.
2. The interview transcripts should then be carefully revised again with the aim of dividing the text into meaningful parts to reduce the data. Every section requires to be given a code that belongs to pre-defined criteria (i.e. specific word or topic).
3. After a signing a code for each text in the interviews, another revision is required to identify codes with similar themes. This method allows for clustering text segments around specific themes that is used for interpretations.

### **6.3 Validity checks**

Due to the nature of this investigation (qualitative approach to the interpretation), there is a high possibility of a biased judgment in the interpretation and analysis performed. Hence the results obtained require a validation check by the people in charge of the business. This is because the informants have an in-depth knowledge of the decision process and the impact of the relocation and AM technology on the company. To ensure the validity of this study the analysis were sent to the interviewees for further check. As a result feedback was provided about the way the findings are presented. Therefore, it can be assumed that findings from this study are of high quality.

## 6.4 Framework development

In order to examine the research question established in this study, an appropriate framework has to be developed. However to do so the first component is to clarify the types of question sought to be answered. This chapter aims to investigate the performance differences before and after the re-shoring decisions and how AM technologies can influence the company's supply chain management. It is essential that the framework developed in this chapter demonstrates a clear logic that links the collected data with the objectives of this study introduced at the early stage of the research. The framework should consist of the main operational factors that are influenced by the manufacturing location decisions. By doing so, company's operation performance regarding two different manufacturing location decision strategies can be compared and analysed.

After looking at the operations management literature, the main operations performance objectives were identified. As a result, five operations performance factors were chosen which are the quality, speed, dependability, flexibility and the cost (Slack et al., 2013). Figure 6-1 was adopted from the book Operation Management by Slack et al. (2013) which illustrates the connection between these factors and their external and internal effects. It should be noted that the original diagram was slightly modified to further emphasis the focus of this research study. As shown in the diagram, responsiveness is the factor that requires further investigation in the context of re-shoring manufacturing. This comprises the flexibility, dependability and the speed of the manufacturing operation. The framework developed in this research allows conducting a rigorous study since it has been widely accepted within the academic community. Meanwhile it enables to collect the key information to drive and generate reliable outcomes. The following is the detail explanation of each factor.

1. Cost: is the most important operations objective for a company since it allows the businesses to compete directly on price. It has been the main motivation behind the offshoring strategies to low-cost countries such as China and other Far East destinations. Accessing cheap labour and resources has been the main motive for the companies to explore manufacturing opportunities outside their home country. Therefore cost has been playing a vital role in the manufacturing location decision. Every company's cost of production is closely linked to the other performance

objectives shown in Figure 6-1. In other words as the overall performance improve consequently the cost of the production will decrease. Hence re-shoring decisions can have significant impacts on each operations objective.

2. Quality is the factor that has the major effect on the customer satisfaction or dissatisfaction. Meanwhile it is one of the main concerns when dealing with the oversea suppliers. It should be noted that the quality could have external impacts as well as internal impacts. The external impact being on the customer satisfaction and the overall brand image. Internal factors such as the resource required to address the problems related to the defect and quality issue.

The quality has also been listed as one of the main reasons behind re-shoring manufacturing to the UK (MAS, 2014). The inconsistency in the quality of the product/components has been among the major challenges when the companies engage in offshoring and outsourcing strategies (Davis et al., 2006; Herath and Kishore, 2009). Hence quality plays an important role within the case study framework in the context of re-shoring.

3. Flexibility is one of the three factors that this study is focusing on. It determines the ability of the company to accommodate any changes in the operation. It can be divided into four categories. First one is the product flexibility which is the ability of the company to introduce new products or make changes to the already existing products. The next category is the mix flexibility. This stands for the extent to which the company is able to manufacture wide range of products. The third group is the volume flexibility. This is the capability of the firm to manufacture different quantities and volume according to fluctuations in the market. The last category is the delivery flexibility which determines how flexible the company is with its product delivery times (Slack et al., 2013).

However Reichhart & Holweg (2007) divides the flexibility into external and internal flexibility. The external being the four factor developed by Slack et al. (2013) and the internal flexibility being other operational factors such as machinery, material handling, operations, routing etc. Flexibility plays an important role in terms of customer satisfaction due to the increase in fluctuations in customer

demand and their unpredictable behaviours. Flexibility can also be considered as an aspect of responsiveness which is the key challenge that the companies are facing and is driving the repatriation of manufacturing units to the UK.

4. Speed is another vital element of the manufacturing operation. Speed of production is defined as the time taken from receiving the customer order to delivery of the product. Many customers demand for a speedy delivery of good which leads to their satisfaction from their buying experience (Santos Bernardes and Hanna, 2009). This requires quick decision making, fast movement of material and information from downstream to upstream in the supply chain.

Speed is also what makes the company more responsive. According to Reichhart & Holweg (2007) responsiveness is defined as “the speed with which a system can adjust its output within the available range of four flexibility types (product, mix, volume and delivery) in response to an external stimulus”. Hence speed and flexibility are both essential to make a company more responsive.

5. Dependability is defined as “doing things in time for customers to receive their goods or service exactly when they are needed, or at least when they were promised” (Slack et al., 2013). This introduces the aspect of operation that requires reliable processes of delivering the material and information on-time. This is also largely influenced by off-shoring strategies as the long supply chains can be disrupted by number of reasons such as hurricanes and tsunamis (Thun and Hoenig, 2011).

The framework provides a suitable platform to conduct the investigation and collect the required information for the case study. Based on this a series of questions were designed to get a clear picture of the respondent’s viewpoint on these performance factors and how re-shoring movement has influenced their firm within the context of this framework. All the five elements are mentioned in the interview guideline however the focus is mostly on the flexibility, dependability and the speed of their production. The following is a company profile and introduction to the case selected in this study.

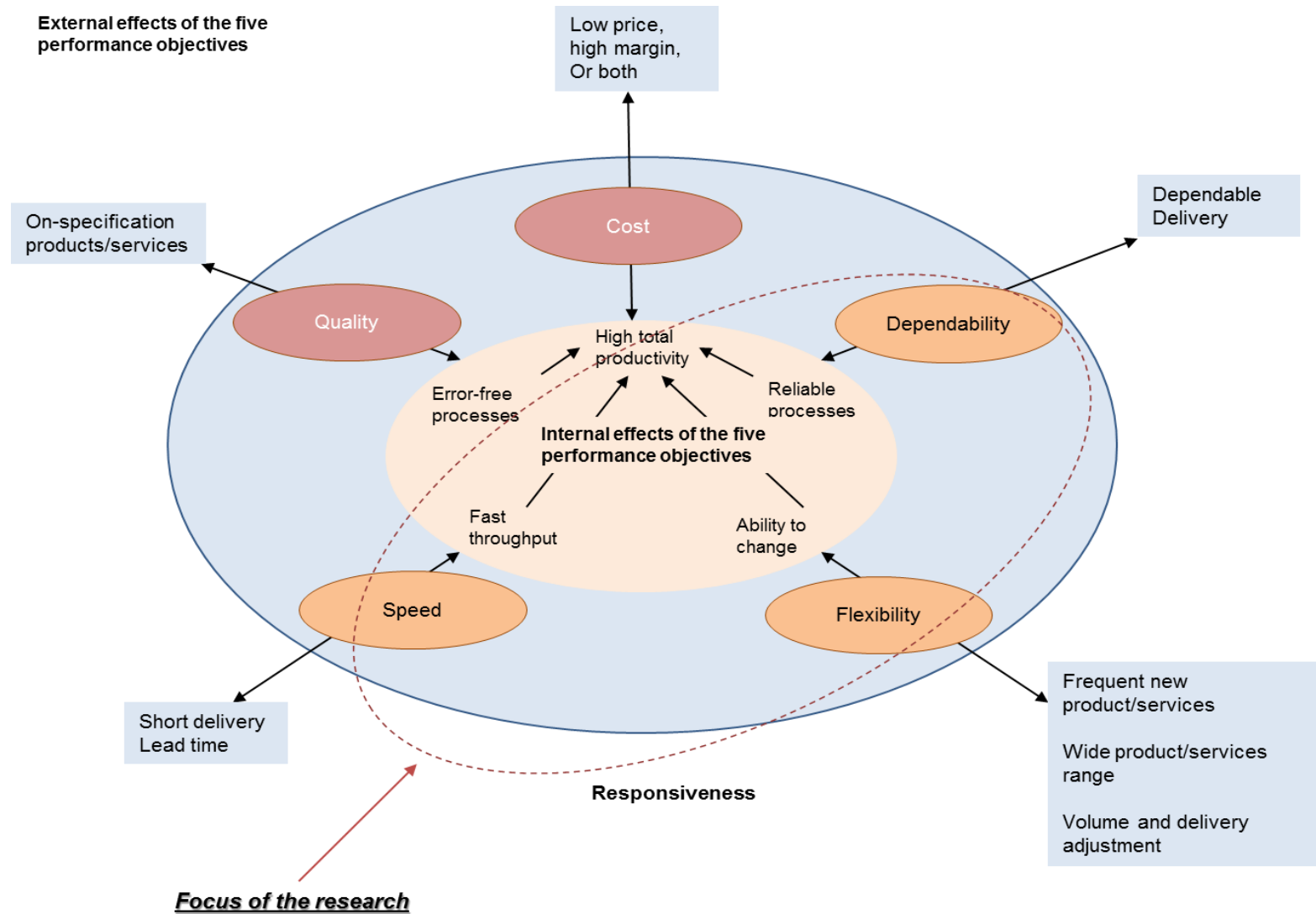


Figure 6-1, Case study Framework (adopted from (Slack et al., 2013))

## **6.5 Organisation profile (Brinsea Product ltd)**

Brinsea Products Ltd is an incubation specialist that has been focusing on egg incubator design continuously since 1976. It is a Small and Medium Enterprise (SMEs), which is located in Weston-super-mare, North Somerset UK. Despite the small size of this business, the company has managed to maintain its global presence and be engaged in an international supply chain. The company currently targets several markets mainly in US, Europe and Middle East. They also hold more patents for egg incubation than any other incubator manufacturer and are the leaders in incubation technology. Hence this further indicates the importance of Intellectual Property (IP) right in this company and is the limitations in accessing the markets such as China.

The products manufactured in Brinsea are made of set of injection moulded plastic parts and electronics which are mainly sourced from overseas locations. The manufacturing processes used in Brinsea are mainly in the form of traditional assembly lines whilst advanced manufacturing methods such as AM technologies are also utilised in different stages in production. The production of the egg incubators goes through a series of workstations in which manual assembly is employed. On the other hand AM is mainly used in the product development stage. However over the past year this technology is also been used to manufacturing parts that are used in the final products.

Brinsea has been expanding its production to China and Far East during the last decade. They now offshore and outsource number of components and products from overseas locations in order to take advantage of low labour cost and cheaper production. However over the past three years the company has come to realise the true cost of offshoring and outsourcing from China. According to the Brinsea's CEO "The offshoring advantages have been fading as the time passes". The offshoring strategy did not remain as beneficial as the initial anticipations. One of the areas that Brinsea was previously offshoring was the injection moulding of the plastic parts. However the company decided to repatriate the production back to the UK based on number of reasons explained in the next section.

## 6.6 Offshoring and re-shoring experience

After conducting the interview with the CEO of the company, the data was transcribed, analysed and presented as following bullet points. The following aspects are the outcomes of the company's re-shoring manufacturing decision to the UK.

- Shorter delivery times (down from 16 weeks to 1 week)
- Lower stock holding (reduced by 8% on average)
- Full insurance cover for the high value tools
- Ability to raise lease finance of new tools
- At least 6 UK jobs created

The first point indicates the substantial reduction in the lead-time from 16 weeks to 1 week. This can ultimately make the company more responsive in their production and product delivery to the end customer. It also reduces the manufacturing throughput time. This is aligned with the investigation done in Chapter 4 and the survey questionnaire conducted in Chapter 5 where responsiveness was mentioned to be the primary reasons behind the re-shoring activities to the UK in the context of supply chain management. Therefore this case study also provides evidence that responsive production was the main reason for and the key outcome of the re-shoring decision.

The next outcome of the re-shoring was 8% reduction in the average stock holding. This can influence the overall operation in number of ways. One of the advantages is minimising the quality issues due to fewer inventories. Therefore product defects can be identified without having to go through a large inventory. Moreover, having considered the company being an SME it is important to not have a big capital tied up in the stock. Therefore lower inventory can mean more cash flow within the business that can be used for further development and expansion of the business.

One of the most important factors discussed over the interview with the CEO was the insurance that could cover all their activities overseas. This was one of the biggest



concerns in the company to find an insurance company that was able to cover all sort of risks related to the production and their assets overseas. However currently the company was unable to raise money to finance tooling located in China. In addition banks require the tooling to be safe and accessible in the UK. According to the CEO such issue was the direct result of lack of transparency in the product supply and the source of materials.

Last but not least, the job creation was another aspect of the re-shoring movement. This is currently receiving governmental incentives in terms of linking multinational industries to the local suppliers in the UK and providing financial supports. Therefore the last advantage mentioned in the interview was regarding the support that re-shoring can provide to the local economy in the UK.

## **6.7 Discussion**

One of the questions raised during the interview was the comparison between the supplier's performance in China and the UK. This was mostly in terms of responsiveness and the quality of the products. According to the company's CEO, some sectors in the UK supply chain are still not capable of fulfilling the company's requirement. Despite having a good infrastructure in the country, the UK suppliers take longer than their overseas competitors to deliver the goods. This itself can be considered as a negative influence on the re-shoring decisions since company may not receive sufficient support from the local suppliers. On the other hand, UK suppliers are capable of supplying world-class goods and can meet the required standards and quality. Therefore Brinsea Product Ltd has no issue with the quality of the parts that are supplied by the UK suppliers. One of the issues that the company had faced two years ago was the issue with the quality of the sockets used in their products, which were supplied by an overseas supplier. The sockets were manufactured in China and the company was sourcing them directly from its manufacturer. According to the company's CEO

*“The sockets were perfectly fine during the first a few weeks of the supply but as the time passed their quality got worse. It reached to a point where they were only ok for the first*

*quality check and after a week they got faulty and stopped working. In this business our customers could be dealing with range of very expensive eggs and this was disastrous for us since they could lose all the eggs leading to customer complaints and a bad image of our products.”*

Once they switched to a UK supplier the quality issue with the sockets were eliminated and in case of any quality issue the reaction time was significantly shorter due to the proximity to the supplier.

As mentioned before AM technology is currently being used in number of occasions in the company. It has so far replaced the involvement of a third party organisation that was previously assisting the company with its prototyping process saving them cost and time in the overall process. AM has also had a substantial influence on the reduction of the overall lead time. It has allowed the company to have series of faster iterations on the product design as well as manufacturing parts of their final products. It is also targeted for further investment on this technology in order to utilise this technology to manufacture more functional products in future.

Another factor that was mentioned as a concern when dealing with the overseas supplier or the agents was lack of trust between the two parties. According to the CEO

*“when we talk to the Chinese we are not too sure who we speak to, whether it is the supplier or is an agent who is connecting us to the manufacturer. For a small company like us it is too difficult to build a trust with Chinese companies and make sure we are contacting the right people”.*

In order to develop a high level of trust between the two parties, Brinsea has to ensure its regular presence in China which can be quite costly for a small business.

As a summary of the analysis, Table 6-1 presents a comparison between the two scenarios of offshoring and re-shoring which compares the five performance objectives developed as a framework. It compares the cost, quality, dependability, flexibility and the speed of the production before and after re-shoring.

No	Performance Objectives	Offshoring	Re-shoring
1	Cost	<ul style="list-style-type: none"> <li>• Cost saving made by accessing cheap labour and resources (mainly plastic) in China.</li> <li>• Some of the products still cheaper to source from China</li> <li>• Capital tied up in the transportation for weeks</li> </ul>	<ul style="list-style-type: none"> <li>• Transportation costs is reduced significantly</li> <li>• No requirement for insuring overseas activities.</li> <li>• No overseas travelling required</li> </ul>
2	Quality	<ul style="list-style-type: none"> <li>• Issues with inconsistency in the product quality. The first couple of weeks appear to be within the standards but then starts to deteriorate</li> </ul>	<ul style="list-style-type: none"> <li>• Less quality issue due to the proximity of the supplier and production to the final assembly process.</li> <li>• Consistence delivery</li> <li>• Supplier assistance in solving technical problems</li> <li>• Any return can take place within a shorter time frame</li> </ul>
3	Dependability	<ul style="list-style-type: none"> <li>• High risk of disruption in on time delivery to the customer due to the long distance and less access to the production location</li> </ul>	<ul style="list-style-type: none"> <li>• Improved reliability in on time delivery of the products due to better communication with the supplier</li> </ul>
4	Flexibility	<ul style="list-style-type: none"> <li>• Poor flexibility due to dealing with a long supply chains.</li> <li>• Slow process of communication with the agents in China.</li> <li>• Limitation in the number of orders due to the shipping process. Hence low flexibility in terms of production volume</li> </ul>	<ul style="list-style-type: none"> <li>• Increase in flexibility in terms of capability of making changes in product specifications within shorter time frame.</li> <li>• Easier communication of feedbacks with customers and suppliers</li> <li>• Flexibility in number of order placed and</li> </ul>

	<ul style="list-style-type: none"> <li>• Low responsiveness to any quality issues and urgent deliveries</li> </ul>	<ul style="list-style-type: none"> <li>• production volume</li> <li>• Better responsiveness to any quality issues and urgent deliveries</li> </ul>
<b>5 Speed</b>	<ul style="list-style-type: none"> <li>• Long lead times and less responsiveness towards any disruption and changes in customer demand in the UK and Europe.</li> <li>• Long product development time</li> <li>• High percentage of late delivery (from suppliers overseas)</li> <li>• High order lead time</li> </ul>	<ul style="list-style-type: none"> <li>• Faster response time and shorter delivery times.</li> <li>• Proximity to the supplier which can ease the communication in the case of any modification to the product specification allowing the company to reduce the overall lead-time</li> <li>• Shorter product development time</li> </ul>

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**Table 6-1, Comparison between offshoring and re-shoring at brinsea product ltd**

## **6.8 Summary**

This chapter compares the company's operational performances before and after making the re-shoring decision. The result indicates that the key improvement was the significant reduction in the production lead-time from 16 week to 1 week. Meanwhile five manufacturing performance factors were selected namely cost, quality, dependability, flexibility and speed to investigate the effects of re-shoring decision. After conducting an in-depth case study, the outcome of the study shows that whilst re-shoring in conjunction with AM technologies can significantly reduce the manufacturing lead time, it can also increase customer satisfaction due to faster respond time, more flexibility in product design and delivery time. Therefore the company can get more product variety within a small time and be able to respond to the customer demand.

# **Chapter 7, Applications of Additive Manufacturing in the supply chain (Case Study in the US, Local Motors and ORNL-MDF)**

## **7.1 Overview**

This chapter aims to provide a comprehensive example of an industrial product where Additive Manufacturing (AM) technologies are utilised to improve company's responsiveness which can potentially be used in the case of re-shoring. The purpose of the material presented in this chapter is to support and compliment the conclusions driven from "Chapter 5". The Chapter 5 provided evidence and illustrated the relationship between the re-shoring phenomenon, concept of Postponement and the application of AM in the industry. The targeted sample was selected from the companies that were involved in making additively manufactured components or are the suppliers of feed stock and raw material for AM in the supply chain. The results obtained from surveying 50 companies

indicated positive evidence that supports the implementation of AM in the UK supply chain to further support re-shoring phenomenon in the UK. In other words AM can be considered as an enabler for the businesses to be more responsive to the turbulent customer demand. It should be noted that the high variety products with short lifecycles were found to be the areas where AM can have the uppermost implications.

The purpose of this chapter is to investigate how the companies benefit from adopting AM technologies in their production. This in turn will address the last research question developed in this study. As a reminder the fifth research question is included as follow:

How does AM influence the supply chain structure in the UK?

This investigation focuses on the framework, five operational performance factors, developed in “Chapter 6” of this thesis. These are cost, quality, speed, flexibility and dependability. In order to collect the required data “Case Study” approach was selected and the data was gathered during author’s two-month visit in the United States. As a result an in-depth study was conducted in two companies that are at the forefront of applying new generation of technology in their production focusing mainly on AM technologies.

## **7.2 Reason for selecting US**

The US was chosen as a destination for the data collection due to number of reasons. The USA has been at the forefront in implementing AM in the supply chain of multiple industrial subsectors, including motor vehicles, aerospace, machinery, electronics, and medical products. According to the report published by the US Department of Commerce “The U.S. is currently a major user of additive manufacturing technology and the primary producer of additive manufacturing systems. In 2011, approximately 64.4 % of all AM systems were made by the companies based in the United States. At the same time the

total global revenue from additive manufacturing system sales was \$502.5 million with U.S. revenue estimated at \$323.6 million” (Thomas and Gilvert, 2014). This shows the extent to which AM technologies are important to the US economy and it has the indications of its growth in the coming year.

The re-shoring phenomenon in the US has received attention from both politicians as well as academic community. The Re-shoring Initiatives was established in 2010 by Harry Moser, which is long before the re-shoring trend gaining momentum in the UK. Meanwhile Re-shoring Initiative has been promoting the new generation of technologies such as big data, robotics and AM technologies. According to the Re-shoring Initiative the combination of the 3D printing (Additive Manufacturing) and re-shoring is long-term and sustainable costs that the manufacturers really need to have in their businesses. Hence AM is becoming a part of re-shoring movement in the US which can be an example and a potential direction for the British industries to adopt and follow in order to ensure and establish a sustainable businesses. The following section is a description on the data collection process.

### **7.3 Data collection**

Prior to the data collection commencing in the US, the contacts were established with the University of Tennessee, Knoxville (UTK). The initial communications were made with two departments, Haslam College of Business and the Department of Industrial and Systems Engineering. During series of Skype conversations with the academics in the UTK, the main objectives of the research were communicated. This was to ensure the mutual understanding of the project and the purpose of the activity. As a result a two-month exchange program for the author of this thesis was arranged during the period of April-May 2016.

Once the author was in the US, a range of businesses was studied and the potential companies for data collection were selected. Through a strong connection between the UTK and the industries in the region, a number of companies were contacted via email

and phone calls. After receiving the initial acceptance, detailed documents with the list of interview questions were sent to the respondents. This allowed sufficient time for the participants to go through the questions and develop the appropriate answers or alternatively recommend another possible source for the required information. In the case of a nil response follow up emails were sent to remind the target respondents.

As a result, connections were made with two industries that are widely known for their production of AM components and research related to the implementation of AM technologies in the US supply chain. These two companies were the Local Motors and the Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory (ORNL). Once the research questions were discussed with the participants, interviews were arranged. The durations of interviews were on average 45 minutes. Note that the interview guideline was produced beforehand with reference to Slack's five operations performance factors, cost, quality, speed, flexibility and dependability (Slack et al., 2013). A series of questions were asked about where AM is being used in the company and how it is helping the company to achieve its goals.

As it has been discussed in the research methodology chapter, the case study approach can be criticised for not being a rigorous enough as a data collection method, however according to Seuring (2008) "if the research process is carried out in a structured way and is well documented then case study research will continue to allow the in-depth analysis of contemporary phenomena". Therefore to increase the reliability of the data gathered, the informant identified for these interviews were all senior members of the companies with in-depth knowledge about the AM technologies and the companies operational strategies. In addition, the interviews were all recorded and well documented throughout the process to ensure a rigorous investigation. The recorded interviews were then transcribed accordingly, in order to be used in the data analysis. Then thematic analysis was used to highlight the information regarding the operations performance factors. In accordance with Taylor & Bogdan (1984), the following are the three steps which were taken for the data analysis.



- The objectives of the research should be revised along with the interview transcriptions in order to determine general theoretical topics which can help to generate a coding framework for the interview transcripts. Note that the coding framework is a set of words (in this case the operations performance factors) or topics that are carefully chosen to represent a general meaning of what has been said in the interviews segments.
- The interview transcripts should then be carefully revised again with the aim of dividing the text into meaningful parts to reduce the data. Every section requires to be given a code that belongs to pre-defined criteria (i.e. specific word or topic).
- After a signing a code for each text in the interviews, another revision is required to identify codes with similar themes. This method allows for clustering text segments around specific themes that is used for interpretations.

The next section provides a brief background about the organisations that were investigated in this study.

## **7.4 Validity checks**

Due to the nature of this investigation (qualitative approach to the interpretation), there is a high possibility of a biased judgment in the interpretation and analysis performed. Hence the results obtained require a validation check by the people in charge of the business. This is because the informants have an in-depth knowledge of the AM production systems and their impact on the company. To ensure the validity of this study the analysis were sent to the interviewees for further check. As a result feedback was provided about the

way the findings are presented. Therefore, it can be assumed that findings from this study are of high quality.

## **7.5 Organisation profiles**

The first organisation interviewed (Local Motors) in this chapter is an automotive company focusing on manufacturing vehicle components using AM technologies. The company aims to localise the manufacturing in the US by investing on series of macro-factories across the US and ultimately around the world. Meanwhile the second company, MDF, is an advance manufacturing centre where the focus is on the areas such as aerospace, defence and automotive. They are responsible for production of various components and parts with the industrial application using AM technologies.

### **7.5.1 Local Motors**

Local Motors is an American vehicle producer, which targets to manufacture low-volume open-source motor vehicle through its multiple macro-factories. Macro-factories are local facilities that aim to bring worldwide Local Motor community together and enable the design and production of new vehicles based on local needs. Hence each macro-factory will meet the customer demand related to that specific region. The company currently has number of facilities in the US as well as Europe such as Belgium and Germany. However it is targeting to increase the number and expand the company in each state in the US, in the UK and other European countries. For the purpose of the data collection in this research study, the facility in Knoxville USA was visited and interview was performed. In addition, this company is opening two other macro-factories in Washington D.C. and Detroit where each facility could produce approximately 2400 cars per year.

Local Motors is the first company that has manufactured 3D printed car. The company also manufactures series of automotive components using AM technologies. It combines

co-creation and micro-manufacturing to develop hardware innovations to the market at unprecedented speed. As a result it engages and empowers global communities of designers, engineers, fabricators and automotive enthusiasts to solve local problems, locally through distributed making. It will bring the internal Local Motors team, the virtual community and the physical community together to manufacture its products. By utilising its online platform, designers, engineers, fabricators and enthusiasts can submit their unique ideas, receive feedbacks and further develop their designs. Therefore it allows full integration across various departments in the company as well as external expertise.

One example of a vehicle manufactured at Local Motors is “Strati” which is an electric car (see Figure 7-1 and Figure 7-2). This car was manufactured in collaboration with Cincinnati Incorporated. This car is the world first 3D printed car that utilises a large scale AM machine developed by ORNL and Cincinnati Inc. The manufacturing process is a combination of additive and subtractive processes. Hence it also includes milling process followed by an assembly process. The manufacturing process to build the first car took total of five days including 44 hours of printing time. However the company has set a goal to reduce the printing time to 12 hours per car. It should be noted that Local Motors manufactures a range of vehicles in which only some components are made out of AM technologies. Hence there is a large degree of customisability in the car panels and feature that can be additively manufactured.

As part of collaboration between Local Motors and Cincinnati Inc, latter company has developed a hybrid additive/subtractive machine that uses the termed "Direct Digital Manufacturing" (DDM). This machine uses a large diameter extrusion head to 3D print objects at high speed, then on the same head it also uses a router to come back and machine surfaces to a more precise specification where required. This means that it can create car-scale forms very quickly and freely to machined precision, but without the necessity of forming tools, etc.



Figure 7-1, Local Motors Strati Car 1 (Local Motors, 2016)



Figure 7-2, Local Motors Strati Car 2 (Local Motors, 2016)

### **7.5.2 Oak Ridge National Laboratory (ORNL), Manufacturing Demonstration Facility (MDF)**

The Manufacturing Demonstration Facility (MDF) is part of the US Department of Energy that helps the industries to adopt new manufacturing technologies to reduce life-cycle energy and greenhouse gas emissions, lower production costs and create new products and opportunities for high-paying jobs. Through the MDF the Advanced Manufacturing Program at ORNL offers a suitable environment for innovation, ensuring that new generation of technologies and design methodologies are developed in the United States and high-tech enterprises have the required infrastructure to implement their ideas and designs. This facility is located in Knoxville in the state of Tennessee, US and collaborates closely with the University of Tennessee in different areas of production energy consumption as well as new generation of technologies such as carbon fibres and composite and AM technologies.

The research in MDF aims to improve the performance of AM technologies allowing more customisation, multi-functionality and lower overall manufacturing costs. Through a close collaboration with various aspects of manufacturing supply chain, ORNL is focusing on ensuring AM technologies as a main stream manufacturing process and introducing its potentials to the companies so it can be used in the industry as a next generation of manufacturing. This is done by identification of the critical equipment and material advancement for AM technologies. Some of the examples of current projects that are being undertaken at MDF are as follow: increasing the build volume;, Optimisation of build parameters such as deposition rate to increase the production speed; improving material properties through introduction of new material and technologies; examination of alternative feedstock materials and investigation of performance enhancement through material combination and functionality of the components. In addition MDF focuses on areas of advanced technologies such as metal AM technologies, polymer AM technologies, roll to roll processing and feedstock for AM and R2R.

MDF is currently working with a wide range of AM technologies, manufacturing metal components to polymer parts. Some of the technologies used in MDF are such as electron beam melting, ultrasonic consolidation, extrusion (FDM), and laser metal deposition for unlimited design flexibility and rapid prototyping. MDF also collaborates closely with the Local Motors to manufacture different types of functional vehicle components including large-scale parts for cars.

## **7.6 Findings**

The data collection process was accompanied by factory visits and detailed explanation of the manufacturing process at Local Motors. With the aim of understanding the product categories being manufactured at Local Motors series of questions were asked whilst going through the production processes. Local Motors is operating in a highly volatile business environment where responsiveness, product variety and customisation play key roles. This is where AM technologies have its highest impact on the company's profitability. In this study the macro-factory located at Knoxville Tennessee was visited. To perform the interview at Local Motors, two senior members of the company helped the researcher with obtaining the required information about the operation. Conversely the MDF interviews were performed at the UTK due to the time limitations and the high security procedures required for visiting the highly confidential research facility.

Having considered the final research question developed in this study, the unit of analysis was selected to be the organisation's performance factors based on the study done by Slack et al. (2013). It should be noted that the unit of analysis might be an individual (e.g. organisational leader), a group of people (e.g. training team), an operation system, a department or an organisation as a whole. This is to identify the boundaries and provide the objects of reasoning that satisfy all the relevant criteria needed to answer the research question. The first operational performance factor discussed in here is the cost of the production.

### 7.6.1 Cost

The reason for selecting the cost, as one of the main themes in the data collection was to understand how AM technologies influence the cost of the production. In other words how does AM compares to the traditional methods of manufacturing. Series of factors were identified throughout the interviews both from the Local Motors and the MDF. The first two aspects of the cost saving was related to the labour costs and transportation of goods. It was clear that the on-site production at Local Motor has led to a significant cost reduction on the transportation from the supplier as well as delivering to the customers. The following quote was recorded at the Local Motor:

*“We won’t need a lot of labour in comparison to a large scale car manufacturer. We have machine operators. There is a single person operating at least two sets of machines at minimum. Two sets of AM machines and milling machines. You have also shipping reduced since we are currently dealing with only small number of suppliers that mainly provide the feedstock for our machines.”* (Local Motors)

And on the transportation side:

*“We don’t have cost related to the transportation and all the requirement for the protections and insurance cost around it to get these vehicle to the destination including the overseas situation the cars are produced on site and on location.”* (Local Motors)

Similarly the interviewee at MDF believed that:

*“Another component of the cost is the labour. How much am I paying for people, that machine is sitting there, doesn’t really care. The machine will work regardless if the light in the room are on, doesn’t need air conditioning and you don’t need humidity control. All it need to control is inside that built chamber.”* (MDF)

Hence the reduction of labour cost and transportation cost are the main two factors under the cost operations performance. However another aspect to the overall production cost is the energy consumption. This plays an important role when the production is located in the western countries such as the UK and USA since the energy cost is normally higher than that of the low-cost countries such as China and India. According to a study done by MDF, the energy cost can be reduced through the Optimisation of the manufacturing processes by considering the energy as a variable rather than accepting it as a cost of doing business. Following is also another point where AM technology can facilitate the energy saving during the production process.

*“Metal additive manufacturing technologies can significantly improve manufacturing energy efficiency by increasing material utilisation and minimising scrap material associated with component fabrication.” (MDF)*

As discussed in “Chapter 5”, the cost of utilising AM technologies in production can be driven by different factors. In other words AM can only be used in certain types of production where it offers its main advantages. As the following quote indicates, it is important to identify the range of products that can be manufactured using AM and then determine if it is economically viable to employ such technologies in production process.

*“So really what I am getting at is what cost of products and processes are most driven by an aspect that can be affected by AM. So that would be either material. If it is an area if you have a high scrap, additive would make sense. If it is a labour issue additive make sense. If it is a significant transportation issue additive would make sense. And another one at least from my perspectives would be the tooling. Where you have such a ... tooling and prototyping. So those become the areas where additive definitely make sense for mass production additive does not make sense.” (MDF)*



### 7.6.2 Quality

Once the cost aspect was covered the interviewees were asked about the quality of the product they manufacture using AM and compare it to that of traditional ones. This is while the quality standard in the additively manufactured product is one of the mostly debated aspects of these technologies among the researchers (Ahuja et al., 2015; Atzeni and Salmi, 2012; Khajavi et al., 2014). Some scholars suggest that the quality of the AM products is still not sufficient according to the standards required in the market (Hague et al., 2003). Conversely Petrovic et al. (2011) believe that with the advancement in the AM technologies the quality of this approach is now at the competitive level.

Comparison between the additively produced component and conventional approach to manufacture the same component shows that in certain areas the quality of the product does not differ. In fact it can also offer advantages such as weight reduction and increase in the strength of the structure. The following quote states the quality aspect of AM technologies at MDF.

*“Elimination of geometrical constraints associated with conventional manufacturing technologies such as casting and machining can result in components that fulfil all of the functional requirements but weigh significantly less than those of conventional design.”*  
(MDF)

It also offers the capability of infrared thermography for further inspection of the quality.

*“With additive manufacturing the goal is to be able to use infrared thermography where you can look at layer by layer and see where you got imperfections and heat rises and stress built up looking at them layer by layer by layer. So I’ve got a complete history of how it was done. If I start block of metal I don’t know what is exactly inside it. So from the quality stand point, theoretically yes I can get better information about that material and part. So from quality stand point I don’t know if there is going to be much of a difference with traditional methods.”* (MDF)

Despite the viewpoint in the last paragraph, Local Motors believes that the traditionally manufactured products have better quality than AM products, while pointing out the significant potential in coming years for the quality aspect of AM products.

*“The quality I think that it is at today’s stages it is lower no doubt that the quality of your traditional method of manufacturing your components and cars. Em .... That’s were a lot of people stepping into the game, mostly in OEMs they look at it that’s not and will never be to the same level of quality that we produce now, but I say that is narrow way of thinking and again like 10 to 20 years working on this everything can drastically change, and change the game. I think that is a narrow-minded way of thinking. I can see why they would think that the way they see it now, but we are more ambitious company we can vision”* (Local Motors)

### **7.6.3 Speed**

The third operations performance factor mentioned during the interview was the speed of the production. All the participants in the study had the optimistic vision on the future development of the technology and increase in the speed of production in coming years. With the advancements these technologies witnessed since the start, there is still number of ways to increase the printing speed in terms of deposition rate and material properties. Another aspect to speed is the overall production speed. This depends on the complexity of the processes and the stages involved in making the product by the reduction in set up, changeover time and number of assemblies.

*“When you look at the speed, there is a lot of aspect to speed. There is with making the part that would be depending on how many steps are involved. If it is something that is a simple part and I can program CNC machine and put it there it is good to go and it is not a big deal. But if it has to go from station to station to station, intermediate steps and all these kind of things then additive would make more sense because you are not handling it*

*as much time. You don't have so much inventory level in the pipeline throughout that just reducing the intermediate steps where you have more time to move from one process to another. And then speed also is to making the part or getting the part delivered customer.”*  
(MDF)

The speed of AM has been improving with a rapid space and will continue to enhance over the coming years (Tuck et al., 2007). The Local Motors has targeted to reduce the production of the body and chassis combination from 24 hours to 12 hours, which is mainly done by focusing on the material deposition rate. It should be noted the first car built at Local Motors required 44 hours of printing that was reduced to 24. However this process is continuing to further reduce the time required for the printing stage.

*“Our target is to print the body of the car in 12 ours but the way I see it in 5 years' time that 12 hours' time I see being much less. Some could argues that in different way that I think it as a functional choice of investment really like whether or not like a companies investing on increasing the speed of deposition rate that put the material faster and more precise. It is just the technology is on the way, it is just money and time to develop the process really to increase that. If you could imagine you are putting down 80 pounds material per hour and you could make that into 160 pounds per hour obviously you doubling your speed on that.”* (Local Motors)

#### **7.6.4 Flexibility**

Flexibility is one of the strongest aspects of AM technologies. The capability of manufacturing parts regardless of the geometrical complexity has made this approach an unprecedented technology enabling businesses to produce parts which are not possible with any other manufacturing methods. In fact once the digital file of the product is developed in 3D format, the printers can produce the object straightaway. The adoption of

such technology has enabled the Local Motors to accommodate the unexpected changes in the production system as well as the last minute changes in the product design. It also allows for more product iterations during the product development stage.

*“There is a difference in manufacturing time now obviously the big companies have lined up for high reproducibility if they ever have to stop their production line they can be down for three month sometimes to make the whole production change or different thing depending on the extent. But us there is virtually no time required for that. We can change the design and hit the print there is no cost to tooling at all. “(Local Motors)*

*“The flexibility in AM is well documented. It is a technology where there are almost no design boundaries. This allows us to design and make parts which are light weight and Optimised in design.” (MDF)*

As a result of the flexibility, more customisation in the product can be achieved. This is through closer communication with the customers. One of the strategies implemented at Local Motors is the involvement of the customers in the product design process. By doing so the customers can design their own vehicle and include the features they like.

#### **7.6.5 Dependability**

The last operations performance factor covered in the interviews was the dependability. This criterion or in other words the on-time delivery of the product to the customer can be seen as a result of improvement in speed and flexibility of the processes. The fast speed of the production combined with the ability to accommodate unforeseen changes in production and products can allow the company to meet the delivery objectives and be on-

time when it comes to ensuring reliable delivery of the products. The following two quotes relates to the company's performance regarding their on-time delivery to the customer.

*“If I make thing in the place that I will be using it, there is more chance of reliable supply goes way up. If I count on the thing coming from overseas lots of things can happen. A lot of things can be happening to it. But the transportation time, containership and all the other stuff. Reliability or dependability can be compromise if I make the produce where I need it.” (MDF)*

*“At Local Motors we deal with the customers directly. They can come over here to order and pick up their products. Therefore the dealerships are also eliminated. It is like a shortcut which it makes the process a lot faster and saves costs.... I would say we are quite strong in this factor (Dependability) thanks to 3d printing” (Local Motors)*

As it can be seen above the capability of producing the products in the same location where the end customers are, is the main factor that improves the delivery of the goods. The following section summaries and further discusses the data collected during the interviews.

## 7.7 Research Discussion

This chapter aims to investigate the impacts of AM technologies on the supply chain management of high value added products particularly in automotive industries and illustrates the changes it can bring to the supply chain in the context of re-shoring phenomenon. With the sophistication of customer desires and demand for shorter delivery times which are currently leading some industries to bring back their manufacturing to the home country, it is essential for manufacturing systems to adapt according to the present challenges and be able to accommodate such requirements. With the utilisation of AM technologies, companies can access the suitable information on customer needs and preferences and provide the products in a timely manner to achieve a high customer satisfaction. In order to do so the company only requires digital data and raw materials for production indicating that components are produced with little to no work in progress.

In terms of cost of the production, AM has the ability to produce highly complex components that require no tooling and therefore reduce the costs of manufacturing, especially for low volume productions. The key element in the cost of AM production is not the labour cost, but the machines and materials necessary for production. As mentioned previously, at the Local Motors one operator is capable of operating two sets of AM machines and milling machines. This indicates significant reduction in manpower requirement. Meanwhile scholars such as Tuck et al. (2007) believe that the migration of manufacturing activities to low-wage countries such as China can be challenged particularly for low volume and customised products due to reduction in labour costs.

The costs of AM systems have been also decreasing significantly in recent years. This is aligned with the existing literature. According to Thomas & Gilvert (2014) who believe that the AM system is also a significant cost factor; however, this cost has continually decreased. Between 2001 and 2011 the average price decreased 51 % after adjusting for inflation. Another limitation associated with using AM for functional products is the limitation in the size of the build envelopes (Tuck et al., 2007). However at Local Motors

a large scale AM systems have been developed unique to their application which is capable of manufacturing an actual size car body with fast deposition rates.

Note that in “Chapter 4”, it was found that the responsiveness of the businesses and achieving shorter lead-times were the primary reasons behind the re-shoring movement in the UK. Hence the capability of AM technologies to accommodate such need in the business environment was shown through the questionnaire design and the case study conducted in this study. Speed and flexibility of the AM methods facilitates fast reconfiguration of processes to cope with consumer demand allowing the businesses to be more agile and responsive, making it a suitable manufacturing strategy for products with short life cycles. AM approach does this by providing down-stream (towards the customer) responsiveness and up-stream stability due to small number of suppliers involved in the process. In other words this can be seen as an application of the concept of Postponement in the supply chain through using AM to build according to the customer order (Van Hoek, 2001). Hence as a result of manufacturing to order, the costs of stockholding can be reduced substantially by providing a generic platform that can be manipulated to any future customer order. Therefore AM can help the company to minimise the obsolescence of stock and improve the responsiveness.

According to the study done by Alford et al. (2000) customisation in automotive sector can be achieved in three forms namely core customisation, optional customisation and form customisation. The core customisation requires direct customer involvement in the design stage of the vehicle. This approach is more suitable for a low volume production due to the nature of the manufacturing processes and the interaction of the customer. Whereas in the optional customisation, the high volume manufacture of vehicles is targeted where the customers select customised “options”. These options can mainly be integrated into the car during the assembly process. Lastly the form customisation is more involved with the flexibility in changing the finance package, service and warranty specifications. The results obtained from Local Motors as a vehicle manufacturer, indicates that AM systems allow for core customisations in which customers are involved from early stages of vehicle design. This is while the company is capable of manufacturing

nearly 3000 cars per year in one facility, each facility requiring a 47000 square feet building.

After looking at the data gathered from the interviews, Figure 7-3 was developed to show a simple comparison between the traditional manufacturing and AM. The Figure is based on interviewee's viewpoint towards AM which is illustrated in five scales, one being the weaker side and five being the stronger side.

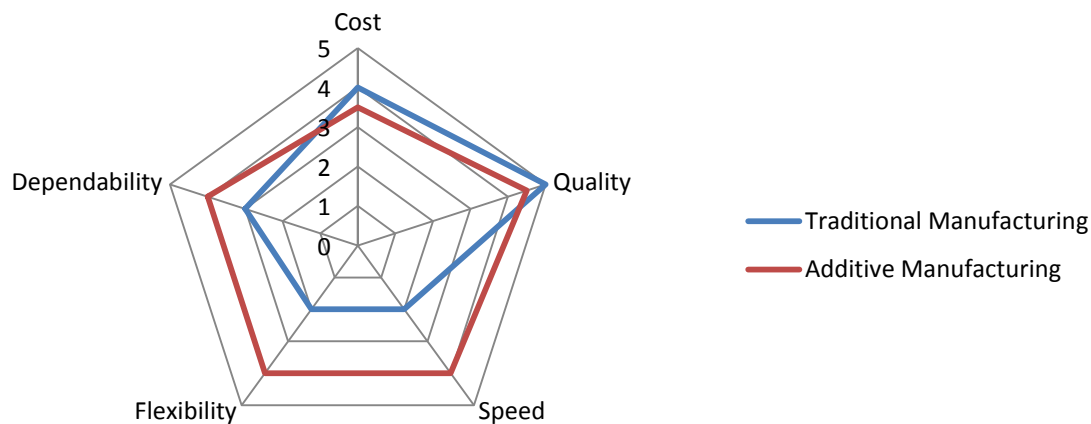


Figure 7-3, Comparison between traditional manufacturing and AM

### 7.7.1 Additive Manufacturing in the context of re-shoring

The results obtained from “Chapter 4” and “Chapter 5”, indicate that re-shoring can be further supported once the supply chains have been shortened and more products are supplied domestically. This way the suppliers are able to adjust their production according to any changes made to initial product specifications or demand fluctuation in the target market. Therefore achieving shorter lead-time in production is considered a vital factor in order to survive in a turbulence market. However the use of AM for the production of end-use parts is in its infancy, there are number of studies which identify the type of products



that can be manufactured using AM (Mellor et al., 2014; Tuck et al., 2007). For instance Mellor *et al.* (2014) have come up with three product characteristics for which AM technologies can be utilised. These factors are as follow:

1. The products should have a degree of customisation,
2. The functionality of the product could be improved through design optimisation, and
3. The products should be manufactured in low volumes. This indicates the importance of the volume that can be manufactured using AM.

Similarly Berman (2013) argues that the AM technologies can substantially affect the benefits of producing small lot sizes in low-cost countries by reduction of the workforce required for the production process. Hence AM can support re-shoring by targeting the high value added products and components that are required in low volumes. Mellor *et al.* (2014) state, “As mass production has migrated to developing countries, European and US companies are forced to rapidly switch towards low volume production of more innovative, customised and sustainable products with high added value”. The cost of tooling is one of the main prohibitive factors that limits the design and manufacture of low volume productions (Tuck and Hague, 2006). The significant cost of tooling limits the product design, range of materials and the complexity of products.

The Figure 7-4 was developed as an extension to the diagram shown in “Chapter 4” (Figure 4-4) to illustrate a simplified supply chain configuration of a company who has re-shored its production back to its parent country and utilised AM technologies. The diagram presents the overall configuration before and after the re-shoring decision is made whilst using additively manufactured components/products through local suppliers.

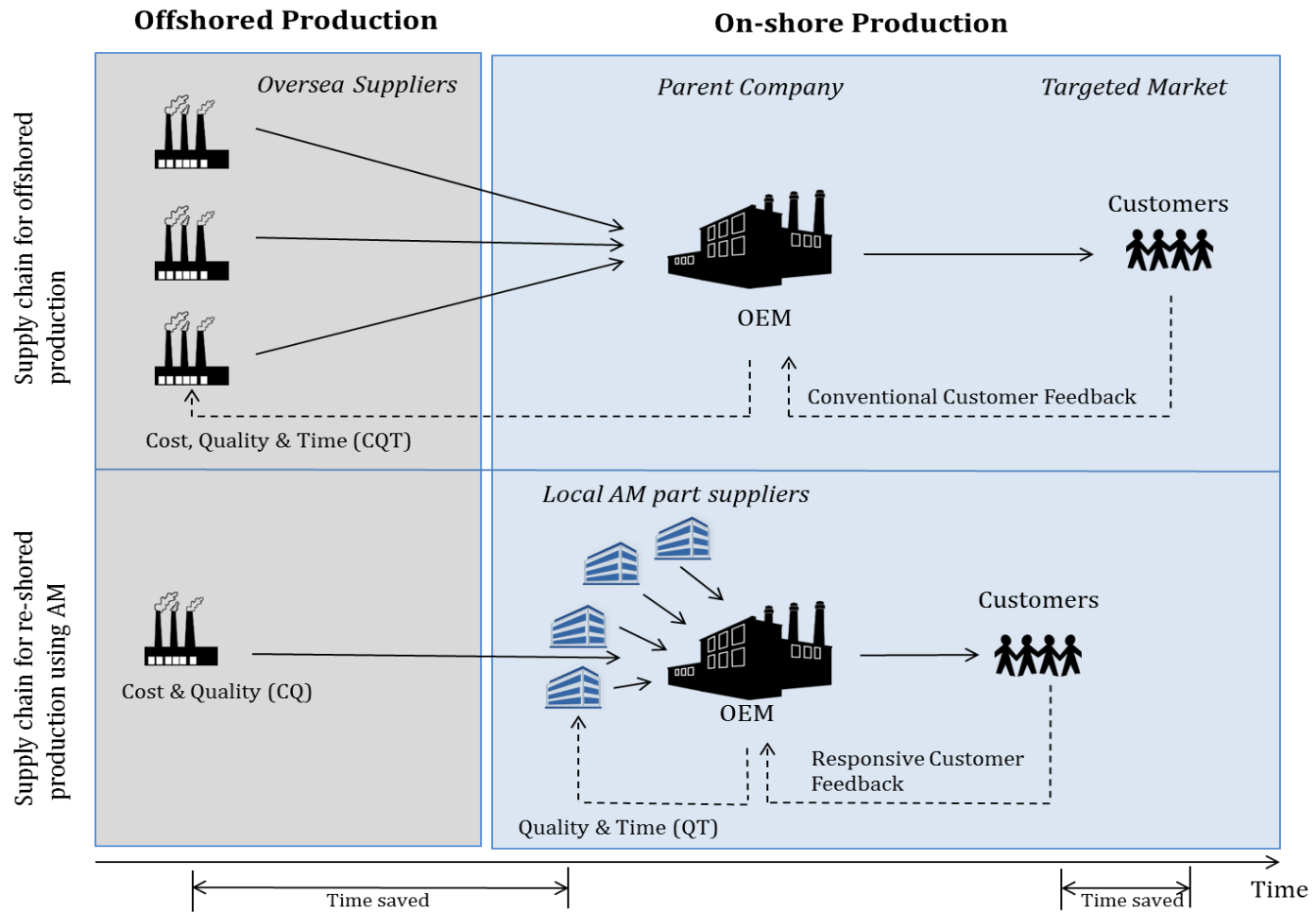


Figure 7-4, A comparison between supply chain of offshore production and re-shored production using AM

As illustrated in Figure 7-4, the top section represents the conventional supply chain in which products are supplied by number of overseas suppliers. In such configuration the main criteria for the selection of the suppliers, are cost, quality and time. Despite considering the time as an important factor, the communications between the supply-chain stakeholders are relatively slow which can ultimately affect the responsiveness of that supply chain. For instance any changes in the product design will have to go through a long process and series of long distant communications and travelling. This can result in less integration between upstream suppliers and downstream customers. Consequently companies can face “hidden costs” such as miscommunications and excessive travelling (Moradlou and Backhouse, 2016). This can greatly affect the down-stream (towards the customer) responsiveness and up-stream stability of the supply chain. The transparency in the supply chain is reduced which ultimately influences the integration of internal processes and flow, suppliers and customers. This also results in less responsiveness, agility, and flexibility in an increasingly turbulent and uncertain world. In addition to this the transportation is another factor that would influence the lead-time and product delivery time. One reason behind this is the enforcement of the governmental policies towards cleaner transportation using slow-steaming ocean transit. Hence the working capital is tied up in the inventories for longer periods.

The second section in the diagram represents the scenario in which the company has re-shored parts of its supply chain back to the UK. By re-shoring production from a low-cost country to the country of its origin, the business can significantly reduce the number of oversea suppliers. This is by keeping the supply of commodity type products oversea and returning the customisable/variable products near to the end customers. According to Tuck & Hague (2006), AM can transform the design which leads to a reduction in both the number of parts necessary for assemblies and a reduction in wastes in terms of time or cost. This was evident in the case of Local Motors where only dozens of parts are required to manufacture the entire vehicle rather than thousands in a case of other vehicles.

Meanwhile the re-shoring companies will be able to take advantage of AM supply chains in which they can easily communicate with its members. In such supply chain the products can be divided into two categories. The first group consists of products in which cost and

quality play important roles where companies still import the products/parts from overseas. The second category is the products where quality and time are the main drivers. Therefore for such strategy responsiveness is the key enabler of winning the market share rather than the overall cost. This is where AM suppliers can improve the responsiveness required for satisfying the customer demand. Similarly Tuck & Hague (2006) argue that AM can help companies to achieve Just In Time (JIT) strategy by reduction in logistics to the customer and reducing delivery costs and time.

Another aspect of AM technologies is its capability to amalgamate with internet technology and other manufacturing systems (MRP etc.). It allows the companies to achieve end-to-end digital integration. According to Brettel *et al.* (2014) “by integration along this value chain it will be increasingly less important, which process is executed in which particular factory or company, as all participating entities can be supplied with access to real-time information and control is distributed to the shop-floor level”. Integration with internet technology will enable the companies to ensure a fast exchange of data between designers and manufacturers. In the case of Local Motors this data can be sent directly to the AM system to manufacture the vehicle. By doing so, the detailed product specifications can be also discussed among the supply chain members while minimising the potentials for miscommunications and language barriers that often occur when dealing with foreign suppliers.

Local AM suppliers can also enable companies to communicate with their customers effectively and efficiently and provide required feedback in a shorter time-frame. This is due to more transparency and better communications with the domestic suppliers allowing JIT manufacture at the factory, rather than the traditional concept of JIT delivery to the firm. Hence as presented in the diagram (Figure 7-4) companies can receive customer feedback preventing the information travelling to other countries and help them to remove the down-stream volatility of customer demand. In addition to this since the AM machine requires only 3D CAD files and raw material to build the part, the application of AM in the manufacturing environment will lead to a reduction of material distribution and stock holding or warehousing costs. The application of AM in the UK supply chain can also assist the companies to establish a long-term relationship with their suppliers based on

trust. Hence as a result better collaboration along the supply chain can be achieved. Any requirement from their customers can be sent back to the AM suppliers allowing any modifications required in a timely manner.

### **7.7.2 Additive Manufacturing and 7 Mega-trends**

After considering the work done in previous chapters and analysing the two in-depth case studies conducted, the implications of AM were compared to the 7 mega trends developed by TCS (TATA Consultancy Service, 2013b). Consequently several points were outlined as most significant impacts that AM technologies have in the context of supply chain management. In order to remind the 7 mega trend, the following bullet points are included.

- Consumerisation of manufacturing. In other words shifting the focus from Business-to-Business (B2B) to Business-to-Business-to-Consumer (B2B2C). This involves establishment of customer-centric business system using interactive websites, digital marketing channels, Point-of-Sale (POS) systems, and e-commerce. As mentioned before such trend can be addressed by engaging the customer in the product development stage. This is currently being done at Local Motors with the help of AM technologies where customers are involved in designing the body and the internal features of their future cars.
- Virtualisation and Digitisation. This comprises the utilisation of software to simulate, visualise, and virtualise the product behaviour and performance under virtual scenarios. Hence it enables the companies to achieve more products testing iteration in a shorter time resulting in a quicker time-to-market. The Cloud technologies can be considered as one of the way to initiate such collaborations. With the use of AM, products can be tested going through number of iterations. For instance at Local Motors customers are able to view their designs prior to production using CAD software. According to Holmström & Partanen (2014) “Three-dimensional printing (or additive manufacturing) is the best-known digital

manufacturing technology and has been adopted for a number of different purposes”.

- **Connected Supply Chain.** A network of interrelated supply chain that can also provide high visibility from suppliers to distributors. This would allow the companies to develop an agile production plan and maintain minimum inventory. In the case of AM technologies, the company can be integrated with its network of suppliers and customers to create value for firms. At Local Motors and MDF, supply chain has been shortened due to the reduction in number of parts used in the products. Meanwhile this has made the supply chain members more accessible since the number of suppliers has been also reduced. However it should be noted that the well-integrated online platform is much more than individual physical mechanisms. It needs some standards for the integration of data, applications, and processes to be negotiated and applied in order for real-time connectivity between the stakeholders (Rai et al., 2006).
- **Complexity Reduction and Modularisation of Business.** Modularisation can be applied in various aspects of the business, products as well as processes. For instance by adopting standardisation and harmonisation, companies can ensure component economies of scale since similar components across product families will be used which also facilitates product updating. Moreover it increases the product variety and also reduces the order lead-time due to fewer components.

One of the strong aspects of AM technologies is the ability for the customisation. The case studies performed in this study shows that the companies are able to offer unique products to each individual customers based on their specification.

- **Product Design, Material Science and Sustainability.** This trend investigates the application of the new generation of materials with higher performances, lower costs and environmentally friendly. Moreover, companies are also obliged to consider the carbon footprint from supply perspective by intelligent sourcing and shortening the supply chains. According to the Local Motors, the material used in the body of the product made can be fully recycled. The material can then go back to the cycle of production after it has been made into a feed stock again. It was also

mentioned that there are significant potential in discovering new materials that can be used in AM.

- Next Gen Technology. This includes the utilisation of embedded electronics, telematics, mobility, telecom services, and conventional engineering systems. A range of opportunities have been identified to use embedded electronics in some of the AM technologies. An example of with is in the “Sheet Lamination” or “Ultrasonic Consolidation” process (Li et al., 2015; Monaghan et al., 2015). Note that this study does not aim to investigate the technical side of AM technologies.
- Evolution of the manufacturing model. This indicates the requirement for a shift from large centralised companies to a network of smaller modularised businesses that offer their core competencies and are closer to the end customers (TATA Consultancy Service, 2013a). With the use of AM technologies, the local suppliers (possible small size companies) can engage in a larger supply chains (Tuck et al., 2007). This was evident at the Local Motors where the company had moved some suppliers from overseas and replaced them with the local suppliers in the US.



**Figure 7-5, Six impact of AM in company's responsiveness**

After carefully analysing the findings and the results in this investigation, six areas were identified (See Figure 7-5) where AM can make the most contributions in terms of responsiveness in the supply chain of re-shoring companies. These factors are; better customisation, less transportation, shorter lead-time, less inventories, accommodating product and process changes. By adopting AM technologies in the production, companies will not only be able to accommodating changes in product and processes but also achieve shorter time to market in introducing new products. Customers interface with the production system within Local Motors also allows the company to develop significant amount of variation in the product designs, making customisation possible. This collaboration and information sharing can also trigger innovation along the supply chain



(Brettel et al., 2014). However there are also some indirect factors that AM technologies can have which influence the supply chain management. For instance the geometrical freedom, multi-material manufacturing and reduction in material waste can reduce the amount of operations and the suppliers involved in the production. This ultimately reduces the manufacturing lead-time and shortens the supply chain.

## **7.8 Summary**

This chapter has outlined some of the effects that AM technologies can have on the supply chain management of the companies who manufacture products with high variety. After conducting two in-depth case studies, AM technologies were found to be beneficial in the automotive sector. This is in terms of shortening the production time particularly where fast re-configuration of the manufacturing process is required and requires the production of customised components. It further emphasise that the application of AM is more suitable for parts and components that are manufactured in low volume at the same time high value. This also can result in a significant reduction in stock costs and inventory levels. The potential for removing the aforementioned costs could ultimately affect the business environment on a global scale, which can result in returning the manufacturing activities to the country of origin, as labour costs are no longer a burden.

# **Chapter 8, Conclusion, further work and future direction**

## **8.1 Overview**

This chapter evaluates the findings and concludes the work conducted in this research. It lists all the original contributions of this study to the overall body of knowledge in the subject area. The research journey taken in this study was started by conducting a broad literature review on the subject of manufacturing location decision particularly focusing on the re-shoring manufacturing activities to the UK. This was to highlight the gaps in the knowledge and the motivation for the research. Then the study aimed to identify the primary reason behind re-shoring production among the UK industries. Once the gap was found to be the operational side of the re-shoring phenomenon and a clear picture behind re-shoring was developed, the author searched for a potential manufacturing strategy to overcome the issue. As a result the concept of Postponement was identified. This study illustrates the connection between the re-shoring phenomenon and Postponement strategies and how the companies can benefit from it. Consequently the Additive Manufacturing (AM) technology was found to be a manufacturing method where Postponement can be implemented for the high value added product where customisation and lead-time play

vital roles. Summary of the contributions from each chapters are discussed separately in the following section. This chapter also outlines the further work required for the research methodology and the findings. It then introduces some recommendations for future research.

## **8.2 Conclusion**

The nature of the contribution made in this study is summarised in the following bullet points. It should be noted that due to the structure of this study, each chapter investigates different aspects of the overall objectives. Therefore each chapter is discussed separately as follow:

- Chapter 2: Due to the limited literature available on the subject of re-shoring the author choses to investigate the shortcomings within the supply chain of the companies who are repatriating their manufacturing activities back to the UK. This chapter adds to the existing literature by determining the feasibility of a manufacturing strategy, 'Postponement', as a possible solution for the companies to adjust and cope with the volatile customer demands and new generation of technologies towards more responsive production and customisable products. As a result this chapter identifies the gap in the knowledge and recommends Postponement as a potential manufacturing strategy to overcome the future challenges related to production responsiveness.
- Chapter 4: This chapter provides the answers to the first and second research questions by providing a clear picture behind the reasons for re-shoring in the UK. The findings indicate that re-shoring to the UK is the result of inadequacy in responsiveness and long production lead times of the overseas suppliers. It then identifies the drivers behind this shortcoming in the component supply from Indian industries perspectives. The outcome of this chapter also indicates that the top factors behind this inadequacy in responsiveness are logistics and transportation, electricity shortage, excessive paperwork and working attitude. Hence in order to improve the responsiveness in production and product delivery, Postponement strategy can be employed.

- Chapter 5: This chapter provides the answers to the third and fourth research questions and can be considered as a starting point into research related to the impacts that the new generation of technologies, particularly Additive Manufacturing, have on the re-shoring phenomenon. It firstly provides further validation of the findings in Chapter 4. Then the result obtained from the questionnaire survey indicates that the Postponement and AM can encourage companies to re-shore the high value added production/supply chains back to their home country. As a result they can shorten their supply chain and make them more responsive to domestic demand using local AM suppliers.
- Chapter 6: This chapter partly answers the fifth research question by providing a comprehensive picture on the re-shoring decision by looking closely into a re-shoring case in the UK. AM's potential as a manufacturing technique and its ability to improve supply chain performance in re-shoring companies is investigated by identifying five operations performance factor. This chapter provides a clear comparison between offshoring and re-shoring decisions that the Brinsea Product Ltd was involved in. As a result it was found that AM technology in conjunction with re-shoring has significantly helped the company to reduce its lead time and be more responsive to its customers.
- Chapter 7: Last but not least, the final chapter answers the fifth research question and provides a detailed explanation on how AM technologies can impact the supply chain performance of companies who are repatriating their manufacturing activities to their home countries. As a result of this investigation, author identified six areas that can be significantly improved with the help of AM technologies and facilitate re-shoring decision. The companies can reduce their transportation, lead time, inventory and substantially improve their customisation capability, meanwhile be able to accommodate product changes as well as process changes in the production.

### 8.3 Further work and future directions

As the re-shoring phenomenon continues to be considered as one of the key manufacturing location strategies by which the companies can significantly benefit from and increase their market share in the domestic market, this topic remains as an important subject within the academic community. Meanwhile it is evident that the Industry 4.0 is gaining dramatic momentum in western countries. Therefore considering the rapid expansion of new generation of technologies such as AM, intelligent robotics, big data and internet of things, it is vital to investigate their impacts on the supply chain management.

While this study has contributions to the body of knowledge, it also has some room for improvement in its research methodology and data collection. However, this might be justified by the nature of a PhD project in terms of time and cost constraints. Upon reflection of the entire research various areas were identified that require an additional approach for data collection in order to improve the generalisability of the results. The followings are series of further works and future research directions that need to be considered.

- As previously indicated in the “Scope and Boundaries” section of this thesis this study only focuses on high value added product where short lead-time, customisations and fast time to market are important. However this leaves the commodity type products unstudied where the cost still plays the key role in selection of manufacturing location and suppliers. Hence further work can be done in order to investigate the other categories products such as commodity type.
- The majority of the companies investigated are directly/indirectly related to the automotive sector. However it is important to note that the findings can differ from industry to industry. Hence this study can be expanded covering a wider range of industrial sectors such as electronics and aerospace.
- This thesis only investigates the Indian industry’s perspectives. Hence the results only provide a viewpoint which may differ from another country. Therefore further research is required to explore the reasons behind the lack of responsiveness from other low-cost countries perspectives (e.g. China). This provides a better picture of re-shoring decision making and enables companies to identify the issues specific to each geographical region.

- The statistical reliability of the findings from survey questionnaire cannot be said to be absolute due to the limited sample size available. It should be noted that currently there is no database for the list of companies that are involved in AM. Therefore identification of number of companies within the market is extremely challenging. However considering the speed of AM growth in the UK, it is expected more reliable statistics on the AM technologies being available. Due to the small sample size for the data collection, it is recommended to target a larger sample in the UK. Hence an extension of this work is required to examine more companies and understand re-shoring and its potentials in the UK.
- Focusing only on the AM manufacturers in the survey study can be considered as a potential source of bias since the questionnaire is strongly linked to the areas of their expertise. However it can be prevented by targeting all the industrial sectors which manufacture high value added products.
- This study also can benefit from using techniques such as Analytical Hierarchy Process (AHP) in order to design and analyse the survey questionnaire. This can replace the simple-multiple-choice format used in this study where the respondents choose one form among the given alternatives. One of the limitations associated with the simple-multiple-choice format is that it limits the participants to express their preference concerning a selected alternative over the others or give any information regarding the relationship among the non-selected alternatives. Whilst applying AHP to the questionnaire can extract the participants opinion more precisely than the traditional method by quantifying the importance of each alternative using weighting method (Sato 2003).

## 8.4 Summary

The purpose of this concluding chapter was to summarise the research project, to discuss the contribution to knowledge in the context of the research objectives and to make proposals for further research. Hence the novelty of the work in each chapter is described separately. Once this was done a number of limitations were identified in terms of the data collection methodologies adopted and the number of companies under investigation. In addition to this several areas were identified where further research can be conducted.

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## **Appendix A**

### **Interview guideline for India**

The document requires having two parts. The first part consists of the introduction and opening questions and second one will be based on the first part of the interview including more detailed questions.

To start the interview an introduction about the project (Aims and objectives) should be given to the interviewee. Assess their knowledge about the re-shoring phenomenon (reverse of offshoring) currently happening in western countries.

#### **Part one**

1. What is your role in the company and how long have you been working in this company? Background? How many people work in your company?
2. What is the product range that you are supplying?
3. Are you considered to be a 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> tier supplier?
4. Which countries do you supply (now and future)? What is the scale of production?
5. Is the demand for your products variable or fixed in terms of volume and product mix/variety (innovative or commodity products)?
6. To what extent do you outsource the manufacturing activities? Where to?
7. How long in advance do you receive your orders?
8. Does agility play an important role in your company? Is responsiveness an issue? Do you considered to be Adaptable to customer specification?
9. Are you familiar with the term Re-shoring manufacturing activities?
10. What is the Indian point of view about the re-shoring? Do the reasons for re-shoring apply to India for example: increasing cost of Transportation, Labour costs, IP, Lead Time, Time to market, Cultural differences, language differences, productivity issues, increase in fuel price, travel costs, higher inventory, quality problems, communication problems, Currency fluctuation, etc.

The second part of the interview will be about the time required for product development and delivery (logistics) to the final destination. Investigation should also take place on human factors, IT facilities and manufacturing equipment.

## **Part two**

1. What is your average lead-time and delivery time to the oversea customers?
2. What is the main problem when it comes to the shortening the lead and delivery time? Development vs production period?
3. Do you face any difficulty with logistics?
4. How closely do you collaborate with your customers in product development stage?
5. Are you familiar with the term Postponement (Postponement is Delaying the production differentiation downstream the supply chain)? If yes in what areas do you implement this strategy?

### *IT Solutions*

6. What types of information technology is used in your company to communicate with your oversea customers? Inter-organisational coordination?
7. How do you receive orders?
8. Any types of platforms for invoice, purchasing and order schedules!!
9. Do you see any IT limitation for further development in your company?
10. To what extent IT solutions such as Customer relation management, *Enterprise Resource Planning (ERPs)* and *Material Requirement Planning (MRPs)* are being used in your companies, CAD in development period?

### *Human Factors*

11. What is the relationship with your customers and suppliers here in India and overseas?
12. How do you collaborate with them?
13. What is the quality standards implemented in your products, ISO/TS16949, ISO/9001?
14. What is the management strategy to achieve those?
15. How could you improve your human factor in order to be more responsive?
16. To what extent is your company depending on skilled labour? Is it available?
17. Do you provide continuous workforce education and training? Multi-skilled and flexible people? Task rotation to familiarise the employees with different tasks? Top management support? Adaptable work force that can deal with non-routine and exceptional circumstances.

18. Flexibility (Numerical, Functional, Financial) in terms of working hours, temporary contracts, part-time, change in skills, individual pay systems, pay for performance and profit sharing plan.

*Manufacturing equipment*

19. Where do you stand in the market competition?
20. What is the production method in your company? How does it compare with the competitors?
21. To what extent automated systems are used in the production?
22. Do you use specialised machine in order to produce the product supplied to the UK?
23. Do you require specialised labour force to work with the system?
24. How often do you upgrade your systems?
25. How would you improve your manufacturing facilities to meet the customer demands and be more responsive?
26. Product volume flexibility!

## **Appendix B**

### 2015 Survey

## **Re-shoring manufacturing activities back to UK in the context of customer focused Postponement strategy**

Professor Chris J Backhouse (Supervisor)

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This study is commissioned within the Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, firstly to develop a better understanding of the primary reason behind re-shoring movement in the UK and investigate the effects of Postponement strategy and Additive Manufacturing (3D printing) on the supply chain of re-shoring companies. This study would be then used as a guideline by the companies that are planning to repatriate entire/part of their manufacturing activities back to the UK. The output of this study may also help the companies to discover the potential advantages of Additive Manufacturing for their supply chain structure. In addition this questionnaire represents a major part in my doctoral research in re-shoring and Postponement. A summary report will be sent to you at the end of this study.

We would very much appreciate your contribution by answering the questions in the attached 3-page questionnaire and returning it via e-mail. All the questions only require a tick and this should not take more than five minutes of your valuable time. A hard copy of the questionnaire is available on request (simply by emailing us with the word "questionnaire" on the subject line). Your responses will be kept confidential and all data would only be reported in an aggregated form.

## **Introduction**

1. Name of the respondent (optional):
2. Position of the respondent in the company:

Please circle the appropriate answer to indicate which of the categories best define your business.

3. Number of employees



☐ 1-50                      ☐ 51-250                      ☐ 251-1000                      ☐ over 1000

4. Gross annual sales (£)



☐ < 1 million    ☐ 1-10 million                      ☐ 11-50 million                      ☐ 51-100 million                      ☐ >100 million

5. Which of the following best describe your business?



☐ Original equipment manufacturer (OEM)    ☐ Tier 1                      ☐ Tier 2                      ☐ Tier 3                      ☐ Others

6. Which Industry sector does your company belongs to?



☐ Automotive                      ☐ Aerospace                      ☐ Chemical & pharmaceutical                      ☐ Food & Drinks  
☐ Clean Technology                      ☐ Oil and Gas                      ☐ Other

7. How would you classify your products?



☐ Raw material                      ☐ Major equipment                      ☐ Accessory equipment                      ☐ Component  
☐ Process material                      ☐ Consumable supplies

### Off-shoring and Re-shoring

8. Please indicate to what extent the following factors are important for re-shoring. 1- *Strongly disagree*, 2- *somewhat disagree*, 3- *neither agree nor disagree*, 4- *somewhat agree*, 5- *strongly agree*

	1	2	3	4	5
• Speedy delivery to customer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Proximity to the end customers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Customization of the products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Rapid new product introduction to the marketplace	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Cost of the production	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Development of new products	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Others (please specify):					

9. Please indicate to what extent you agree with the statements listed below? 1- *Strongly disagree*, 2- *somewhat disagree*, 3- *neither agree nor disagree*, 4- *somewhat agree*, 5- *strongly agree*

	1	2	3	4	5
• Responding quickly to customer demand is important factor in your company?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Responding quickly to customer demand is an important factor in encouraging re-shoring manufacturing?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Postponement Strategy

Definition of Postponement: *Postponement centres around delaying activities in the supply chain until real information about the markets are available*

10. Please indicate to what extent you agree with the statements listed below? 1- *Strongly disagree*, 2- *somewhat disagree*, 3- *neither agree nor disagree*, 4- *somewhat agree*, 5- *strongly agree*

	1	2	3	4	5
• Postponement strategy helps production to be more responsive to the customer demand	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• Postponement strategy can enable re-shoring by making companies more responsive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• UK based suppliers are capable of supporting further postponement strategies in the UK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Additive Manufacturing (AM)

11. Please indicate to what extent you agree with the statements listed below? 1- *Strongly disagree*, 2- *somewhat disagree*, 3- *neither agree nor disagree*, 4- *somewhat agree*, 5- *strongly agree*

	1	2	3	4	5
• AM technologies can be considered to be the implementation of a type of postponement strategy (ETO)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technologies can help re-shoring by enabling the companies to customise the products according to the customer specifications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technologies can help re-shoring by using local suppliers in the UK	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technology can help re-shoring companies to develop new products more quickly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technology and digital data exchange can help re-shoring by reducing miscommunications with foreign suppliers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technology and digital data exchange can help re-shoring by shortening the supply chain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technology can help reshoring by offering shorter lead-time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
• AM technologies can help re-shoring by responding faster to customer demands	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Any comment: |

Thank you for your support of this research effort. We will send you a copy of the study's findings when they are completed.

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