

**CRANFIELD UNIVERSITY**

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**Development of an Impact Assessment Framework for  
Lean Manufacturing within SMEs**

**SCHOOL OF APPLIED SCIENCES**

**PhD THESIS**

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**Development of an Impact Assessment Framework for  
Lean Manufacturing within SMEs**

**Supervisors: Dr Essam Shehab & Professor Rajkumar Roy**

**October 2007**

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# AFFIRMATION

Except for the generically accepted terminologies, concepts and ideas, or where specific citation is conducted, this thesis is the result of my own research and does not include the outcome of work done in conjunction. Furthermore, no part of this thesis is the result of work submitted for considerations of any awards; diploma or degree at any university or college.

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## ABSTRACT

**Keywords:** *Impact Assessment, Lean Manufacturing, SMEs, Fuzzy Logic, Knowledge Based System, Relative Cost, Lean Readiness, Lean Impact/Benefit*

The main aim of the research work presented in this thesis, is the development of a novel framework with the capability of assessing the impact of implementing lean manufacturing within small-to-medium sized manufacturing firms (SMEs). By assessing the impact of lean implementation, SMEs can make informed decisions on the viability of lean adoption at the conceptual implementation stage. Companies are also able determine their status in terms of lean manufacturing affordability.

Thus, in order to achieve the above-stated aim, the following were the main set research objectives; (1) identifying the key drivers for implementing lean manufacturing within SMEs, (2) investigating the operational activities of SMEs in order to understand their manufacturing issues, (3) exploring the current level of lean manufacturing usage within SMEs so as to categorise users based on their levels of involvement, (4) identifying factors that determine the assessment of lean manufacturing, (5) developing an impact assessment framework for justifying lean manufacturing within SMEs, (6) developing a knowledge based advisory system and (7) validating the impact assessment framework and the developed knowledge based advisory system through real-life case studies, workshops, and expert opinions.

A combination of research methodology approaches have been employed in this research study. This comprises literature review, observation of companies' practices and personal interview. The data collection process involved ten SMEs that provided consistent information throughout the research project life. Additionally, visitations to three large size manufacturing firms were also conducted. Hence, the framework and system development process passed through several stages. Firstly, the data were collected from companies who had successfully implemented lean manufacturing within their premise. The second development stage included the analysis and validation of the dataset through company practitioners. An impact assessment framework was thus

developed with the aid of regression analysis as a predictive model. However, it was realised that there were few correlations between the dataset generated and analysis. The reasons for this were unclear. , a knowledge based advisory system was adopted to conceptualise, enhance the robustness of the impact assessment framework and address the problem of the imprecise data in the impact assessment process.

Three major factors of impact assessment were considered in the framework and the system development process, namely relative cost of lean implementation, a company lean readiness status and the level of value-added to be achieved (impact/benefits). Three knowledge based advisory sub-systems that consisted of the abovementioned factors were built. Results obtained from them were then fed into the final system. The three sub-systems were validated with the original set of data from companies. This enabled the assignment of a number of input variables whose membership functions aided the definition of the fuzzy expert system language (linguistic variables) used. The final system yielded heuristic rules that enable the postulation of scenarios of lean implementation. Results were sought and tested on a number of firms based within the UK, for the purposes validation. These also included expert opinions both in academic and industrial settings.

A major contribution of the developed system is its ability to aid decision-making processes for lean implementation at the early implementation stage. The visualisation facility of the developed system is also useful in enabling potential lean users to make forecasts on the relative cost of lean projects upfront, anticipate lean benefits, and realise one' degree of lean readiness.



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I DEDICATE THIS RESEARCH WORK  
TO THE LOVING MEMORY OF  
MY LATE DAD  
HILLARY LAWRENCE ACHANQA  
WHOSE SUDDEN DEATH  
WHEN I WAS BARLEY  
4 YEARS OLD LEFT  
A NEVER ENDING MISERY



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4. Achanga, P., Shehab, E., Roy, R., and Nelder, G. (2006), Return of investment duration for lean manufacturing within SMEs, *Proceedings of the 8<sup>th</sup> International Conference on Stimulating Manufacturing Excellence in Small and Medium-sized Enterprise (SMESME2006)*, Coventry University, Coventry, UK ISBN: 1-84600-012-2, pp.27-33.
5. Achanga, P., Shehab, E., Roy, R., and Nelder, G. (2005a) Lean manufacturing for SMEs: enabling rapid response to demand changes, *Proceedings of the 15<sup>th</sup> International Conference on Engineering Design (ICED2005)*, Institution of Engineers, Melbourne, Australia, August 2005, ISBN: 1-904670-00-8, pp.148.
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## **ACHIEVEMENT**

Emerald Award Winner for a Highly Commended Paper 2007: Critical success factors for lean implementation within SMEs, Journal of Manufacturing Technology Management Vol. 17, No.4, pp.460-71, 2006 (See appendix G).

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## **GLOSSARY OF TERMS**

AP	Adaptable Production
AM	Agile Manufacturing
AHP	Analytical Hierarchy Process
AI	Artificial Intelligence
ANN	Artificial Neural Networks
AM	Autonomous Maintenance
AS-IS	Current Practice
BERR	The Department for Business Enterprise and Regulatory Reform
CAD	Computer Aided Design
CIPD	Chartered Institute of Personnel
CNC	Computer Numerical Controlled
DTI	Department of Trade and Industry
EEDA	East of England Development Agency
EFQM	Excellence Framework Quality Model
EPSRC	Engineering Physical Science Research Council
ERP	Enterprise Resource Planning
FIS	Fuzzy Inference System
FL	Fuzzy Logic
FS	Fuzzy Set
GT	Group Technology
IA	Impact Assessment
IEE	Institution of Electrical Engineers
IQA	Institute of Quality Assurance
ISO	International Organisation for Standard
JIT	Just-In-Time
KBAS	Knowledge Based Advisory System

LAA	Lean Aerospace Architecture
LAI	Lean Aerospace Initiative
LAI	Lean Aerospace Institute
LEM	Lean Enterprise Model
LV	Linguistic Variables
MAS-East	Manufacturing Advisory Service in East England
MF	Membership Function
M	Muda
MI	Maintenance Improvement
MP	Maintenance Prevention
MRP	Manufacturing Resource Planning
NN	Neural Networks
NGT	Nominal Group Technology
OEE	Overall Equipment Effectiveness
PDVSM	Product Development Value Stream mapping
PCB	Printed Circuit Board
QCD	Quality Cost Delivery Agency
RA	Regression Analysis
SAS	School of Applied Sciences
SME	Small-to-medium size manufacturers
TMS	Total Maintenance System
TO-BE	The Proposed Model
TP	Total Production
TPM	Total Productive Maintenance
TQM	Total Quality Management
TPS	Toyota Production System
TTL	Transition-To-Lean

VA	Value Analysis
VE	Value Engineering
VSM	Value Stream Mapping

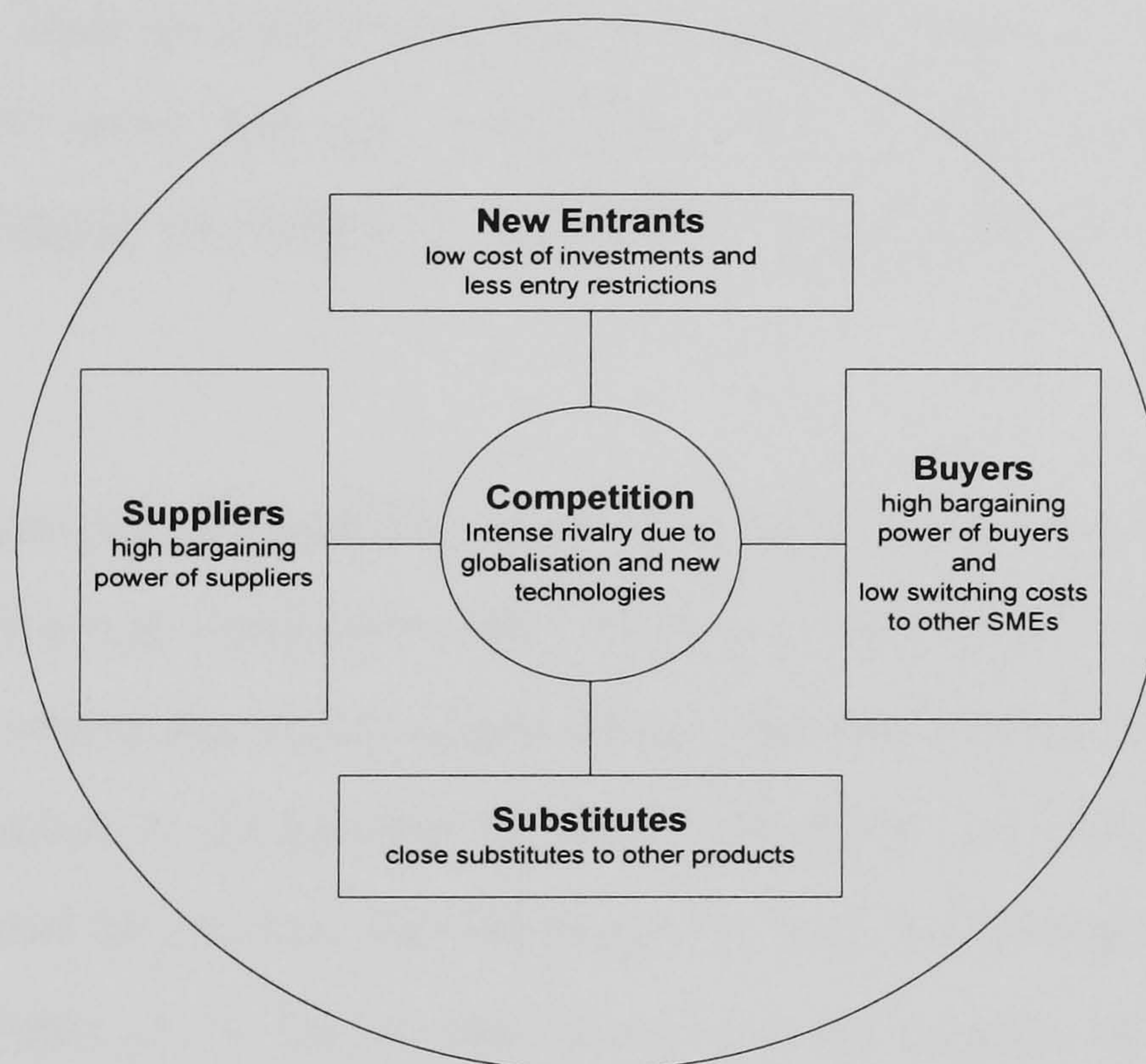


# CHAPTER (1)

## 1 INTRODUCTION

### 1.1 Background

The effects of globalisation and emerging technologies are having enormous impacts on the manufacturing industry around the world. This scenario has seen the exponential upsurge in new entrants to the market environment, prompting stiff competition in the market place (Umble *et al.*, 2003). The competitive market pressures engulfing the wider small-to-medium size enterprise community in general, place them in a precarious position since they must operate in a reactive manner to ever changing circumstances. Inevitably, many small-to-medium size enterprises become vulnerable because they operate in sectors where there are few barriers to new entrants and where they have little power to dictate to suppliers their needs as illustrated in Figure (1.1).



**Figure 1.1: Porter's 5 Forces (1985)**

Never-the-less, the current manufacturing environment in which the small-to-medium size enterprise sector operates as a whole is challenging. This is due to the fact that creation of a small business venture does not require most times, high technological



arrangement and large financial involvement. Inevitably, such scenarios allow for numerous entrants into the venture because of the low cost of investment and less entry restrictions. Consequently as many businesses are created, buyers are provided with unlimited choices due to low switching costs, a fact which promotes their price control structure as they are able to switch providers at will. Moreover, buyers are also able to substitute products due to varieties. Additionally, most of these firms are not able to control their supply chain sources as it would be the case in a larger firm. Hence, the whole operational environment of these firms promotes their vulnerability in adapting to the current competitive rivalry.

## **1.2 Research Motivation**

The heightened market competitiveness and other manufacturing issues challenging the survivability of most UK small-to-medium size enterprises described in the previous section; have been the motivating factor for conducting this research study. This inference is advanced from the notion attached to the small-to-medium sized enterprise sector as a whole. They are highly valued as part of the business ecology for their role in the sustenance of most national economies, and are an important element of governmental strategies (Achanga *et al.*, 2005a; Denton and Hodgson, 1997; Levy, 1993).

Conversely, as a result of the problems associated with SMEs' inability to place barriers capable of restricting new entrants to their ventures, a growing desire is raised by other providers seeking to join the market-share. Hence, the manufacturing industry in the UK is witnessing a decline in the number of small-to-medium size manufacturers (SMEs), as work is transferred to Far East and elsewhere, in search of cheaper operating costs as demonstrated in Table (1.1). To be able to survive and qualify in such a competitive environment, SMEs should seek for further innovative intelligent manufacturing paradigms. Lean manufacturing offers an ideal solution in initiating cost reducing strategies like, the identification and elimination of wastes in the entire manufacturing environments. There is also a greater need for companies to embrace initiatives such as lean manufacturing that have the capability of enhancing their productivity processes.

The term lean manufacturing was initiated by Womack *et al.* (1990) at the Massachusetts Institute of Technology, in the US. The genesis of these authors' work hinged on waste reduction within the factory, then on quality, cost and delivery; before the focus shifted to customer value in 1990's (Baines, *et al.*, 2006). Although lean manufacturing is emerging as a dominant paradigm for the improvements of most manufacturing operations in the UK, and perhaps globally, its usage within the confines of SMEs is still at a very low level. There appear various reasons pertaining to this stalemate. Perhaps more significantly, is the view held by most of these companies. They fear that the application of lean manufacturing similar to other productivity improvement initiatives within companies could also require large sums of money to pay for the cost of its implementation (Achanga *et al.*, 2006a, 2006b).

**Table 1.1: Trend in the existing UK SMEs (Source: Benchmark Research, 2004)**

	1997	1998	1999	2000	2001	2002	2003	Change since 1997	3 Year Trend 00-03
<b>Process Industry</b>	5,240	5,261	5,076	4,899	4,437	4,247	4,076	-22.20%	-16.80%
<b>Discrete Industry</b>	6,195	6,254	6,237	6,009	5,884	5,763	5,251	-15.20%	-12.60%
<b>Total</b>	11,435	11,515	11,313	10,908	10,321	10,010	9,327	-18.40%	-14.50%

Companies also do not know how to analyse the likely benefits they are able to derive from engaging in such a venture (Kaplan and Norton, 1992). Additionally, few companies are able to assess the impact of lean manufacturing at an early stage, in order to determine its viability since traditional cost management systems are deemed ineffective in achieving this objective (Northrup, 2005). This stalemate creates an atmosphere of uncertainty amongst potential UK small-to-medium size manufacturing (SMEs) lean users (Achanga *et al.*, 2006a), and adds to the challenges of implementing lean manufacturing within UK SMEs.



### **1.3 Research Context**

The scope of this research investigation focuses on the subject of lean manufacturing utilisation within the confines of SMEs. The research investigation explores lean usage in SMEs engaged in discrete and process manufacturing. However, studies have encompassed some large sized manufacturing organisations, as a means of obtaining useful information from work and best practices that have been applied (see Rogerson and Deasley, 1996).

### **1.4 Research Aim**

The research set out in this thesis addresses the problem of SMEs' inability to absorb lean manufacturing by highlighting the cost-benefit analysis of lean implementation at an early stage. Hence, to achieve this desire, the main aim of the research presented in this thesis is to:

#### **Research Aim:**

Develop an impact assessment framework for lean manufacturing within SMEs.

### **1.5 The Collaborating Partners**

This research study was commenced by the collaborative efforts of (BERR), the Department for Business, Enterprise and Regulatory Reform (formerly the DTI) and its initiative known as the Manufacturing Advisory Service (MAS-East) in the East of England, in conjunction with the Engineering Physical Sciences Research Council (EPSRC) and Cranfield University. MAS-East was jointly funded by BERR and the East of England Development Agency (EEDA). Their main objective was to provide manufacturing businesses with expert advice through hands-on support, training and events. MAS-East aimed at delivering significant measurable improvements to businesses by helping them improve their performance and productivity using lean manufacturing techniques. However, the improved productivity and performance of individual companies was measured using the recognised Quality Cost Delivery (QCD)



model. Average improvements in companies in each of the areas following MAS-East intervention were as follows:

Productivity Improvement = 25%

Scrap/Defect Reduction = 26%

Improved Space Utilisation = 33%

On-time Delivery Improvement = 26%

Increased Stock Turnover = 33%

Overall Equipment Effectiveness = 45%

Additionally, MAS-East offered the following services, supported by fully qualified manufacturing professionals:

- One-day fully funded diagnostic and advisory visit
- Subsidised support
- Referrals to technology or industry organisations
- Access to an expert help line and web service
- Information on regional events.

This research partnership was initiated to facilitate the involvement of SMEs in the use of lean manufacturing principles. The study was therefore based at Cranfield University School of Applied Sciences (SAS), with continuous interactions with ten carefully selected SMEs in the locality to provide consistent information throughout the entire research project life. Below are the profiles of some of the SMEs involved in the research investigation.

### **1.5.1 Autoglym**

Autoglym is a manufacturer of vehicle care products for a number of markets. Founded 30 years ago, the company also supplies care products for motorcycles, trains, buses, haulage, airplanes and automatic car washes in various sizes that range from 100 milliliters to 25,000 liters road tankers. With an annual turnover of £17.5 million and a



workforce of 120, the company's major business drivers is led by high volume sales built on a reputation of high quality products. The company was motivated to implement lean manufacturing because it wanted to get more out of the staff employed at that time. It was felt that the people on the shop-floor could contribute more to the running of the factory. More recently it saw a need to become more efficient and able to meet increased customer demand.

### **1.5.2 Art Marketing**

Art Marketing is a manufacturer of framed art and photograph frames. With high volume productivity, Art Marketing supplies their products directly to retailers. Located in two sites within the UK, the company which has existed for 23 years employs approximately 102 staff and generates £6 million annual turnover. The ever increasing pressure on providing products to their major outlets at lower prices and reducing profit margins against the Far East imports, were the major motivations for Art Marketing to implement lean manufacturing.

### **1.5.3 Dutton Engineering**

Dutton Engineering manufactures sheet metals and supplies to retailers and end users. Founded 1972, Dutton Engineering employs 70 personnel and generates approximately £3.5 million turnover annually. Gaining competitive advantage was the main motive behind the company wanting to implement lean manufacturing. Moreover, the company wanted to gain and sustain high profitability in overall market-share.

### **1.5.4 Quadrant Engineering**

Quadrant Engineering is a medium volume producer of cable assemblies for end users, mainly telecommunications users. With a workforce capacity of 142 permanent employees in the UK, 55 in the Czech Republic and about 10 else where, Quadrant has existed for approximately 25 years, realising a turnover of £15 million annually. Quadrant implemented lean manufacturing within their business as a survival strategy. The company wanted the quickest response time possible to the market at the most efficient process while maintaining low cost of production. This notion came about as a

result of the competition in the cable industry and their desire to gain larger market shares, hence implying that they have to discount prices yet supply customers at the best quality possible.

### **1.5.5 Recycle IT Ltd**

Recycle IT Ltd is a not for profit charitable company that was formed 10 years ago. It recycles used computers for re-sale to retailers and end users. With an annual turnover of £750k, the company employs 15 people from disadvantaged backgrounds. Being a social enterprise, the profit margin realised from the business operations is so thin. Therefore, to breakeven, it became imperative that non value-added activities are discarded completely. This was the main driving force for the company to implement lean manufacturing.

### **1.5.6 Rustons Electronic Ltd**

Rustons Electronic Ltd is an electronics service industry offering design through to manufacture of instrumentation as defined by the client. The company offers surface mount technology and conventional print circuit board (PCB) assembly through to complete electro-mechanical system builds. They also assemble cables, looms and harnesses. Additionally, offering conformal coating and encapsulation of product in resin to enhance safety and environmental features. With an annual turnover of £3.2 million and a workforce capacity of approximately 70 people, Rustons has been in existence for 28 years. The company's mission statement is to gain competitive knowledge and experience within the electronics industry, enhanced by latest technology and equipment. Rustons implemented lean manufacturing with the objectives of continually improving the manufacturing facility to embrace change, so as to keep the cost of product down, and remain competitive.

### **1.5.7 Sensonics Ltd**

Sensonic Ltd is a low volume high mix manufacturer of vibrations controls and other electronic gadgets. Supplying end users; specifically power stations and anyone with any critical process-rotational gadgets so that vibrations are managed, the company



employs approximately 90 staff with an annual turnover of £1.75 million. The sole motive of lean manufacturing implementation within Sensonics Ltd emanated from the company's desire to remain competitive in the market share. To do this, it needed to invest in new machinery so the production process became efficient and rapid.

### **1.5.8 Transfixt Ltd**

Transfixt Ltd is a medium volume manufacturer of a wide range of self-adhesive tape and cable products that include adhesives tapes and finger-lift transfer. With an annual turnover of £2.5 million and employee base of 50 staff, the company which has been in operation for 15 years to date, implemented lean manufacturing because its strategic desires in new business acquisition and profit maximisation. The company thought lean would allow them reduce the cycle time as a way of retaining its client base.

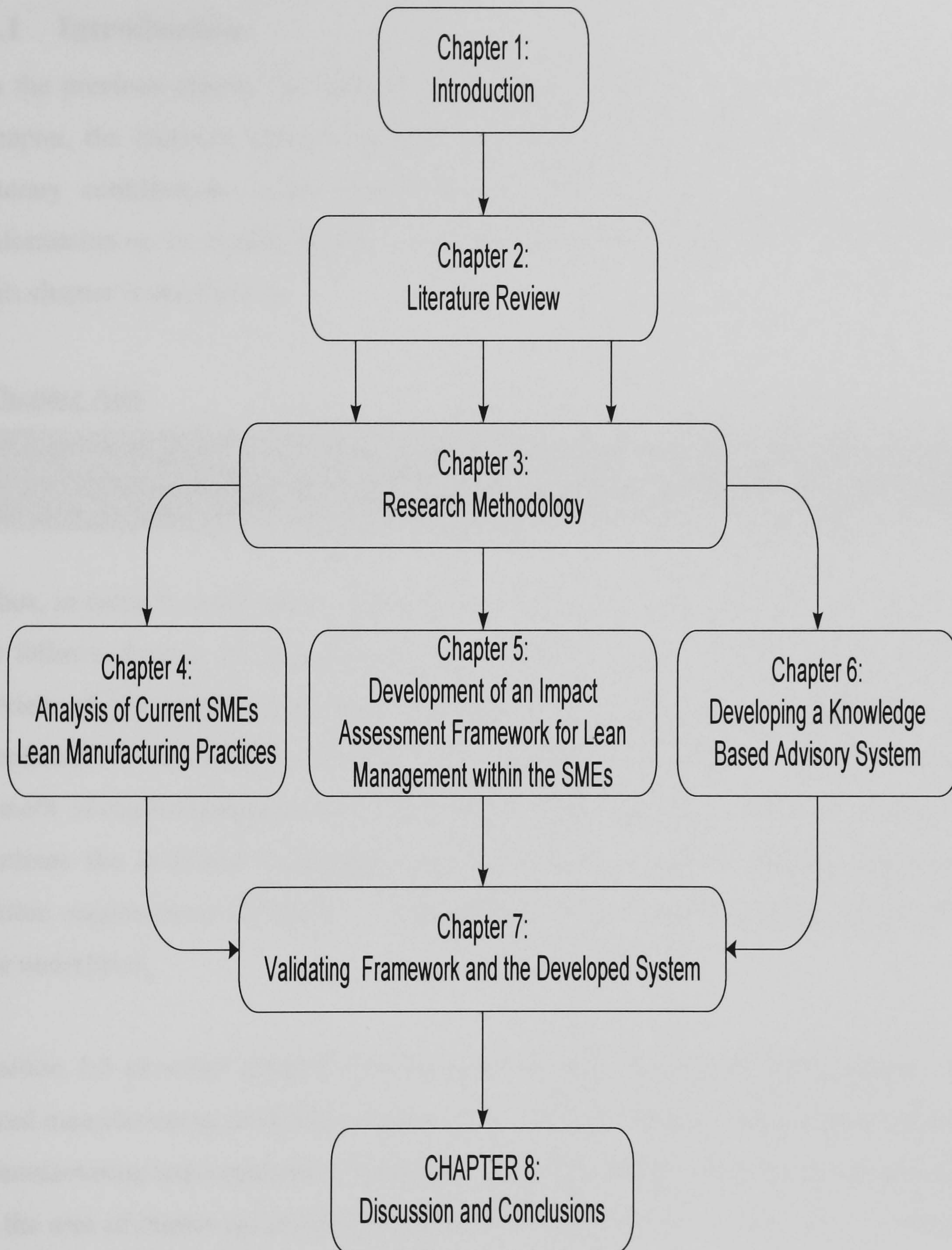
## **1.6 Thesis Structure**

The remainder of this research thesis is composed of seven chapters as illustrated in Figure (1.2). Chapter 2 provides critical review of related work in lean manufacturing, small-to-medium sized industry, cost issues, knowledge bases system and summary of the research gap. In Chapter 3 the research methodology adopted for the research study is presented and discussed. This particular chapter also discusses the overall research process followed in Chapters 4, 5, 6, and 7 respectively.

The analysis of current lean manufacturing practices referred to as “AS-IS” within the investigated SMEs is outlined and described in Chapter 4. The chapter presents findings obtained from investigations carried out on several SMEs located in the East of England. Furthermore, the development of the proposed model (impact assessment framework) referred to as the “TO-BE”, is presented in Chapter 5. The chapter also documents the description of the lean impact assessment framework development and its application within the SMEs community. Chapter 6 provides the development of knowledge based advisory system to conceptualise, enhance the robustness of the impact assessment framework and address the problem of the imprecise data described and discussed in the previous chapter. Moreover, Chapter 7 demonstrates the validation of the developed framework and the knowledge based advisory system. Finally, Chapter



8 presents discusses and concludes the overall research work. It also highlights the limitations and the recommended future work.



**Figure 1.2: Thesis layout**



## CHAPTER (2)

### 2 LITERATURE REVIEW

#### 2.1 Introduction

In the previous chapter the fundamental research issues have been outlined. In this chapter, the literature review has been examined and provided an insight into the literary contributions made towards lean manufacturing. Moreover, background information on its implementation within SMEs is also highlighted. The main aim of this chapter is therefore to:

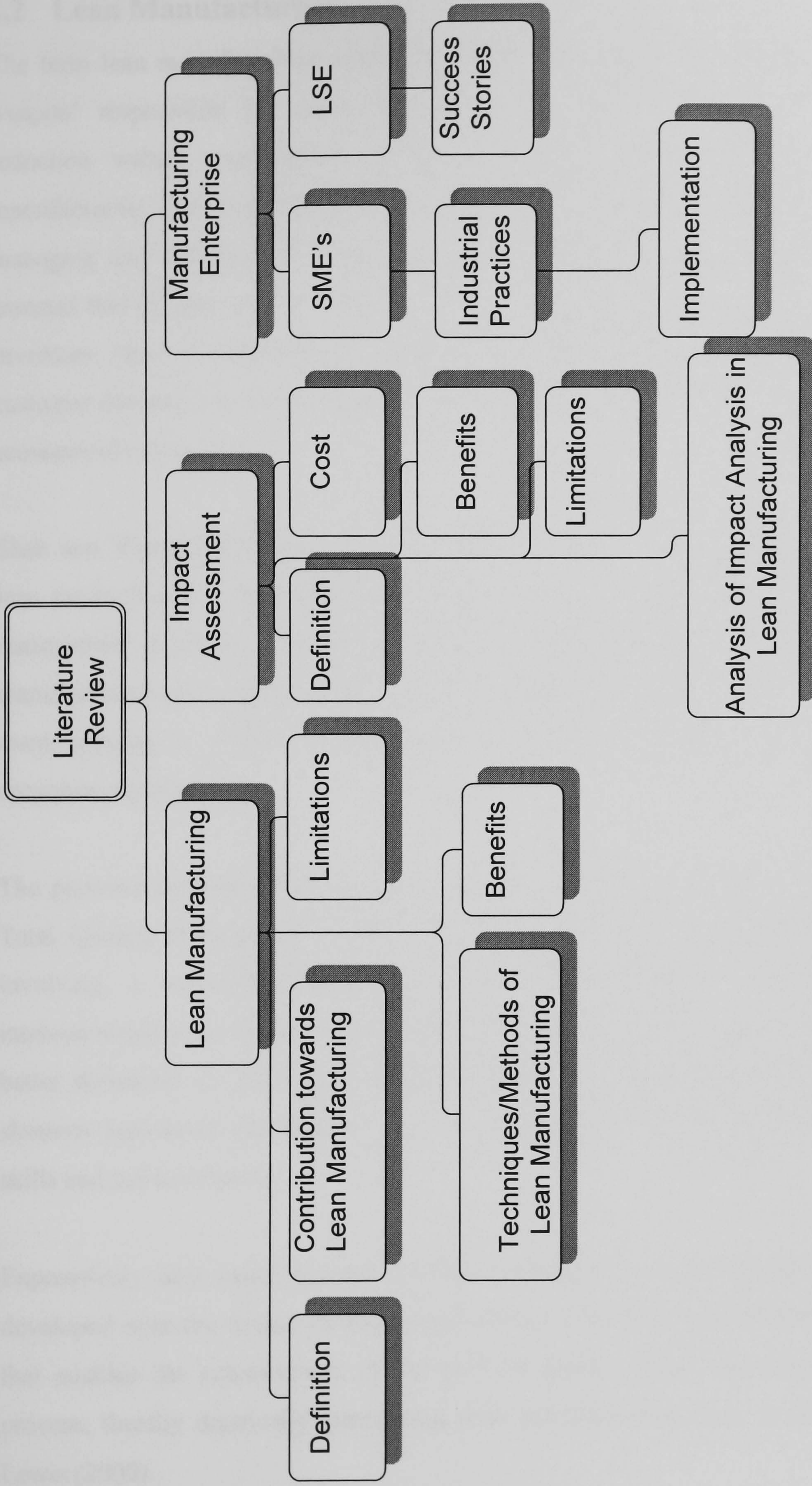
#### Chapter Aim

To examine the academic literature on the subject of lean manufacturing, particularly the implementation issues within SMEs, as a means of influencing research design for knowledge need.

Thus, in order to successfully achieve the above aim, this chapter has been organised as follows. Section 2.2 introduces and provides the origin of lean manufacturing. A review of the current contribution towards lean thinking is also highlighted and conducted in this section. Furthermore, the section also presents a review on the benefit of implementing lean manufacturing within a business. However, Section 2.3 outlines the available techniques/methods used in lean manufacturing application within organisations. In Section 2.4 the practices of lean manufacturing within SMEs are underlined.

Section 2.5 provides insights into the practices of lean manufacturing within large sized manufacturing enterprises. Section 2.6 describes difficulties associated with lean manufacturing implementation. Section 2.7 presents and discusses research work done in the area of impact assessment of implementing lean manufacturing and provides the available frameworks in use. A critical assessment of the overall literature review is contained in Section 2.8. Finally, Section 2.9 provides concluding remarks to the literature review exercise.





**Figure 2.1: Classification of literature review related to the research project**



## 2.2 Lean Manufacturing

The term lean manufacturing was first coined by Womack *et al.* (1990), as a 'secret weapon' responsible for waste elimination and quality improvement, hence cost reduction within organisations. According to Detty and Yingling (2000), lean manufacturing is a comprehensive philosophy for structuring, operating, controlling, managing and continuously improving industrial production systems. Phillips (2000) asserted that the goal of lean manufacturing is the reduction of waste in human effort, inventory, time to market and manufacturing space to become highly responsive to customer demand while producing world-class quality products in the most efficient and economical manner.

Shah and Ward (2003) supported the aforementioned statements while asserting that lean production is a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality systems, work teams, cellular manufacturing and supplier management. Cook and Graser (2001) maintained that lean manufacturing is a broad collection of principles and practices that can improve corporate performance.

The previous authors further maintain that lean production is very closely related to Total Quality Management (TQM) and derives from the Toyota production model, involving a reconceptualisation of the entire production process; a closely interconnected system from which buffers are removed. Creese (2000) conferred that a better definition of lean manufacturing is that it is a manufacturing philosophy that shortens lead-times and reduces costs by eliminating waste yet improving employee skills and job satisfaction.

Expressively, lean manufacturing can thus be deduced to mean a production paradigm developed over the decade to help organisations customise their products in a manner that enables the enhancement of the product quality, while reducing wastes in the process, thereby drastically minimising their manufacturing costs as demonstrated by Lewis (2000).



### 2.2.1 Contributions towards Lean Thinking

The subject of lean manufacturing has undoubtedly attracted extensive publicity from both the academic and industrial worlds as demonstrated in Table (2-1).

**Table 2.1: The evolution of lean thinking; Adapted from Hines *et al.*, 2004**

Phases	1980-1990 Awareness	1990-mid 1990 Quality	Mid 1990-2000 Quality, cost and delivery	2000+ Value system
Literature theme	Dissemination of shop-floor practices	Best practice movement, benchmarking leading to emulation	Value stream thinking, lean enterprise, collaboration in the supply chain	Capability at system level
Focus	JIT techniques, cost	Cost, training and promotion, TQM, process reengineering	Cost, process-based to support flow	Value and cost, tactical to strategic, integrated to supply chain
Key business process	Manufacturing, shop-floor only	Manufacturing and materials management	Order fulfilment	Integrated processes, such order fulfilment and new product development
Industry sector	Automotive – vehicle assembly	Automotive – vehicle and component assembly	Manufacturing in general – often focused on repetitive manufacturing	High and low volume manufacturing, extension into service sectors
Shingo (1981, 1988)	Shingo (1981, 1988) Schonberger (1982, 1986) Monden (1983) Ohno (1988) Mather (1988)	Womack <i>et al.</i> (1990) Hammer (1990) Stalk and Hout (1990) Harrison (1992) Andersen Consulting (1993, 1994)	Lamming (1993) MacBeth and Ferguson (1994) Womack and Jones (1994, 1996) Rother and Shook (1998)	Bateman (2000) Hines and Taylor (2000) Holweg and Pil (2001) Abbas <i>et al.</i> (2001) Hines <i>et al.</i> (2002)

Most of these publications have attributed the significance of lean manufacturing to the re-engineering of several business processes as highlighted by (Cook and Graser, 2001; Bicheno, 2000). In essence, these authors have made claims on how organisations have benefited from lean initiatives, by eliminating wastes that are predominant in most manufacturing environments.

However, since its inception by Womack *et al.* (1990) in their famous ‘The machine that changed the world’, lean manufacturing has become increasingly popular amongst large sized manufacturers. Several authors have detailed the capabilities of lean manufacturing in enabling companies to reduce inventory levels and other unnecessary wastes, consequently reducing manufacturing costs (Bicheno, 2000; Creese, 2000; Hines *et al.* 2004; Muran *et al.*, 2002; Panizzolo, 1998; Shah and Ward, 2003; Phillips, 2000; Womack *et al.*, 1990; Womack and Jones 1996). Therefore, different contributions have been made toward lean manufacturing implementation and other associated factors, such as inventory level, time, and quality.



Harrison *et al.* (2002) for instance, surveyed the status of lean thinking in the supply chains of the UK aerospace organisations. The key themes of his work focused on the current state of the supply chain strategy in the different organisations and the relative importance of such strategies in achieving competitive advantage in the market place, at present and future times. Whereas the benefits of the previous authors' work provided some possibilities of enabling one to see where the UK aerospace industry sits in terms of development of lean supply chain, they however do not provide analytical cost – benefit issues in this context. Katayama and Bennett (1999) also explored the feasibility of lean production principles working in collaboration with other approaches such as Agile Manufacturing (AM) and Adaptable Production (AP) techniques. Considering that agility has four underlying principles such as delivering value to the customer, readiness for change, regards for human knowledge and skills and the formation of virtual partnerships; it can be concluded that the aforementioned principles are directly embedded within lean thinking.

However, for lean manufacturing to effectively eliminate waste, reduce operating costs and improve productivity within a manufacturing environment, certain characteristics have to be adhered to as a precursor to achieving realistic expected outcomes. Womack *et al.* (1990; 1996); Schonberger (1982); Hall (1983); Goldratt and Cox (1984), have listed these characteristics of lean philosophy as being customer, simplicity, visibility, regularity, synchronisation, pull, waste, process, prevention, time, improvement Gemba, variation and participation. They further maintain that the external customer is the originator and the final destination of any business venture. Therefore in their opinion, businesses should aim at satisfying the customer by understanding a particular customer's needs so they are provided with what they exactly want, at the time the customer needs it.

### **2.2.2 Lean Manufacturing Benefits**

Lean manufacturing has evolved as an alternative to mass production which relied on long runs of limited varieties of products for a steadily expanding marketplace of, yet homogeneous tastes referred to in this section. Thus, for businesses to qualify and



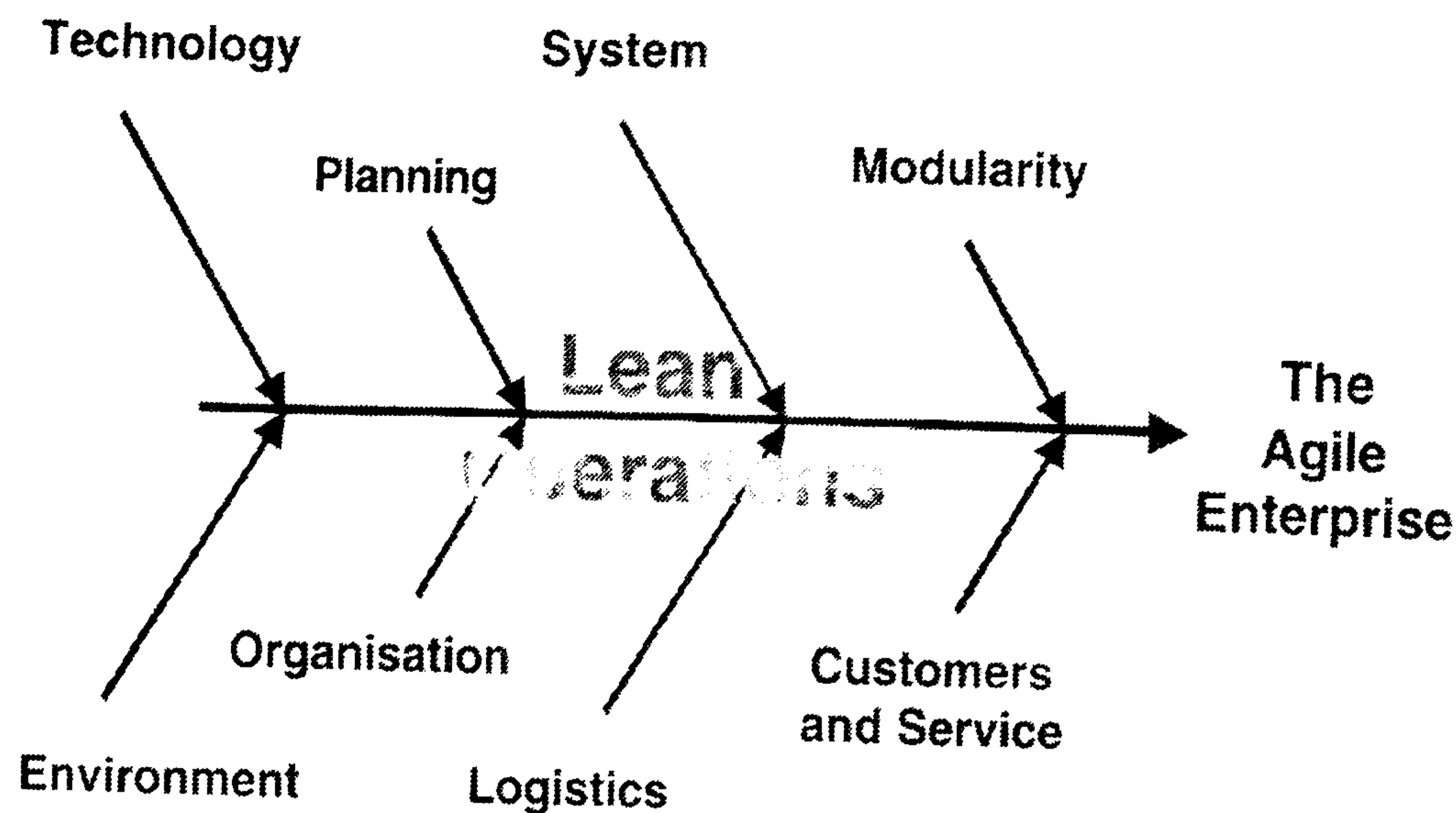
continue surviving in such precarious market conditions, they ought to devise means of eradicating non value-added wastes that propel the overall cost of their operations. The application of lean manufacturing within business functions has diverse impacts such as the improvement of working procedures and realignment of organisational practices. Besides enabling a company to develop products faster and with fewer engineering hours, Karlsson and Åhlstöm (1996) seem to suggest that lean product development has other benefits such as the collaboration between functional areas within the company to enhance the manufacturability of product development.

Lean manufacturing therefore is a very significant productivity improvement technique whose benefits can be described as the reduction of wastes in an organisation (Fullerton and Watters, 2001). These wastes can be deduced as; the wastes of overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary motion and defects.

Haan and Yamamoto (1999) stated that production planning and disciplined linking up to the plan is critical for zero buffer production. Vastag and Montabon (2000) upheld this view when they maintained that just-in-time (JIT), manufacturing resource planning (MRP), total quality management (TQM) and other productivity improvement techniques are investment in progressive manufacturing, hence a necessity for manufacturing organisations.

This is because; these concepts have been confirmed from previous studies to have enhanced good manufacturing practices and efficient flow of materials through production processes. According to Bicheno (2000), the central spine of 'fish' is lean operations itself as demonstrated in Figure (2.2). Processes revolve around the manufacturing environment, which in this instant covers the customer, suppliers, and distribution chain. Thus it is imperative that an understanding of all those factors be taken into account while adopting lean manufacturing.





**Figure 2.2: The fish bond diagram of lean operations (Bicheno, 2000)**

### Key Observations

- Companies that use lean manufacturing apply this to all areas. From general operations to the overall costs, improvement can be significant with the adoption of lean manufacturing. This is because; as high quality products are made, due to efficient lean process, customer expectations are not only held high, but they are met accurately and on time..
- The productivity improvement initiative challenges the tolerance of waste tolerance and inventory storage. Lean manufacturing therefore offers clear, consistent and chronological flow of the production process from start to finish. This helps organisations in fault detection, since emerging faults can be detected at an early stage, thereby allowing for solutions to be made instantaneously.
- Lean manufacturing is argued to be necessary in today's global markets where buyers, not sellers, control prices; yet demand instant gratification with near perfect product. As a result, large original equipment manufacturers (OEMs) now demand very small lot sizes, multiple models and quick response from suppliers.



- Lean manufacturing has the potential to provide new management approaches for many SMEs, particular older firms organised and managed under traditional push systems. Improvement results can be dramatic in terms of quality, cycle times, and customer responsiveness. If fully implemented through a complete organisational change, lean manufacturing can help SMEs achieve world-class performance
- Additionally, lean manufacturing enables people within organisations to enjoy their job tasks. Moreover, their involvement in the entire process, equips them with added sense of responsibilities, thus job empowerment, and enrichment.

## **2.3 Lean Manufacturing Techniques/Methods**

Lean thinking is an integrated set of industrial principles and methods, as opposed to a ‘one size fits all’ panacea for manufacturing productivity, referred to in Section 2.2. It is an imperative paradigm that each and every business must deal with in its own issues and plan its own way forward. Organisations should therefore elect the most appropriate lean technique/method that is ideal to individual manufacturing needs. Below are a summary of some of the notable techniques/methods.

### **2.3.1 Toyota Production System**

Toyota Production System (TPS) is a brainchild of the Japanese innovative production management systems. After the end of World War II, the Japanese motor industry faced some stiff competition from their European and American counterparts. This prompted Toyoda Kiichiro, Toyota Corporations first president to realise that the corporation’s only means of continuous survival and possibly competing with rest of world, was the invigoration of a more robust style of manufacturing that would allow for product variety at reduced costs (see; Womack and Jones 1996).

Having visited the American Ford Rouge Plant in Detroit after his uncle Toyoda Kiichiro, Eiji Toyoda, was a young engineer at Toyota Corporations who wanted to study and appreciate the major production system of the Ford’s assembly line. Back at



home in Nagoya, Eiji Toyoda together with his Production genius, Taiichi Ohno agreed in principle that mass production was not sustainable in the Japanese economy (Womack *et al.* 1990). They then went onto developing the now popular Toyota Production System. Toyota Production System's main objective is to increase product efficiency by consistently and thoroughly eliminating waste (Ohno, 1988). Taiichi Ohno thus identified the seven fundamental wastes (MUDA) that are predominant within the manufacturing domain. These wastes can be deduced as the wastes of overproduction; waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary motion and defects.

### **2.3.2 Just-In-Time**

Just-in-time (JIT) is one of the numerous techniques that form the nucleus of lean manufacturing. Currently JIT is being used extensively by organisations that are trying to get lean. JIT evolved from the Toyota Production System discussed in the previous section. Literally the idea of applying JIT within an organisation is about producing goods or services when and only when they are needed (Betts and Johnston 2003). The overall objective of JIT's application within a business is to continuously improve organisational productivity and quality simultaneously (White and Pearson, 2000).

There are several reasons to JIT, which is why organisations are able to cope with changes in the external environment, including multi-functional workers and efficient facility layouts (Aase *et al.*, 2003). To support the forgone statement, several industrial practitioners have to date, adopted the use of a "just-in-time game". For example, the use of Lego Bricks to simulate a mock shop-floor activity is one such testimony of how companies can effect JIT systems within their organisations. Indeed, the benefits of such mock-up operations are beyond description. The workforce is able to plan activities using dummy features, which in real terms save costs. This is because, if something is not tried through mock-ups, there is a likelihood of using actual materials, in which case an error or fault occurrence can be costly. Whereas, by using Lego Bricks, adjustments could be made until a near success is envisaged.



However, the use of JIT principles in a manufacturing environment is critical to the subject of inventory management. The higher the inventory levels within the manufacturing environment, the higher the likely level of costs requiring management, hence the justification of the JIT application within organisations. Oke and Swejczewski (2005) support this notion in that many studies have highlighted inventory levels in operations. However, in reality many manufacturing companies have found it difficult to minimise the level of inventories as demonstrated by these previous authors. Their assertion is further supported by others such as Haan and Yamamoto (1999) who also found out that even in Japan, the originator of JIT practices, still have many factories unable to reach the goal of reduced level of inventories. Lines (1999) compounds, this line of thought when he argues that sometimes high levels of finished goods inventories may be needed in order to achieve high customer service levels.

Moreover, inventory level management, which is a critical issue in manufacturing, has been found to be difficult to maintain; hence it is regarded as the biggest source of waste in a production environment (Karlsson and Åhlstöm, 1996). To further compound the above statement, Safayeni *et al.* (1990) assert that there is a lack of consensus on JIT's interpretation and meaning. He argued that the meanings of JIT range from an emphasis on inventory reduction and inventory turns, to a new vocabulary of pull versus push systems; to people working with different habits, attitudes and work organisation. One way or the other, JIT is a very significant lean manufacturing paradigm to enable organisations to make-to-order products so that unnecessary wastes are eliminated hence reducing the cost of manufacture.

### **2.3.3 Total Quality Management**

Total Quality Management (TQM) is another of the several lean manufacturing techniques to have been adopted by the US manufacturers in the 1990's (Withers *et al.*, 1997). The evolution of TQM was started as a result of consumers demand for greater value in terms of quality and relative factors such as on-time deliver at reduced prices. This notion therefore agitated several manufacturing firms into reshaping their business

processes drastically, as a means of attaining competitive advantage over quality, flexibility and higher productivity (Vonderembse and White 1996, Jasinowski, 1995). According to Ho (1994), Vonderembse and White (1995), TQM is a philosophical approach to management that is based on gaining comprehensive advantage by focusing on customer satisfaction within a continuous improvement environment. Hence, Withers *et al.* (1997) insistence that the aftermath of globalisation has placed enormous challenges on the manufacturing firms into providing consumers with variable options. This increases the complexity of product and service provisions, meaning that the operational management strategy has to shift to planning and competitive viability in order to achieve these expectations. Moreover, for TQM concepts to be successfully applicable within a manufacturing domain there should be some critical parameters at play (Withers *et al.* 1997). They list the following factors as the most pertinent ones.

- Fact-based decision making
- Extensive employee training
- Employee empowerment
- Team problem solving
- Responsiveness to consumers

#### **2.3.4 Value Stream Mapping**

Value stream mapping (VSM) is a process mapping method to document the current and future states of the information and material flows in a value stream, from customer to supplier. Hines and Rich (1997) define VSM as a visualisation tool oriented to the Toyota Production Systems that helps in understanding and streamlining work processes. Value stream mapping is hailed as a very significant tool used in the implementing lean manufacturing principles, as documented by Hines and Taylor (2000); James-More and Gibbons (1999). Rother and Shook (1999) and Sullivan *et al.* (2003), assert that value stream mapping is generated from the phrase “value stream” where, all the value-added and non-value-added actions required to bring a specific



product, service or combination of products and services to a customer, including those in the overall supply chain as well as those in internal operations are identified.

VSM is a subset of Value Engineering and Value Analysis (VE and VA). The two methods have traditionally been used for cost reduction in engineering design (Bicheno, 2000). Today, the power of VE/VA method now ensures its use as an effective weapon for quality and productivity improvement in manufacturing and the service industry. VSM according to Rother and Shook (1999) is an enterprise improvement technique to visualise an entire production process, representing information and material flow, to improve the production process by identifying waste and its resources.

To crystallise and support the artefacts of the VSM technique, Hines and Rich (1997) developed seven-map typologies based on different wastes inherent in value streams. The use of these tools either singularly or collectively; are driven by the types of wastes that they intended to remove. Hines and Rich (1997) further maintain that the seven-mapping tools are drawn from a range of existing functional ghettos such as logistics, operations management and engineering. The seven-mapping typology consists of process activity mapping, supply response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis and physical structure. A major benefit of these tools the authors claim, is the ability to aid researchers or practitioners to identify wastes in individual value streams, hence providing an appropriate route for waste removal or reduction.

### **2.3.5 Total Productive Maintenance**

Total Productive Maintenance (TPM) is a brainchild of Preventive Maintenance (PM), and works identically to Total Quality Management (TQM). The idea behind TPM is that of having zero tolerance at breakdowns as well as defects. This production technique is very central to the lean manufacturing ethos since it also has the attributes of making problems visible so that they are not buried but dealt with right away. TPM also calls for simplicity in the tasks people carryout as well, allowing the workforce enjoyment while carrying out work they are assigned to do. The essence of

implementing the lean manufacturing technique of TPM is the provision of a cost-effective operation and support of the available manufacturing system.

Chan *et al.*, (2003), asserted that TPM is a methodology whose aim is to increase the availability of existing equipment so as to increase its capacity. According to Swanson (2001), the essence of TPM is to increase the availability and effectiveness of existing equipment in a given situation, through the effort of minimising input (improving and maintaining the optimal level of equipment to reduce its lifecycle cost), as well as the investment in human resources, resulting in better hardware use.

The previous authors seem to infer that many systems in the manufacturing environments do not perform as intended in terms of their overall equipment effectiveness (OEE), hence generating less than full capacity with low productivity at a very high cost of production. This cost the authors argue, is always associated with maintenance labour and material costs. Wireman (1990) concurs with the aforementioned statement in that the cost of maintenance, according to a study he conducted in 1998 on a selected group of companies, increased annually from 200-600 US dollars from the periods of 1979 to 1989, testimony to the abovementioned arguments.

Alnajjar and Alsyonf (2003) suggest that issues surrounding the maintenance function are of paramount importance, in its role within improvement on manufacturing quality. Safety and cost-effectiveness amongst others become a prerequisite. Chan *et al.* (2005) therefore maintained that the urgency of maintenance and support problem within the manufacturing domain motivated the Japanese to develop the concept of TPM in 1971. Their reference to the work of Nakajima (1988) quotes that TPM is a maintenance system that describes a synergetic relationship amongst all organisational functions, so that the product quality and other related elements of efficiency of a product lifecycle are improved.



Chan *et al.* (2005), further reiterated that Nakajima's (1988) inference on TPM is ascribed to three fundamental functions of effectiveness indicated by; its pursuit of economic efficiency and profitability, (1) Total Maintenance System (TMS) which including (2) Maintenance Prevention (MP) and (3) Maintenance Improvement (MI). There is Total Participation (TP) which includes the involvement of all employees as well as Autonomous Maintenance (AM) by operations in small groups.

### **2.3.6 The Kanban System**

Kanban is a Japanese word meaning card or visible. Kanban is a production system that has been around for quite a while, and insists on a pull flow system. Price *et al.* (1994) assert that the Kanban system is a tool to achieve JIT production as it is informative and driven from a signal card. The concept of lean manufacturing production dictates that the production process should flow from one point to the next, only when there is need for it to move. Domingo *et al.* (2007) therefore advocated for a materials flow system that prevents the accumulation of intermediate stocks in a production line.

Hemamalinin and Rajendran (2000) argue that Kanban systems differ from conventional manufacturing systems due to the existence of an infinite in-process inventory of containers, or constraints on buffer capacity between workstations and consequential station blocking. Kanban systems therefore support the notion of push-pull since it ascertains that the product will be dealt with whenever it is triggered and vice-versa. There are different types of Kanban, namely; Single Card Kanban, and Product Kanban. By using the Kanban system, the idea of waste elimination is truly enhanced, since no production will be carried out in excess. At the same time, faults are detected when products move across points, thereby rendering resolutions on time.

### **2.3.7 Cellular Manufacturing**

Cellular manufacturing according to Boughton and Arokiam (2000) is central to the lean thinking and Toyota Production Systems. Cellular manufacturing has for many years been advocated as; the preferred way to arrange the shop-floor resources of an organisation (Parnaby, 1986). Black (1991) and Agarwal *et al.* (2003) refer to cellular

manufacturing as the application of Group Technology (GT) principles to production wherein by exploiting similarities inherent in the production of parts; many of the benefits associated with mass production can be achieved in less repetitive batch environments. However, Rao (2003) states that the key issue in cell designs is to identify families of related parts and groups of dissimilar machines, so that the part families assigned to a machine group are completely processed in the cell. Moreover, the cell design must satisfy one or more of a number of attributes such as; part machine assignment to one unique cell, number of parts and machines admitted to a cell should be within the acceptable limits and the utilisation of machines and resources should be adequately maximised. It may be postulated that the aim of cellular manufacturing is to create a single dedicated centre for the manufacture of a product.

Never-the-less, the benefits of layout improvement by cellular manufacture as opposed to functional manufacture are numerous. First and foremost, cellular manufacture reduces travel distances between machines, equipments and or point of manufacture due to the short distances in between the layout. There is also the benefit of reductions in waiting times as small batches are transferred. Indeed, small batch transfers reduce delays and sort queues reduce work-in-progress. Ultimately, there's an increased focus on customer needs as the workforce are alleviated from having to concentrate on demanding tasks that involve counting, checking or inspection. Moreover, cellular manufacture simplifies the production planning and control as fewer transactions are dictated. The workforce are thus able to absorbed production information quite clearly, meaning companies are able to operate almost purely specific customer needs, hence eliminating the possibility of manufacturing products out of specifications.

### **2.3.8 Kaizen**

The term Kaizen refers to a Japanese word meaning continuous improvement (Bicheno 2000). Kaizen is one of the philosophies behind lean manufacturing operations. The underlying theme of Kaizen is that, the customer is the very master upon which products are made. Therefore, it is imperative that quality issues are addressed coherently, since quality itself begins with the customer. This, (Bicheno, 2000) argues, is because



customer perceptions are constantly changing. Therefore, the art of improvement should be continuous in order to match such dynamism. The importance of Kaizen methods to lean operations cannot be underscored since this links to everyone's involvement in the production process. Kaizen also ensures that the following are maintained within the workplace environment:

**(i) Rule Query**

Rule query is the ability of workforce to question the legitimacy and significance of rules within a given organisation. The underlying principle behind the use of Kaizen is to enable the workforce to carry out such queries without any reservations. This is because; human beings are not robots who should follow rules without getting the feel for their contributory roles towards the organisational prosperity.

**(ii) Getting to the Root Cause**

The Kaizen method requires that, management and the workforce should have the hindsight of getting to the root cause of problems instead of issuing blame. That way, everyone knows a problem has to be addressed, instead of waiting for them to occur, apportion blame and, then try to sort them out, as this would be too late and time wasting. According to the Productivity Portal (2000), KAIZEN is a relatively low cost, simple, team-based approach. The principles/approach behind it can be underlined as follows.

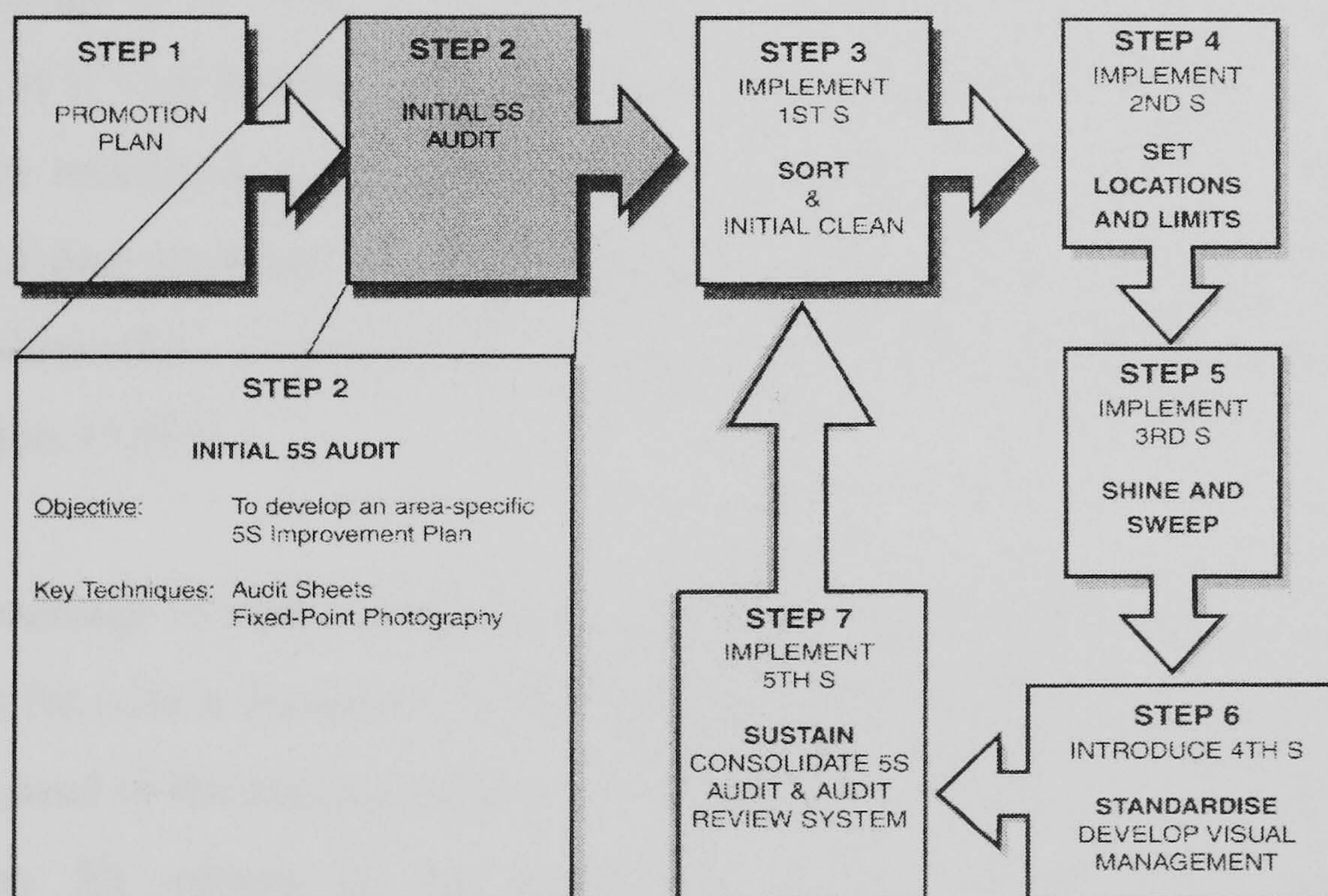
- Discarding conventional fixed ideas
- Thinking of how to do things, not why it cannot be done
- Avoiding making excuses, instead questioning current practices
- Doing things right away even if it will only achieve 50 percent of target instead of seeking perfection.
- Ensuring mistakes made are corrected right away
- Throwing wisdom at a problem, not money
- Asking "WHY?" five times and seeking for root causes
- Seeking the wisdom of ten people rather than the knowledge of one



- Not asking workers to leave their brains at the factory gate

### 2.3.9 The 5S Approach

The 5S is a method used in the facilitation of the lean manufacturing process. The 5S approach is not simply a system for house keeping; rather a method for organising, standardising and improving the whole of a manufacturing process. The sole objective of the technique is to ensure total eradication of unwanted items within the working environment of an organisation. The improvement methodology works in a plan of 5 steps, as shown in Figure (2.3). The initial plan is to have the 5S ideology inculcated within the organisational set up. The entire workforce has to be sold the idea of the technique and the likely benefits associated with the adoption of such a technique. This kind of strategy enables the sustenance of the 5S method for the unforeseeable future. The initial step also takes into account the area maps, and the tagging of items to ensure identification.



**Figure 2.3: The 5S process (Productivity Europe, 1998)**



Then the second step, which involves the setting up of locations and limits to ensure that only, required items are kept at specific stations. This is followed by the step of 'shine and sweep' which allows for the identification of abnormalities. This step is ideal, since dirty and filthy environment provides a wide platform for cost incurrence. The fourth step enables the standardisation and guarantees best working practices, while maintaining and consolidating the previous three steps. Step five then sustains the 5S methodology as a whole, so that the intended organisation process improvement is continuous.

## **2.4 Lean Manufacturing Practices within SMEs**

SMEs are reputable for their contributory roles in most national economies. They are also perceived as the main drivers of economic growth, product innovation, and job creation in the UK (Stanworth and Purdy, 2003). Numerous authors have published on the importance of SMEs sector to national economic sustenance (see Zulfiqar *et al.*, 2007; Achanga *et al.*, 2004; DTI Financial Services Panel SME Sub-Group, 2001). Therefore, it is vital that the SME community strives to adopt best practices as a means of not only remaining competitive, but as well operating innovatively. However, the adoption of best practices by small manufacturing enterprises has always posed many practical, theoretical, financial and organisational challenges as highlighted by Denton and Hodgson, (1997).

Thus, the concept of lean manufacturing has been a focus of attention within large size enterprises for over a decade or so (Rothenberg, 2004). Large size enterprises have paid increasing heed to the concept of lean manufacturing perhaps as a shift in global market, fostered by the advent of the competitive rivalry of the 21<sup>st</sup> Century market environment. Large size firms have been achieving productivity improvements for decades using lean productions. This may be because they realised that they could no longer remain in contention by continuing to operate a traditional mass production, large batch sized operation for make to order models. Instead large sized firms have shifted to a higher variety, small lot size, and make-to-order model (only producing what the customer wants when he exactly wants it (Achanga *et al.* 2004).



Conversely, the application of lean manufacturing within SMEs has had a slow impact in comparison to large firms (Conner, 2001). This fact can be attributed to the reasons discussed in Section 2.6. Financial capability enables large sized organisations to benefit from research and development initiatives. Large sized organisations have greater capital base at their disposal, which facilitates their productivity improvement initiatives in a manner that SMEs cannot match. For example, a large sized firm can spend millions of pounds in testing experiments that it hopes can change the way the organisation conducts its production system. This could be done with the hope of obtaining outcomes in a 5-10-year duration. SMEs on the other hand cannot afford to gamble such huge amounts of resource (time and money) as they rarely have this in the first place. Ramaswamy *et al.* (2002), support the foregone observation arguing that JIT, a manufacturing philosophy successfully implemented mostly in large-scale industries is rarely adopted within SMEs. For this reason, large sized organisation such as the Ford motor company, Rolls Royce, and other large sized construction companies directly benefit from lean manufacturing applications in comparison to SMEs, most of whom have not even understood the lean.

#### **2.4.1 Other Manufacturing Improvement strategies within SMEs**

Whilst lean manufacturing is perceived to offer ideal solutions for identifying and defining manufacturing issues within SMEs, there are argued to be several other manufacturing operations improvement strategies available. Davies *et al.* (2002), emphasise this notion, calling for the adoption of learning methodologies with capabilities of meeting the dynamic nature of SMEs' learning traits. The previous authors cite results from earlier studies that indicate few SMEs as being academically contemplative or conventionally rigorous in their learning ways (Powell, 1998; 1999). Beaver and Jennings (2001) support this statement arguing that the small firm owner-manager requires specific, transferable management skills directly related to entrepreneurship, professional management and leadership within the operating environment of these businesses.

Thus, Davies *et al.* (2002), suggest that these learning constraints on the part of SMEs are a direct reflection of their entrepreneurial engagements, where their size and scale of working (hand-to-mouth existence), does not permit them to release staff for sufficient time to take part in realistic higher education, no matter how well designed or delivered. Conversely, McAdam *et al.* (2007), assert that increasing market changes has led to a need for increased innovation within SMEs as well; yet many of these companies are founded on a single technological innovation which leads to the design and manufacture.

To overcome these drawbacks, Shaw (1999) and MacAdam (2002), concur that any attempt to effectively incorporate innovations within SMEs must address these companies as operating in a unique business context. Moreover, performance improvement initiatives for operations abound that can be adopted within manufacturing SMEs. Thomas and Barton (2005) therefore proposed an SME based six sigma strategy with the main aim of reducing manufacturing service costs, and creating significant improvements. His approach to customer satisfaction and bottom-line savings combines statistical and business process methods into an integrated model of process product and service improvement. However, this development may be considered idealistic due to the resource requirements, as most SMEs may not be able to afford this investment.

## **2.5 Lean Manufacturing Practices within Large Sized Manufacturers**

The application of lean manufacturing practices within large size organisations is extensive. Several authors highlight the outcome of results of lean deployment within larger firms (Cook and Graser, 2002; Hines *et al.*, 2004; Muran *et al.*, 2002; Panizzolo, 1998; Shah and Ward, 2003; Phillips, 2000; Womack *et al.*, 1990; Womack and Jones 1996). Most of these publications expose large manufacturing firms deploying and utilising the concepts of lean manufacturing within their organisations. Scarbrough and Terry (1996) infer that the drive towards leanness is seen as conferring dramatic improvements in productivity and quality that no other system can match. They conducted a research exercise on Rover and Peugeot car manufacturers in the UK, with their evidence hinging the management of labour processes and responses as the basis for a lean production environment.



Furthermore, Wallace (2004) detailed the emergence of lean thinking into the Curitiba Volvo Truck manufacturing plant. One of the evidential pointers from Wallace's (2004) study was the affirmation of the employee educational level as being a major limiting factor to the growth profile in a lean production. Conversely, Michaels (1999), reports how his work on lean supply chain initiatives deployed in a Large Aerospace Company (LAC) threatened traditional business practices and the long-standing well-understood, relationship between its various stakeholders.

## **2.6 Difficulties of Implementing Lean Manufacturing**

The application of lean manufacturing within organisations is perceived to attract enormous challenges. Mora (1999) submits that only 10 percent or less of companies succeed at implementing several lean manufacturing techniques including TPM. The author's argument is echoed by Bashin and Burcher (2006) who maintain that despite the discernible benefits, the implementation record of lean manufacturing suffers. The prevailing opinion suggests that an aspiring lean enterprise shall only succeed if it views lean as a philosophy rather than another strategy. Sohal and Eaggleston (1994) concur noting that only 10 percent of companies have the lean manufacturing philosophy properly instituted. Moreover, it is believed that less than 10 percent of the overall UK companies have yet to accomplish successful lean implementation within their premises (Baker, 2002; O'Corribui and Corboy, 1999).

Never-the-less, there appears to be varied reasons as to the impediments of successful lean projects within companies. Numerous manufacturing issues exist within organisations. Ironically, most of these issues go on undetected or remain underestimated. This scenario emanates from the fact that, the operational activities within manufacturing organisations are more often than not, disparate. As a result, linking the causes of these problems to their exact effects becomes very complex. Below are some of the factors that are believed to hinder the application of lean manufacturing within organisations.

### **2.6.1 Cost of Lean Implementation**

Financial incapacitation is viewed as one of the major hindrances to adoption and implementation of successful lean manufacturing within SMEs. The fear that applying lean manufacturing, like any other productivity improvement initiative within any organisation, could require large sums of money to pay for consultants, as well as aiding the implementation of these ideas. The training of people to utilise the techniques also calls for money. In some instances, production of firms may be halted in order for the workforce to embrace such knowledge, a fact that SMEs view as an unnecessary loss of resources, more especially if they do not anticipate the immediate returns.

### **2.6.2 Misapplication**

Due to the competitive nature of the current manufacturing market environment, most firms have been shelved with unpredictable future certainties, as a result of the declining manufacturing performances. In their quest to continue surviving, managers have opted to adopt the lean manufacturing concept in a rush. Pavanasker *et al.* (2003) stated that misapplication of many lean manufacturing tools by companies in haste of being lean resulted in many failures that emanated from inadequacy in understanding of the purposes of the tools in question. For this reason, the implementation of the lean methodology will definitely not impact on the overall organisational profitability since no change will occur in that respect. Hence, to achieve successful implementation and subsequent adoption of the lean manufacturing concept, a combination of factors must be facilitated concurrently. These include an early understanding of the lean principles and its operational activities within any organisation.

### **2.6.3 Cost Drivers**

Identifying and ranking factors that generate costs within the organisations, is very crucial to both the cost saving exercise and the lean manufacturing application that insist on waste elimination and performance improvement, which increases profitability. In their examination of the relationship between contextual factors and the extent of implementation of lean and other manufacturing practices that enable the effective lean function, Shah and Ward (2003) concluded that plant size, plant age, and extent of



unionisation are one of the greatest contributors of the successful or failure of lean application.

#### **2.6.4 Complexity**

One difficulty with lean manufacturing is that the complexity of the new approach takes a long time to implement fully. If managers use a few of the basic lean tools only to pick their anticipated faults, a quick fix approach, the real potential for dramatic and continuous improvement is usually lost. There has also been arguments advanced in the manner lean manufacturing would respond to the various manufacturing systems such as mass customisation in use by the automobiles community (Alford *et al.* 2000).

#### **2.6.5 Employee Involvement/ Human factors**

The application and successful adoption of the concept of Lean Manufacturing can only be sustained in a smooth and structured manner if and only when employees of the organisation concerned are involved. More often than not, senior management striving to improve performances drag consulting firms within their operatives and continue appraising themselves with concepts such as lean manufacturing, while ignoring the importance of involving the general workforce. The problem this mishap creates is the fact that no change is enforced since the knowledge would have remained within the confines of just a handful of people; mostly the senior managers.

Many industrial consultants approach efficiency at a strategic level and deal primarily with senior management. They thus ignore the scope for practical solutions that workers need only a little prompting to discover. The fixes prescribed by traditional consultants can fail, meanwhile because employees have had no involvement at all in their formulation. The above statement therefore instigates the argument in favour of employees' involvement in lean initiative right from the very start. This is because, workforces at both the strategic, managerial and operational levels have most times differing skills, therefore, interlinking their interactions in the implementation of lean manufacturing only benefits the organisation since a more methodological approach to problem solving can be shared mutually enterprise-wide.

Job enlargement/enrichment policies, worker's greater motivation and responsibility are all factors that if not understood or considered carefully lead to complete failure of any lean initiative. Ironically, the above issues are one of the very many ignored by organisations while attempting to adopt and implement any improvement initiative. Equally, if human factor or rather human resources is not handled appropriately, the application of lean manufacturing will always fail, yet human resources are not easy matters to comprehend. Reference according to Croci *et al.* (2000) state that, while issues like off-line short-term scheduling, sequencing, real-time control and rescheduling of automated manufacturing or assembly systems are well established widely and discussed in literature, human resources have seldom been considered a critical management parameter.

#### **2.6.6 Organisational Culture**

Creating a supportive organisational culture is an essential platform for the implementation of lean manufacturing. Gilbert (2004) illustrates this. He states, "High-performing companies are those with a culture of sustainable and proactive improvement. Manufacturing, almost more than any sector, is a global industry. The ability to operate in diverse environments is a pre-requisite for managers". This testifies to the importance of organisational cultures in strategic initiatives. Most large organisations are conscious of this, regardless of their choice of cultural models or success in using them, but many SMEs by default, reflect in their culture the personality of the owner/manager and are constrained by this in terms of the changes they may be able to undertake.

#### **2.6.7 Sustainability of Lean Principles**

One clear-cut reason for lean manufacturing failure in organisations is sustainability. This can be said to emanate from a number of factors. First and fore most, the complexity of the new approach takes a long time to implement fully. Therefore if managers use a few of the basic lean tools only to sort out the immediate faults, the real potential for dramatic and continuous improvement will usually be lost. The involvement of the entire workforce is another factor that would halt sustainability. All



workers should be invited or given a participatory chance, so that they feel part of the process. Change of leadership, as well as strategy could also enhance sustainability failure.

### **2.6.8 Concurrency in Paradigms**

The fundamental question most organisations wishing to adopt productivity improvement initiatives face is, as to whether initiatives should be adopted sequentially or concurrently (Åhlstöm1998). Faced with such dilemma, most SMEs may find it difficult to make conclusive judgments as to whether they should try and have other productivity improvement paradigms running concurrently along side the existing ones (Naylor *et al.* 1999). Studies have also shown that most times organisations concentrate on a particular paradigm in isolation (Naylor *et al.* 1999, Prince and Kay 2003). In the words of Naylor *et al.* (1999), “as new paradigms are developed and promoted there is a tendency to view them in a progression and isolation. The forgone assertion emanates from the fact that, there are other productivity improvement initiatives such as the agile manufacturing that have come up, so organisations should promote them in parallel with existing ones.

### **2.6.9 Size of the Organisation**

Size of the organisation is an important factor that determines whether a company achieves a successful lean manufacturing application. This is because; implementing lean manufacturing takes into consideration a number of issues such as the implementation of new plants. This could retard the transformation of the current production strategy depending on the firm’s capacity.

## **2.7 Impact Assessment of Lean Manufacturing**

Impact assessment may be referred to as the evaluation of the effects of lean implementation on a business against the expected value-adds. This notion is significant in the assessment of the overall benefit lean project may bring to a company. Karlsson and Åhlstöm (1996) maintain that there should be a way to measure progress made in an effort to become lean. Hayes and Pisano (1994) supports the above argument while

insisting that the word 'progress' is ideal, because lean can be seen as an intended direction, not as a state or as an answer to a specific problem.

Hence, the notion of impact assessment is a significant process in the persuasion of business managers/owners, as they make strategic decisions on the adoption of new productivity improvement initiatives such as lean manufacturing. Hines *et al.* (2004) affirmed the above arguments maintaining that, a critical point in the lean thinking is the focus on value. Value according to the above authors, represents a common yet critical shortcoming of the understanding of lean. Moreover, there is also a greater need for adopting measures on financial investments on any productivity improvement initiatives as demonstrated by Barker (1996), Karlsson and Åhlstöm (1996).

Authors such as Copestake, *et al.* (2002), have made significant contributions towards impact assessments. They argue for a need for a practical qualitative impact assessment protocol for microfinance. They proposed a methodology referred to as qualitative impact protocol (QUIP), which contributes towards development of microfinance impact assessment by improving clarity for qualitative analysis based on in-depth, semi-structured, narrative or long interviews. Their proposed context is supported by Tetumble (2000) whose assertion maintained that huge organisational stakes, coupled with high intensity of risks of failure associated with implementation of most productivity improvement projects, derive a very urgent need for the evaluation of investments on these initiatives.

The previous author thus presented a framework for evaluating Enterprise Resource Planning (ERP) projects. Although his framework deals with the complex problem of evaluating ERP projects while incorporating participatory learning and decision-making processes based on Nominal Group Technique (NGT) and adopting the Analytical Hierarchy Process (AHP), still it manifests the importance attached to the evaluative assessment frameworks. Hence, several lean manufacturing frameworks have been proposed and developed by different scholars and practitioners alike.



### 2.7.1 Lean Manufacturing Frameworks

Several researchers have made various contributions to framework developments in the area of lean manufacturing. Achanga *et al.* (2006a) proposed the development of a framework for assessing the impacts of implementing lean within SMEs at the conceptual design stage. Their framework is aimed at enabling designers of lean process to adjust lean inputs so cost of implementation is greatly reduced. Currently, practitioners involved in the design of a lean process within companies tend to omit certain critical aspects of the fundamental ingredients within their planning process in the implementation drive. For example, most lean service providers do not analyse conceptually, detailed cost elements due to be encountered while planning the design process of a lean project.

To achieve this goal, the authors assert that organisations should look at how best to design the entire lean implementation process at the conceptual stage of the project life cycle. Specifically, the framework aids the lean service providers in identifying the inputs involved in the implementation of lean manufacturing while they structure the overall project map. The identification of the cost generating inputs also allows the subsequent measure, of such cost inputs. It is a fundamental aspect of ensuring a lean project adds value to a business, since cost analysis of the entire project is conducted at the initial planning stage. Companies can therefore adjust these inputs if it is explicitly contended that their retention would attract higher costs of implementing lean.

Hines *et al.* (2005) developed a framework for lean product lifecycle management. Their framework is based on theoretical model and is made up of six distinct stages which starts with the development and understanding of customer (including internal strategic) needs and establishes current product lifecycle management status-quo. This approach is intended to outline how a single project can be managed more effectively from both a technical and people-based perspective.

These previous authors further maintain that the output of their framework is the development of an improved future state for managing product lifecycles and extends to

a full process multi-product environment that describes some of the fundamental steps required for effective lean overall process management. McManus *et al.* (2005) also reviewed the application of lean improvement techniques to product development process based on the Lean Aerospace Institute (LAI) technique known as Product Development Value Stream Mapping (PDVSM) method. The PDVSM is a brainchild of the LAI research effort in lean product development in which scholarly research outputs expertise best practices and realistically engages in the translation, adaptation and expansion of value stream mapping concepts to the unique needs of the product development processes. The previous authors insist the overall aim of applying their technique of PDVSM is the enhancement of the fundamental processes of product development so they are reliably efficient.

Mathaisel (2005) proposed a Lean Enterprise Architecture (LEA) framework for enterprise re-engineering in the design construction, integration and implementation of an enterprise using systems engineering methods. The above author assert that LEA framework uses a multi-phase approach structured on the transformation lifecycle phases and portrays the flow of phases necessary to initiate, sustain and continuously refine an enterprise based upon lean principles and systems engineering methods. However, LEA framework does not possess a specific process for defining performance requirements or improvement metrics systems that are necessary for successful implementation of engineering process and architectural details.

Chen *et al.* (2004) developed a web-based decision support and analysis tool for lean manufacturing assessment and implementation. The above tool assess the current level and possible improvement area of companies that are not contemplating lean manufacturing or have already been in the process of implementing lean manufacturing within their business. The above authors claim that their decision support and analysis tool provides both qualitative and quantitative information to support decision makers on lean manufacturing implementation.



However, being a web-based tool, its applicability within the confines of most SMEs may be a problem due to their current lack of inclination in absorbing such technology features. Moreover, the tool assumes that a potential user willing to utilise it will have already applied lean before, hence having viable resources to invest in lean. This may mean that potential lean users who have not got prior experience would miss out. Furthermore, the decision support and analysis tool's major success is dependent entirely on the accuracy of surveys effectiveness. Thus, the tool is as good as the results obtained from the survey conducted.

Chua and Tyagi (2001) presented a framework known as Process-Parameter-Interface using lean principles. Their framework aims at achieving psychological objectives such as reduction in the share of non value-adding activities, increased transparency, process simplification and increased output flexibility. The above model's engine, through its information based scheduling capability, helps to reduce the resources both in number and length. Although a viable and realistic framework, this model seems to focus mainly on the Architecture-Engineering Construction (AEC) sector only. It is believed the aforementioned limitation is emanated from the model's strong implications for the entire project.

Potok *et al.* (2000) proposed flexible agent framework that is based on rich representation of manufacturing resources and advanced analysis of techniques. The authors maintain their framework can address two key problems within the manufacturing supply chain. Firstly they assert that the framework enables the formulation of lean or efficient manufacturing supply chain. Secondly, the above authors maintain that the framework analyses the material and plant flow throughout the supply chain. The two functionalities above are facilitated through a solid representational structure for a manufacturing environment whose adaptation is supported through the layered structure of the architecture and through multi-level analysis mechanisms.

Moreover, Buzby *et al.* (2002) described the application of lean principles to streamline the quote process. The above authors' work was conducted on multi-national and commercial equipment whose research aim was to present how lean principles could improve the waste areas of the administrative function of the quotation process. Baker (1994) developed a time-based restructuring and benchmarking frameworks capable of measuring value-adding capability of batch manufacturing within organisations. The above framework is claimed to provide a path to lean manufacturing within an assembly operations that is possible to enhance business process re-engineering and benchmarking.

Never-the-less the research contributions highlighted above have generated varied frameworks within the field of lean manufacturing. Critically, it can be asserted that these frameworks have been focused mainly on lean manufacturing implementation issues. They have not focused on how to address the problem of cost and benefit analysis of lean deployment at an early implementation stage. Although Mejabi (2003) presented a framework for planning and performance measurement and benchmarking system for lean manufacturing, where a standard set of lean manufacturing metrics can be applicable to a variety of manual and automated manufacturing operations; a financial cost of waste measure developed from data on current performance levels, and the planning framework developed on a lean scorecard, his framework falls short of providing realistic cost-benefit analysis prior to lean implementation.

### **2.7.2 Predictive Models in Impact Assessment**

The effects of lean production on earnings are both positive and negative and involve income and assets (Biscontri and Park, 2000). Although Ward *et al.* (1988) maintained lean manufacturing improves productivity positions of an organisation, contrarily increased parameters such as raw-materials and new training costs during lean implementation can affect the overall profit margins of an organisation wishing to adopt lean (Curtis, 1995). In order to reduce these occurrences, the implementation of lean manufacturing should be carefully planned prior to any engagement. This may be carried out by analysing the forecasted impact at the conceptual implementation stage.



To do this, the use of predictive models is encouraged in this instance. Rygielski *et al.* (2002), define predictive models as those taking patterns discovered in the database, and predicting the future. Numerous studies have been fronted in the area of predictive modeling as highlighted by, (Crespo and Webers; 2004 Rygielski *et al.* 2002). Baesens *et al.* (2004) maintain that these models include neural networks, decision trees and lately, soft computing techniques. However, Neural Networks (NN), sometimes referred to as Artificial Neural Network (ANN), is a novel form of soft computing that falls within the confines of artificial intelligence (AI). Moreover, artificial intelligence enhances the computer's capability so it is able to handle spontaneous problems, hence requiring the integration of experiences or interactions of unrelated sources, and making decisions that cannot be clearly defined in numerical forms.

### **2.7.3 Regression Analysis**

Regression analysis may be referred to as, a method for determining the association between a dependent variable, and one or more independent variables. Published literature outlines the goal of regression analysis as, one that determines the values of parameters for a function that causes the function to best fit a set of data observations that is provided (NLREG, 2007). In linear regression, the function is a linear (straight-line) equation that should predict a value based on input parameters provided. For example, if it is assumed the value of an automobile decreases by a constant amount each year after its purchase, and for each mile it is driven, the following linear function would predict its value (the dependent variable on the left side of the equal sign) as a function of the two independent variables which are age and miles (NLREG, 2007). The use of regression analysis as a predictive model cannot therefore be underscored as supported by Mihelis *et al.* (2001). There are different trend regression types namely; linear, logarithmic, polynomial, power, exponential and moving average.

### **2.7.4 Fuzzy Logic**

The use of fuzzy systems has been in existence since the 1920s when they were first proposed by Lukasiewicz (the inventor of reverse Polish notation), (Durkin, 1994). However, fuzzy logic (FL) in the sense of the fuzzy set (FS) theory was invented in the

mid-sixties as a mathematical framework for formalising the theory of approximate reasoning (Zadeh, 1975). Several researchers have adopted the use of fuzzy logic in achieving desirable outcome with unlimited or incomplete data. This involvement is claimed because the approximate reasoning of a fuzzy set theory can properly represent linguistic terms (Liang *et al.* 1991). Proponents of knowledge-based systems have argued that a fuzzy set theory has the capability of capturing the uncertainty under conditions of incomplete, non-obtainable and unquantifiable information (Kulak *et al.* 2005).

Hence, a fuzzy logic model for assessing the quality of steel production was also developed (Collantes and Roy, 1999). Their inference stems from the fact that, a fuzzy logic approach handles missing data for decision-making. Fuzzy logic in this instance provided the possibility of filling the incomplete records by looking for different trends and patterns in the database. Moreover, a hierarchy related to the decision-making problem for selecting a value stream mapping tools in a lean manufacturing context was also developed (Singh *et al.* 2006). The above authors' efforts emanated from the problems associated with the complexity in selection of detailed mapping tools for the identification of wastes at a micro-level.

The deployment of fuzzy approach to map the linguistic relationships exists between the wastes and tools to drive out the imprecision and vagueness in the relationships, hence providing a significant tool for decision-making. Shehab and Abdalla (2002) also proposed a set of fuzzy logic models to overcome the uncertainty in the cost estimation. The input cost drivers of their developed fuzzy logic model had components such as volume, shape complexity and surface finish. The above authors' model has three independent variables each consisting of a number of membership functions that contain forty-five rules.

#### **2.7.5 Knowledge Based Systems (KBS)**

A knowledge based system can be defined as a computer system that is programmed to imitate human problem-solving by means of artificial intelligence and reference to a



database of knowledge on a particular subject. Blackwell (2003) infers that a knowledge based system uses knowledge about some domain to arrive at a solution to a problem from that domain. KBS have been applied in various domains as exemplified by Rao and Pratihari (2006). The aforementioned authors also developed a fuzzy logic based expert system to predict the results of finite element analysis, while solving a rubber cylinder compression. Although the works of Rao and Pratihari (2006) focuses on a different research area, their approach to the expert system development is relevant to the research investigation presented in this thesis. This is because, the previous authors system development strategy depends on the analysis of different input parameters as demonstrated in the knowledge based advisory system development demonstrated in Chapter 6.

## **2.8 Critical Assessment of Literature Survey**

The literature review discussed in this chapter demonstrates that numerous research studies have been directed towards lean manufacturing implementation. However, no significant research contribution has been focused to date, on how to assess the impact (cost-benefit analysis) of implementing lean manufacturing at the conceptual implementation stage. Moreover, the research literature does not provide knowledge on how to pre-assess the impact of lean manufacturing quantitatively and qualitatively before implementation.

Thus, the literature review exercise conducted in this chapter has identified varying arguments advanced in relation to the methods and approaches of applying lean manufacturing within organisations. This therefore shows that, there is no single set of procedure that has been universally agreed as the ultimate way of approaching the lean concept as well as justifying through monetary terms the benefits derived from using such a paradigm. The foregoing statement further expresses the predicament SMEs encounter in their quest for analysing the rationale of deploying lean manufacturing in terms of cost benefits.

Hence, it is significant to note that, though several authors have made important contributions to lean thinking, sceptics have argued that most contributions have so far focused on its implementation in large organisations (Achanga *et al.*, 2004, 2005b; Conner, (2001). With the notable exception of White *et al.* (1999) and Conner (2001), there appears to be little empirical evidence in publications on the implementation of lean practices and the factors that might influence it in SMEs (Bruun and Mefford, 2004). There is also a tendency of fear inhibited by SMEs on the cost perspectives of lean implementation. They fear that implementing lean manufacturing is costly and that the return on investment might not be immediate. Coupled with a lack of clarity in how they can logically implement lean manufacturing in their businesses, SMEs are finding it difficult to buy into the lean concept (Achanga *et al.*, 2004).

### **2.8.1 Research Gap Analysis**

Analytical observations generated a number of research gaps from the literature review exercise conducted in Chapter 2. The analysis thus provided some research gaps. Followings are some of the fundamental issues that published literature does not discuss significantly.

- In evaluating the lean manufacturing concept to SMEs, it is not clear as to what is the best fit for its implementation. Questions can be raised as to whether SMEs need it whole or piecemeal. At the moment, no significant literary work exists in this area.
- Despite the much-acclaimed importance of lean manufacturing within organisations, there is currently no clear mechanism for enabling SMEs to take up the lean concept. Companies are not aware of how to assess their eligibility of lean uptake. Currently, there is no substantive literary guide in this area.
- There are also a lack of structured frameworks to aid organisations in determining the impacts and the expected benefits of implementing lean manufacturing within their organisations.



- Despite the much-acclaimed importance of the benefits of lean manufacturing, SMEs have not bought into the idea whole-heartedly. Yet there is no resounding justification for this stalemate in literature.
- For the few organisations that have embraced lean manufacturing as a productivity improvement initiative, studies have also found things not running perfectly well. Again, there has been no clear reasoning behind such failures in existing literature.
- The review has also shown that there exist a lack of structured methodology that can aid organisations in determining the expected benefits of using lean manufacturing within their organizations.

## **2.9 Summary**

The literature review conducted in this research study encompassed the subject of lean manufacturing and its applicability within organisations. The literature review has encompassed various areas of lean manufacturing implementation as summarised below. Firstly, the literature review exercise presented a background study on lean manufacturing, indicating contributory roles by several authors. Most of these contributions advocated the benefits implementing lean concepts bring to an organisation in terms of waste eradication, hence reduction in the overall cost of production. Furthermore, the background section of the literature review demonstrated various industrial contexts where the concepts of lean manufacturing have been deployed with great success, but they fall short of documenting how the implementation impact were assessed in the respective cases.

Additionally, the literature review exercise provided a critical analysis of several lean manufacturing techniques and methods. This was useful in that it enabled the study to make criteria for selecting the most suitable approach for conducting the impact assessment of lean manufacturing within SMEs. Conversely, none of the investigated

techniques/methods provide mechanisms to apply a cost-benefit analysis evaluation of lean implementation for business at the conceptual stage. It is important to note that the value and benefits of conducting a cost-benefit analysis prior to lean implementation as follows. Companies can make decisions as to whether they are ready for lean or not. Companies can also forecast the likely cost and benefit they may attract before embarking on lean implementation.

However, in the area of lean manufacturing practices within companies, the literature review focused mainly on lean utilisation within SMEs, but further analysis entailed lean applicability within large size organisations as a basis of making comparisons. Despite the presence of contemporary success stories, it is evident there is insignificant publications of how these companies have made the impact assessment of lean manufacturing at inception.

Literature review in the area of lean manufacturing implementation highlighted the difficult issues encountered by companies who envisaged deploying the concept within their business. Whereas several reasons such as cost of lean implementation, lean tool misapplication and complexity on how to implement new lean approaches have been advanced, literature survey falls short of revealing how these difficulties can be pre-measured both quantitatively and qualitatively. This notion implies that organisations who may foresee the possibilities of such detriments are less likely to pre-calculate their probable cost effect.

In the area of lean manufacturing impact assessment, literature review has provided several framework developments that have been deployed directly within lean manufacturing domain, or within similar area of research interest. Although these research contributions tended to portray a desire to tackle the problem of evaluative judgments on lean manufacturing investments, there appears limited research work demonstrating how to conduct these evaluative assessments before embarking on lean implementation. However, the literature review also made critical analysis on the possibility of adopting predictive models as a means of realising both the negative and



positive effects on any lean project. The literature review thus involved the soft computing techniques and their potentials in terms of assessing the impact of lean manufacturing at an early stage. A further drawback to most of these techniques is their interactions in other areas of manufacturing in general, but not precisely conducting a cost-benefit analysis.

In conclusion, the literature review has provided a critical assessment of previous work within the research domain. The review has also highlighted the analytical observations on research gaps not currently addressed. Moreover, the highlighted research gaps in Section 2.8.1 provided fundamental guidance in terms of the research design. This is because; the perusal of the literature provided significant information such as, the research questions and existing research problems. The study therefore designed specific research process for data capture, analysis and validation based on the research needs identified through literature. Thus, the literature review has provided an impetus for identifying key drivers for implementing lean manufacturing within SMEs as underlined in the first research objective set out in Section 3.1.1; *identifying the key drivers for implementing lean manufacturing within SMEs*.



## CHAPTER (3)

### 3 RESEARCH METHODOLOGY

#### 3.1 Introduction

The literature review presented in the previous chapter has demonstrated a number of research gaps that were identified by the research investigation within the knowledge domain. Of paramount importance, the literature survey specified three fundamental gaps in the knowledge regarding lean manufacturing implementation within SMEs. These gaps have facilitated the development of the aim of this research study which is to; *develop an impact assessment framework for lean manufacturing within SMEs*. Hence, a hybrid research methodology was deemed necessary for the execution of the identified research tasks. Therefore, this chapter presents the research methodology designed and utilised in the overall research investigation.

#### Chapter Aim:

To demonstrate the research methodology explored in the investigation of the entire impact assessment of lean manufacturing implementation within SMEs.

The remainder of this chapter is structured as follows: Section 3.2 provides the overall research objectives. In Section 3.3, the research scope is highlighted. Section 3.4 outlines the research hypothesis. Section 3.5 presents the research questions adopted for accomplishing the hypothesis. The identified unit of analysis for the research study is presented in Section 3.6. Moreover, the design of research methods is presented in Section 3.7. The research methodology adopted is discussed in Section 3.8 and Section 3.9 summarises the overall chapter.

#### 3.2 Research Objectives

In order to achieve the overall research aim of developing an impact assessment framework for lean manufacturing within SMEs, a number of involvements such as the retrieval of information and other relevant activities were conducted. These activities embodied the collaboration of numerous stakeholders, from different sources. Hence,



the study had to identify the research scope and accomplish a number of research objectives as outlined below.

1. Identifying the key drivers for implementing lean manufacturing within SMEs- Literature review.
2. Investigating the operational activities of SMEs in order to understand their manufacturing issues- Visit to companies.
3. Exploring the current level of lean manufacturing usage within SMEs so as to categorise companies on their lean performance.
4. Identifying factors that are to be used to assess lean manufacturing in a company.
5. Developing an impact assessment framework for lean manufacturing within SMEs-proposed use of regression analysis.
6. Developing a knowledge based advisory system for lean manufacturing within SMEs, and
7. Validating the impact assessment framework and the developed knowledge based system through real-life case studies, workshops, and expert opinions.

### **3.3 Research Scope**

The scope of this research is in the premise of lean manufacturing utilisation within the SMEs community. The research focuses on the manufacturing SMEs who are engaged in the manufacture of discrete and processed products. However, at the early stage of this research project, an investigation encompassed the remits of larger sized manufacturing enterprises for the purposes of obtaining relevant information concerning lean application. The intention was to verify as to whether these organisations have better approaches that could be emulated by the SME players.

### **3.4 Research Hypothesis**

The research hypothesis was based on the gaps identified from the literature review exercise presented in the previous chapter. A fundamental issue raised from the research gap was the notion that SMEs practitioners are not certain of the actual cost of

implementing lean within their business. It was also contended that these companies fear that implementing lean manufacturing costs much money and time, yet they are not able to anticipate the likely timeframe, they would be able to realise any value-add from this venture. The foregone statement thus facilitated the creation of the research hypothesis; *whether developing a novel framework for assessing the impact of implementing lean manufacturing would motivate SMEs' adoption*. To fulfill this research hypothesis, the following research questions were designed to guide the focus of this assumption.

### **3.5 Research Questions**

- Is it possible to assess the impact of implementing lean manufacturing within SMEs?
- What are the factors for assessing lean impact?
- How can the impact of implementing lean manufacturing be assessed?
- Can assessing the impact of implementing lean manufacturing reassure SMEs about its benefits?
- What is the most suitable delivery medium for the impact assessment framework?

### **3.6 Unit of Analysis of the Research Project**

Trochim (2001) refers to unit of analysis as the entity being analysed in ones analysis. The author cites examples as being; individuals, groups or social interactions. Hence, SME is the unit of analysis in this research investigation. This is because; SMEs are qualified as having an annual turnover that does not exceed EUR 50 million, and/or a total annual balance sheet not exceeding EUR 43 million. Each SME employs from two to fewer than 250 people. Moreover, SMEs can be characterised as per the number of people they employ, the type and volume (low, medium and high) of the products they manufacture, and the complexity of the manufacturing process.

Considering that no two companies are likely to have the same annual turnover, this research has identified size as the context of the unit of analysis for assessing the impact



of implementing lean manufacturing within these companies. This is due to the fact that SMEs have certain characteristics which communalise them, yet they also have different capacities in terms of financial and personnel resources. SMEs size as the context of the research unit of analysis, takes into consideration companies that employ more than two people and not exceeding 250. In addition, companies being investigated are deemed to be realising annual turnovers of more than £100 thousand and not exceeding £15 million.

### **3.7 Design of Research Methods**

One of the challenges raised in conducting real world research lies in how to contain complex and generally, poorly controlled situations (Robson, 2002). Several authors including (Oakley, 2000), have acknowledged the use of randomised control experiments as they seem to allow the experimenter to develop and pre-determine what kind of experiment is going to be conducted, together with the chosen methodology. This type of design is known as fixed design or quantitative (scientific). Quantitative research method stems from ideals and suppositions maintaining that experimental steps should be based on tried and tested procedure to yield realistic outcomes. This is significant since scientific approach enables the control, operational definition, replication and the hypothesis verification (Burns, 2000). Robson (2002) maintains that there is a growing advocacy by a large number of research fields such as (educationalists, health-related, social workers and marketers) for another form of research type known as qualitative design. Unlike the fixed type of design, qualitative or flexible design infuses a far lesser pre-specification, hence enabling the research study to unfold as the process progresses (Robson, 2002).

However, there seems to be a higher need for the adoption of the use of qualitative or flexible design methods. Robson (2002) asserts that it is because such designs permit the use of data in the form of both numbers (quantitative), as well as in the form of words. Contrarily, using qualitative research design may create difficulties in terms of assigning numerical values. This is evident when the data obtained in the form of words (qualitative) are needed to be configured to indicate numerical values.

A synopsis of both the quantitative and qualitative research approaches in terms of the capabilities of how each one can be used to carryout research studies, are underlined below.

- Although quantitative results can be replicated and verifiable, its response to environmental forces is complicated.
- Qualitative research design on the contrary, reacts and reverberate real-world issues. It has provisions to accommodate unique accounts. Moreover, qualitative research design engages participants and conducts a thorough examination of objects in minute details. The downside of qualitative research design though, is that it is time consuming and creates enormous problems when it comes to the point of verifying the authenticity of the research results. In other words, how to conduct validation in qualitative research design still harbours unanswered questions, since sceptics insist there are always the possibilities of bias and compromises.

Based on the comparative analysis presented above, this research investigation decided to follow the qualitative research approach. This decision was arrived at based on a number of factors, but most importantly, because of the fact qualitative research design offers flexibility, engages real-life issues and encompasses participants. In this instance, qualitative research befitted the fundamental requirements for this study as the research would surround environments, people and to some extent numerical values.

### **3.7.1 Data Collection**

There are several research techniques employed in data collection by researchers within the premise of qualitative or flexible research designs. These can be described as surveys, literature review, observations and interviewing.



### **(i) Surveys**

Surveys in qualitative research may be taken to express descriptions of the population samples being analysed (Sapsford, 1999). Surveys are regarded as essential in the identification of the research sample size and structure, hence providing the research outcomes with a broader spectrum across different entities being investigated (Westbrook, 1995). However, surveys as a data collection technique is deemed to be inappropriate in providing the actual world accounts, thus availing few benefits to the research investigation (Robson, 1993). Moreover, others have argued that data collected through surveys can be treated as shallow when compared with those collected from other modes of data collection (Remenyi, 1995).

### **(ii) Literature Review**

Literature review can be treated as a key data collecting technique, since it is being extensively used in qualitative research designs. The fundamental point of conducting literature review is the conveyance of the established knowledge on the relevant domain, to the other interested parties. Burns (2000) maintains that literature review spurs the genre of the researcher not only as a means of exploring the existing concepts, but rather to discover new ideas. Fink (1998) asserted that literature review is a systematic method for identifying, evaluating and interpreting the existing body of recorded work produced by others in some discipline.

Although literature review is one of the significant data collecting techniques in the qualitative research design, it is crucial that researchers observe a number of pitfalls that can limit the realisation of good data collection. The review should be broadened to capture relevant subject domain in order to generate an evaluative critique. The use of precise technologies in the description of information should also be observed as a precursor to enhancing realistic outcomes.

### **(iii) Interviewing**

Interviewing is another important aspect of data collection within qualitative research. Hughes (1996) maintains that interviewing has a high preference within the research community as a data collecting method. This is based on the premise that interviewing

process generates interactive dialogues amongst interested stakeholders. This could engage personal dialogues (face-to-face), electronic forums (e-mail, telephone) and paper based mediums (posted questionnaires).

Interviewing mediums play pivotal roles in determining the reliability of the results of data gathering within qualitative research designs. Partington (2001) asserts that much of the qualitative data gathering requires multiple interviews so as to cover various ranges of issues involved. To successfully achieve a true reflection of the information being sought, interviewing sessions should concisely observe a number of issues such as; listening and questioning, clarity in questionnaires, time-scales for respondents and getting exactness in the interpretation of responses like transcripts.

#### **(iv) Observing**

The art of observing the occurring activities within an identified setting for qualitative research design is not a new phenomenon within academia. Observation is one of the major techniques for data gathering within qualitative research. Flick (2002), contends that methodological discussions about the role of observations as a research method has been the cornerstone of qualitative research. Observation as a data collection mechanism facilitates the accomplishment of the goal of attaining an insider's knowledge of the field. This is conducted through the researcher's continuous attachments as part and parcel of the field being investigated. However, observational procedures fall within five categories. Covert versus overt; non-participant versus participant; systematic versus unsystematic; observation in natural versus artificial situations and self observation versus observing others.

### **3.7.2 Research Evaluation and Validation**

Evaluation may be referred to as a systematic assessment of the worthiness or merit of some object (Robson, 2002). Evaluation is thus a technique used to test the authenticity of the research conduct and provides useful feedback to the research body. It involves many of the same methodologies used in traditional social research. However, evaluation normally takes place with a political and or political dexterity, sensitivity to multiple stakeholders and other skills that social research in general does not rely on. At



a fundamental level, the evaluation of social interactions is concerned with making an assessment of finding the merit of an activity or programme and assessing it against the goals that were established at the outset.

Love (1998), asserts that evaluation may be classified as internal or external. Whereas internal evaluation engages members within an organisation to appraise the impact of an entity like a project its function usually engages those outside the organisation. The former is conducted with a specific interest to the organisation being evaluated, while the foci of the latter are to interest those outside the organisation such as financiers and policymakers. Evaluation therefore enables the ascertainment of the degree of effectiveness of the qualitative research output. To achieve this, Love (1998), suggests that evaluators should formulate the right type of questions for carrying out evaluative tasks. This, the author argues, is fundamental to the eventual success or failure of the evaluation program effectiveness.

However, some academicians have argued that the assessment and evaluation of qualitative research outcomes still raises huge problems, since researchers tend to select only information deemed relevant from the research modes such as interviews and observations (Flick, 2002). The author further states that it becomes ambiguous on how a particular researcher treats the rest of information he views as being irrelevant. To overcome this shortcoming, investigators involved in qualitative research can use techniques such as expert opinion, case study and triangulation.

### **(i) Expert Opinion**

The rationale behind using expert opinion in qualitative research investigation is to; construct data evaluation functions within the framework and to confirm the overall structure. Fink (1998) believes that experts are individuals who are knowledgeable about the main topic area being addressed. Their knowledge and opinion may guide a researcher's perspective. Other authors such as Ince (2000), argued that the cardinal principles of the use of experts in the evaluation of qualitative research study is that, they should consist of people who have studied or worked in the same area long enough.

The elicitation of information from experts is usually carried out through a technique known as Delphi. Delphi technique is a commonly used method in qualitative research studies to obtain information and judgements from people within a common expert knowledge and in a particular domain (Cornish, 1977). Information from experts is usually solicited without the need of physically bringing together participants face-to-face. To date information sought may be exchanged through the use of electronic modes such as e-mail and fax. According to Alder and Ziglo (1996), the objective of most Delphi applications is the relevance of its reliability, mostly effected by creating exploratory ideas which are collected structurally and distilled from a group of experts.

A number of authors have advanced procedural steps to follow when using Delphi techniques (see Fowles, 1978 and Martino, 1978). A detailed investigation on the works of all the above authors has provided the following ten steps for the Delphi method.

1. Formation of a team to undertake and monitor a Delphi on a given subject.
2. Selection of one or more panels to participate in the exercise. Customarily, the panellists are experts in the area to be investigated.
3. Development of the first round Delphi questionnaire.
4. Testing the questionnaire for proper wording (e.g., ambiguities, vagueness)
5. Transmission of the first questionnaires to the panellists.
6. Analysis of the first round responses.
7. Preparation of the second round questionnaires (and possible testing).
8. Transmission of the second round questionnaires to the panellists.
9. Analysis of the second round responses (Steps 7 to 9 are reiterated as long as desired or necessary to achieve stability in the results).
10. Report preparation by the analysis team to present the conclusions of the exercise.



The use of Delphi technique in qualitative research study has attracted much criticism as much its proponents. In particular, critics have queried Delphi's novelty in terms of its capability in carrying out scientific and complex problems accurately (see Sackman, 1974; Armstrong, 1978; Martino, 1993). Never-the-less, Delphi technique is an appropriate information and knowledge elicitation tool from experts as advanced by Helmer (1977) and Robson (2002).

## **(ii) Case Study**

The other technique commonly used to augment the authenticity of the assessment and evaluation of qualitative research outcomes, is case study. Yin (1993), maintains that case studies as a qualitative research method have been used extensively by distinguished scholars of various disciplines. Case studies therefore have become a preferred research methodology. Other authors such as Robson (2002), Gill and Johnson (1997), have stated that case study method is a necessary approach especially in a research scenario where empirical investigation of a particular contemporary phenomenon is within real-life context. In other words, case study method is a necessity if it is deemed research investigation is attributed to some practical real-life undertaking. Gomm *et al.* (2000) confer that case study means different things to different people. The authors insist case study is sometimes used as a method of supplement to other experimental techniques, whereas others use it to promote a distinctive and self-sufficient approach to studying the social world. Conversely, case study as a social research approach has always faced negative appraisals in that, those who indulge in its use, are viewed as having downgraded their academic disciplines (Yin, 1993). However, It should only be fair to assert that case studies are always challenged, more so, on the insights resulting from it which end up not being appreciated.

To rebut this negativity, Yin (1994) urges for a fair, accurate and non-biased evidential presentation in case studies as a means of curtailing the problem of scientific generalisation that might be raised.

**Table 3.1: Schedule comparison of case study with experimental and survey approaches: Gomma *et al.*, (2000)**

<b>Schematic comparison of case study with experimental and survey approaches</b>		
<b>Experiment</b>	<b>Case study</b>	<b>Survey</b>
Investigation of a relatively small number of cases	Investigation of a relatively small number of cases (sometimes just one).	Investigation of a relatively large number of cases.
Information gathered and analysed about a small number of features of each case.	Information gathered and analysed about a large number of features of each case.	Information gathered and analysed about a small number of features of each case.
Study of cases created in such a way as to control the important variables.	Study of naturally occurring cases; or, in 'action research' form, study of cases created by actions of the researcher but where the primary concern is not controlling variables to measure their effects.	Study of a sample of naturally occurring cases; selected in such a way as to maximise the sample's representativeness in relation to some larger population.
Quantification of data is a priority	Quantification of data is not a Priority. Indeed, qualitative data may be treated as superior.	Quantification of data is a priority
The aim is either theoretical inference- the development and testing of theory- or the practical evaluation of an intervention.	The main concern may be with understanding the case studied in itself, with no interest in theoretical inference or empirical generalisation. However, there may also be attempts at one or other, or both, of these. Alternatively, the wider relevance of the findings may be conceptualised in terms of provision of vicarious experience, as a basis for 'naturalistic generalisation' or 'transferability'.	The aim is empirical generalisation, from a sample to a finite population, though this is sometimes seen as a platform for theoretical inference.

The above author further concurs that; case study should be reinforced through the use of resourceful materials obtainable from some of the following sources; Interviews, direct observation, physical artefacts and documentation. This is because; interviews if conducted properly provide significant insights into case studies since human interactions can always be one of its constituents.



Although time consuming, direct observation encompasses activities that happen in real-time, hence provide viable sources for case study research. Moreover, physical features provide relevant insights such as technical operations and cultural doctrines. Finally, observation documents if designed and created logically, is a potent source of case study approach. This is because; the gathered of information can be reviewed repeatedly thereafter.

### **(iii) Reliability and Validity**

Reliability and validity is another technique employed in the rebuttal of selective plausibility in research evaluation. To compound the importance of reliability and validity in research evaluation, Robson (2002) raises these rhetorical questions: “How do you persuade your audiences, including yourself, that the findings of your enquiry are worth taking account of? What is it that makes the study believable and trustworthy?” In essence, reliability and validity form the corner stone in establishing trustworthiness in a research investigation. Fink (1998) supports this argument in that, reliability and validity are some of the ideal criterion for carrying out an evaluation on the merits of a study data collection, analysis methods and for assessing the adequacy of results and conclusions.

Several authors such as Robson (2002), submits that the onus of trustworthiness relies on the thoroughness and robustness of the conduct of a researcher’s conclusions in a qualitative design. Therefore, one should not concern himself adversely with the reliability of his methods and research practices if the above conditions are realistically met. Furthermore, reliability and validity may be confined in the mind of a researcher, where his belief on what he thinks or sees may be the ultimate.

### **(iv) Triangulation**

The third technique used in the solicitation of research evaluation is known as triangulation. Triangulation may be referred to as the use of a number of research approaches in the investigation of the same study. In the words of Robson (2002), triangulation is a widely used research mechanism that enhances the authenticity of

validity in flexible research. Triangulation may be employed in both qualitative and quantitative research investigations.

Four types of triangulations are used in research studies. They are; data triangulation, which embodies human and time; theoretical triangulation which refers to the use of two or more theoretical perspectives in the interpretation of a phenomenon; methodological triangulation which involves the use of more than one method; sometime inter and intra methodological interactions. Finally, there is the investigator triangulation which refers to the use of several observers rather than a single one. Although sceptics like Flick (2002) have argued that triangulation is a much lesser strategy for carrying out evaluative activities in research conducts as compared to validity, its usage is still well acclaimed in research cycles. More especially, triangulation is deemed to possess some richness and complexity when it attempts to explain human behaviour (Robson, 2002; Burns, 2000).

### **3.8 The Selected Research Methodology**

In order to fulfil the fundamental requirements of a doctorate thesis, this research project has employed a hybrid research methodology in its investigation. This included a combination of different research approaches discussed in Sections 3.7. Specifically, the research methodology adopted a process which encompassed the use of techniques such as literature review and visitations to companies. Moreover, the research process was composed of five phases as demonstrated in Figure (3.1).

#### **3.8.1 Phase 1: Identification of the Research Process**

In phase one of the research process, the objective was to identify the most suitable research approach for the entire research investigation. This activity encompassed the examination of both the quantitative and qualitative research approaches. Deeper analysis enabled the evaluation of their strengths and weaknesses. Consequently, a decision was made to adopt the qualitative research approach based on the reasons discussed in the closing paragraphs of Section 3.7.



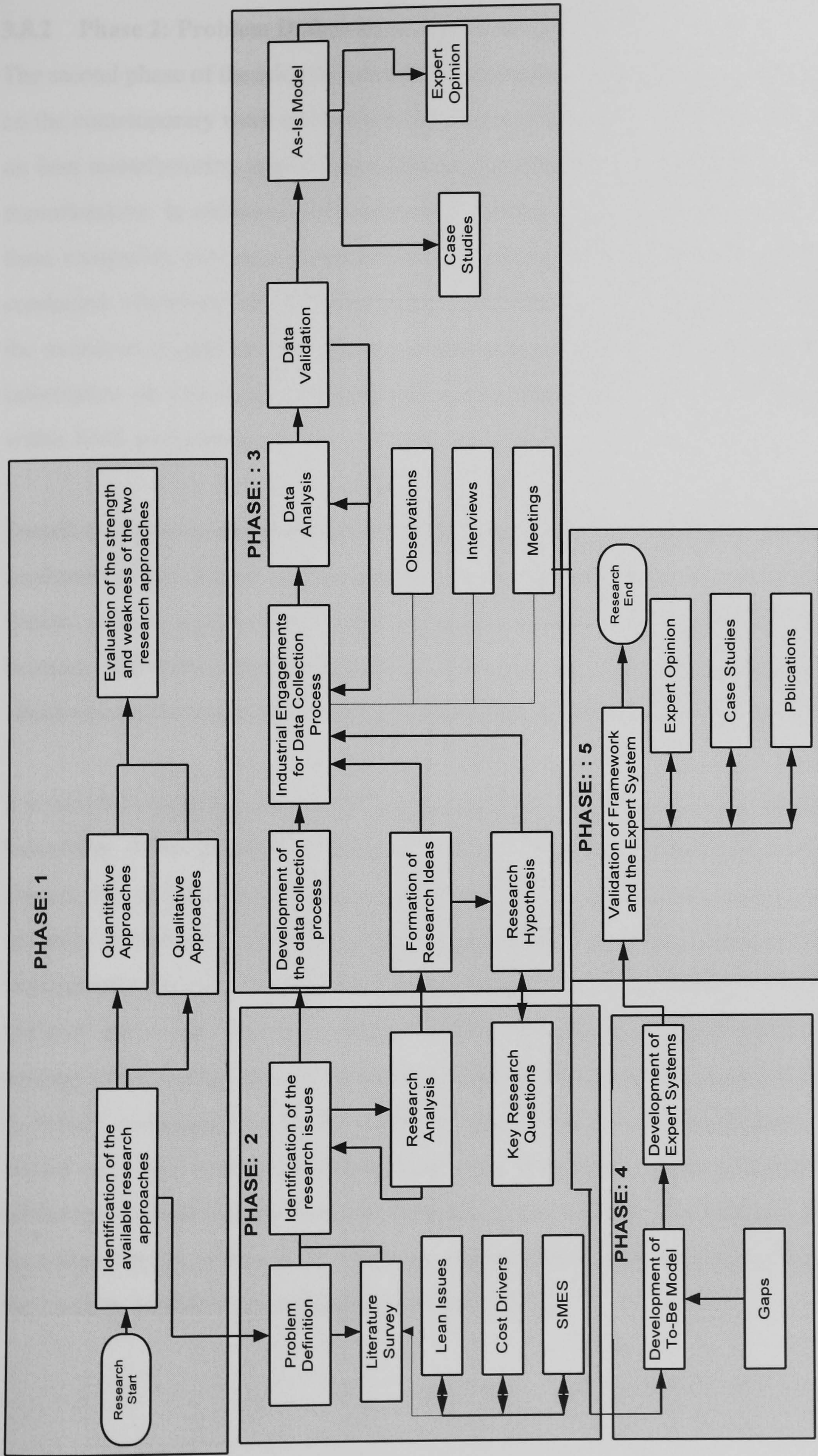


Figure 3.1: Scenario of the research methodology



### **3.8.2 Phase 2: Problem Definition and Literature Survey**

The second phase of the adopted research methodology constituted a background review on the contemporary work on the relevant subject areas. These areas included literatures on lean manufacturing application within the premise of both SMEs and larger sized-manufacturers. In addition, cost issues and how they are fundamental to the survival of these companies were also reviewed. It is significant to note that, the literature review conducted extensively at the initial stages of this research investigation, demonstrated the existence of gaps in knowledge. In particular, the review did not provide specific information on issues that affect the successful implementation of lean manufacturing within SME companies.

Therefore, there became a need for further research within the existing SMEs that had implemented the lean concept previously. The idea behind this move was to investigate further, so as to determine such factors deemed critical for lean implementation. This is because; real-world engineering problems normally contain discrete design variables which can create complexity both in the identification and definition of problems.

It is therefore imperative that research investigations contain both the inside and outside knowledge of the problem domain, as a way of realising realistic research outcomes. Hence, this research investigation was directed to a number of companies for the purposes of exploring the inside of the existing industrial issues. Furthermore, company engagements provided a platform for the collection of data deemed relevant for the research study. Ten Carefully selected SMEs who had successfully implemented the concept of lean manufacturing within their premises were engaged in the research study. A further investigation into the works of three large sized manufacturers was also carried out. This was to investigate what work was done by these companies in lean utilisation. In addition, the research intended to emulate any best practices that might have been applied within these large size manufacturers as illustrated in phase three of the research methodology highlighted in Figure (3.1).



### **3.8.3 Phase 3: Development of the Data Collection Process**

The third phase of the research methodology necessitated the collection of data from companies. This was aided by the engagements of companies as discussed below.

#### **(i) Company Investigations**

Companies were contacted at the first instance by telephone, e-mail, fax and letter. After the initial contacts were made, a review meeting was arranged between the researcher and the SME concerned. The review meeting enabled the researcher to carry-out direct observation of the activities within a particular company. This was significant to the research findings since; observatory exercise enabled a visual assessment of the general manufacturing issues at stake. While in companies, the researcher conducted informal meetings, observations and interviews. These activities occurred almost in the aforementioned sequence.

#### **(ii) Informal Meetings**

The researcher met and discussed a number of research issues within each investigated company. These meetings were carried out with the respective company practitioners as a means of formalising the research process within the investigated companies. This was carried out in a more cordial and informal format. The main objective of conducting informal meetings was to enhance the employee-researcher relationship building amongst these companies. More often than not, company workers, especially the shop-floor staff would be dismissive of any foreign person discussing with them any work related issues.

In their minds, they seem to treat such visits (research-related) as an encroachment on their normal schedules, something that might lead to job retrenchment. The consequence thus lies on the worthiness of cooperation and perhaps subsequent answers, these employees would give out if they feel the relationship is not favourable. Therefore, informal meeting played crucial roles in initiating the research scene. It should also be remarked that, at this stage little notes were taken as everyone still seemed to be cynical about the role of the researcher, hence note-taking would hinder progress.

### **(iii) Observations**

On completion of the informal meetings, the researcher carried out direct observation exercise which lasted for approximately 1 hour at each particular point of observation. Real-time information sought from the observation exercise was recorded in a specially improvised data collection sheet; copy provided in appendix (C). The essence of conducting observatory exercise was to obtain further information on manufacturing and lean issues within these companies. For example, observations were focused on both the performance of workforce during their daily tasks and the timeframe to carry out these activities.

### **(iv) Interviews**

Eventually, information from the observation data collection sheet was analysed. This facilitated a need for further information retrieval, prompting the need to conduct some interviews, so results from observations could be verified. Personal interviews were conducted through prepared semi-structured questionnaires (see appendix B). They involved a number of key personnel in the company that included the general workforce of the companies concerned. This selection criterion was used as a means of acquiring information in a blanket format so as to make the study more representative. A 1-3 hour interviews were conducted using semi-structured interviewing techniques. This was done with planned short breaks in between so as to gather as much information as possible in a limited time without demoralising the interviewee. It was believed that way; answers to pertinent questions could be provided resolutely.

However, in order to succinctly find out from these companies their perspectives on the factors that are critical for lean implementation, a number of questions were tailored to enable the extraction of ideas that give a true reflection on the interviewee's perception on them. The research therefore set a number of questions that embodied the companies' definition of lean manufacturing and whether that company had implemented lean before. The designed questionnaires were significant for enabling the retrieval of the relevant and accurate information on lean manufacturing utilisation within these companies. For instance, by asking questions about a company's major business drivers;



how such a company views and perceives the concept of lean manufacturing and where lean has been implemented; and at whatever cost; the study was able to deduce a number of issues.

First and foremost, it could be verified instantly based on information provided as to whether such a firm understood and was actually practicing lean or not. This was significant for the retrieval of information on the factors that are critical to lean implementation due to the following. By knowing about the management type of such a company, it was found to be useful in determining its motives to adopt the lean concept. The study also wanted to find out relationships between lean adoption and the management style in these SMEs. Again it wanted to determine as to whether the type of management style actually influenced or deterred the absorption of the lean concept. Phase three of the research methodology also included other activities like; the analysis and validation of the collected data. Additionally, an AS-IS Model was thus yielding some research gaps as discussed in Sections 4.5.1-4.5.2 respectively.

#### **3.8.4 Phase: 4 Development of the TO-BE Model**

The fourth phase of the research methodology involved the development of the TO-BE Model. This particular phase was compartmentalised in twofold. The first part entailed the development of the framework model, whereas the second phase involved the development of a knowledge based system. Both of these activities engaged company visits, where interviews and research meetings were conducted for the formalisation of the research knowledge.

However, in the case of lean impact assessment framework development, the researcher involved qualitative data collection methodology that was utilised in the previous phases. These approaches also included the use of interviews and extensive observations. The purpose of these activities was for data collection from companies involved. Interview sessions were facilitated through the aid of semi-structured questionnaires, observation data collection sheets and Dictaphone, for voice recording.

Moreover, correspondences between the researcher and the collaborating partners were fostered through the use of electronic mediums such as; telephone, fax and e-mails.

Within companies, the research process also engaged a number of company staff at various levels (management and shop-floor). This was planned to enable the researcher realise an all inclusive information retrieval strategy where bias and omission would be reduced. Furthermore, the captured data sets were analysed, prompting the proposition of the TO-BE models (impact assessment framework and the developed knowledge based system). Additionally, the development of these models included the use of other scientific decision-making techniques such as; flowcharts predictive models (regression analysis model) demonstrated in Chapter 5.

The use of regression analysis predictive model was selected for the facilitation of the TO-BE model in assessing lean impact within SMEs. This was done in order to determine as to whether there existed some association between the independent and the dependent variables such as; the duration of lean implementation, the man-days efforts and the total cost of lean implementation. This line of thought was derived because; the representation of companies' clusters within the regression analysis would provide better understanding of their behaviors, based on the above stated factors such as; duration of lean implementation and man-days effort. It was thought, this would provide company practitioners with a good measure of assessing their positions prior to lean implementation. Moreover, the use of regression analysis has user-friendly features that would not require much time to learn.

However, as presented in Section 5.5.2, the failure of the regression analysis to determine the desired association between the identified variables in Table (5.1), engineered an alternative approach to address this impasse. Subsequently, a fuzzy logic expert system was deemed relevant for the execution of this task as demonstrated in Section 6.1.



### **3.8.5 Phase 5: Validation of the TO-BE Model**

In the final phase of the research methodology, a number of validation modes such as expert opinion and case studies were employed at this level. These approaches were elected because the research needed to test the merit and worthiness of the framework and the developed knowledge based advisory system. Carefully selected case studies and expert opinions were sought as illustrated in Sections 7.3-7.5 respectively. Moreover, the formation of these validation workshops and case studies necessitated both company and expert involvements. Hence, the validation exercises were conducted chronologically in that; internal session (within the academic setting) was used to verify the completeness and readiness of the developed models, prior to embarking onto the industrial domain. The external validation sessions were to enable the research outcomes gain access to the industrial settings, in order to test its worthiness and merit, as compounded by Easterby-Smith *et al.* (2002).

## **3.9 Summary**

This chapter has structurally presented the research methodology used in the investigation of impact assessment study of lean manufacturing implementation within SMEs. The hybrid research methodology presented within this chapter, is the investigative research approach used in the entire thesis. These included two most utilised research methodologies within research arena; quantitative and qualitative research approaches. The chapter therefore presents and illustrates the strengths and weaknesses of these research approaches. It also provides the scope of the research project. This included a description of the research hypothesis and the designed research questions for the formalisation of the overall research investigation. A detailed account of the process of designing a research method and all its attributes such as data collection, research evaluation techniques and reliability are further presented and discussed within the chapter. Finally, the chapter has provided the elective research techniques adopted for the actual research investigation. These have included literature review and company engagements for the purposes of data collection, validations and triangulations.



## CHAPTER (4)

### 4 ANALYSIS OF CURRENT SMEs LEAN MANUFACTURING PRACTICES

#### 4.1 Introduction

This chapter presents and discusses current lean manufacturing practices (AS-IS) within the investigated SMEs. The chapter presents findings obtained from investigations carried out on a number of SMEs located in the East of UK. This has involved all the operational and manufacturing issues in these companies. The chapter also provides the main objectives of the industrial investigation and highlights the data collection methodology used. A summary is made, by describing why the AS-IS scenario has facilitated a need for further research in developing an impact assessment framework (TO-BE Model) for lean manufacturing implementation.

#### Chapter Aim:

To investigate the current lean manufacturing practices within SMEs and highlight the challenges and bottlenecks.

The remainder of this chapter is thus structured as follows. Section 4.2 presents the motivation for conducting industrial research and the data collection technique used. Section 4.3 highlights some of the major manufacturing issues within SMEs. Section 4.4 discusses the practices of lean manufacturing within SMES, while Section 4.5 provides the conducts and comparative analysis of lean specialists. Section 4.6 presents the validation mode used in the AS-IS. Finally, Section 4.7 summarises the entire research work within the chapter and further presents the key observations made.

#### 4.2 Data Collection Process

As highlighted in Chapter 1, the operational success of SMEs is without a doubt, very crucial for the survivability of the UK economy. This notion is therefore one of the key motivating factors of conducting this research study. Currently, most of these companies operate within challenging business environments, hence the proposition for lean



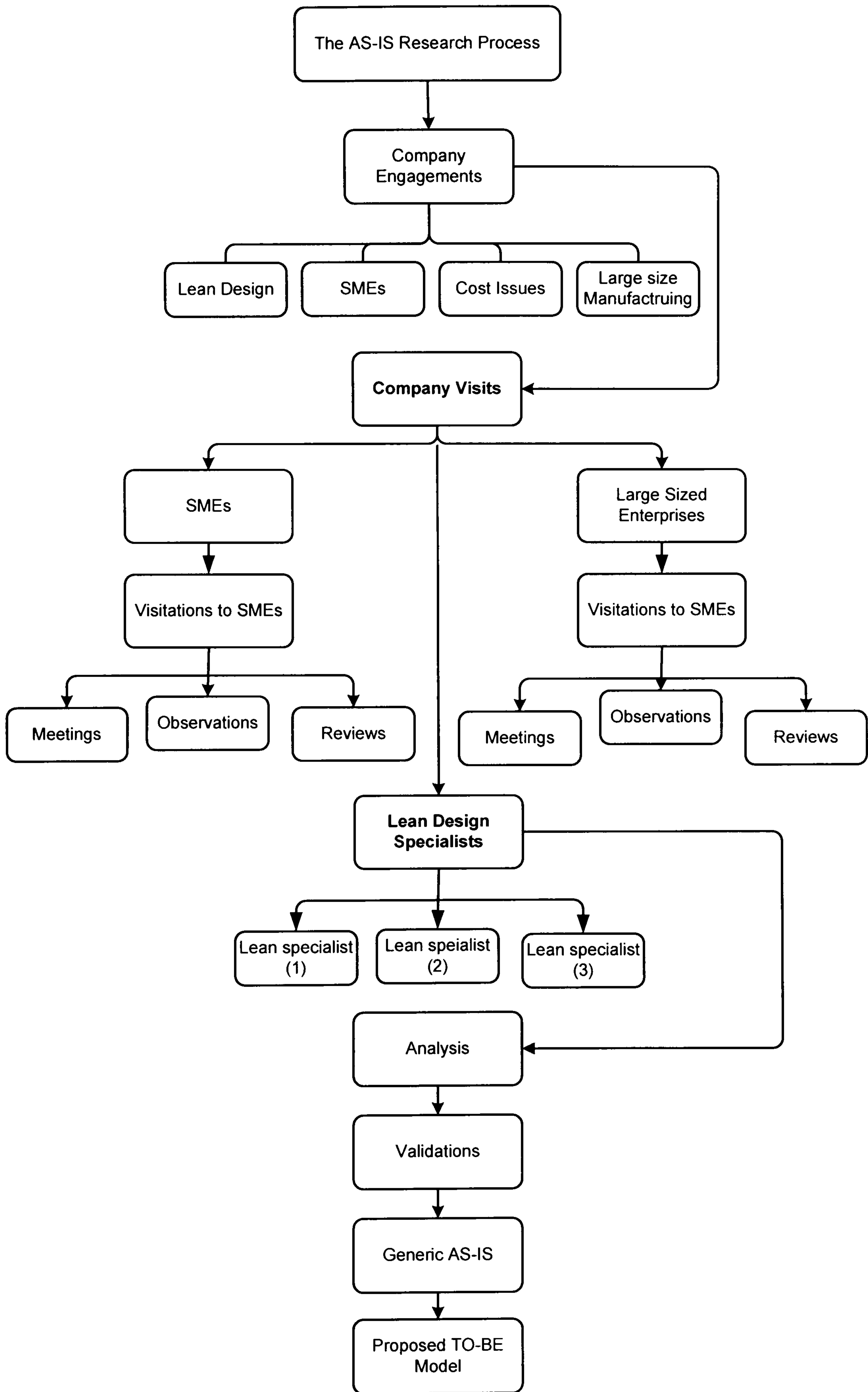
manufacturing adoption as a productivity improvement initiative, to help these companies assert themselves within the business ecologies. However, as discussed in literature review provided in Chapter 2, most SMEs have not been receptive to the idea of lean adoption. Literature review exercise presented in Chapter 2, does not provide conclusive reasons pertaining to this stalemate.

Hence, there rose a need for further investigation into the artefacts of some of these companies to try and comprehend these issues. The main objective of company visits was to explore the operational activities of the investigated SMEs, so as to determine their major business drivers. The industrial research study was also intended to investigate how SMEs currently practice lean manufacturing concepts and then formulate the current status-quo (AS-IS). Finally, it was hoped results obtained from the company investigations would aid the designing of a roadmap for further research in order to develop the problem solution (TO-BE Model).

The investigation adopted a list of research questions as a means of enabling the study to obtain a meaningful outcome from this research project. The questions asked embodied the following areas:

- The type of product a particular SME manufactures and its volume level classified herein as; (high, medium and low).
- The companies' size in terms of employees and its annual turnover.
- The management type (whether independent or owner-managed), and structure of the organisations.
- The companies' major business drivers and the manufacturing issues.
- The strengths and weaknesses of the organisations, including their potential sources of competitive advantage and finally,
- The current status of their lean manufacturing applications.

Based on the above research areas, the study devised a number of data collection techniques for the retrieval of information from the investigated SMEs.



**Figure 4.1: The AS-IS data collection process**



These included; observation exercise, through the use of observation data collection sheets, semi-structured questionnaires, and flow chart diagrams highlighted in the appendix section of the thesis. The data collection approach was elected based on the need of accomplishing the set objectives; understanding the operational nature of SMEs and making an assessment of how lean manufacturing is being utilised as demonstrated in Figure (4.1). Several visits were made to ten carefully selected SMEs and three large sized manufacturing enterprises based in the East of UK. Visitations to these ten SMEs took approximately 6-7 hours in each company. The research investigation concentrated on the issues surrounding lean manufacturing implementation within the business of these firms.

**Table 4.1: Characteristics of the investigated SMEs**

Characteristics	Investigated SMEs									
	1	2	3	4	5	6	7	8	9	10
Management type	IM	IM	OM	IM	IM	OM	IM	IM	IM	IM
Annual turnover (£) millions	3.50	4.00	0.75	5.00	3.50	2.00	2.10	4.00	5.85	1.00
Volume of production	L-H	L-H	L	L-H	M	L-H	M	M	H	M
Area lean applied	P	P	W	P	P	P	P	P	P	P
Duration in days	10	15	10	10	18	12	10	10	15	10
No. of employees	65	98	15	65	200	9	36	25	80	30
No. of employees involved	13	50	12	20	25	5	10	8	15	12
Total spend (£) thousands	5.0	4.0	2.5	10.0	4.0	2.0	2.7	1.5	3.5	1.5
Return on investment (ROI) (£)	0.12	0.50	0.05	0.40	0.55	0.01	0.30	0.17	0.25	0.19
Reduction in lead times (weeks)	6-2	4-2	8-3	4-2	6-2	5-2	6-3	6-2	6-2	4-2

**Key:** IM= independently managed, OM= owner managed, L= low, M= medium, H= high, P= piecemeal, W= whole

However, these companies were engaged consistently in terms of information gathering for the entire research project life. The study thus embraced a number of significant factors within the investigated companies. The aim was to obtain first-hand information on their manufacturing issues. The characteristics of the visited companies included but not limited to the type of product, such a company manufactures; the size of company in terms of the number of employees and or its annual turnover; and the nature of their manufacturing processes as demonstrated in Table (4.1).

Formally, the data collection exercise was started by the contacts made to a particular company. This was done through the use of e-mail, telephone or facsimile facilities. As the research progresses on, telephone and e-mail contact medium took preference because of the convenience they provided to the researcher. On securing an invitation to the respective host company, the researcher visited these companies and carried out direct observations on the existing practices within these organisations. This included, how these companies performed their daily operations, their staff concentration level and what lean principles were being used. Observatory exercise was then followed by a diagnosis of what the real issues (AS-IS) were, in terms of the manufacturing problems.

Realistically, the researcher would visit a particular company and conduct a-thirty-minute informal meeting with the point of contact, as a basis of familiarisation. In such instances, the researcher would be able to structure how best to investigate the entire firm with specific priorities. Such informal meetings would provide the researcher with guidelines on who to approach on specific information. Observation exercises were planned to last from between 1-3 hours on any given day, depending on the size of the company and the manufacturing operation or area of research interest. However, most times, these observation exercises were repeated if it was deemed necessary. A case would be where if it was felt some information gathered may be containing omissions; especially after conducting interviews that may not corroborate what was observed in the first instance.



The researcher would take notes and crosscheck them for consistency and accuracy. This was mainly done after obtaining further information from the company experts. Formal meetings usually engaged a number of personnel at any given time. These were planned to constitute a mixture of the workforce in order to allow for a synergistic discussion over the investigated matter. The mixture of the workforce engaged usually constituted a manager (senior), team leader, shop-floor staff and particular personnel with expert knowledge in an area of interest. These meetings usually lasted between 45 minutes to 2 hours, but had break slots so as not to disinterest the information providers. More often than not, interview sessions were conducted thereafter. These sessions were also planned to last from between 1-3 hours depending on the level and rigour of the research area of investigation.

Relevant data such as lead-time, delivery-time and profit figures were also captured. This information was retrieved through the observation of activities, and the interviewing of key experts to bolster the assessment made on the observation exercise and data analysis. A verification exercise was done through expert opinions as a means of validating the findings. The interviewing exercise involved a number of questions such as;

- Is this company independently managed or it is owner managed?
- What are the major drivers of your business?
- What is your definition of lean manufacturing?
- What has motivated the company to implement lean manufacturing?
- Where has lean been implemented in your organisation (piecemeal or whole)?
- What were the criteria for choosing that specific area?
- How many People were involved in the exercise?
- What training if any, did the staff undertake?
- What were the difficulties encountered in training and how were they overcome?
- What were the direct and indirect costs involved in the implementation of lean manufacturing? (E.g. labour costs and consultancy fees).

The interview sessions were structured to last not more than three hours. The intention was to gather as much information as possible in a limited time without demoralising the interviewee. It was believed that way; answers to pertinent questions could be provided resolutely. Finally, the overall information obtained from the interviews, and summaries of both the informal meetings and observations, were compared with that from the literature survey in way of analysis. Results were validated through workshops in the companies concerned. At the same time, expert opinions were sought to verify and validate the actual findings. Conversely, the analytical exercises were also conducted. These were done outside of the company premises. The researcher invented a validation matrix that contained details of the ten investigated companies. They included annual turnover and a company's management status (independent or owner-managed). A comparative analysis of the company characteristics were then compared with the prior set questions in order to find out similarities in responses.

### **4.3 Major Manufacturing Issues within SMEs**

Several SMEs operate within complex and challenging business settings. These companies are characterised by a number of challenges that impede their operational structures. The manufacturing issues are regarded as major inhibitors to SMEs performance, since they are constantly constraining these companies' strategic goals like the implementation of lean manufacturing. These factors ripple through the entire SMEs framework, hence their vulnerability. Below are some of the main manufacturing issues within SMEs premises.

- Leadership deficiencies
- Inadequate funding
- Soft issues (including people)
- Poor supportive corporate cultures
- Lack of good technology and skills enhancement
- Complex manufacturing flows
- High inventory levels
- Low quality products



- Longer lead-times

Of the investigated companies, only two were able to deviate from the main fold in terms of leadership qualities. However, it was apparent these two companies were owner-managed, therefore did not want to be seen as lacking in management qualities, or were not able to realise the impact of quality leadership. This statement may be confirmed from one of the answers provided by one such firm; “I have been running this company for over 15 years. If I did not know what am doing, the company would not be in existence”.

Despite this strong assertion about the owner-manager’s confidence in his operations, certain factors obtained from the interview indicated negative perceptions about his company. For example, the company had a similar number of employees like another company independently managed from the investigated set, yet their final returns differed significantly. Also, the owner-managed company was confirmed to have been passed on from father-to-son, whereas the independent-manager was hired because of his potentials. In summary, it can be concluded that the ten investigated companies appeared to concur with most issues highlighted in section 4.3, save for leadership traits. Followings are some of the identified issues affecting the performances of SMEs.

#### **4.3.1 Leadership and Management**

Conversely, lack of strong leadership and capable management traits have been found to be one of the major issues hindering the performance of most SMEs. A greater number of these companies by default are owner managed, yet more often than not, these owner managers do not have adequate management know-how. Moreover, strategic improvement initiatives are now the norm for most organisations throughout the world today. In essence, good leadership qualities are a precursor to the facilitation and the integration of all infrastructures within an organisation, since strong leadership and management permeates a vision and strategy for generating, while permitting a flexible organisational structure. Good leadership ultimately fosters effective skills and knowledge enhancement amongst its workforce. Unfortunately, most SMEs leadership

behaviour and rewards are too easily focused on the management of a continuous series of short-term crises, whilst the implementation of strategic ideas like lean manufacturing that could create a firmer base for success by reducing costs and improving use of resources, can be subject to continuous postponements ‘until better times’.

#### **4.3.2 Financial Incapacitation**

Financial incapacity is one of the main manufacturing issues facing SMEs practitioners. Adequate funding is a critical factor in the determination of any successful project. This is due to the fact that finance covers the avenues through which other useful provisions like consultancy and training can be made. The study has realised that SMEs are financially weaker and harbour poor financing arrangements. Moreover, financial adequacy is a prerequisite to organisational growth since adequate funding promotes the training of people to utilise the productivity improvement techniques.

#### **4.3.3 Low Skills and Expertise**

The financial incapacitation discussed above ripples through the SMEs strategic framework, hampering critical success factors such as skills and expertise. The future of manufacturing in the UK also lies in the use of intellectual capital and ability to innovate and differentiate. Most SMEs employ people with low skills levels, and they do not foster the ideology of skill enhancement. This in the final analysis derails the very basic core of improvement strategies that would promote the fundamental growth needs of these companies. Moreover, low level employee skills would not harness the desire for technology development.

#### **4.3.4 Poor Supportive Corporate Culture**

The creation of a supportive organisational culture is an essential platform for the success of the 21<sup>st</sup> Century business undertakings. High-performing companies are those with a culture of sustainable and proactive improvement. Manufacturing, almost more than any other sector, is a global industry. Unfortunately, most SMEs organisational cultures lag behind in regards to nurturing high performing cultural models capable of supporting blame-free cultures capable of generating and stimulating team ethos. Most



large organisations are conscious of this, regardless of their choice of cultural models or success in using them, but many SMEs by default, reflect in their culture the personality of the owner/manager and are constrained by this in terms of the changes they may be able to undertake.

#### **4.3.5 Complex Manufacturing Flows**

It is evident that most SMEs are characterised by a large number of projects that run simultaneously at any given time. For example, the implementation of quality assurance programmes such as the ISO 9000 is taken up by these firms sometimes without due objectivity, but rather for the face value- just to be seen pulling together with others in the same direction. Coupled with their inability to react to untimely demand schedules, most SMEs stock-pile inventories with a view of meeting unexpected customer demands.

### **4.4 Lean Manufacturing Utilisation within SMEs**

The utilisation of lean manufacturing concepts within SMEs premises has not witnessed a fast-moving progress. Literature review conducted in Chapter 2 provides that most of these firms still harbour a myth that the implementation of the concept within their business, like any other productivity improvement initiatives, will cost too much money and time. Moreover, the expected benefits from implementing such a venture are not definite. This perception created a need for further research investigation within some existing SMEs within the research locality to succinctly confirm the true account and behavioural aspects of these companies with regards to lean manufacturing utilisation discussed below.

#### **4.4.1 Classification of SMEs in Lean Usage**

The Manufacturing Advisory Service, a collaborating research partner of this research project, had conducted a phone survey on a number of SMEs based within the South East of UK. This was to try and engage these companies in lean manufacturing adoption as illustrated in Table (4.2).

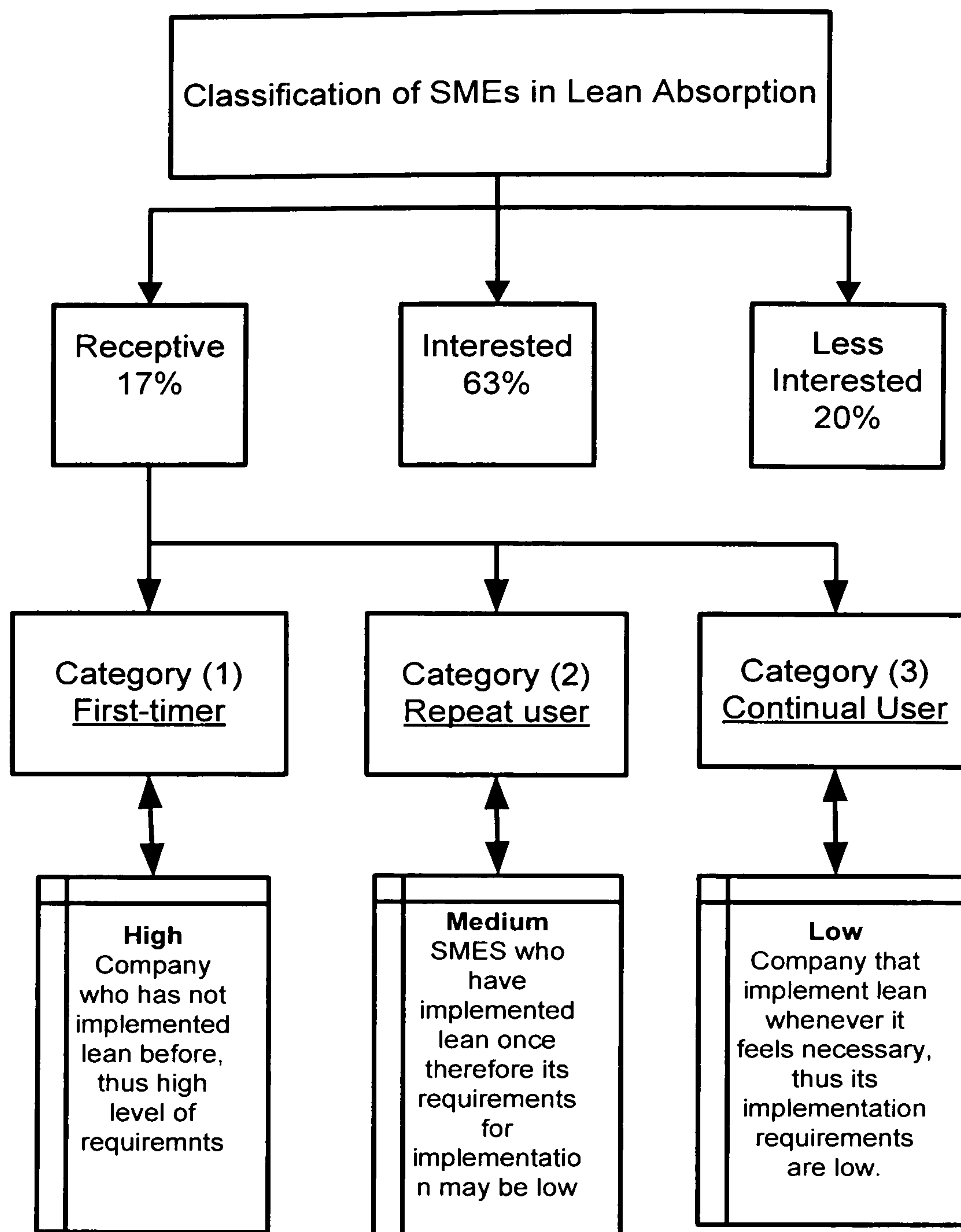
**Table 4.2: Total number of company surveyed within the UK counties**

Total Number of SMEs and MAS Reviews		
County	Total number of manufacturers	Total number of reviews
Bedfordshire	1064	76
Cambridgeshire	1458	58
Essex	3477	99
Hertfordshire	2543	57
Norfolk	1071	65
Suffolk	1259	57

The researcher has therefore analysed the data provided by the MAS (appendix D), and conclusive analysis indicate the following findings. 63 percent of these companies showed some interest in lean manufacturing, although most were not certain of the projected benefits. 20 percent had nothing to do with lean manufacturing, while 17 percent expressed interest to implement it instantly as demonstrated in Figure (4.2). The researcher's inference based on these results is that, whereas 20 percent of the SMEs are in the categories whose perceptions would not change irrespective of any circumstances, the higher percentage of 63 are those that have the potential to adopt lean manufacturing.

From the above findings, the study was able to classify SMEs into three categories as follows. Firstly, the receptive category is used to refer to companies willing to accept the concept of lean manufacturing in their business outright as highlighted in Figure (4.2). These are the types of SMEs who have the ingredients expected of a 21<sup>st</sup> Century business undertakings. They have the willingness to absorb new ideas and are therefore more inclined to change for the better, at any cost. The second classes of SMEs are referred to as the interested category. Interested category describes SMEs that appeared to know little about lean manufacturing, are uncertain of the benefits they might achieve but are willing to discuss it. Finally, the less-interested category encompasses SMEs that have nothing to do with lean manufacturing, and so would not change no matter what.





**Figure 4.2: The Classification of SMEs in lean usage**

However, the receptive category has also been profiled in accordance with its lean needs. They exist in three divisions; these have been referred to as First-Timers, Repeat and Continual. First-timer category of lean need refers to, a company who has never implemented lean in its business at all. The Repeat category is that company who has implemented the concept in its premise once. The Continual type is the company who uses lean on a regular basis for continual improvement.

The research results achieved thus far indicate that of the three classes, the Receptive category has experienced a significant improvement on their cost-effectiveness once they had adopted lean. Ten such companies admit to having experienced massive improvements in their manufacturing facilities, as a result of the changes lean

manufacturing brought about, which caused a steep reduction in factors such as lead-time and on-time delivery demonstrated in Table (4.1).

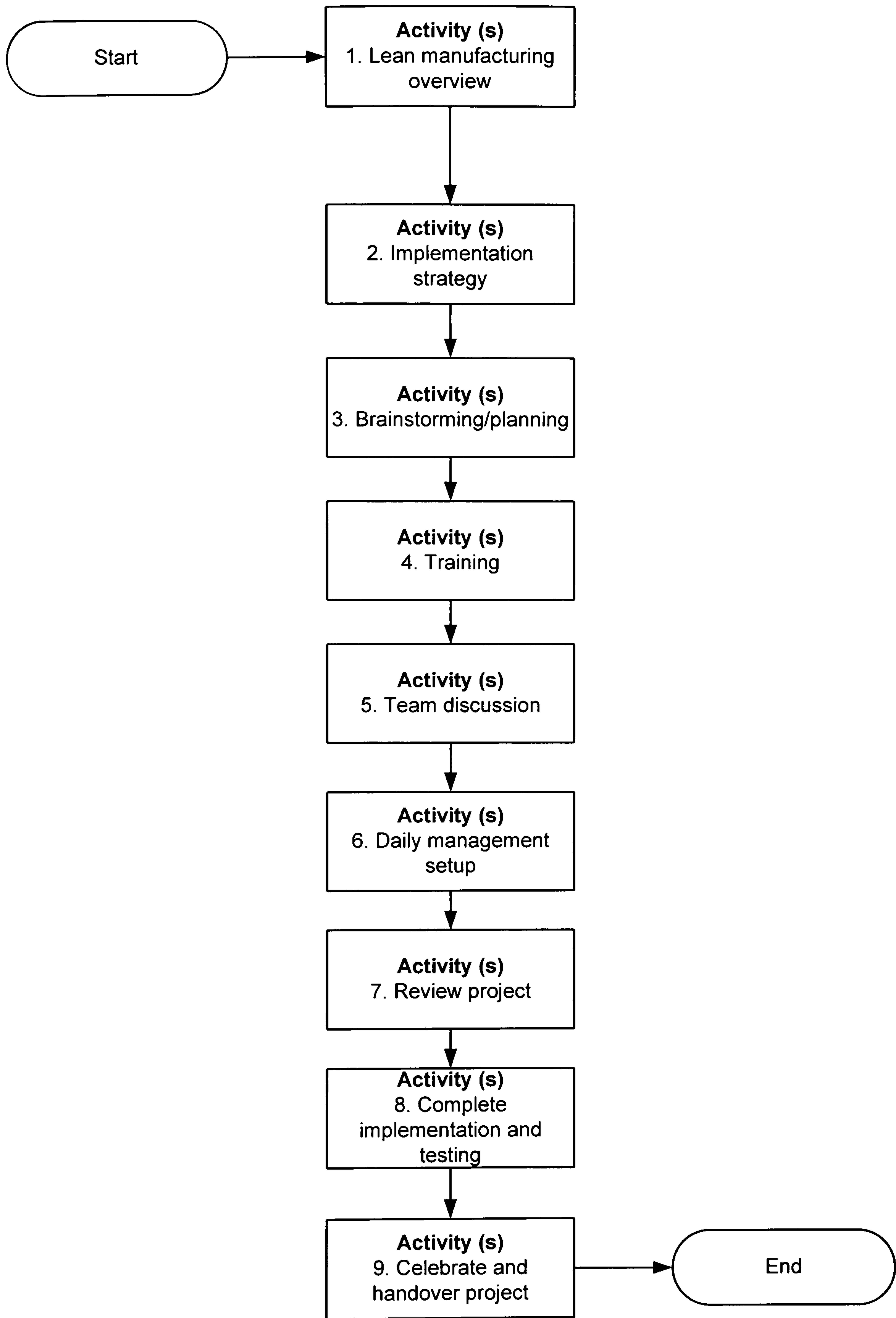
It is fair to remark that these companies are viewed as model companies and are currently being emulated by a vast number of other manufacturing firms within the locality. For instance, one such company has hosted a couple of workshops to share its past experiences on the lean initiative, while making clear the cost-benefit that has been derived from the project. The research study also shows that whereas the investigated companies are those that are engaged in the manufacture of high-variety products, the complexity and other factors such as annual turnover and numbers of people employed have not been a barrier to the success of the deployment of the lean concept. This is contrary to the views held by several other firms who maintain that, lean manufacturing is only applicable in low variety environments.

The hierarchy of lean needs illustrated in Figure (4.2) as; high, medium and low, implies that a First-Timer company will have a high need to apply lean within its own business. This is due to the fact that a company who had not implemented the concept before, lacks the basic knowledge and skills, hence its need for lean requirements will certainly be more than the one who has used it once and is looking forward to repeating it, or the one who uses it continually. This analysis is important and helpful in determining the actual value-add of lean activities.

#### **4.5 Activities of the SMEs Lean Specialists (AS-IS)**

The investigation of the company characteristics highlighted in Table (4.1) also included the exploration of the conducts of several lean specialists who were involved in implementing lean manufacturing within their business. These are companies that provide consultancy and guidance to SMEs on how to implement lean manufacturing. However, an AS-IS approach of how they conduct lean implementation is demonstrated in Figure (4.3). Usually, the first day is initiated by the explanations of the lean overview to the entire company workforce.





**Figure 4.3 The AS-IS Lean Implementation Model**

This is followed by the implementation strategy of the overall lean project, brainstorming of the problems within the organisation and training in lean concepts. On completion of the training, lean is then implemented, where daily monitor of the project is ensured. Furthermore, a review process is conducted to assess work that has been done, before conducting further tests and eventually celebrating the success of the project.

The research study also perused the conducts of two other lean providers (consulting organisations) whose names have been omitted for confidentiality purposes. These were mainly done through literature surveys. Moreover, investigating these two lean specialists was done for the purpose of making a comparative analysis on their undertakings. The first lean specialist's approach is started by the specialists conducting awareness and consensus of the lean benefits to a potential organisation lean is to be implemented. This is followed by the assessment of the problems within the organisation lean concept is intended to solve. Training in the lean concepts is then conducted including organisational and cultural awareness. Value stream synchronisation is also carried out in order to translate operational improvements into growth indicators.

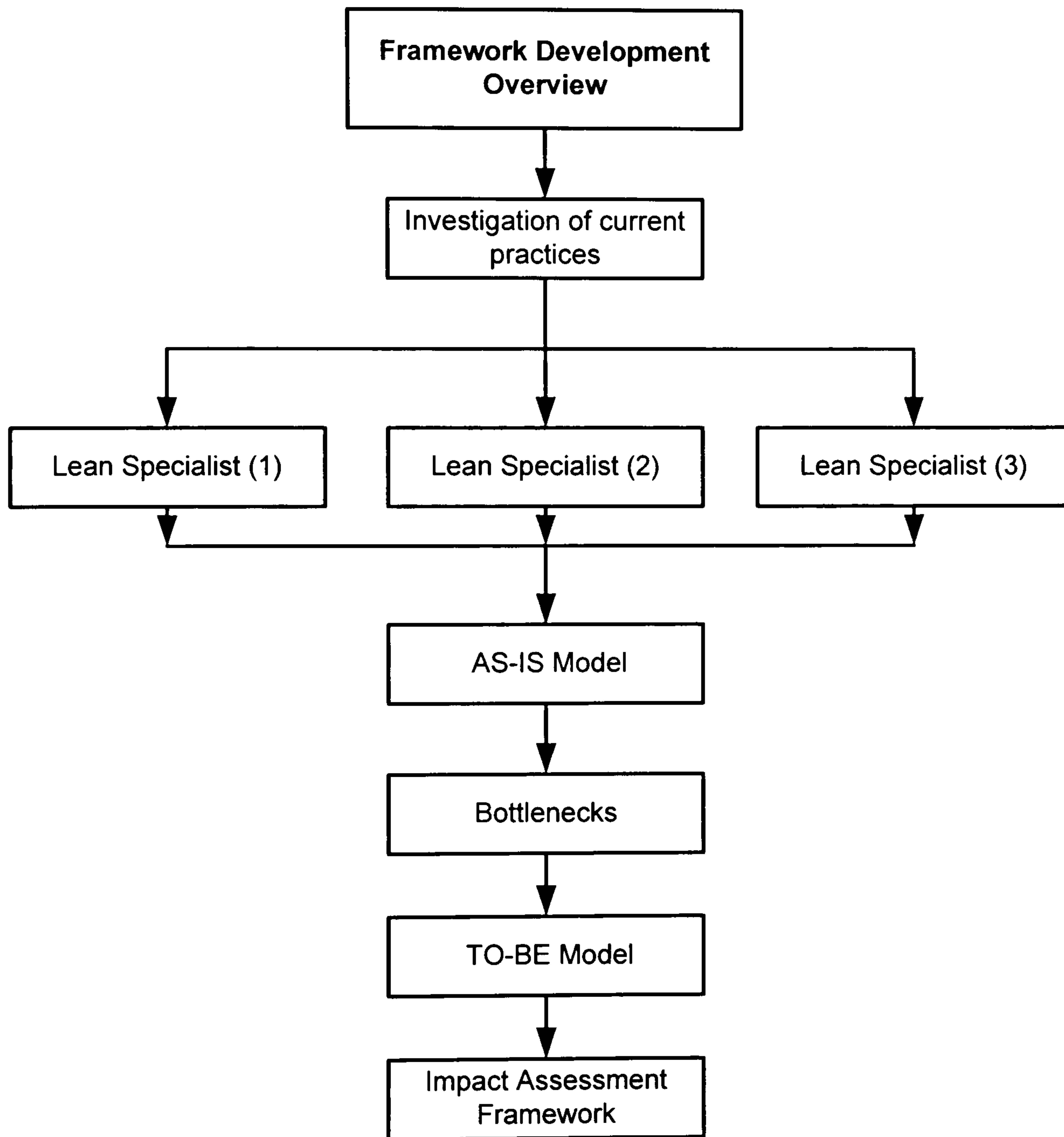
The second lean specialist's approach provided a showcase scenario within its client's business. The format of this company's methodology is organised in a number of modules consisting of presentations exercises and hands-on simulations. The packages are delivered at any point in the lean implementation process and takes from between two to twelve days. Figure (4.4) highlights the assessment process of these three lean specialists.

#### **4.5.1 Comparative Analysis**

A deeper analysis of the approaches used in Figure (4.4), enabled the composition of the similarities and dissimilarities embedded in them. The composition of these three approaches indicated the strengths and weaknesses in their process capabilities. The existence of these traits thus facilitated the mapping-up of all the similarities and



differences within the three approaches referred to as the AS-IS Model. A comparative analysis demonstrated in Table (4.3) provided the research with ability to compare and contrast features within the three approaches. The comparative analysis exercise was conducted with the aid of information obtained from one existing lean manufacturing specialist. A further literature survey was conducted to investigate the conducts of the other two lean specialists.



**Figure 4.4: Assessment of three lean specialists**

The researcher inquired as to how the first lean manufacturing specialist performed lean manufacturing implementation within SMEs. Results showed that particular lean specialist had a framework that demonstrated the activities it performs while, implementing lean manufacturing within these companies. These included; problem

diagnosis within a company they hope to implement lean manufacturing and then follow on other respective activities such as; training of workforce, teambuilding and brainstorming of ideas on why lean is good for an organisation.

**Table 4.3: Comparative analysis of the current approaches**

Companies	Review manufacturing issues	Problem Diagnosis	Conduct training	Enhance teambuilding	Brainstorm ideas on lean	Monitor Project progress
1	√	√	√	√	√	√
2	√	√	√			
3		√	√		√	

#### **4.5.2 Bottlenecks from the Current Practices**

The comparative study presented in Table (4.3) provided the following bottlenecks from the analysis conducted on the three approaches currently in use. These three approaches do not carryout a number of tasks within the confines of impact assessment, but more significantly; they lack the following fundamental characteristics in their lean implementation drives.

- Qualification of degree of lean needs is not addressed within the current practices. These approaches do not consider as to what extent, a particular company may need lean. Questions as to whether a potential lean user actually requires lean manufacturing or something else is not addressed. Current practices also do not take into consideration whether a potential lean user would require the implementation of the concept as whole or on a piece-meal basis.
- Capability assessment is one element not considered within current approaches. They do not assess the capability of the potential lean users in terms of its lean requirements. Moreover, these approaches do not seek to find, if a potential lean user has the required resources in terms of manpower and expertise.



- Pre-implementation exercise is one feature current practices do not take into account. Risk assessment is not carried out at the pre-implementation stage of the project on the three approaches. Risk assessment is important because it enables a potential lean user to assess the overall feasibility of the project's success or failure. This gives a potential lean user good judgment as to whether the project should be postponed to a later date, abandoned completely or whether the company should put in place contingency plans.
- Project evaluation is also not contained within the structures of the current approaches. They do not carry out evaluative assessments of the project's outcomes. Furthermore, they do not consider whether another lean iteration should follow on completion of the first project. In other words, considerations of life after first implementation drive, and its value to the business is not done at all.
- Impact assessment which is the fundamental basis of this research study is not tackled within current practices. Lean specialists 1, 2, and 3 approaches do not carry out a number of important tasks demonstrated above that would be required for ideal lean implementation in companies. Most importantly, current approaches do not assess the overall impact of implementing lean manufacturing on a potential user. These approaches do not provide a potential lean user with a clear picture of the likely costs of the project in terms of direct and indirect costs. Moreover, a potential lean user is not able to forecast any tangible returns on what it may achieve after it has implemented lean. At the same time, the duration of the expected returns on the lean investment is not considered at all by these three approaches.

#### **4.6 Validation of the AS-IS Model**

The AS-IS model was designed and developed based on information and data gathered from industrial practitioners. The collected data was tested, analysed and validated through industrial practitioners and expert opinion. Validation workshops and case

studies were organised at each individual SME. The validation exercise was conducted through workshops and a number of case studies organised with each of the companies investigated. The constituent of the validation sessions embodied two lean specialists, a senior manager of the company lean had been implemented, two shop-floor staff and a lean champion, usually a team leader or a supervisor.

The validation process was initiated by the researcher who asked the senior lean specialist to relay to the audience (validation), the entire lean implementation process. This was sought to include how each lean specialist conduct their business of lean implementation. A flowchart of the entire three lean specialists was made available at each validation session that involved such a company. The main aim of this information was to facilitate the mind-mapping process of lean implementation at the validation session. The whole session was designed to last approximately 3 hours. The researcher played a pivotal role in moderating the contributory insights from the validation team, in order to comprehend whether they concurred with what the senior lean specialist was presenting. However, following are some of the observations and comments made by these experts from the AS-IS exercise.

In particular, the researcher sought to confirm the accuracy of the information captured in the AS-IS lean implementation model highlighted in Figure (4.3). The researcher did this to verify the authenticity, relevance and importance of each activity to lean manufacturing implementation within SMEs. Questions were prompted to the validation panel about information obtained on other lean specialists providers obtained through literature survey. These included the number of days it takes to successfully implement lean manufacturing and how accurate such time projections may be.

Thereafter, the researcher analysed the provided information and further interacted with the respective lean specialists on a consistent basis. This mechanism was elected in order to address the ambiguity that might have arisen in the validation process. Communications with the stakeholders in the validation process were conducted through telephone, e-mail, and fax, and to a large extent, physical engagements.



Furthermore, inputs from academic experts were deemed vital in authenticating the rigour of the research process. Hence, results from the AS-IS model were also validated through various academic publications such as; peer reviewed journals and internationally recognised conferences, detailed in the publication section of this thesis. The AS-IS validation exercise thus yielded the following observation.

- SMEs are characterised by a number of manufacturing issues that restrain their ability to perform effectively.
- In their quest to survive, SMEs take on many ambiguous initiatives that most times fail to add value. Failure of such initiatives has formed part of the lean negation.
- Due to the lack of a structured approach for aiding SMEs in assessing the likely impact of implementing lean manufacturing, many SMEs are unclear as to what is required to carry out the implementation.

## 4.7 Summary

This chapter has presented the investigative results on the SMEs lean manufacturing practices and further highlights the challenges and bottlenecks in these companies. The chapter has stated the SMEs' current management and operational framework. Moreover, how these companies embrace and apply the concept of lean manufacturing within their business is presented and discussed. This has taken into consideration the classes of SMEs in terms of lean usage and how lean specialists conduct their business within SMEs.

The chapter has also addressed the intended set objectives highlighted in Section 3.1.1 thus follows. As part of objective (2), *investigating the operational activities of SMEs in order to understand their manufacturing issues*; this objective has been addressed by unearthing the major manufacturing issues that are deemed to be challenging the successful operations of SMEs highlighted in Section 4.3.

Additionally, the chapter has addressed research objective (3); *exploring the current level of lean manufacturing usage within SMEs, so as to categorise users based on their levels of involvement as follows*. It is realised that SMEs hold different perceptions on the value of lean manufacturing to their business, leading to a categorisation of lean classes mentioned in Section 4.4. It should be pointed out that the Receptive category, which is regarded as currently employing best practices, also do not have a set framework that can structurally guide potential lean users in assessing the impact of lean implementation.

However, in terms of research objective (4); *identifying factors that determine the assessment of lean manufacturing within SMEs*; this has been addressed as follows. The chapter facilitated the accomplishment of objective (4), as it provides factors such as cost of lean, employees' skills and the level of value-add expectations from a prospective lean project. Hence, the accomplishments of these objectives relate to the hypothesis presented in Section 3.4, which concerns SMEs' inability to embrace lean manufacturing concepts. Thus, to achieve this assumption, an understanding of the lean impact in terms of the cost-benefit analysis is conducted.



## CHAPTER (5)

# 5 DEVELOPMENT OF AN IMPACT ASSESSMENT FRAMEWORK FOR LEAN MANUFACTURING WITHIN SMEs

### 5.1 Introduction

A review of numerous lean manufacturing tools, techniques and frameworks were conducted in Chapter 2. Subsequent company investigation presented in Chapter 4 was aided by the research methodology highlighted in Chapter 3. These exercises were done in order to examine, analyse and determine their relevance to the research study. Conclusive observations from the review and company investigations demonstrated in the above-stated chapters drew a number of research questions. Of particular interest, it was observed that; existing lean manufacturing tools, techniques and frameworks do not perform impact assessment for lean manufacturing within SMEs.

To overcome the above drawback, an impact assessment framework for lean manufacturing within SMEs is proposed. Thus, in this chapter, the development process of the impact assessment framework for lean manufacturing within SMEs is presented. The chapter also describes the data collection and validation process followed. The chapter therefore aims to:

#### **Chapter aim:**

Demonstrate, discuss and summarise the development process of the impact assessment framework for lean manufacturing within SMEs.

To achieve the above aim, the chapter has been structured as follows. Section 5.2 provides the motivating factors and the data collection process used in developing the impact assessment framework. An analysis of the impact assessment is contained in Section 5.3. Section 5.4 presents and describes the framework development process. Section 5.5 demonstrates the functionalities of the developed framework. The overall chapter content is summarised in Section 5.6.



## **5.2 Motivation and Data Collection Process**

The motivation for developing an impact assessment framework for lean manufacturing implementation, is to enable small-to-medium manufacturing enterprises (SMEs), assess the impact of implementing lean concept within their business at an early implementation stage. Businesses should be able to evaluate their current operations in terms of; “where they are, where they are going and where they would like to be. By examining itself through such questions, a business will know whether the adoption of lean manufacturing would be a worthwhile initiative.

To achieve this objective, the research intended to find out reasons pertaining to company desires to adopt the concept of lean manufacturing generically. Iterative dialogue with collaborative stakeholders, compounded with literature survey provided a number of reasons. These are research and development (R&D), problem driven and competitive rivalry. The above reasons were compounded with the scenario analysis of the cost, readiness and lean impact factors on the set of the investigated SMEs whose characteristics are outlined in Table (5.1). The provision of such information helped in the formulation of the impact assessment factors listed in the previous cited table (cost, readiness and impact/benefits). The gathered data were analysed and validated through various expert sources that embodied people in academia and industry to authenticate the validity and its accuracy.

## **5.3 Analysis of Impact Assessment**

Impact Assessment (IA), is the evaluation of the components that involve lean implementation and expected return thereafter. First and foremost, a business or a company needs to consider the positive and negative effects of implementing lean on the overall business performance. Additionally, there are numerous outcomes lean implementation is anticipated to contribute to a company's productive performance. For example, a company needs to spend some resources to launch lean prior to the eventual derivation of any benefits. Such resourceful commitments are treated in the framework as the cost, or the negative impact of lean implementation. This is because; the resources being invested will automatically affect a company's position resource-wise in the short-term.



The other lean effect on a business can be analysed as the benefits (impact), a company attains after its successful implementation. In other words, the return on investment (ROI) or value-add of what the implementation of lean would bring to a business. Given the dearth of knowledge on this subject, visa-vie the importance attached to the two sides of the lean effect to a business, this research has therefore investigated the influence of both factors into detail.

### **5.3.1 Quantitative Vs. Qualitative Impact Assessment**

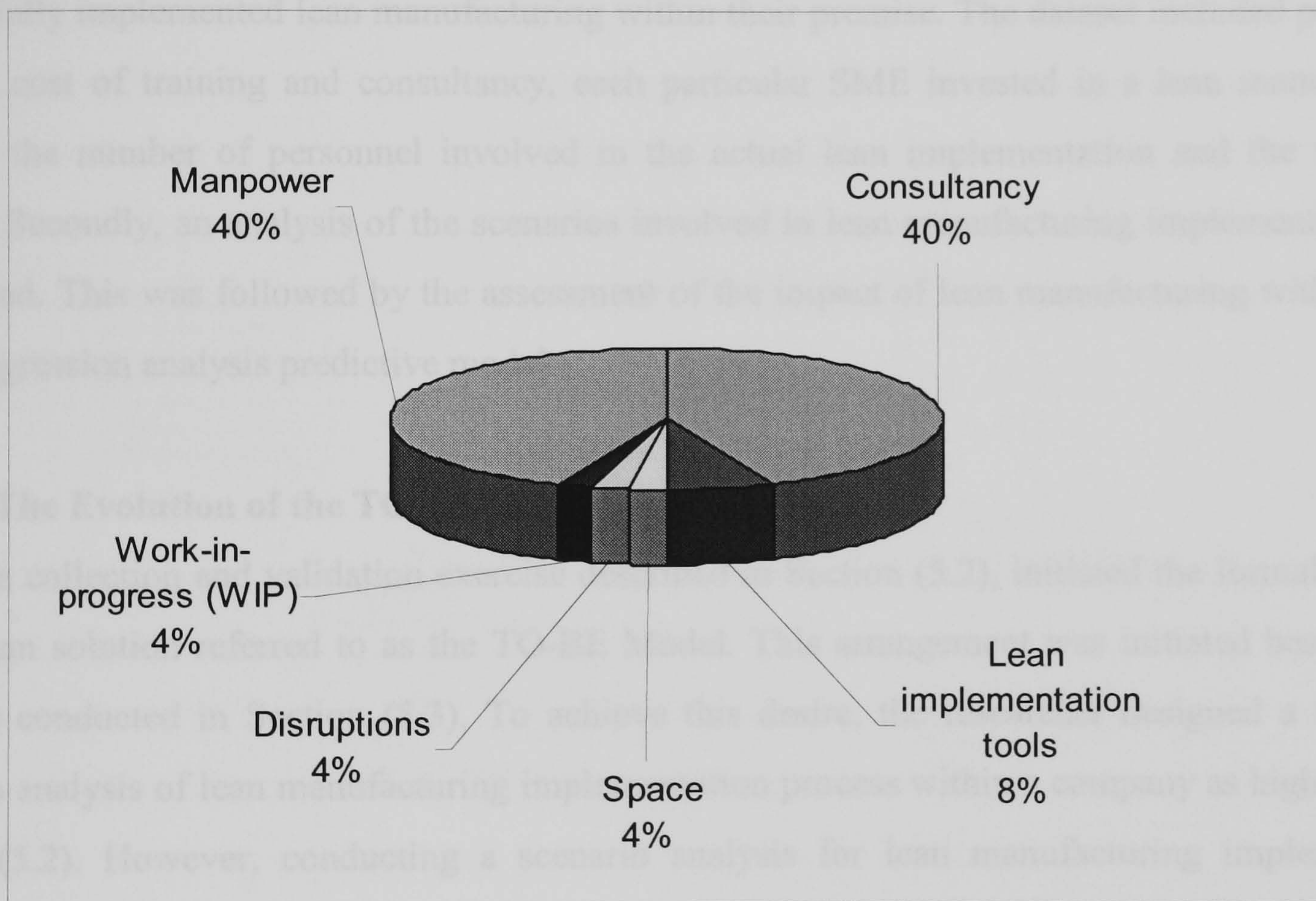
Quantitative aspects of the lean impact are referred to items that can be assigned numerical figures, hence easier to measure. Meanwhile, qualitative aspects of the lean impact refer to items that are not easily identifiable, thus difficult to quantify. In essence, negative impact (cost of lean implementation) are categorised in twofold, direct and indirect costs. Direct costs are quantitative, whereas indirect costs are hidden costs that are not easily identified, thus treated qualitatively. Examples of direct costs are issues such as cost of training and consultancy. Indirect costs embody issues like; the cost values assigned to work-in-progress (WIP), as workforce abandons routine operation in order to attend lean activities.

Positive impact (benefits of using lean) are also divided into to classes; tangible and intangible benefits. Tangible benefits are identified easily and are quantifiable. They are measurable outcomes resulting from lean application and can thus be assigned financial figures. Examples are; reduction in lead-times, increase in productivity and consequently, the financial returns achieved, commonly referred to as ROI. Intangible benefits refer to unforeseeable benefits derived from lean such as; results of motivated workforce emanating from good organisational culture lean may bring.

However, hypothetical inference had earlier on been drawn on the likely cost drivers engaged in a potential lean project. These inferences were obtained from discursive interactions with company practitioners while the research analysed the practices of some SMEs in lean utilisation discussed in Chapter 4. However, one of the key observances made was the perception held by most of the SME practitioners on what constituted lean cost drivers and their proportions as summed up in Figure (5.1).



Never-the-less, most investigated SMEs believe the implementation of lean manufacturing would attract certain costs such as; the fees to pay for a consultant who should be able to plan and guide the lean manufacturing implementation process. It thus appeared most investigated SMEs anticipated consultancy fees and effort of manpower to be the two most significant cost factors in such a project, since they each represent up to 40 percent. However, other factors such as WIP and disruptions had lesser percent attraction each. This implies that WIP did not constitute a major constraint in the mindsets of these company practitioners. Moreover, disruption to their business was treated as something minor, perhaps because of the fact that they would not commit to any project whose initial negative effect on their business performance is viewed as adverse.



**Figure 5.1: Proportion of lean cost drivers**

In any case, most firms seemed to plan their lean interventions in such a manner that enabled their staff to continue operations under such circumstances. For example, within a given department, a few staff may be selected to continue with routine schedules, as the other set of employees attend the lean project engagements. However, as lean is implemented, certain interventions may require realignments of the process flow within the shop-floor. In return, this may affect machinery,



wherever they might be shifted. The problem with such a task is that companies are then required to make provisions for extra holding spaces, which usually comes at an extra cost, in terms of rates and maintenances. Space and lean implementation tools (tape measures and paints, for example), appear to constitute a minor percent margin. Moreover, venue was not considered as a cost incurring factor since employees may be trained within the manufacturing environments whose cost would have been catered for already.

## **5.4 Framework Development Process**

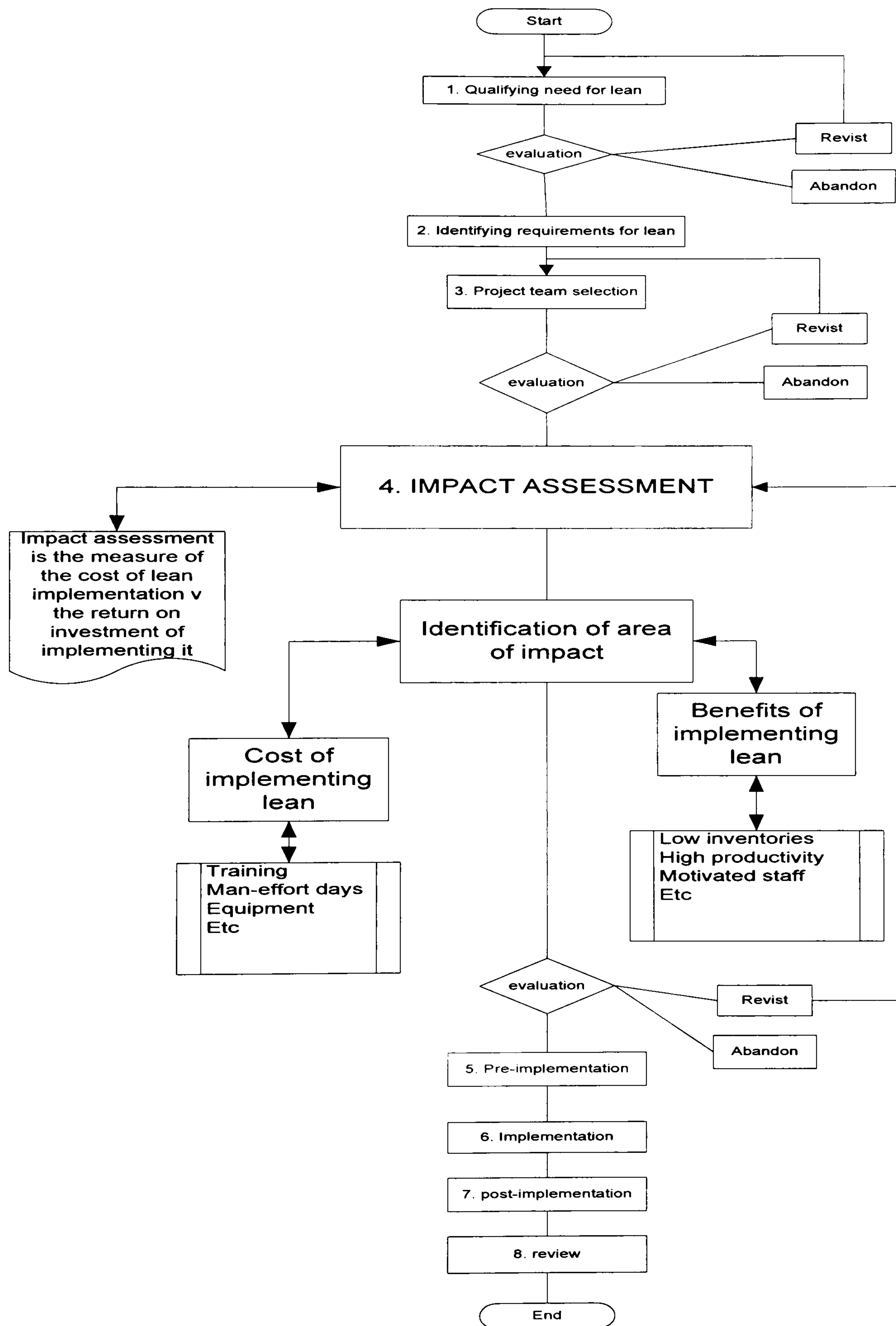
The development of the impact assessment framework for lean manufacturing within SMEs encompassed various research processes. Firstly, the data were collected from companies who had successfully implemented lean manufacturing within their premise. The dataset included parameters such as cost of training and consultancy, each particular SME invested in a lean manufacturing project; the number of personnel involved in the actual lean implementation and the value-add returns. Secondly, an analysis of the scenarios involved in lean manufacturing implementation was conducted. This was followed by the assessment of the impact of lean manufacturing within SMEs using regression analysis predictive model.

### **5.4.1 The Evolution of the TO-BE Model**

The data collection and validation exercise described in Section (5.2), initiated the formalisation of a problem solution referred to as the TO-BE Model. This arrangement was initiated based on the analysis conducted in Section (5.3). To achieve this desire, the researcher designed a structured scenario analysis of lean manufacturing implementation process within a company as highlighted in Figure (5.2). However, conducting a scenario analysis for lean manufacturing implementation within a business was considered ideal, since it provided the researcher with a platform for consolidating the fundamental issues such as; why a company may want to implement lean manufacturing (qualifying lean need). This activity was also deemed useful because it presented the researcher with the capacity of understanding how companies' lean need may subsequently impact on the overall cost of its implementation, as discussed further in Section 6.3.1. Hence, the scenario analysis structure consisted of eight logical phases as highlighted below.

Phase one of the scenario analysis focuses on where the business qualifies its need for lean. This analogy was derived based on the inference that; a company can qualify its need for lean by carrying

out investigations of its current manufacturing issues. This is an important objective within the premise of the framework, since it would enable a business to identify, determine and recognise the issues that its business faces before it can think of solving any problem.



**Figure 5.2: Critical Evaluation of the Structure of Lean Manufacturing Implementation**



This could be carried out through a process mapping approach, where a firm takes an overall view in making a clear assessment of where lean would be most needed within its organisation. For example, qualifying need for lean takes into consideration issues such as the lead-times and high inventory levels. If results of this initial phase are not conclusive, the project may be reassessed or abandoned completely.

Phase two considers a potential lean user's level of requirements. This stage determines whether the company is intending to apply lean for the first time in its business. If so, then such a company's requirements for lean like consultancy and training may be huge since such a firm may not have had the necessary experience as Repeat or Continual users.

Phase three dealt with the assessment of a company's resources in terms of manpower and timescales. A company has to identify the people it expects to select for the project. If this is not sufficient, then it may abandon the project completely, or revisit it as demonstrated in phase one. The next phases are impact assessment, pre-implementation, implementation, review and evaluation respectively. However, this research study interest concentrated on the impact assessment phase as a significant aspect of decision-making process for lean application within a business.

## **5.5 Functionality of the Impact Assessment Framework (TO-BE Model)**

Impact assessment is conducted by the definition and the identification of costs drivers that the implementation of lean would accrue to a business. Once the motives of why lean is needed for a company is known, then factors that are anticipated to generate cost during the implementation phase can thus be identified. These factors are obtainable while identifying requirements for lean. They are the lean drivers required for implementing a successful lean project to a company. These factors can be considered for example as; the cost of venue for training, consultancy or specialised guidance on lean implementation, training on lean principles plus other logistical requirements.

As lean gets implemented its initial intervention does affect some business drivers within the company in the short-term as illustrated in Figure (5.3). Such effects generate costs that a company wishing to implement lean should acknowledge and account for. The more often affected business drivers can be identified as the customer and workforce.

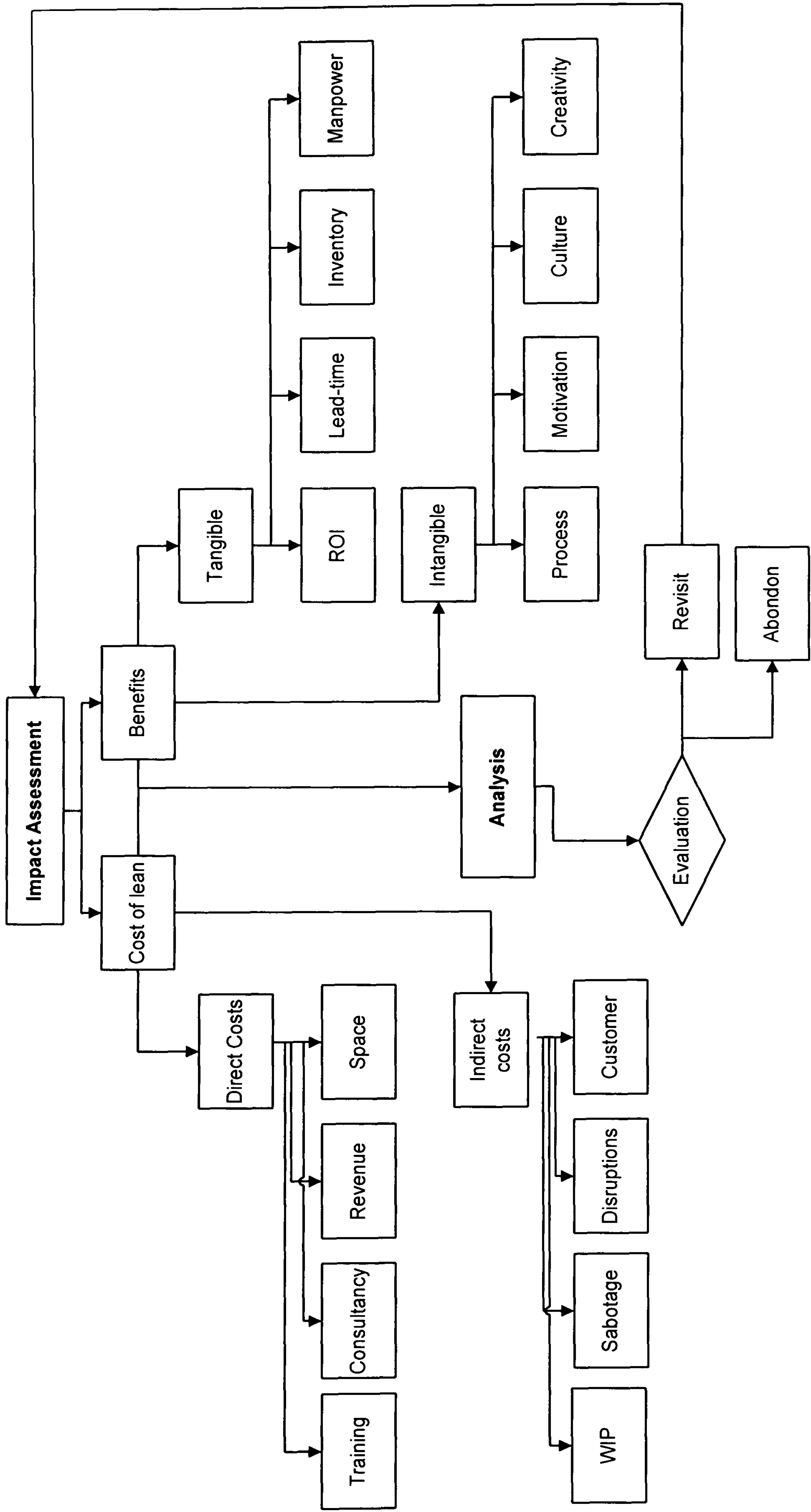


Figure 5.3: Impact assessment Framework (TO-BE Model)



It is evident that the implementation of lean manufacturing in the initial stages causes disruptions to the process flows. This is because; things get scattered within the area of intervention as the new system is put in place.

Ultimately, such occurrences affect the productivity cycle times which also impact on the delivery time. Consequently late deliveries to the market brought about by the aforementioned issues have adverse effects on the overall business performance. For example, a company's financial position is affected since income may be tied up due to long payment days. Moreover, customers may also get dissatisfied and switch to other providers, hence a reduction in customer retention portfolio.

The other business driver that may be affected is the workforce performance level. When news of lean uptake is spread across the enterprise, employees most times think of it mainly as a job cutting exercise. They fear that lean would shed their positions within the company, therefore they become demoralised. In such instances, workforce may deliberately under perform, resulting into under capacity affecting the targeted output yields and its quality. This means that costs on defected products rise, as they will have to be re-worked, rejected or thrown away completely as wastes. Furthermore, under capacity also leads to discontentment from customers as well as loss of revenues.

### **5.5.1 The deployment of Regression Analysis**

The proposed TO-BE Model's functionality was conceptualised with a deployment of a predictive model regression analysis (RA). A list of company parameters was identified to facilitate the operationalisation of the predictive models' functionality. These included details of companies characteristics demonstrated in Table (5.1). The essence of testing these company details using regression analysis model was to find out whether there existed certain relationship(s) amongst some or all of the listed parameters. For example, a number of tests were carried out in attempts to realise the above desire. Specifically, input parameters such as gross value-add from a potential lean achievement was tested against a projected cost of implementing lean.

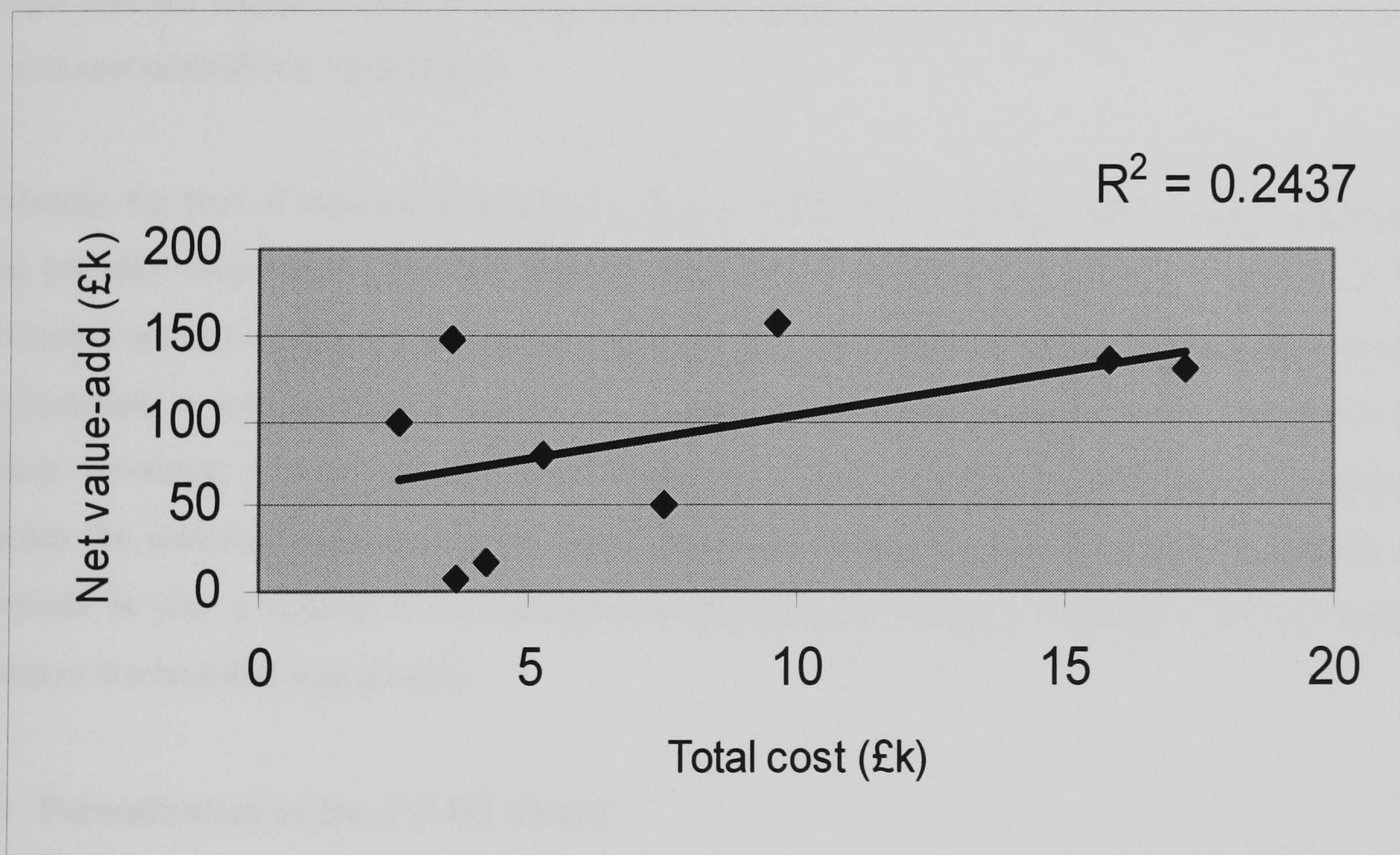
**Table 5.1: Characteristics of the investigated SMEs**

	<b>Nature of business</b>	<b>Years in operation</b>	<b>Workforce capacity</b>	<b>Number of Employees involved in lean project</b>	<b>Annual turnover (£m)</b>	<b>Main reasons for implementing lean</b>	<b>Duration of implementation (weeks)</b>	<b>Total cost of lean implementation (£k)</b>	<b>Gross value-add in pounds (£k)</b>	<b>Duration of ROI (months)</b>
<b>Company 1</b>	Electronics	28	65	25	3.20	Optimisation	2	5.0	412.0	3.00
<b>Company 2</b>	Cable assembly	25	207	20	15.00	Competition	4	12.0	289.0	3.00
<b>Company 3</b>	Vibrations controls	25	30	6	1.40	Clear vision	4	7.0	70.0	1.00
<b>Company 4</b>	Computer recycle	10	15	14	0.75	Disparate operations	4	2.5	85.0	1.50
<b>Company 5</b>	Framed arts	23	102	40	6.00	Competition	4	4.0	1,104.0	2.50
<b>Company 6</b>	Sheet metals	34	70	20	3.80	Competitive advantage	2	2.5	803.0	1.00
<b>Company 7</b>	Plastic materials	15	50	8	2.50	Communication	4	4.0	100.0	1.50
<b>Company 8</b>	Vehicle care products	30	120	8	17.50	Cost reduction	4	2.5	147.0	3.00
<b>Company 9</b>	Passenger & goods lifts	22	100	11	5.00	Cost reduction	4	4.5	125.0	3.00
<b>Company 10</b>	Furniture	8	8	7	0.40	Cost reduction	4	3.0	45.0	1.50



In order to achieve a determined line of best fit, a correlation representing an  $R^2$  of 0.7 onwards was desired. A number of parameters contained in Table (5.1) were matched against each other to test for any correlations as exemplified in Figures (5.4).

The research extracted the highlighted parameters for further analysis. The first test was conducted on the net value-add figure verses the total cost of lean implementation. When the RA test was run using linear regression, an  $R^2$  of 0.2437 was achieved. These scenarios rolled out on the other identified parameters listed in Table (5.1). Moreover, tests were also carried out using non-linear regression. Results highlighted very low  $R^2$ . However, it could be observed that a number of outliers appeared within the line of best fit. Some of the extreme outliers were removed with the hope of improving the outcome. The highlighted results thus presented the research study with a stalemate, as no conclusive inference could be drawn based on what the RA tests had contributed.



**Figure 5.4: Analysis of lean cost verses net value-add**



### **5.5.2 Regression Analysis Results**

Results from regression analysis yielded no correlations between the parameters used in the tests as described in the previous section. No conclusive inferences could be derived as to why such results occurred because the dataset used in the predictive model was tried and tested for accuracy with the respective companies involved in the research investigation, for the purpose of validation. Hence it was concluded that the biggest cost factor so far, based on these analysis, is the time of people involved in the actual lean implementation. This assertion stemmed from the fact that external consultancy cost is calculated for a specified period of time, therefore it may be fixed.

Moreover, evidential insights provided that most times, implementation of a lean project to a company does not need more than two lean specialists (consultants), whose major roles would be to plan, execute and direct the available resources with a potential lean implementing company. Additionally, these lean specialists have the expertise knowledge of how to implement lean concepts and are therefore able to define realistic timescales of how long lean interventions may take as a cost controlling mechanism.

Conversely, the cost of internal manpower is always variable depending on the size and experience of the potential employees involved. The involvement of the internal manpower capacity in lean intervention usually means the abandonment of routine job tasks. Therefore, when these activities are quantified, a substantial cost effect is realised by companies who desire to embrace lean ventures. However, it was realised that the biggest cost item (internal manpower) also does not influence the resultant outcome of the other parameters tested against it. It may be argued, this occurrence is just a reflection of management decision in setting a timetable of how long to implement a scheduled lean project.

### **5.5.3 Formalisation of the TO-BE Model**

As a result of the observations highlighted in the previous section, a decision was made to formalise the impact assessment framework for lean manufacturing using company case studies. The rationale for adopting this line of approach was to initiate further case studies in attempts to find out what might have contributed to the failure of relationship building discussed in the previous section. A number of issues were brought into contention. These included a company starting point of lean



implementation, the type of market pressure engulfing them, and whether such a firm had previous lean experience. A ratio analysis was desired in determining these companies' lean starting points. It was believed this approach would aid a further definition of the relative contribution of each cost factor. Consequently, a net value-add figure of each company was divided against the total cost of the lean implementation. Results achieved provided ratios that enabled the conclusive judgment of where most of these companies fitted within the designed matrices based on the averages and standard deviation. Company expertise were sought to confirm the standing of these firms' ratios as, the provided figures were also company availed. However, this line of thought could not lead to a meaningful and timely conclusion; hence the research opted to adopt other alternatives.

## **5.6 Summary**

This chapter has presented a description of the lean manufacturing impact assessment framework development process. It provides the data collection and validation methodologies used. Moreover, the functionality of the framework is highlighted and results achieved are discussed. Hence, the chapter has achieved the research objective (5) set out in Section 3.1.1; *developing and impact assessment framework for lean manufacturing implementation within SMEs*, by performing the following. An impact assessment framework for lean manufacturing within SMEs was designed and developed using the dataset collected from SMEs who had previously implemented lean manufacturing within their business. This Task was conducted in order to address the hypothesis presnetd in Section 3.4 that presumes an understanding of the lean impact in terms of cost-benefit analysis would motivate SMEs lean uptake. The framework development process thus underwent through a number of stages that involved the designed of a TO-BE Model and further formalised with the case studies involving companies. A regression analysis failure to realise expected correlation between the companies' dataset thus motivated the implementation of the developed framework using an alternative expert system to address this problem.

## CHAPTER (6)

# 6 DEVELOPING A KNOWLEDGE-BASED ADVISORY SYSTEM

### 6.1 Introduction

In the previous chapter, the development of an impact assessment framework for lean manufacturing within SMEs was conducted. The chapter also presented how Regression Analysis predictive model was initiated within the developed framework. However, there appeared inconclusive outcomes, on a number linear and non-linear tests carried out on these exercises; perhaps due to data impreciseness described in Section 5.1.1. Consequently, a fuzzy expert system was selected to try and address this impasse. This is because; fuzzy expert systems offer the capability of capturing natural language of people and convert it into computational language which can be used for decision-making in daily life. Hence, Chapter 6 outlines and discusses the development of a knowledge based advisory system for implementing the developed impact assessment framework for lean manufacturing within SMEs, presented in Chapter 5. This chapter therefore aims to:

#### **Chapter aim:**

**Develop a knowledge based advisory system for implementing the developed impact assessment framework presented in Chapter 5**

To achieve the above aim, the chapter has been structured as follows. An overview of the creation of a fuzzy inference system is outlined and discussed in Section 6.2. Section 6.3 provides the development process of the knowledge based advisory system. In Section 6.4, the developed system's functionalities are demonstrated. The final heuristic rules generated by the knowledge based advisory system are illustrated in Section 6.5. Section 6.6 presents the available conditions within the knowledge based system for decision-making. Section 6.7 summaries the work presented in the overall chapter.



## 6.2 Overview of Fuzzy Inference Systems

The knowledge based advisory system described in this chapter was developed with the aid of a fuzzy logic expert system. However, creation of a fuzzy logic involves the design of a Fuzzy Inference System (FIS).

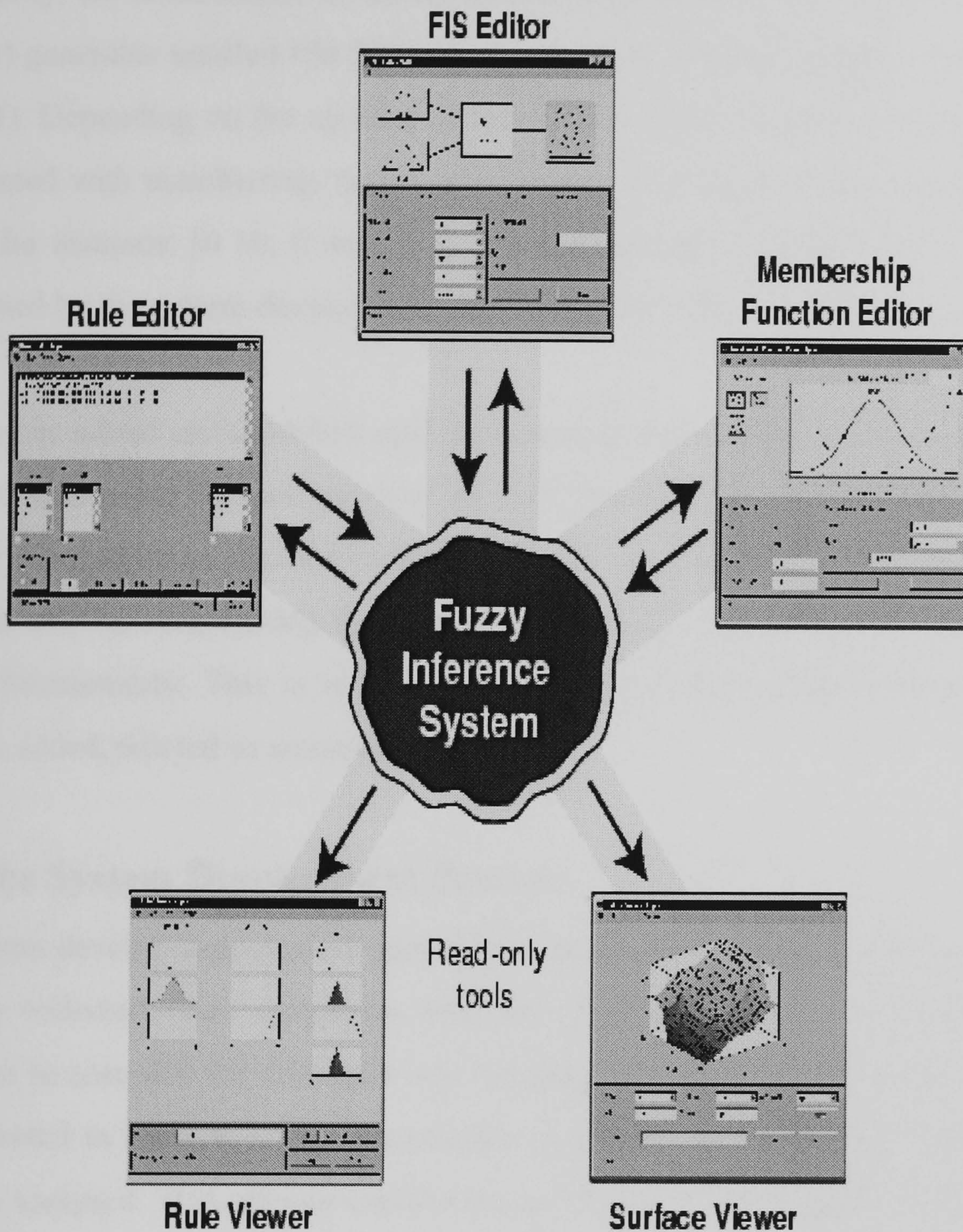


Figure 6.1: An illustration of the 5 principle components of the FIS (Roy, 2003)

FIS is the overall architecture that drives the operations of a fuzzy system. Furthermore, the development of the FIS is facilitated by the use of MATLAB toolbox that generates this system. A diagrammatic illustration of the five principle components of the Fuzzy Inference System in the



MATLAB toolbox is highlighted in Figure (6.1). As can be visualised from the Graphical User Interface (GUI) tools demonstrated in the aforementioned figure, the GUI is used in the facilitation of the design and development of the Fuzzy Inference System for decision-making process.

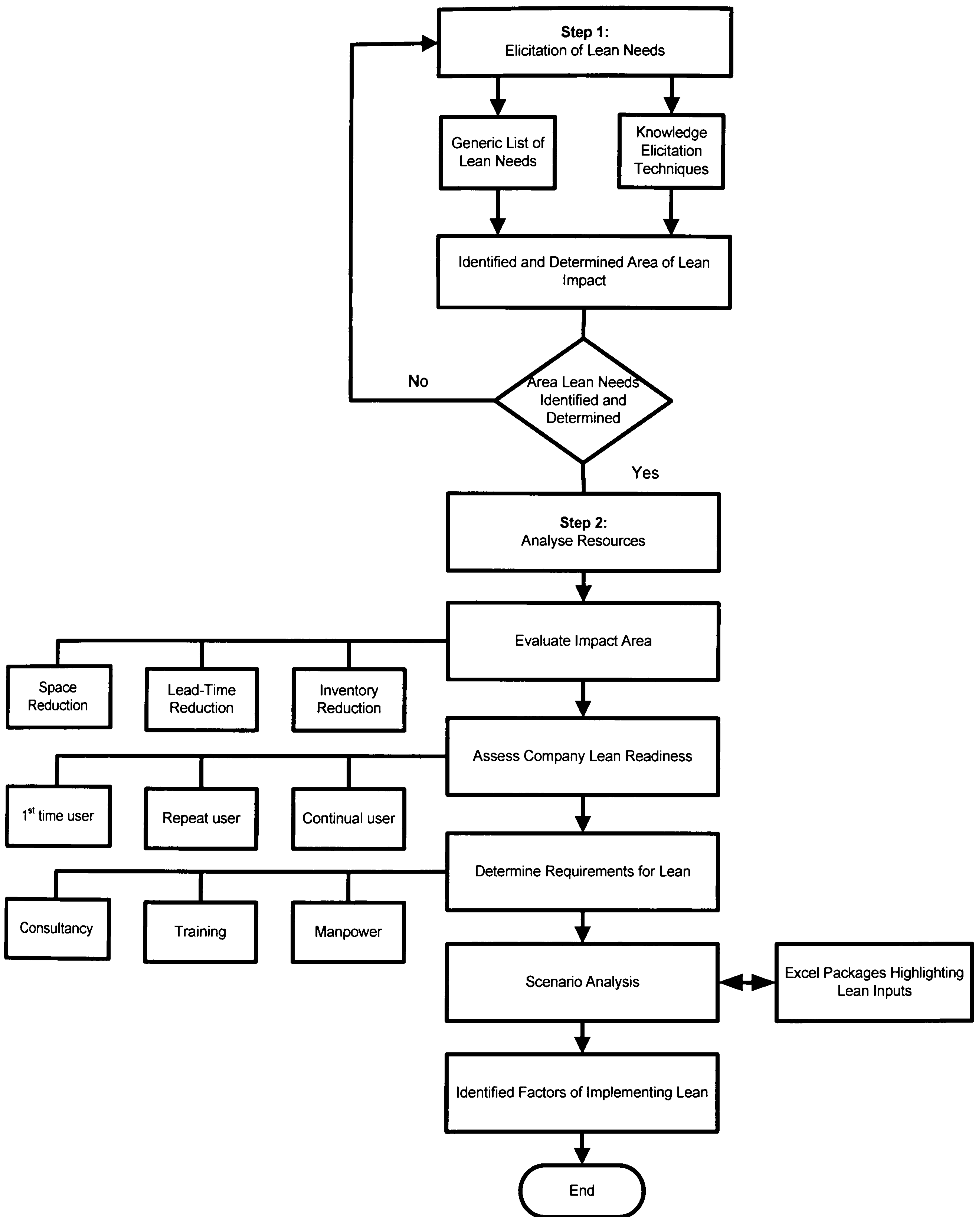
In summary, the functionality of the GUI is commenced as follows. A MATLAB prompt (command window) generates untitled FIS Editor with an input labelled; (input1) and another output labelled (output1). Depending on the number of inputs the system is expected generate, each input variable is presented with membership functions. These require range setting which depends on the chosen vector, for instance; [0 10, 0 and 100]. The membership functions and the desired set ranges are determined by the system development, in accordance with the expected outcome.

This may be edited and modified until such desired limit. Additionally, membership functions have different types of curves such as; trimf, trapmf, gbellmf, gaussmf, sigmf dsigmoid and smf. Moreover, they are selected based on their suitability for the set tasks. On completion of naming the selected variables and the membership functions, one can thus write down the rules governing the overall system functionality. This is achieved by the use of Rule Editor, where the input rules can be selected, added, deleted or amended.

### **6.3 The System Development Process**

The system development process passed through several stages. The first stage was the analysis of the data collected from companies who had implemented lean manufacturing previously. It is important to note that the data used was the same one used in the testing of the regression analysis demonstrated in Section 5.5.1. In particular, a number of lean impact factors were identified and critically analysed. This activity entailed the involvement of a number of parameters namely; cost of lean implementation, a company lean readiness status and the value-add returns (benefit/impact), as presented in Sections 6.3.1-6.3.3 respectively. To achieve these requirements, company lean needs had to be elicited as presented in Figure (6.2).





**Figure 6.2: Lean Needs elicitation Scenario**

**Table 6.1: The lean needs elicitation techniques**

<b>Technique</b>	<b>Strength(s)</b>	<b>Weakness(s)</b>
Concept sorting	<ul style="list-style-type: none"> <li>○ Draws interactions</li> <li>○ Fast and easy to use for experts</li> <li>○ May lead to visualisation of structures</li> </ul>	<ul style="list-style-type: none"> <li>○ Familiarity of domain knowledge is a must</li> <li>○ Failures to distinguish dimensions</li> <li>○ Bias and over simplification of category</li> <li>○ Retards comprehensiveness</li> </ul>
Expert sources	<ul style="list-style-type: none"> <li>○ Experienced judgement</li> <li>○ Reliability in information</li> </ul>	<ul style="list-style-type: none"> <li>○ Difficulty in extraction in case of humans</li> <li>○ Time consuming</li> <li>○ Consensus building may be difficult</li> </ul>
Focus group	<ul style="list-style-type: none"> <li>○ Dedicated to the cause of problem solve</li> </ul>	<ul style="list-style-type: none"> <li>○ Time consuming</li> <li>○ High cost</li> </ul>
Interviews	<ul style="list-style-type: none"> <li>○ Communication opportunity</li> <li>○ Wide level of information</li> <li>○ Promotes knowledge construction</li> <li>○ Ease of analysis</li> <li>○ Resolve to abstraction of detailed knowledge</li> <li>○ Flexible</li> </ul>	<ul style="list-style-type: none"> <li>○ Require high order of communication</li> <li>○ Requires interpersonal skills</li> <li>○ Deeper domain knowledge</li> <li>○ possibility of bias</li> </ul>
Laddering	<ul style="list-style-type: none"> <li>○ Good for early exploration of documents</li> </ul>	<ul style="list-style-type: none"> <li>○ Requires high level negotiation skills in persuading experts to elaborate</li> </ul>
Literature survey	<ul style="list-style-type: none"> <li>○ Stimulates thinking</li> <li>○ Promotes new findings (gap analysis)</li> <li>○ Ease of access</li> <li>○ Forum for disseminating ideas</li> </ul>	<ul style="list-style-type: none"> <li>○ Lack of control in information</li> <li>○ Verification of facts may be difficult</li> </ul>



**Table 6.2: The lean needs template**

<b>Need</b>	<b>Cause(s)</b>	<b>Effect(s)</b>
High level inventory	<ul style="list-style-type: none"> <li>○ Build-to-stock</li> <li>○ High demand expectation</li> <li>○ Unplanned schedules</li> <li>○ Seasonality</li> </ul>	<ul style="list-style-type: none"> <li>○ Material wastage</li> <li>○ Costs on rent and maintenance</li> </ul>
Poor material handling	<ul style="list-style-type: none"> <li>○ Longer moves</li> <li>○ Longer travel distances</li> <li>○ Complex routes</li> </ul>	<ul style="list-style-type: none"> <li>○ machine breakdown</li> <li>○ high level of WIP</li> <li>○ Poor fault detection</li> <li>○ Poor staff/process monitor</li> </ul>
Complex manufacturing flow	<ul style="list-style-type: none"> <li>○ Poor planning</li> <li>○ Poor flow stream of components, products and information</li> </ul>	<ul style="list-style-type: none"> <li>○ Longer setup times</li> <li>○ Longer lead-times</li> <li>○ Longer delivery-times</li> <li>○ Longer payback period</li> <li>○ dissatisfied customers</li> </ul>
Poor quality products	<ul style="list-style-type: none"> <li>○ Producing wrong specification</li> </ul>	<ul style="list-style-type: none"> <li>○ High rejects</li> <li>○ Dissatisfied customers</li> <li>○ Financial loss</li> </ul>
Low productivity	<ul style="list-style-type: none"> <li>○ Staff under utilisation</li> <li>○ Low OEE</li> <li>○ Machine breakdowns</li> <li>○ Poor planning</li> </ul>	<ul style="list-style-type: none"> <li>○ Under delivery to the market</li> <li>○ Loss of revenues</li> </ul>
Dissatisfied customer	<ul style="list-style-type: none"> <li>○ Supply of wrong products</li> <li>○ Poor quality products</li> <li>○ Late delivery</li> <li>○ Under delivery of quantities demanded</li> </ul>	<ul style="list-style-type: none"> <li>○ Loss of customer base</li> <li>○ Loss of revenues</li> <li>○ Bad reputation</li> </ul>
Longer lead-times	<ul style="list-style-type: none"> <li>○ multiple flow lines</li> <li>○ too many change overs</li> <li>○ machine breakdowns</li> <li>○ Bottlenecks</li> </ul>	<ul style="list-style-type: none"> <li>○ Long delivery times</li> </ul>
Poor employees team ethos	<ul style="list-style-type: none"> <li>○ Poor communication</li> <li>○ Employee ineffectiveness</li> <li>○ Undervaluation of employees</li> <li>○ Weak corporate cultures</li> <li>○ Poor management/leadership traits</li> </ul>	<ul style="list-style-type: none"> <li>○ Low level productivity</li> <li>○ High defects</li> <li>○ high rejects</li> <li>○ Low rate of turnover</li> </ul>

Thus, it was inferred that lean needs elicitation can be conducted using a number of knowledge elicitation techniques described in Table (6.1). These techniques have both strengths and weaknesses that can provide choices of suitability in conducting this task. Moreover, a number of lean needs can be availed from company sources.

However, the two functions of the lean needs elicitation are then used to identify and determine a potential company lean needs and the subsequent area of impact. These lean needs can be tested and qualified using the elements of generic lean needs contained in the lean needs template displayed in Table (6.2).

The identified company lean needs are thereafter qualified by matching a particular company's available resources. This process is conducted by the facilitation of step two of the final framework in Figure (6.2), which is the resource analysis phase. For example, if the identified lean needs provided that a company has high level inventory, the causes are considered to be; the building of stock levels, unplanned schedules and seasonality, as demonstrated in Table (6.2). The resultant effects on these issues are material wastage and obviously overhead costs on rent and maintenances of the warehouse. Equally, companies' financial position shall pre-determine the urgency of the "need". Resource analysis then enables a company to make critical judgments of lean affordability (manpower and other lean factors).

On completion of the resource analysis, the impact areas of lean applicability are thus evaluated. This process is set to include the investigation of whether implementing lean would improve areas such as lead-time reduction and space reduction. However, if it is contended that all is possible, then a company's lean experience is prejudged to determine the degree of lean readiness. Results would then be used to determine the level of lean requirement for a company whether on a piecemeal or wholesome basis. A scenario analysis is then conducted with the aid of a Microsoft Excel package highlighting lean inputs as illustrated in Table (6.3).

The above task within the developed framework encapsulates information obtained from company scenarios that had implemented lean previously. It also abstracts the fundamental variables that are



deemed to impact the cost and benefits of lean. For example; goodness at lean and poor at lean versus small company, and large company as illustrated in Table (6.3).

**Table 6.3: SMEs lean scenario analysis**

<b>Company Lean Status</b>	<b>Company size 1 Small</b>	<b>Company size 2 Large</b>
Good at lean	5-15k	25-100k
No lean at all	10-25k	50-200k

The above scenario exemplifies how a company lean need may be identified based on factors such as company size, lean experience and the cost structures of company samples that had previously implemented lean manufacturing. This analogy is meant to act as a precursor in stimulating the perception and eventual persuasion of a potential lean implementing company. On completion of the scenario analysis, the second stage of the system development process involved the lean impact analysis presented in Section 6.3.1. Result from the analytical exercise in Section 6.3.1, was then used to design three knowledge based advisory sub-systems (1-3), as illustrated in Figure (6.3).

### **6.3.1 Analysis of Cost Impact**

The cost impact of lean manufacturing implementation has some attributes that can be summarised as follows:

#### **(I) Company Size (Workforce Capacity)**

Size of a company influences the overall cost of implementing lean manufacturing within a company due to the following reasons. To implement lean manufacturing, a company needs to select people to be trained on the use of lean concepts. Therefore, the number to be trained will determine the cost. This implies that, the higher the number of people to be trained, the higher the cost of training. There also exists the cost of employees being distracted away from their routine schedules as they attend lean manufacturing activities. Employees become unproductive at such moments, hence a cost impact to the company concerned.

### **(ii) Company Lean Experience (Readiness)**

How ready a company is in embracing lean manufacturing, has significant bearing on the actual cost of its implementation. Companies (SMEs) who implement lean manufacturing within this research context can be referred to as *receptive*. Receptive SMEs fall within three categories of lean readiness. There are those SMEs who are receptive but have not implemented lean manufacturing before. They are termed as First-time users. First-timers are SMEs whose degree of lean readiness is low because they require a very high level of resources and other relevant ingredients to implement lean.

For example, they require money for employees' sensitisation about the benefits of lean manufacturing. They also require money for training in the use of lean principles as well as consultancy fees. This is because; First-timers would not have implemented the lean concepts before, therefore their employees need to undergo proper training in the use of lean concepts and tools, a process that can take longer to grasp for a First-Timer.

In the case of a Repeat-user, the cost of lean implementation will be slightly lower than that of First-timer. It is because they have implemented lean before (normally once) and may have an edge over a First-timer. The cost effects on a Repeat-user may be moderate as compared to a First-timer.

The third category of receptive SMEs lean class is that of Continual-user. A Continual-user attracts far less lean cost compared to the two categories mentioned above. This is due to the fact that they may not need certain requirements as would be the case in those who have not used lean at all, or used it only once. For example, a Continual-user may not require the services of a lean specialist or consultant, since most times such companies have 'change-agents' or trained lean champions within their confines. In essence, the actual cost of lean implementation may be less and the duration shorter.

### **(iii) Extent of Lean Area of Applicability (Percentage of employees engaged)**

Companies may implement lean manufacturing within their entire business (wholesome) or on a piece-meal basis (bit-by-bit). Thus, the wider the area of lean applicability, or rather the higher the number of personnel to be engaged, means the higher the cost of implementation. This factor ripples



through other variables that determine the final cost of lean implementation. For example, a company lean readiness has a great influence on what the actual cost of lean would be.

A company lean readiness coupled with its size certainly has a direct involvement on the lean cost as well. This is because, if a company is first time user, employs many people and wants to implement lean in the entire business, and then the cost structure will be very high due to obvious reasons. Firstly, such a company has not got lean experience and will have to train and engage many of its working staff resources.

#### **(iv) Process Complexity**

Process complexity may also have a significant bearing on the cost of lean implementation. A company with complex processes may pose a great deal of difficulty for the concept of lean manufacturing to be adopted. This may be in terms of the effects and how to address them when lean has been embedded. For example, the realignment of tools and equipments within the shop-floor as lean is being rolled over may pose adverse consequences in terms of bottlenecks to the current production process. The eventuality in such a scenario would be the increment in the overall cost of lean implementation. The wider the affected area, may mean the wider the cost as the lost of production or work-in-progress should be attributed to the eventual lean cost.

#### **(v) Company Strategy of Implementation**

The duration it takes to implement lean, affects its overall cost. The longer it takes for a company to implement lean manufacturing, shall mean that such a company may attract higher cost and vice-versa. Duration also has linkages to other variables such as company size, company lean readiness, the area of lean applicability, such a company has. For example, if a company employs many people and has not implemented lean before; and wants to implement lean enterprisewide; and has complex production process, then it may take longer for such a company to implement lean, consequently attracting higher costs as discussed above. Hence, company strategy of lean implementation forms a critical path in how long lean implementation may take.

### **6.3.2 Analysis of the Level of Lean Readiness**

In terms of the impact of the level of lean readiness to a company wishing to implement lean manufacturing, there appear a number of attributes conjoined to level of lean readiness. These include;

#### **(i) Management Support**

Management support is key to lean readiness. Supportive management initiatives may lead to successful lean projects. If management does not believe in lean, then it may never be implemented at all. If it's forced or pushed on them by the higher authority such as the board level, managers may pretend to have accepted it but contrarily, lean would fail as it requires determinative effort to succeed. So the higher the level of management support in a lean project may determine as to whether such a company is ready for lean or not.

#### **(ii) Financial Availability**

Funding opportunities ensue companies can bring in productivity improvement projects such as lean manufacturing. Finances allow for training of employees to be conducted and also provide possibilities of hiring consultancies. Conversely, finance alone shall not make lean successful as it has to conjoin with other factors such as management support.

#### **(iii) Employee Educational Level**

Employee educational level factor is of paramount importance to a company wishing to implement lean manufacturing. A highly educated workforce is easier to train on lean principles as compared to low level ones. Educated personnel are able to absorb new ideas more flexibly without much reservation as in the case of the uneducated ones. Yet having a well educated workforce is not enough on its own to provide a company wishing to adopt lean ideas. Educated workforce factor should piece-up with others like management support and financial availability to determine how ready a company is for lean uptake.

#### **(iv) Corporate Culture**

A good corporate culture is the one that supports its workforce. It provides an environment of team ethos and blame-free atmosphere. Therefore, if a company has the above-stated mission statement,



then it may assume that it has one of the appropriate ingredients that could add-up with others to qualify its lean readiness. Moreover, a good corporate culture should be supported by willing managers who aspire to promote its mission statement. Additionally, there must be funding opportunities to drive through changes and employees should have acceptable level of education to be classed-ready for lean.

### **6.3.3 Analysis of the Projected Lean Benefits (Impact)**

The following listed factors are some of the fundamental benefits a company should aim to achieve out of any preferred lean project.

#### **(i) Inventory Level**

Stockpiling higher levels of inventories runs against lean principles as it is perceived as attracting high cost in terms of maintenance and tied-up funds. Lean principles are envisaged to promote a production process where goods are only produced when there is need, and delivered on-timely (JIT). Lean adoption is supposed to eradicate the notion of high level inventories in order to boost cash flow.

#### **(ii) Productivity**

Lean manufacturing enables companies to maximise their overall equipment efficiency (OEE), inclusive of manpower capacity. This means that total throughput is increased as many units are generated flawlessly with fewer resource inputs. This can only be possible with a motivated workforce, shorter-changeovers and simplified processes.

#### **(iii) Simplified Manufacturing Process**

Good planning and the employment of simplified manufacturing procedures by lean concepts, allows companies to eliminate delays. Companies can then reach the marketplace more expeditiously. Simplified manufacturing processes reduce cycle time so productivity is increased.

#### **(iv) Motivated Workforce**

Lean manufacturing also promotes the notion of job ownership, hence getting workforce engaged endlessly other than waiting for what to do next. Staff shall give their very best if they feel the

organisation they work for, values their inputs. Hence, the higher the productivity of units achieved, may mean employees will have an inclination for incentives so as to work harder for better rewards. This may also mean staff concentrates on doing their set tasks so the end product is error free.

#### **(v) Reduced Lead-Time**

A fundamental objective of most businesses is to reach the customer on timely. This means that the lead-time taken to make a product is reduced significantly. Lean manufacturing is envisaged to offer this desire. Thus, any firm wishing to embrace the lean manufacturing, certainly wishes to ascertain that it will be able to enable it achieve its manufacturability within the agreed time scale. Lead-time is therefore a key factor in the analysis of lean impact.

#### **6.3.4 Development of the Knowledge Based Advisory Systems**

The development of the knowledge base advisory system (KBAS) presented in this chapter has passed a number of activities. The first activity was the identification of the necessary input and output parameters for the envisaged KBAS. However, preceding this phase, there was the analytical assessment of the probable parameters involved in lean impact assessment conducted in Section 6.3.3. Information for this task was derived from the impact assessment framework (TO-BE Model) demonstrated in Figure (5.3). Within this framework, two distinct lean parameters were identified; cost and benefit/impact of lean implementation. The cost parameters are subdivided into direct and indirect as detailed in Section 5.3.1. Additionally, the cost parameters have the following drivers; direct: training fees, consultancy fees and space. The indirect parameters bear the following drivers WIP, sabotage, disruptions and customer dissatisfaction. These drivers are the ingredients that generate the actual cost of lean implementation within any given company.

On completion of the lean implementation, a company anticipates desirable outcomes as benefits/impact. This benefit/impact, is both tangible and intangible, and has the following attributes; tangible: lead-time reduction, improved employee motivation, simple and flexible manufacturing processes, low inventory levels and increased productivity. Thus, it was realised that the defined lean input and output parameters recorded above, needed some extra parameters in order to consolidate a concrete and robust system. Hence, a third input parameter referred to as lean readiness was selected to achieve this objective.



However, the researcher presented this analytical assessment detailed in Section 6.3.3, to a number of practitioners within the companies highlighted in Table (5.1), for the expert view purposes. Specifically, they were asked as to whether the presented inputs (cost and readiness of lean), and output parameters (lean benefit/impact of lean), in their opinion provide realistic and relevant factors in conducting lean impact assessment. These exercises were subjective in that the researcher needed to formulate a meaningful and an acceptable system within the SMEs community. It is important to reiterate that the dataset used at this point (see Section 6.3.3), was company reported and validated in a number of workshops and case studies highlighted in Chapter 4.

Satisfactory confirmation thus led to the design of three separate systems, based on each parameter identified in paragraphs above. These systems were later named as sub-system 1, 2, and 3, as demonstrated in Figure (6.3) and had the following details. In sub-system 1, the input parameters were considered as; company size, lean readiness and lean impact. Sub-system 2 had management support, financial availability, corporate strategy and employee educational level. Finally, sub-system 3 constituted inventory level, manufacturing process, motivation level and lead-time.

In the case of sub-systems 1 and 2, the selected membership functions and their defined linguistic variables were demonstrated as company size: VerySmall, Small, Large and VeryLarge. These linguistic variables represented numerical values from, [0] VerySmall; to [250] VeryLarge companies. The lean readiness parameter had the following selected membership functions defined linguistic variables, MnagementSupport: Poor, Fair Good; Financial availability: Poor, Fair Good; CorporateStrategy: Poor, Fair Good and EmployeeEducationl: Poor, Fair Good.

The third sub-system contained the following selected membership functions and their defined linguistic variables; InventoryLevel: Low, Medium, High; ManufacturingProcess: Simple, Moderate Complex; Lead-time: Short, Medium, Long and Productivity: Low, Medium, High. These three sub-systems were run in fuzzy logic. Each of the sub-system generated a number of heuristic rules. In the case of sub-system 1, twenty heuristic rules were realised. Sub-system 2 and 3 generated twenty nine and thirty six heuristic rules respectively, as exemplified in Tables (6.4-6.6 respectively), and detailed in appendix (E). When these three sub-systems were up and running, they were also validated with experts. Most of them had been involved in the validation of the data used in the



system. Expert opinion were sought to verify the system's relevance, accuracy and usability, and used almost the same validation formats detailed in Chapter 7. It was realised information from the three sub-systems could be better utilised in another system.

**Table: 6.4 An example of heuristic rule in sub-system 1**

<p><i>If compnysize is small</i>  <i>And companylean experience is FirsTimer</i>  <i>And LeanImpact area is Awareness</i>  <i>Then cost is VerySmall</i></p>
--

**Table: 6.5 An example of heuristic rule in sub-system 2**

<p><i>If Mangmentsupport is Good</i>  <i>And Financialavailabiltiy is Good</i>  <i>And Corporatestrategy is Good</i>  <i>And EmployeeEducational level is Good</i>  <i>Then LeanReadiness is Ready</i></p>
--

**Table: 6.6 An example of heuristic rule in sub-system 3**

<p><i>If Inventorylevel is Low</i>  <i>And Manufacturingprocess is Simple</i>  <i>And Staffmotivationlevel is High</i>  <i>And Lead-time is Short</i>  <i>Then Productivity is High</i></p>
---

Consequently, a final system was designed using the following input parameters; Relative Cost and Lean Readiness, and an output parameter as; Lean Impact. Moreover, these parameters (input and output) had almost the same selected membership functions, save for lean readiness impact and value advice parameter (output), whose details had the following selected membership functions and defined linguistic variable; Lean Readiness: FirstTime user, Repeat user and Continual user. Lean Impact: Awareness, Piecemeal, Constrained and Widespread. Value Advice: Don't Do It, Possibly Do It Probably Do It and Do It.



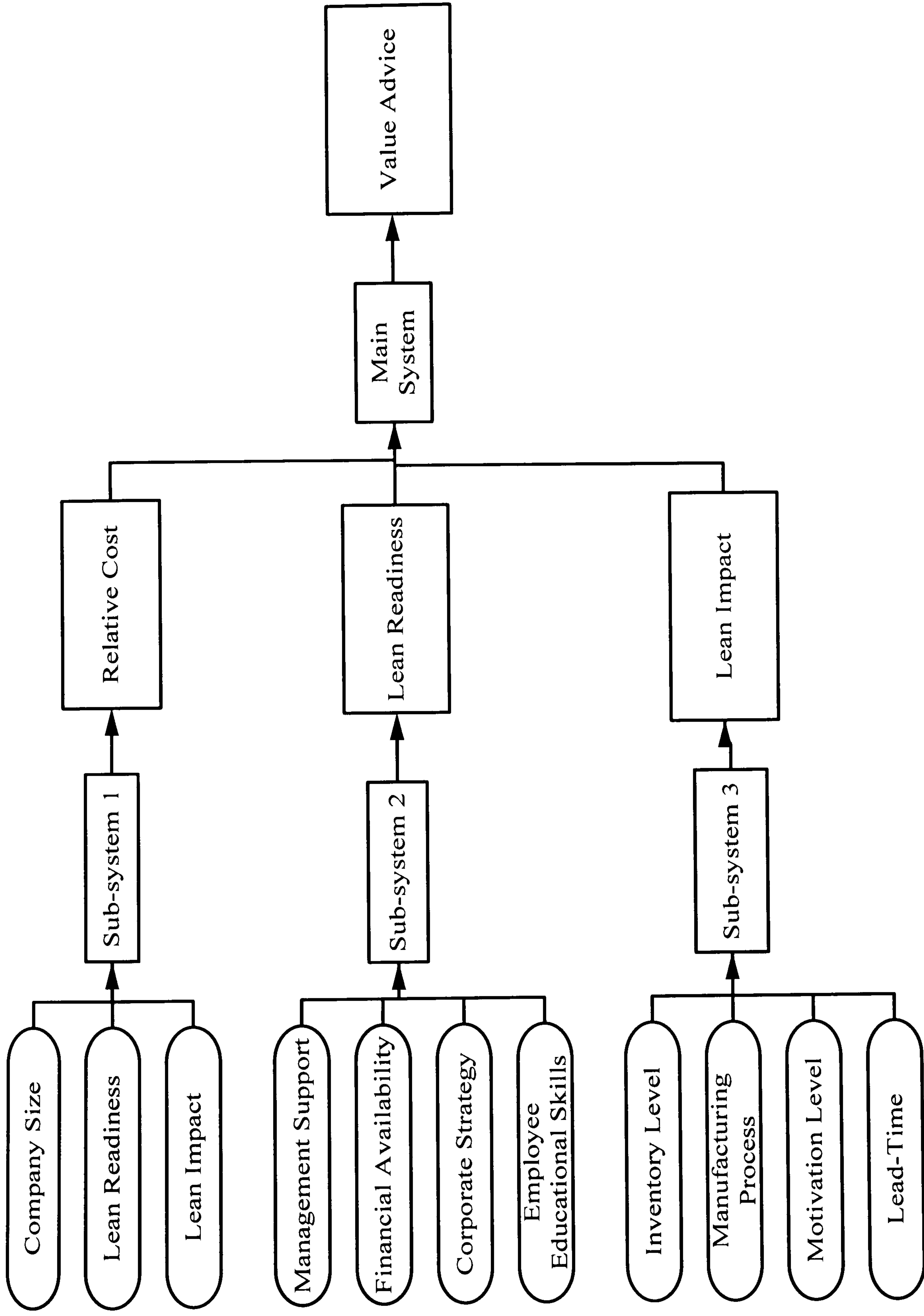


Figure 6.3: Architecture of the overall structure of the developed system

A number of heuristic rules were then generated using different combinations. This process was extensive, since the visualisation facility in the developed system did not provide adequate reading at such points in time. The researcher therefore sought different expert opinions both in academia and industry as a measure of achieving better results. Eventually, eight heuristic rules were generated as the final set, and whose details are listed in Table (6.7). These rules were also validated by experts at different levels. For example, the experts were provided with the membership functions and were allowed to make combinations of the linguistic variables to create a single rule of their choice. The topography of the surface viewer would be analysed and adjustments made on the both the rule viewer and the membership functions curves as discussed in Section 6.2. This process involved a number of experts, where they concurred with the final eight rules.

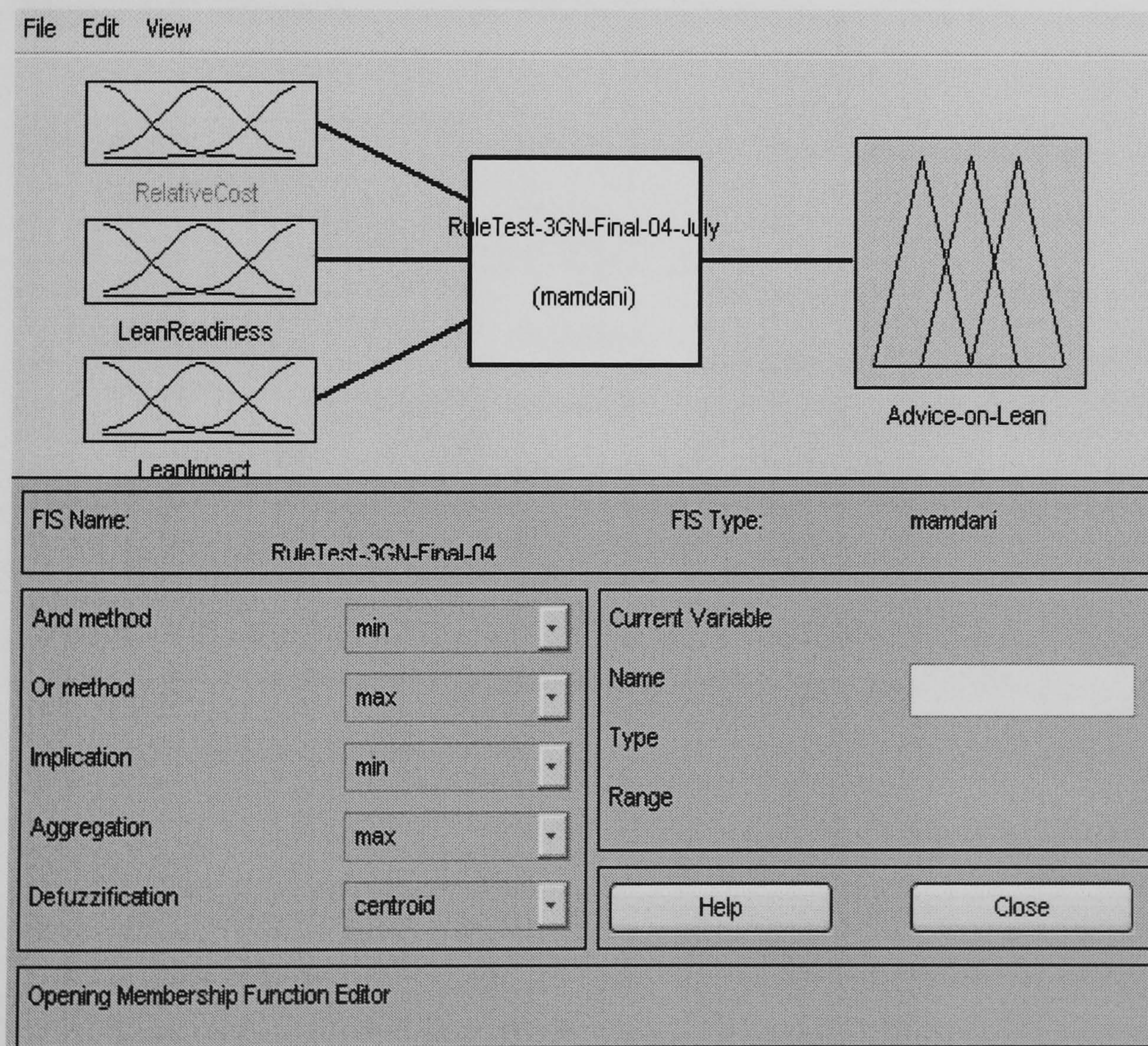
## **6.4 System Functionalities**

The developed KBAS presented in this chapter performs a number of functions. These include; a demonstration of the lean implementation factors such as the relative cost, a potential lean company would pay. The system also highlights a company lean readiness status and the eventual value-add expectations thereafter. These functionalities are aided by the developed system's interfaces demonstrated in Figures (6.4-6.13) respectively.

First, the system's interfaces enable a user to create the FIS of the value advice system (Figure 6.3) as a whole. The FIS are built with the help of the highlighted parameters; relative cost, lean readiness and lean impact. These factors can be created with the facilitation of the membership functions that provide a user with the following options. (i) Defining the linguistic variables, (ii) moderating the membership functions to enable the system realise realistic results. Figure (6.4) exemplifies a scenario of the relative cost membership functions formation. As evident from this figure, the FIS have the following parameters; company size, lean readiness and lean impact, and depended on the expected outcomes. For example, the membership function of the cost parameters was defined using linguistic variables such as; verysmall, small, large and verylarge. These linguistic variables represent numerical values.



Hence, if it is contended that the cost of lean implementation is very small, the numerical representation implies that the cost value falls within a range of [0-25k]. Moreover, the interface allows the user to display and edit the ranges as desired. Furthermore, these functionalities are also typified in the membership functions of lean readiness and lean impact/benefit parameters. However, the differentiations are on the choices of the linguistic variables adopted for each parameter. In this case, the lean readiness linguistic variables are defined chronologically as; [NotReady, SomeWhatReady, JustAboutReady and Ready]. These variables represent the vector range of [1-10] of the elected parameter as illustrated in Figure (6.7). On the benefit parameter, the FIS have involved the membership functions of inventory level, productivity level, cycle time and staff motivation. These membership functions have defined linguistic variables such as [Awareness, Piecemeal, Constrained and Widespread].



**Figure 6.4: Interface highlighting FIS of the final system**



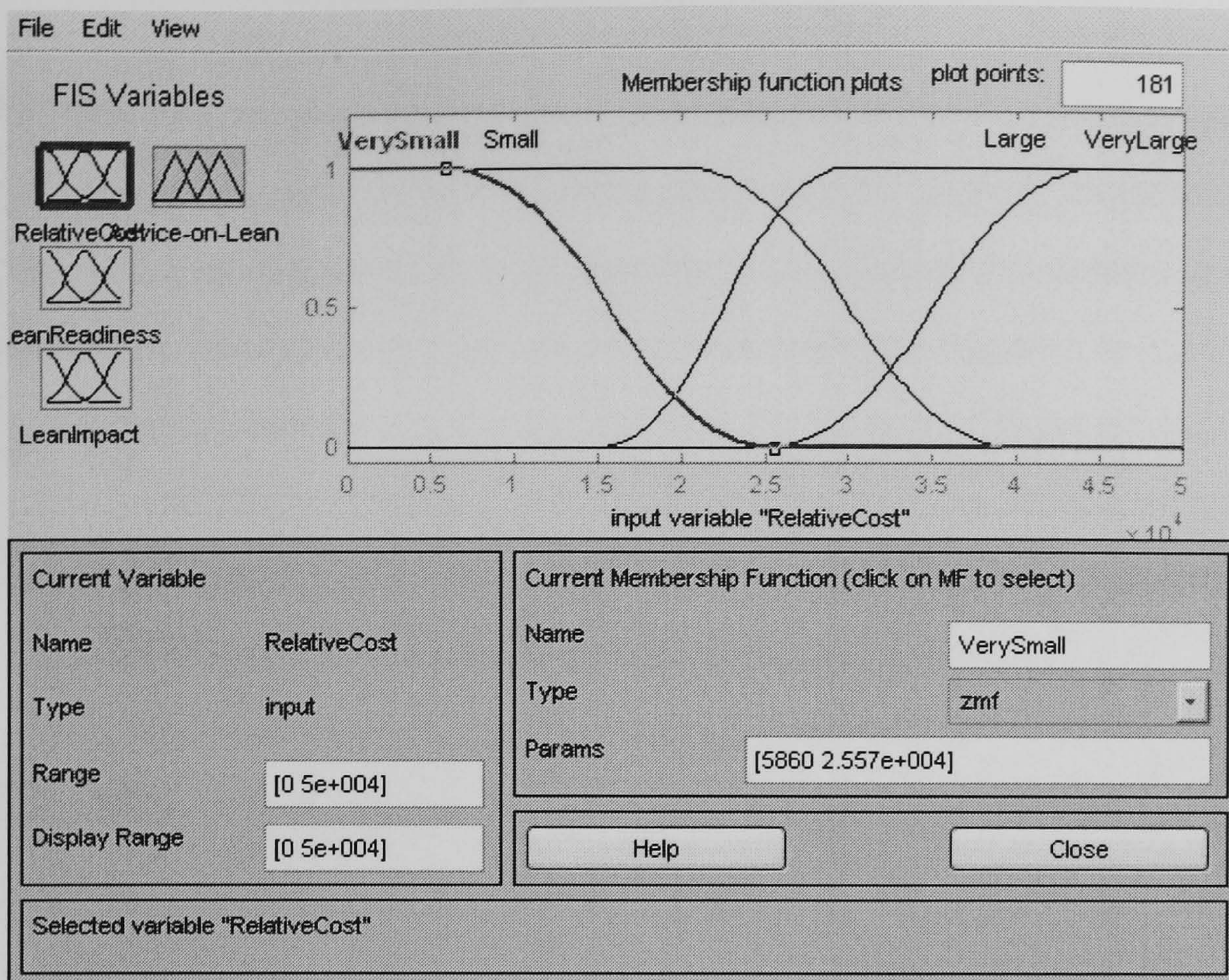


Figure 6.5: Illustration of the MFs of relative cost of the final system

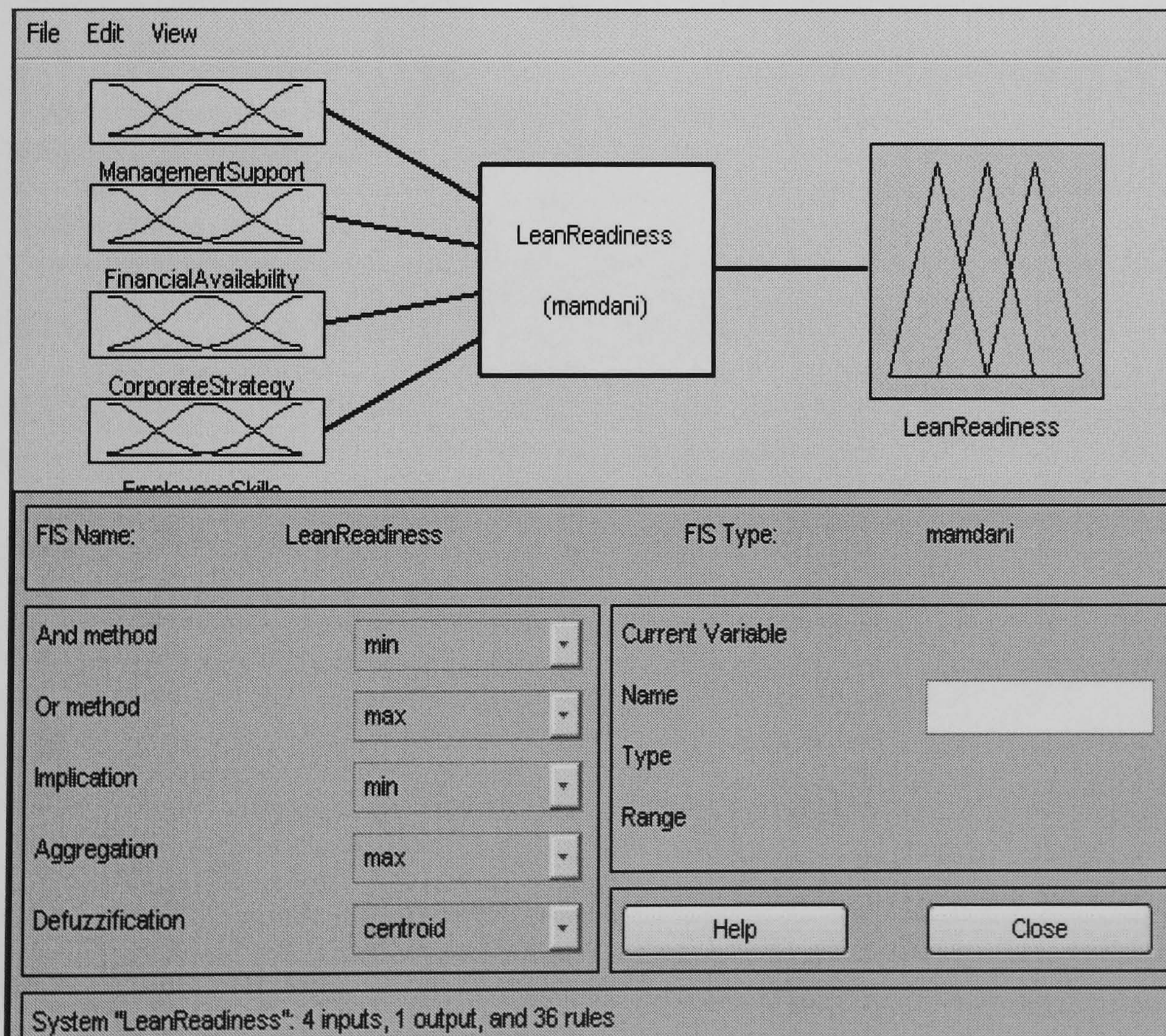


Figure 6.6: A demonstration of the FIS of lean readiness



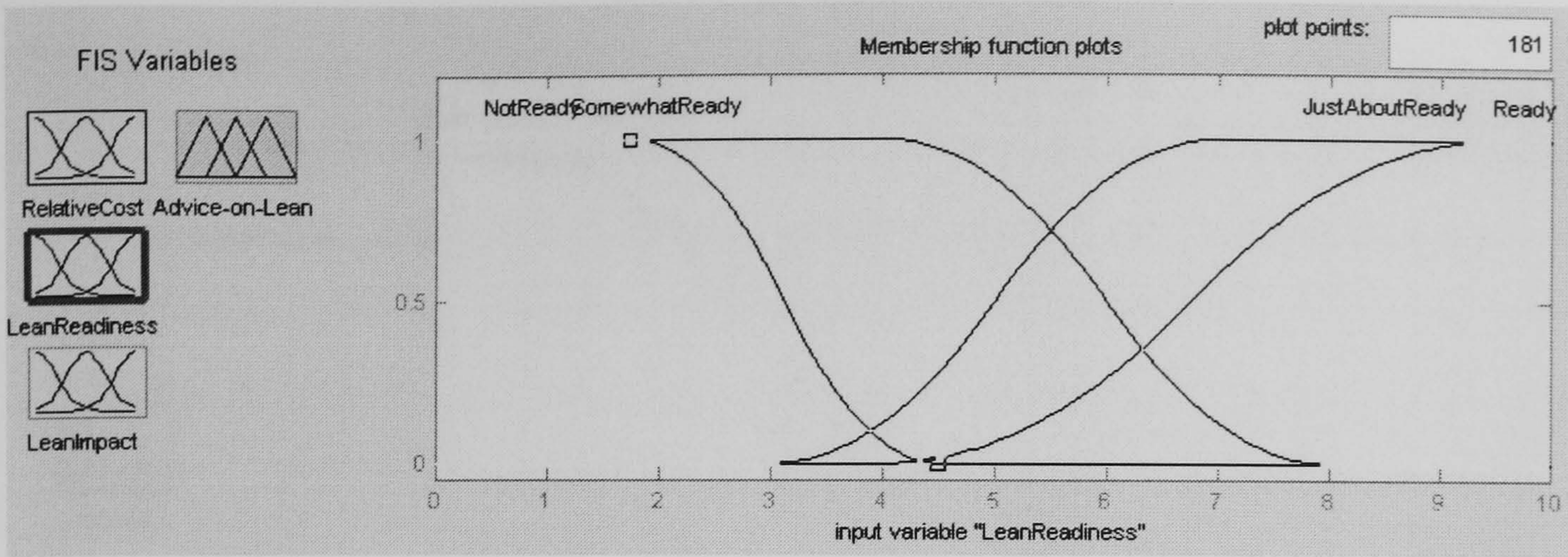


Figure 6.7: A representation of the MFs of lean readiness

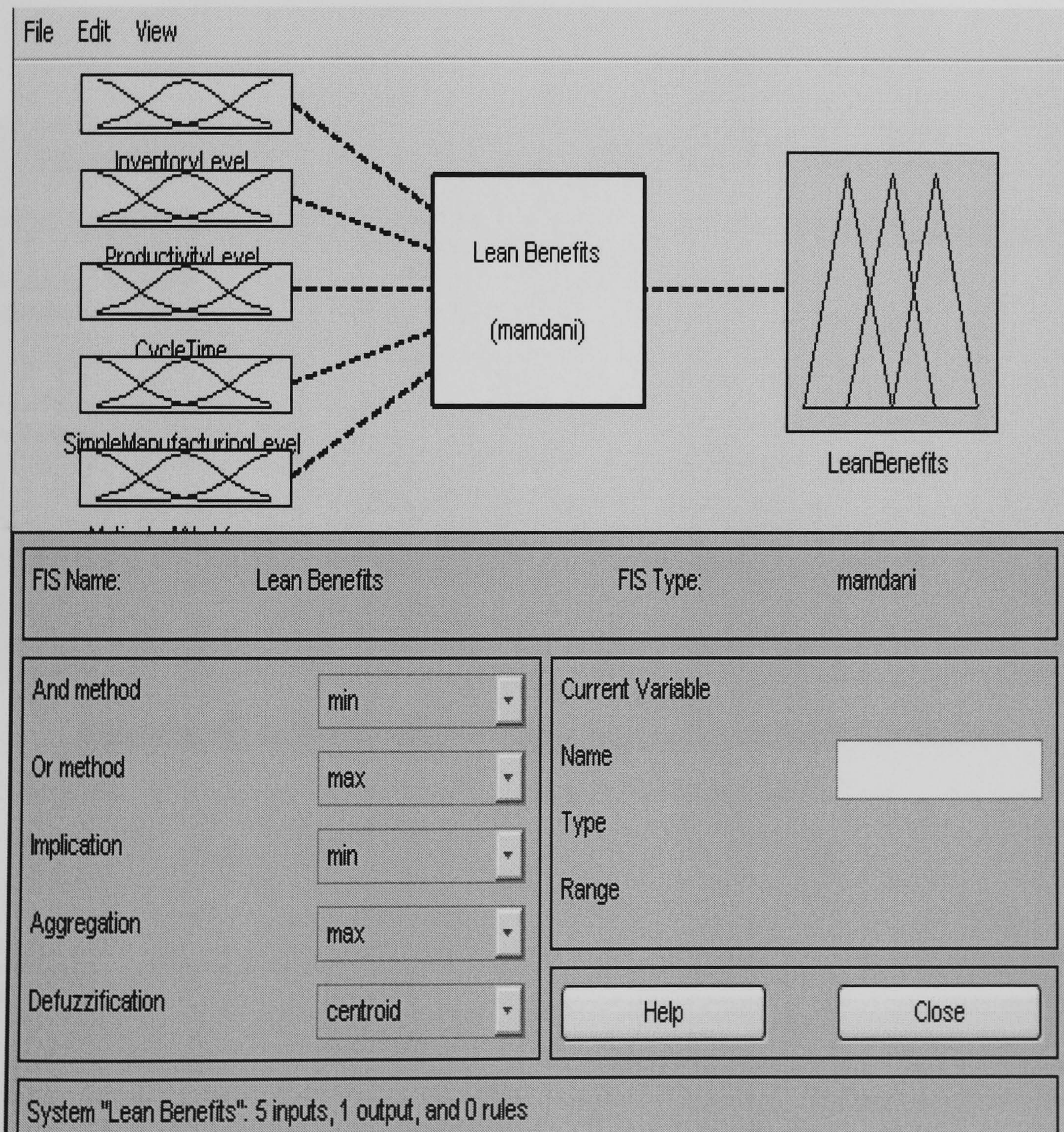
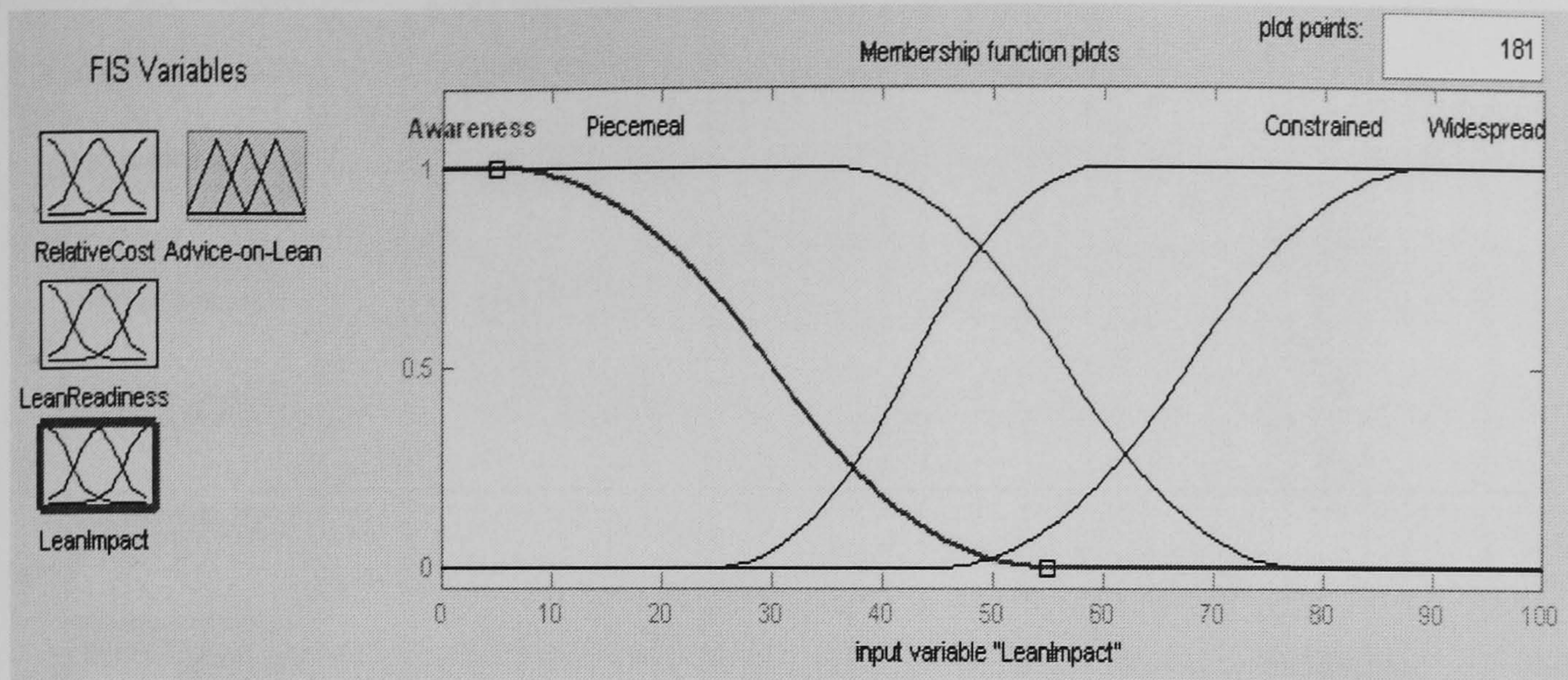
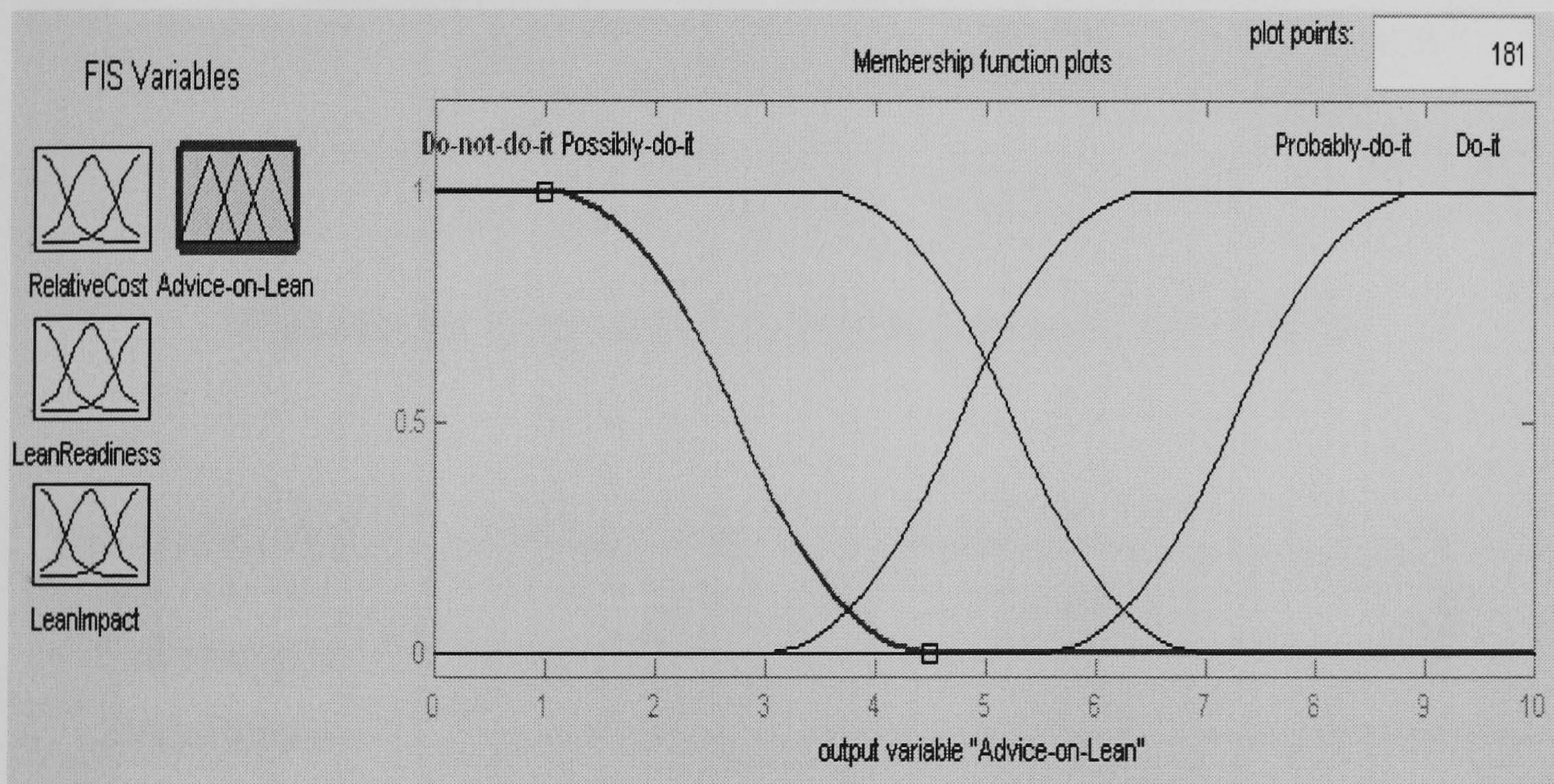


Figure 6.8: An highlight of the FIS of lean impact





**Figure 6.9: A representation of the MFs of lean impact**



**Figure 6.10: A demonstration of the MFs of lean advice statements**



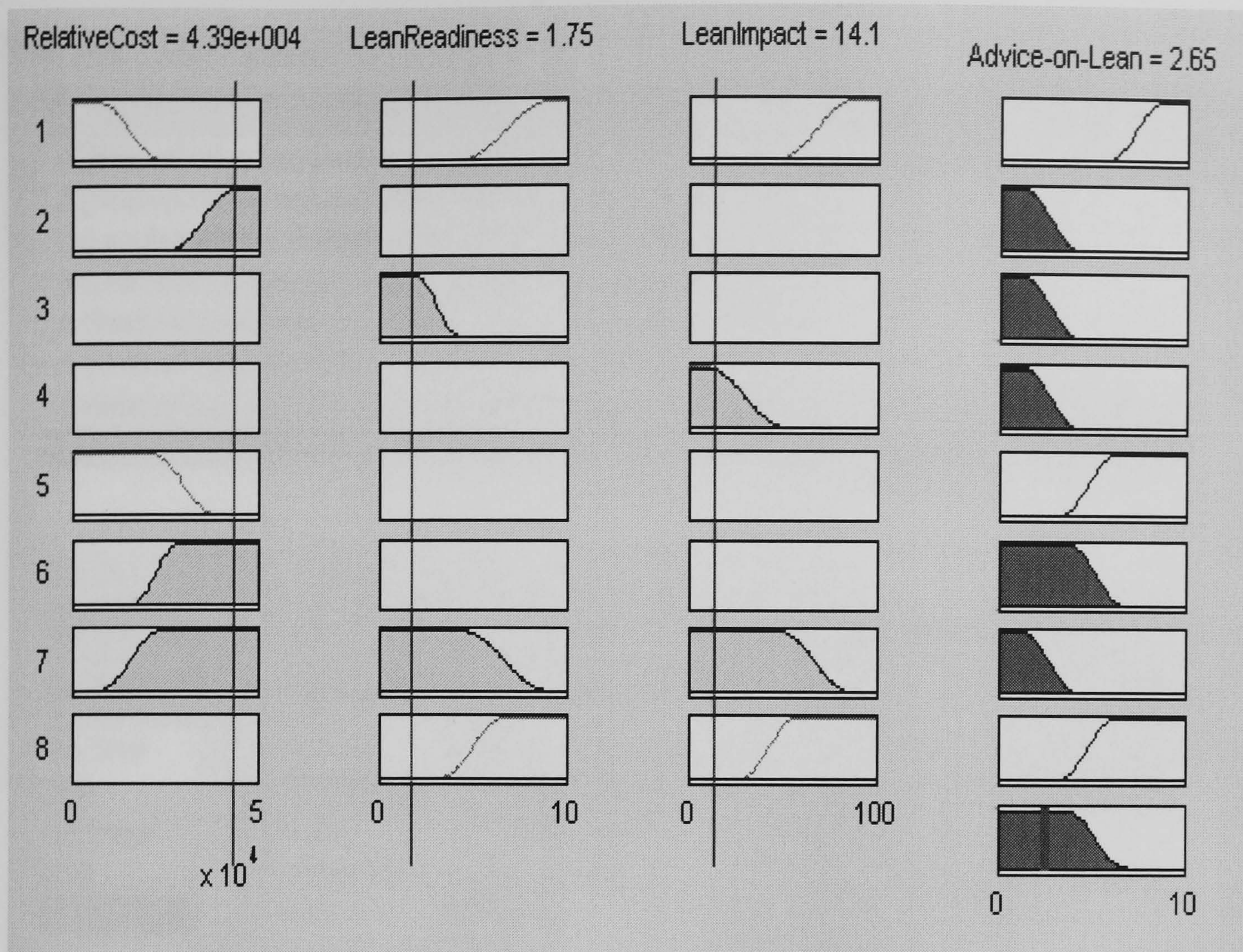


Figure 6.11: Rule viewer highlighting extreme low points

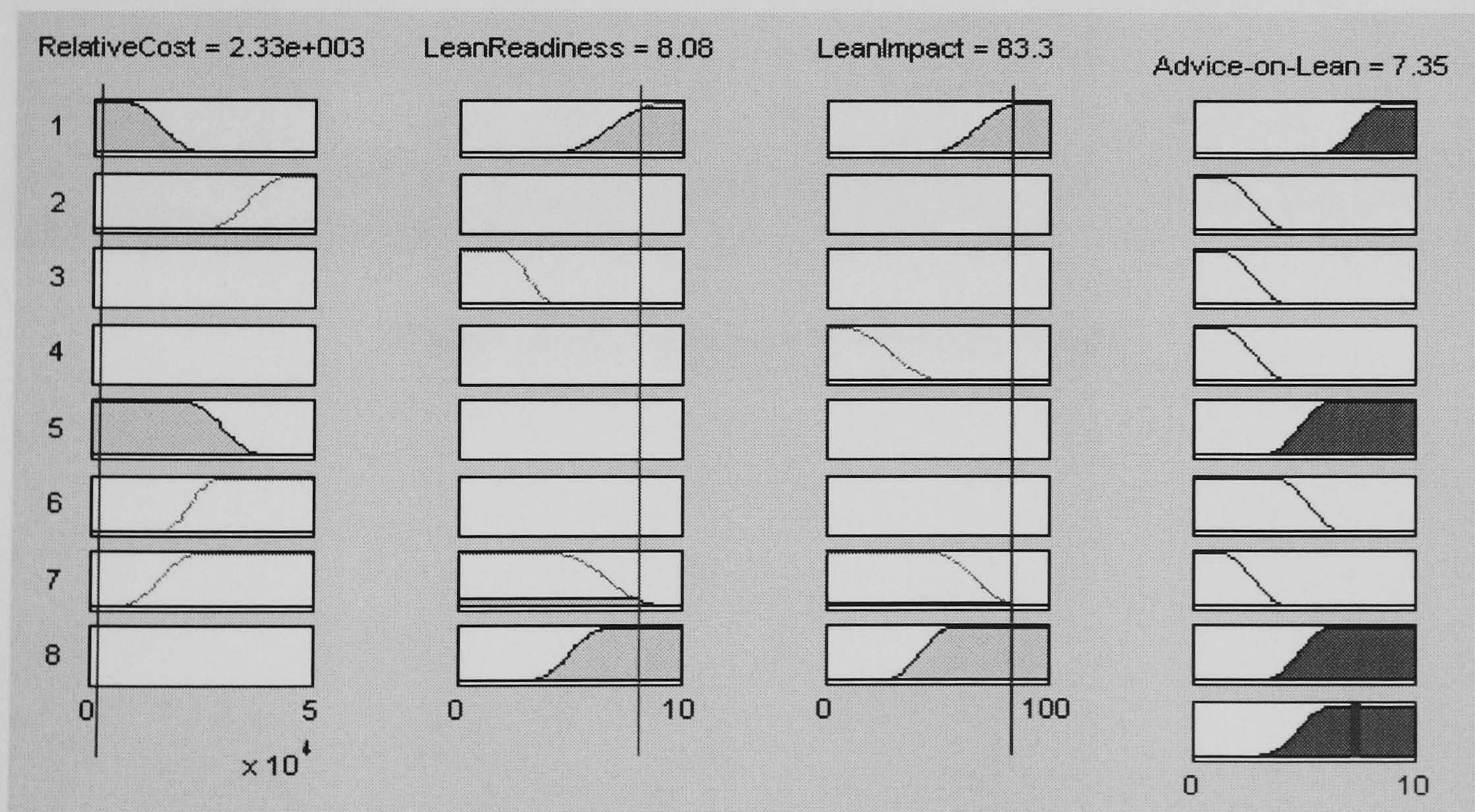


Figure 6.12: Rule viewer highlighting extreme high points



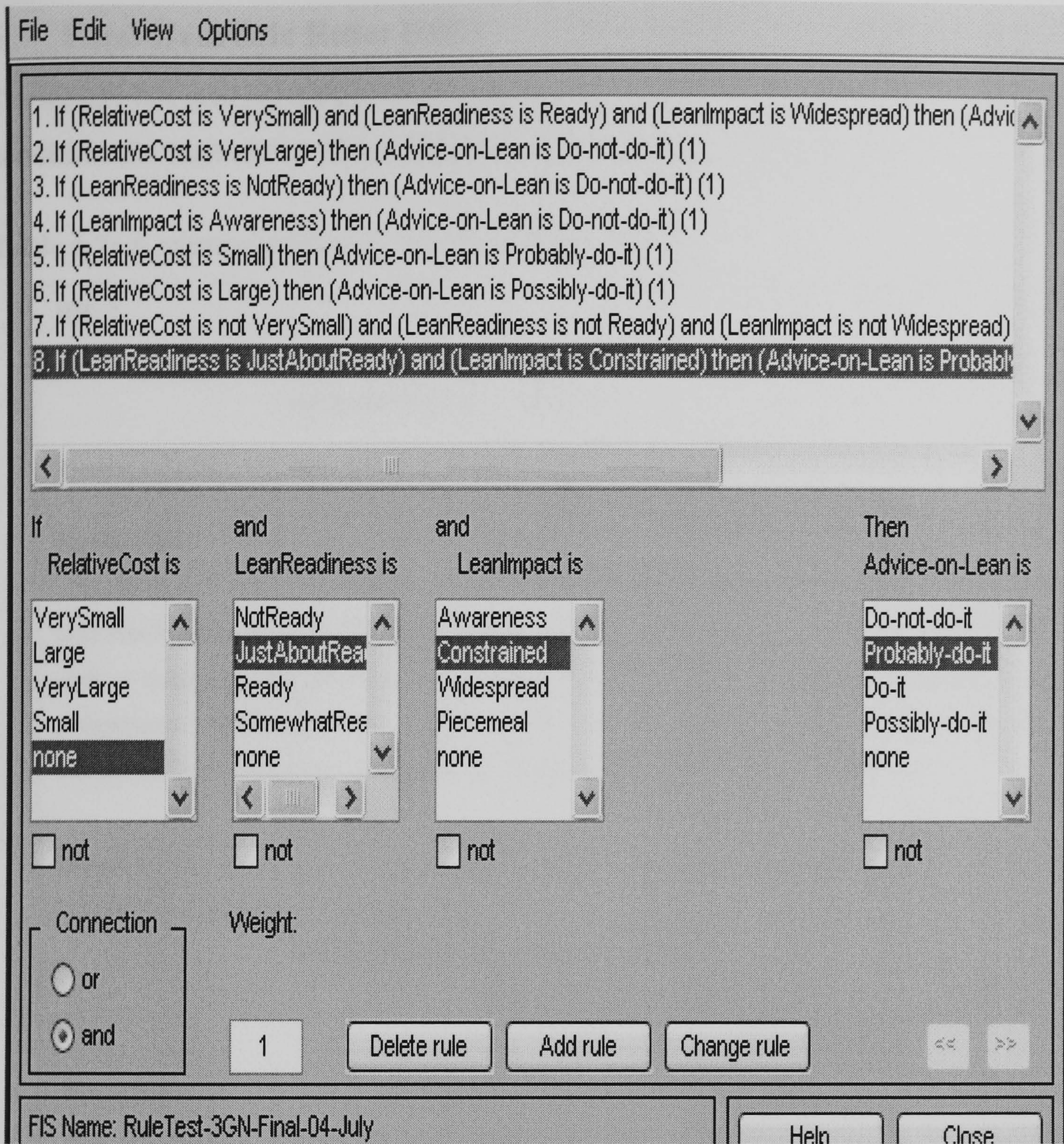


Figure 6.13: Interface of the rule editor





## 6.5 Final Heuristic Rules (HR)

The system has generated eight final heuristic (HR) rules that are used for highlighting conditions for lean advice within SMEs as demonstrated in Table (6.1).

**Table 6.7: A representation of the final heuristic rules**

**HR: 1**

If Relative-cost of lean is = Verysmall

and LeanReadiness = NotReady

and LeanImpact = Verylow

then advice on lean = Do-not-do-it

**Assumption:**

The above rule takes into consideration the view that the implementation cost of lean would be very small (between 0-5k), although a company lean readiness shows a not ready status, meaning such a company has not implemented lean before, and has no trained personnel in lean perspectives. Additionally, the impact expected is very meagre. Therefore, based on these inferences, it is realistic for a company not to implement lean at all, at least for now.

**HR: 2**

If Relative-cost of lean is = Large

and LeanReadiness = SomewhatReady

and LeanImpact = Low

then advice on lean = Do-not-do-it

**Assumption:**

This rule takes the view that, because the implementation cost of lean is large, yet the companies lean readiness is not conclusive; somewhatready, therefore the expected value-add anticipated from such a venture is deemed low. Hence, implementing lean would not be untenable (Do-not-do-it).

**HR: 3**

If Relative-cost of lean is = Small

and LeanReadiness = JustaboutReady

and LeanImpact = High

then advice on lean = Probably-do-it

**Assumption:**

In HR3, it is contended that relative cost of lean implementation is affordable (small) and lean readiness status is just about ready; whereas the expected benefits is high. Therefore, there is a good degree of inclination to implement it (probably-do-it), rather than not doing it at all.

**HR: 4**

If Relative-cost of lean is = Large

and Leanreadiness = JustaboutReady

and LeanImpact = Low

then advice on lean = Do-not-do-it

**Assumption:**

In the case of HR4, it is highlighted that the prospect of lean implementation may attract high costs (large), although the company's lean readiness status is deemed to be almost ready (just about ready). Additionally, the expected value-add from the lean venture would be low, meaning that the project is not viable.

**HR: 5**

If Relative-cost of lean is = Small

and LeanReadiness = SomewhatReady

and LeanImpact = Low

then advice on lean = Possibly-do-it

**Assumption:**

In HR5 scenario, it is maintained that much as the company lean readiness status is only about 60 percent plus ready (somewhat ready), on the positive side, the projected cost of lean deployment is viewed as small. The result thus stimulates a desire for one to contemplate implementing lean (possibly-do-it).

**HR: 6**

If Relative-cost of lean is = Verymall

and LeanReadiness = Ready

and LeanImpact = VeryHigh

then advice on lean = Do-it

**Assumption:**

This rule provides for a do it situation because of the affordability of cost (very small) and the company's lean readiness status which demonstrates a readiness position. Moreover, the expected benefits potential is deemed to be of a high magnitude.



**HR: 7**

If Relative-cost of lean is = VerySmall

and LeanReadiness =JustaboutReady

and LeanImpact = VeryLow

then advice on lean = Probably-do-it

**Assumption:**

In this instance, the projected cost of lean implementation is seen as very small, and the expected benefits also indicate a very low outcome, but the readiness status gives an insight of almost ready position (just-about-ready). The company might therefore want to go for it (probably-do-it).

**HR: 8**

If Relative-cost of lean is = VerySmall

and LeanReadiness = SomewhatReady

and LeanImpact = VeryLow

then advice on lean = Possibly-do-it

**Assumption:**

This rule highlights a non conclusive judgement of implementing lean (possibly-do-it) approach, because of two reasons. First, the expected cost input is very small suggesting any company may see it as affordable. Secondly, the company lean readiness is also not to the acceptable point of readiness yet (somewhat-ready).

## 6.6 Available Conditions for the Knowledge Based System

The final generated heuristic rules, for the developed knowledge based advisory system highlighted in the previous section, provide four different outputs which are the conditions for giving value advice to a potential lean user. The four conditions are presented and discussed as follows.

### (i) Do it

The model will return the advice statement 'do it' when all the indications are strongly and clearly in favour. The Lean Readiness rating will be high indicating that the company has invested in lean training, has staff with experience of implementing lean



initiatives and has had success with previous initiatives. Lean impact will be moderate, to high indicating that there are expected to be financial and operational benefits of the proposed lean project. Cost of Implementation will be low indicating that there is little financial risk. Advice in this case would be simply to go ahead. This outcome might appear to be superfluous, a company in this position would hardly need to be told, but it is necessary to build confidence in the system. A user entering such parameters, even as a ‘what-if’ scenario, would expect to see a positive recommendation.

### **(ii) Probably do it**

The model will return the advice statement ‘probably do it’ when there are strong indications in favour but also reason to pause for thought in at least one of the decision parameters.

- If Lean Readiness is high, then it is likely that reservations centre around the expected cost-benefit. It may be that costs seem relatively high, or lean impact seems relatively low. Advice in this case would be to reassess the costs and benefits, put in place risk management to cover identified contingencies and then to proceed.
- If Lean Readiness is low then this is the area to be addressed – because in this case the cost and impact parameters would necessarily be positive for the statement ‘probably do it’ to be returned. A number of steps could be taken to improve Lean Readiness, with further training, appointment of an internal lean champion, or an external lean consultant to supplement the company’s own lean knowledge being the most obvious. Advice in this case would be context-dependent and focused on one or more of these actions.

### **(iii) Possibly do it**

The model will return the advice statement ‘possibly do it’ when there are some positive indications but these are tempered by weaknesses in other parameters. If Lean Readiness is the strong indicator, then cost will be showing moderate, to high and impact moderate



to low. The danger in this case is that the company's lean capability and urge to improve will lead it into projects that do not return sufficient advantage for the business.

- If cost can be reduced or the project revised to generate additional impact, then the recommendation could shift to 'probably do it', so advice would be to focus on these two points. There might still be a case for pursuing the project, even if it is marginal in cost-benefit terms, as a means to retaining and motivating lean resources in the company, but this should be a conscious decision.
- If Lean Impact is the strong indicator, then cost will be showing moderate to high and readiness moderate to low. The danger in this case is that the company will pursue a project in the hope of high impact, but fail through high costs or over-ambition, and in doing so damage the prospects for future lean initiatives. Advice would be to break the project down into smaller steps, so that costs can be controlled and readiness improved by using each step as a training and lean-awareness opportunity. Timescale will be increased but risks significantly reduced.
- If Cost is the strong indicator (i.e.: cost is very low), then impact will be showing moderate to low and readiness moderate to low. The danger in this case is that the company might adopt the habit of a 'busy fool', pursuing small-scale projects that succeed individually but that collectively fail to generate sufficient impact. A case can be made for such a project if it is used deliberately to increase Lean Readiness, through training and experience and the advice would be to proceed only if this is the case.

#### **(iv) Don't do it**

The model will return the advice statement 'don't do it' in the absence of a strong positive signal in any one of the parameters. The advice in this case would be to look for small-scale opportunities that start to improve the company's situation. A low cost, low-



to-medium impact project that included training or knowledge-transfer through consultancy to improve Lean Readiness would be ideal. A series of such projects should see the company progressing until its proposals are rated ‘possibly do it’ then ‘probably do it’. A company could also fine-tune the model to its own circumstances by adjusting the membership functions and rules, and then use it to test the comparative effect of a range of proposals.

## **6.7 Summary**

A description has been made on a developed prototype knowledgebase system for assessing the impact of lean manufacturing within SMEs at an early stage. The developed system constitutes a model that generates heuristic rules capable of setting conditions for lean advice. The system provides a more generic set of membership functions that may work across-board. Moreover, visualisation facilities depicted in Figures (6.4-6.13) is perceived as a useful tool that is much easier to understand and interpret. Hence, this chapter has demonstrated the accomplishment of the research objective number (6) set out in Section 3.1.1; *developing a knowledge based advisory system for assessing the impact of implementing lean manufacturing within SMEs*. This objective contributes to the accomplishment of the hypothesis presented in Section 3.4 which presumes an understanding of the lean impact in terms of cost-benefit analysis would motivate SMEs participation in lean uptake.



## CHAPTER (7)

# 7 VALIDATION OF THE FRAMEWORK AND THE DEVELOPED SYSTEM

### 7.1 Introduction

In this Chapter, a description of the validation of the framework and the developed knowledge based advisory system is conducted. The essence of validation stems from the fact that, research conduct must be tested for worthiness or merit. Easterby-Smith *et al.* (2002), summarise the criteria for validity, reliability, and generalisability from a constructivist viewpoint as:

- for validity to be achieved, the study should clearly gain access to the experiences of those in the research setting,
- to prove transparency in the research outcome, it should be demonstrated how sense was made from the raw data,
- and, the concepts and constructs derived from the study should have relevance to other settings to draw generalisability.

Hence this chapter aims to:

#### Chapter Aim

Describe, discuss and demonstrate the process of the framework validation and the proof concept of the developed knowledge based advisory system.

The remainder of the chapter is structured as follows. Section 7.2 presents how the research designed the case studies used in the validation of the framework and the developed system. In Sections 7.3 to 7.6, details of the validation process involving respective experts and industrial practitioners used in the validation exercises are presented and discussed. These sections also highlight the experts' and companies' profiles used in the exercises. Moreover, resultant outcomes and the experts' inferences are described. In Section 7.6, a demonstration of the validation process involving ten experts of mixed backgrounds (academia and industry) is presented. This section details the activities of the fourth case study, where the determination of the developed



system's confidence is conducted. The overall key observations derived from the validation exercises are highlighted in Section 7.7. The chapter is summarised in Section 7.8.

## **7.2 Design of Case Studies**

To determine the potentials of the developed model's usability, and its effectiveness in assessing the impact of implementing lean manufacturing within a company, a number of case studies were employed as a means of testing the validity of the developed system. Four different case studies were performed at different stages in this process. These arrangements evolved from the idea that experts both within the academia and industry would make provisions for determining issues such as:

- The extent to which the developed system assesses the relative cost of implementing lean manufacturing,
- Whether the developed system provides realistic scenarios that enable a potential lean user in making informed decisions, so as to implement lean or not,
- The degree of usability in terms of provision for friendly and easy to understand user interface,
- And the determination of the developed system's desirability to the industrial community.

Thus, the formalisation of the above issues required the design of a case study approach. This is because; the nature of the research investigation necessitated an exploratory descriptive case study methodology to match-up expectations of the criteria for validity, reliability, and generalisability highlighted in Section 7.1.

## **7.3 Case Study 1: Consultancy Firm A**

The first case study was held at the Cranfield Fellowship Manufacturing Centre, and involved three consultants from consultancy firm [A]. The experts had some good knowledge of the research project and what it was trying to achieve. They were involved in data collection process, and were thus well positioned to test the developed system's



effectiveness and its worthiness. This particular validation session also provided a perfect opportunity for the researcher to identify the system limitations and also make recommendations for further improvement before embarking on industrial settings. Furthermore, the experts involved in the validation process at this stage, had good academic and industrial experiences since they were all hired by the consultancy firm [A], as Lean Specialists.

### **7.3.1 Validation Process (1)**

The validation session which lasted for 3 hours, covered almost all the aspects of the developed system's functionalities. In particular, the experts were interested in understanding as to whether there existed some relationships between the collated dataset, and the system's influence on them. The experts were taken through a step-by-step approach in the system usability. They asked questions at each particular demonstration and were provided answers. The experts' inquired on how the data were operationalised in the system development process. For example, they needed to know how numerical figures were converted to qualitative assumptions of the defined linguistic variable; verysmall, small, large and verylarge. Finally, the experts made recommendations on the best way forward in how the system's capability and credibility could be industrially tested.

### **Expert Inference (1)**

The experts agreed on the assignment of the numerical figure into qualitative descriptions within the system. They upheld that usually, the cost of lean implementation within SMEs range from one thousand pound as was the case in the Consultancy firm [A], to anything up to fifty thousand pound. SMEs are able to flex these cost values provided they foresee immediate returns on funds invested. Their inferences cite the current system development as a guiding path towards better impact assessment process using expert systems, a notion which is still at a very low level within these companies.



## **7.4 Case Study 2: External Consultancy**

The second case study was also held at the Cranfield Fellowship Manufacturing Centre, but involved three external experts and one former personnel of Consultancy firm [A], now working for Cranfield Consultancy. The expert from Consultancy firm [A] had some knowledge of the research project and what it was trying to achieve.

### **7.4.1 Expert Profiles**

A summary of the experts' profiles have been captured as follows.

#### **Expert: (1)**

With a good experience of lean manufacturing and mass customisation, expert one has spent over 15 years working across different sectors in helping people to achieve dramatic improvement in delivery, quality, cost and cash flow. His previous research work involved the implementation of lean manufacturing in the design of a commercial aircraft. As a member of Institution of Electrical Engineers (IEE) and Chartered Institute of Personnel and Development (CIPD), he also combines technical capacity and works with others to deliver performance and embed them in organisations.

#### **Expert: (2)**

Expert number two is an experienced manager whose working experience cuts across the UK and Europe as a whole. His area of specialty includes product and process improvement to enhance new product introduction, customer satisfaction, financial and operational performance. He is also a Lead Assessor to ISO 9001 and a member of the Institute of Quality Assurance (IQA).

#### **Expert: (3)**

The third expert is a practical consultant with extensive experience of lean, six sigma, design and development. His main theme is knowledge transfer to ensure sustained performance in industrial operations.



#### **Expert: (4)**

The fourth expert was an internal Cranfield Consultant whose main role in the validation session was to, carryout an independent observation for consistency and transparency. His comments were obtained last after everything else was concluded by the three external experts. The essence of doing this was to discard the idea of him being an influence in the validation thought process. The role of this particular expert was to remotely observe the entire event so he could later make a true account of what transpired in the overall evaluation exercise. This session was well positioned to test the developed system's usability and its subsequent industrial application. It also provided a perfect opportunity for the research to identify limitations and also make recommendations for further improvement before embarking on industrial settings.

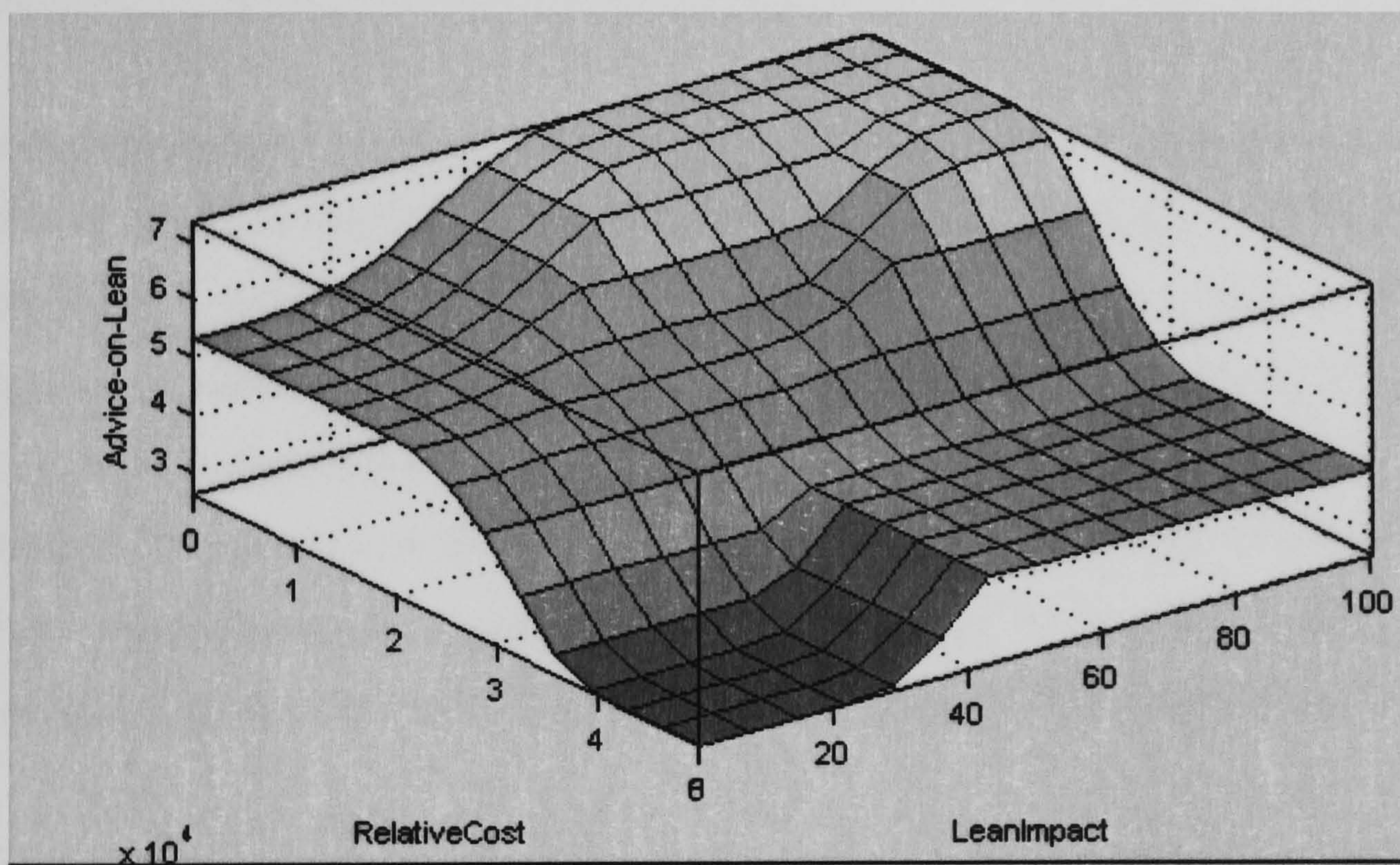
#### **7.4.2 Validation Process (2)**

The session which was started with a PowerPoint presentation by the researcher, lasted for approximately one and half hours. The researcher provided the panel with the overall research background once again, and further reinforced the need for the developed system. The experts thus inquired about the inputs so as to test its accuracy. All the three experts who were involved at this stage knew nothing about the research project's background, save for the generically available research concepts. An overall demonstration of the developed system's functionalities was performed to the audience. An illustration of the system's development phases was also performed. These included how the heuristic rules were generated and reduced to modify their relevance. Additionally, the experts were then allowed to appreciate the system by operating it themselves.

The above session was followed by a question and answer slot. For example, question was put to experts as follows; *“In your opinion, does the developed knowledge based advisory system presented, provide a realistic, logical and valuable approach in conducting impact assessment of lean manufacturing within a business?”* The experts' response was that they like the idea of assessing relative cost, readiness and impact of lean manufacturing implementation within a business.



They acknowledged that the system has the capability of providing an overview of the parameters stated above (relative cost, readiness and impact). Moreover, the experts believe the approach of using the KBAS to assess the lean impact is novel and provides a sound logic in making pieces of advice on whether to implement the concept or not, based on the impact assessment scenarios. In particular, they like the KBAS surface curves that highlight relationships between the listed parameters in a systematic manner. Illustratively, it can be seen from the surface viewer highlighted in Figure (7.1) that, if relative cost of implementing lean manufacturing decreases or remains very small and the other parameters (readiness and impact) are higher, there is an inclination of a business desire to implement lean manufacturing (Do it). Conversely, if the cost was zero, and the other impacts are higher, a business may not probably do it because of the perception that; “something being offered for free, may be valueless”.



**Figure 7.1: Topography of relative cost v. lean impact**

However, the curve tends to highlight that as relative cost begins to increase gradually and readiness and impact also increase, there is a higher inclination of making a decision to “do it”, because the cost is not zero and not very high, yet realistically acceptable in comparison to the level of impact due to be achieved thereafter.



On the fronts of input parameters such as employees skills, the experts' views are that employees' skills should be treated in the full mode because employees' skill alone as a parameter is trivial. This is because; employees' skills can be readjusted provided management can accept and allow or give them the opportunity to perform without restrictions or blames. In the experts' opinions, evaluation of management support should be treated on what they (managers) do and not what they say, as quite often the inverse is true.

The experts further concurred that quite often there is a tendency of a lack of understanding of the impact as people tend to overstate benefits and yet underestimate costs because it makes things (their business) appear better. Therefore understanding the overall business structure is critical. Business should look at the start and end of their supply-chain so they can order the required supply.

However, the experts conclusively agreed with the heuristic rules embedded within the KBAS and maintain that they give meaningful inferences, of choices of advice to take while making a decision based on the developed system's guidance. For example, the rule matrix provides an indicator that if cost is very low and the company readiness is very low and the expected impact indicator is very low as well, one may be inclined into absorbing it. The essence of this thinking is based on the premise that if relative cost is very low, companies may assume that by bringing in lean, they could do something on their readiness perspective and impact factor as a means of improving their positions.

The experts' opinion on the fuzzyfication of the linguistic variables was unanimous. They agreed on the KBAS input linguistic variables and the resultant outputs of; Don't Do It, Possibly Do It, Probably Do It and Do It respectively. As demonstrated in table (7.1), it can be seen that by combining the choices of levels of the relative cost, readiness and impact parameters, one can make an informed decision based on the pieces of advice provided herein.



**Table 7.1: Linguistic variables v. value advice statements**

**Relative Cost**

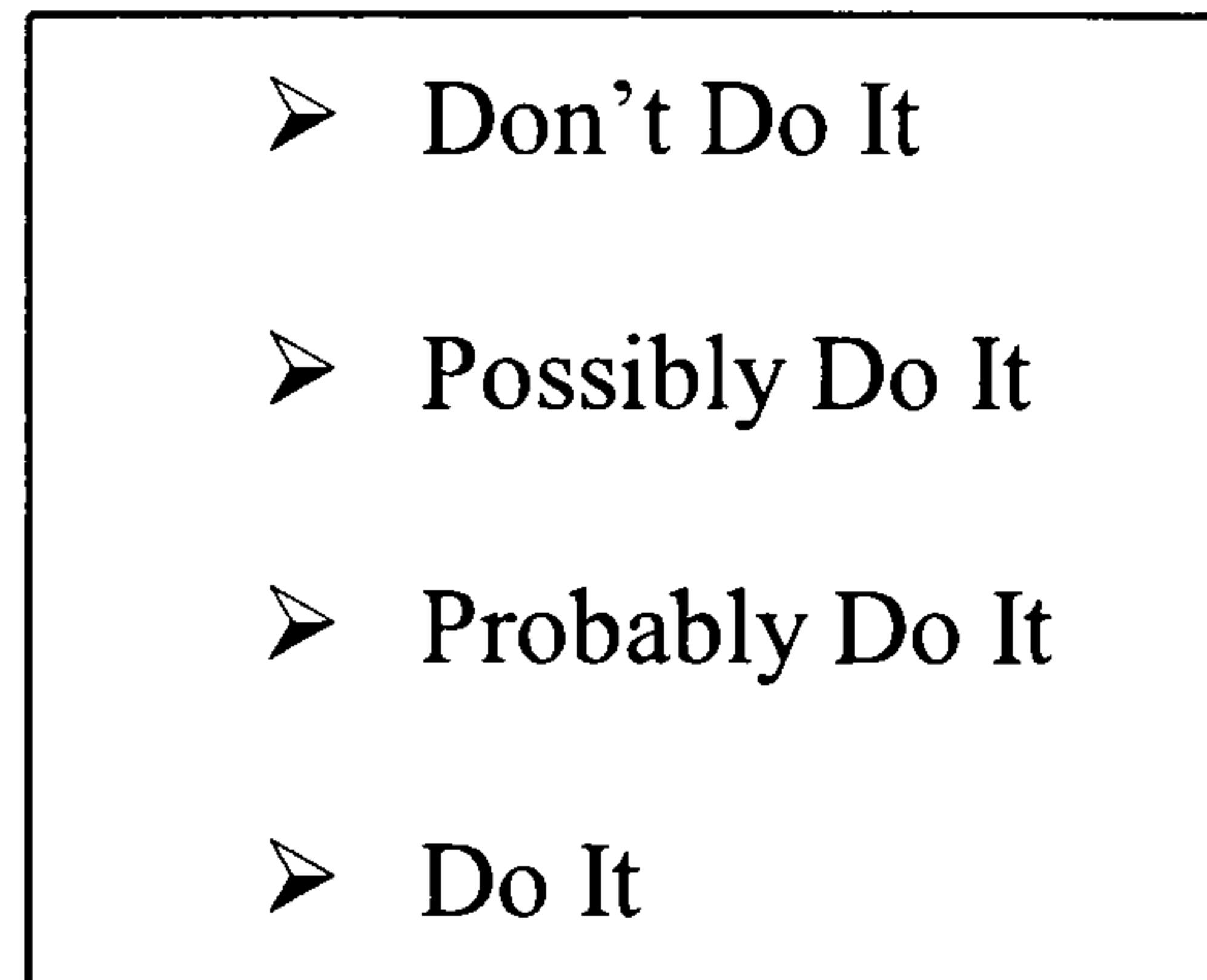
- Very small
- Small
- Large
- Very large

**Lean Readiness**

- Not Ready
- Somewhat Ready
- Just about Ready
- Ready

**Lean Impact**

- Awareness
- Piecemeal
- Constrained
- Widespread



**7.4.3 Experts Inference (2)**

The experts concur on readiness parameter as significant in offering advice on lean uptake. However, unlike relative cost and impact parameters which can easily be operationalised, readiness parameter is hard to define let alone measure. Although they view the KBAS as a viable approach to lean impact assessment, the system should be simplified for eventual practical application in an industrial domain. Their key concern is the identification of the audience (user). This is due to the fact that the KBAS in their opinion seems to operate as a black-box, where SMEs, who are the intended audience, may not have the technical and expertise to operationalise its usage resource wise. They recommend more work to be carried out in simplifying the user interface and its applicability.

However, they infer on the four statements seeking to advice a potential lean user: “Do it, probably do it, possibly do and don't do it” respectively, as follows. The validation session confirmed the researcher's earlier perception that someone would do it if they are ready with all the required resources, and foresee realistic returns. “Don't do it” statements shall imply a company has not reach the benchmarking of implementing lean



due to its lack of resources and other necessary ingredients such as awareness. However, in their view, such statements are linear logics that all it does best is represented by the results from the KBAS. Therefore, future work requires the deployment of a consultant or expert system in order to interpret the results for the end user.

## **7.5 Case study 3: Industrial Practitioners**

The third case study was conducted to test the developed systems industrial worthiness. Four experts from different industrial settings were involved in this process. These companies were; D Ltd, H Ltd, I Ltd and P Ltd; all based in Bedfordshire. The constituent of the experts involved two Managing Directors, an Operations Manager and a Lean Engineer. Listed below are the company profiles of the respective experts.

### **7.5.1 Company Profiles**

A summary of the profiles of the companies involved in the industrial application and validation is highlighted as follows.

#### **(i) Company D Ltd**

Company D Ltd is firmly positioned as one of the leading suppliers of domestic and commercial heating controls. Founded in 1992 following the acquisition of the long established company D, and the subsequent merger with the Heating Division of company D Ltd, the company now employs 140 personnel and has a turnover exceeding £10 million annually. Company D brings to the market unsurpassed experience in the areas of traditional electromechanical controls, advanced electronic controls, radiator thermostats and other self-acting controls. Company D is an example of a company to have fully adopted the use of lean manufacturing concepts within their organisations.

#### **(ii) Company H Ltd**

Company H Ltd was established in 1898 and has since been designing and manufacturing innovative specialist equipments for the entertainment industry (television and film studios). With an annual turnover of £1.5m and a staff capacity of 20, the company is the main distributor of television and film studio equipments for the



entire UK market, and has a global presence as well. Company H implemented lean manufacturing sometimes ago in the areas of staff awareness and some few interventions. It did not progress the idea of lean applications further, although it hopes to start it once again.

### **(iii) Company I Ltd**

Company I Ltd has 70 employees and makes over £6m annually. It's the name of company I Ltd that is synonymous with motor control centres, and innovation in the area of high-voltage products. Company I Ltd have the in-house ability to design and supply packages, handling the contracts from concept to completion and guarantee on-time delivery. Company I Ltd can provide solutions and innovation in a wide range of control gear. From single wall-fixing starters, to complete electrical packages incorporating components to suit the customer requirements. The company is at a very early stage of lean manufacturing adoption since management views it as a springboard to success.

### **(iv) Company P Ltd**

Since their inception in 1969, Company P have established themselves as a leading specialist in the supply of high quality sheet metal fabrication works, producing components and equipment to the highest possible standards at extremely competitive prices. With an annual turnover of 1£m, and a highly skilled workforce of 25 people, Company P are committed to ensuring the highest levels of precision and system concept, meeting the demands of the client on-timely. This is achieved through the utilisation of computer aided design (CAD), computer numerical controlled (CNC) equipment and the latest machine technologies. The company claims to be on the right path towards lean manufacturing absorption, more especially with its recent appointment of a dedicated Lean Engineer to oversee its developments.

## **7.5.2 Validation Process (3)**

The session was started by a presentation made by the researcher. This was a PowerPoint presentation whose content was to exhibit the background to the research study and to show the experts the motivating reasons for adopting the use of a KBAS in



carrying out impact assessment of lean manufacturing. The presentation lasted for approximately 15 minutes. The time schedule was tailored as a measure of providing an exciting session so the experts would not lose interest. The experts put forward a number of questions in attempts to understand the whole process. The presentation also included a demonstration of the developed KBAS as presented in the snapshot in Figures (6.4 to 6.3).

In particular, the experts were shown the entire interfaces of the developed KBAS, clearly detailing the development stages, and pointing out what each and every interface does. An elaboration of the membership functions and the definition of the linguistic variables were also conducted. During this period, the experts where clearly explained a number of issues. For example, they were told what it meant, when it is stated that ‘relative cost is verysmall, small, large and verylarge. Additionally, they were also informed of the linguistic variables of basic membership functions used in the KBAS and its respective numeric inferences.

The above step was followed by a demonstration of the designed heuristic rules, and how the KBAS generated them. At this point, the experts were allowed to test the validity of the designed rules. This was conducted in a manner where each rule was highlighted, and the expert panel discussing its relevance, logic and genuineness before eliminating or accepting it. The process was aided by the use of a designed template highlighted in Table (7.2). This process was termed ‘rule qualifier’ and lasted for approximately an hour. For example the experts identified the rules illustrated in Table (7.3) and argued over it as follows:

**Table 7.2: Rule modifier for relative cost of lean**

	<b>IF</b>	<b>AND</b>	<b>AND</b>	<b>THEN</b>
<b>RULES</b>	<i>Relative cost is VerySmall</i>	<i>Lean Readiness is Ready</i>	<i>Lean Impact Widespread</i>	<i>Advise is: Do-It</i>
1				
2				
3				



In the experts view, a potential lean user will be inclined to absorb the concept if they believe the cost is realistic or achievable. In this context, verysmall is highlighted numerically by the KBAS membership function as not exceeding £25 thousand. Moreover, the selected rule provides a condition portraying the company to be at a point of readiness. This means that, such a potential company has attained almost all the required standards for implementing lean manufacturing. These requirements can be cited as; having trained personnel, or having some lean agent within the organisation to champion the lean cause. Moreover, despite the fact that the relative cost of implementing lean manufacturing is being displayed by the system as very small, on the contrary the system returns the potential impact (benefit), from lean implementation as being huge (widespread) for the amount of money required. The above procedure was continued on rule modification until the session achieved the desired outcome.

**Table: 7.3 An example of lean advice statement**

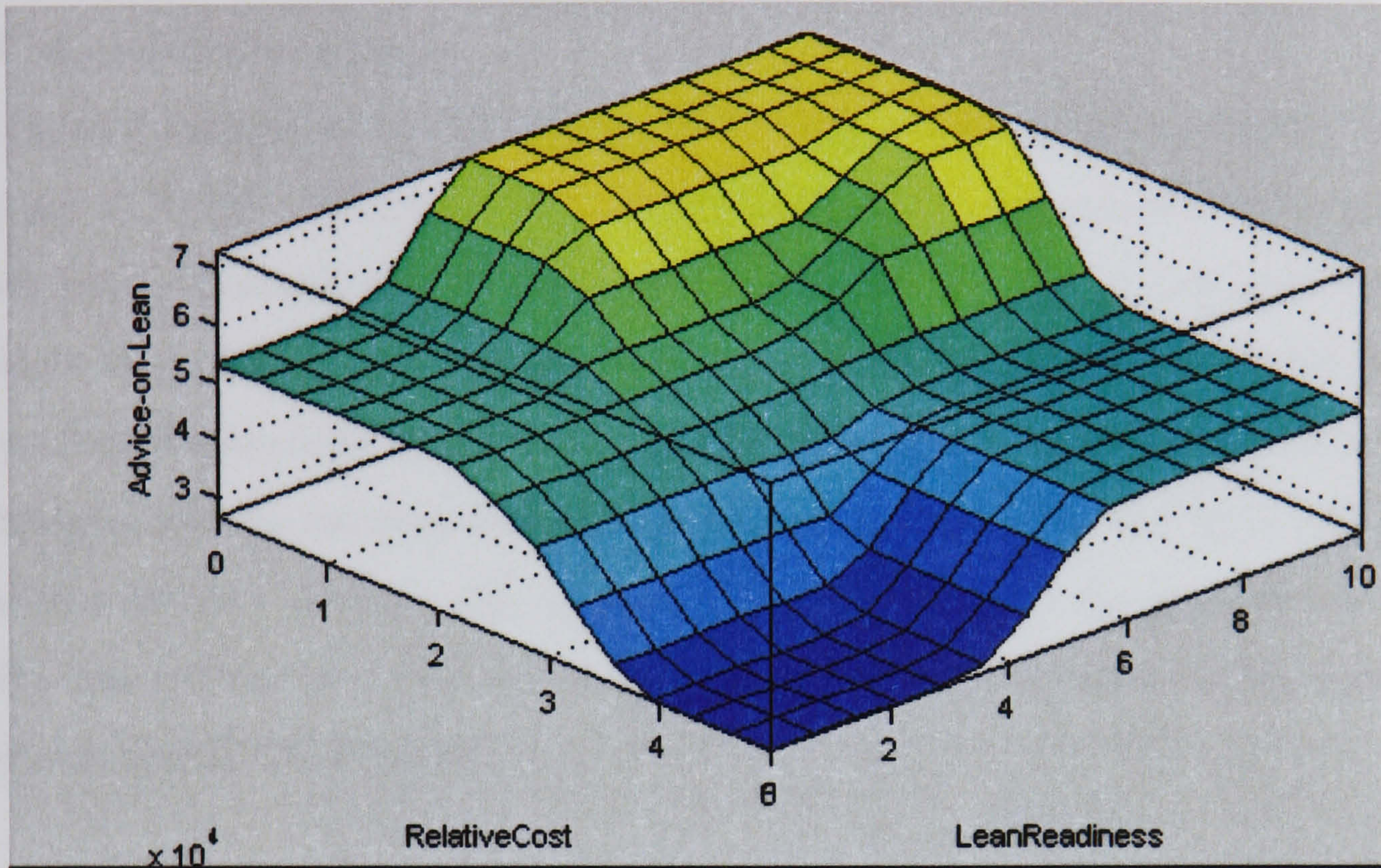
*If relative cost is VerySmall  
And LeanReadiness is Ready  
And LeanImpact is Widespread  
Then advice on lean implementation is Do-It*

The experts then had the opportunity of observing both the rule and surface viewers of the developed KBAS. A demonstration of interpretation of the rule viewer was conducted. For example, experts were shown the rule viewer of the relative cost of implementing lean manufacturing within a company as highlighted in Figures (6.11) and (6.13) respectively. They were first shown extreme points of the designed parameters (when the relative cost is very high; approximately £43 thousand), and the lean readiness is perceived to be at its lowest (a scale of about 1.75) and the envisaged impact standing at (mere 14.1 %).

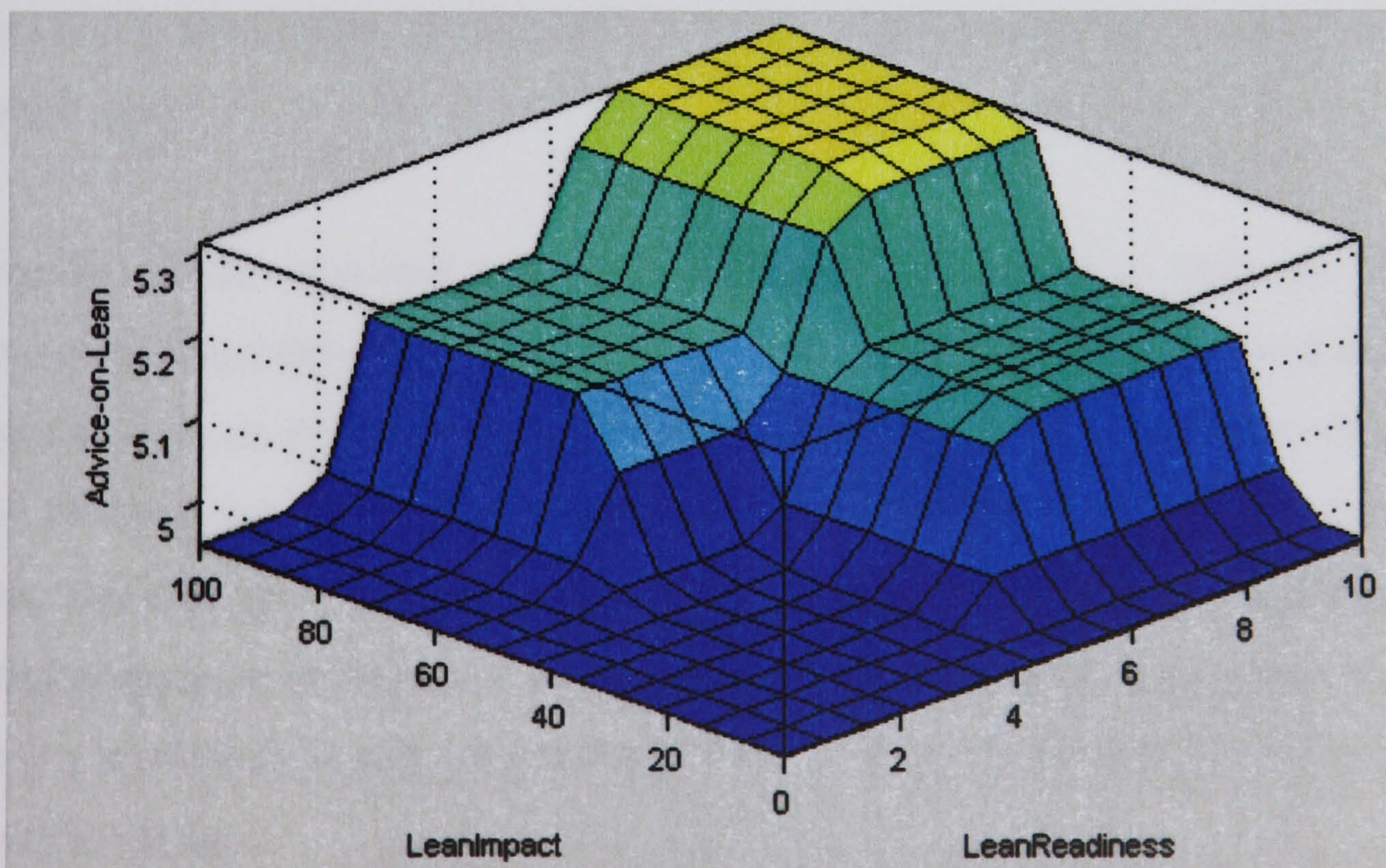
The rule viewer seems to back the designed rules' logic which implies lean should not be implemented (Do not do-it) in such a scenario. This is because; the cost is perceived to be enormous, and the company is returned as not ready at all. Additionally, the



expected returns on the lean investment are postulated as meagre. Therefore, the experts agreed with the validity of the operationalisation of the developed KBAS, as in their opinion, it provides realistic, logical and relevant guidance on decision-making process on lean uptake.



**Figure 7.2: Topography of the relative cost v. lean readiness**



**Figure 7.3: Topography of the lean impact v. lean readiness**



The above process was followed by a demonstration of the surface viewers highlighted in Figures (7.2 and 7.3) respectively. It was evidently clear that the experts appeared much interested in viewing the topographies of the surface viewers and the interpretative inferences, more than any other element of the KBAS.

### **7.5.3 Expert Inferences (3)**

The experts' inferences on the behavioural patterns of the surface viewers in Figures (7.2) and (7.3) run as follows. The orange portion of the topography of Figure (7.2) demonstrates a scenario where a company's positioning in terms of lean advice is to do it straight away. This is due to the fact that at the orange lining, the relative cost is really low yet the company lean readiness is extremely high. In a scenario where cost begins to climb higher and the company lean readiness is interpreted as not very high, a degree of probability of lean adoption may ensue. This continues with the incremental rise in relative cost and decline in the lean readiness status where lean advice would ultimately become untenable (Don't do it).

In Figure (7.2), a similar reasoning was adopted on the relative cost of lean manufacturing implementation; save for the related variable which in this instance became the lean impact (expected benefits). The experts were of the opinion that if relative cost is low and the forecasted lean impact is high, companies would be urged to do it straight away.

Conversely, if the expected impact is anticipated to be lower than the cost of implementation and the cost is unrealistically high, the advice would be not to do it. The interpretive view on Figure (7.3) by the experts was that the steep drop from the orange portion of doing it to greenish parts (possibly doing it) may be ascribed to a number of reasons. For example, an individual company may have a strategy of deploying lean manufacturing such as having a change agent to champion the cause which is why a decision may be sudden and not gradual in this context as illustrated in the topographic view of the surface.



A brief recess ensued before the experts were given the opportunity of exploring the KBAS at their discretion. The researcher deliberately allowed the experts to use the system on their own without guidance. This was intended to limit any possible influence on the outcome of the experts' comments about the system usability. This process lasted for about 30 minutes. The time scale was planned as a means of providing these people the opportunity of trying and testing the system at a calmer pace, since they were regarded as novices (first time users) of the developed KBAS.

The experts were then given the chance to ask questions and air out their opinions or make comments based on their observation of the developed system. This session lasted for approximately an hour as it was designed on a brainstorming fashion. Particularly, the session centered on the relevance, genuineness, accuracy, ease of understanding (by the user) and the intended audience or rather, the eventual end user.

**Table 7.4: A Sample of Closed Question**

*Q. Does the KBAS perform cost assessment of lean impacts as you would expect?*

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6
Explain the reason for your choice:					

The validation process was finalised by a questionnaire session. Experts were provided questionnaires which had both open and closed questions as sampled in appendix (E). The designed closed questions were varied with a scale rating of 1-6, with [1] being the lower and [6] being the upper end. Examples of such questions are depicted in Tables (7.4) and (7.5) respectively.

The rationale behind designing the validation questionnaire with both open and closed ended questions emanated from the fact that, both have positives and negatives in their



usage. Open ended questions are good in situations where both parties want to understand each other, share control of the conversation, listen to each other, and when there is sufficient time for the conversation to allow proper sharing and listening.

In situations where time for the conversation is limited, or the conversation is less about understanding each other and more about making a fast decision, close ended questions can be more appropriate. As with both open and closed ended questions, the technique must be **used sincerely and properly**, since any kinds of questions, if used poorly can result in the other person feeling like he or she is being cross-examined, attacked or otherwise interrogated.

**Table 7.5: A sample of open-ended question**

*Q. What are your general observations relative to the proposed benefits of the developed knowledge based advisory system?*

*Please, explain your answer.....*

Never-the-less, it can be pointed out that the questionnaire design involved a careful and pragmatic process. This took a number of iterations where a set of questions were selected and thereafter mocked-tried with arbitrary experts. The essence of doing this was to ensure the questionnaire was well structured and contained clear and straight forward questions for the respondents. For instance, the opening paragraphs of the designed questionnaire clearly highlighted the aim and objectives of the entire questions.

The questionnaire development underwent rigorous assessment that also involved the participation of experts in the field of questionnaire design. This was an important element in the questionnaire design process, because it ascertained whether the listed questions had the capabilities of enabling the researcher to acquire relevant and precise information from the targeted respondents. The process was thus a significant element



in the evaluation and the assessment of the knowledge based advisory system's authenticity.

Information gathered from the validation session was captured mainly through the use of a Dictaphone. Handwritten notes were recorded in the observation data collection sheet copy listed in appendix (F). The captured data was later transcribed and analysed. Thereafter, cross-checking exercises were conducted with the participating experts in the validation process as a means of prevailing accuracy. These exercises were done mainly through phone calls and e-mails to the respective persons.

## **7.6 Case study 4: Determination of the System Confidence**

A fourth case study was initiated as a means of testing the developed systems accuracy and confidence. The essence of carrying out this procedure was to test results generated by the developed system against expert opinion. Illustratively, a scenario may exist where the system generates a condition as highlighted in Table (7.6).

**Table: 7.6 an example of lean advice statement**

<p><i>If relative cost is verysmall And lean impact is widespread Then advice on lean implementation is Do-It</i></p>
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The above condition is unanimous, therefore a projection of a tolerance limit of over 80 percent certainty within the system remit. This means that the decision to perform lean manufacturing based on the system advice is to do it without any reservation because one is ready. The research reverted to the original hard dataset that were used to design and build the system as highlighted in Table (7.7). This approach was selected because it was a desired option by most experts, since they thought it presented them with tangible and realistic mode of measure in terms of the system's practical credibility and accuracy.



### 7.6.1 Validation Process (4)

To test the confidence level of the system's score ranges, expert opinions were obtained. Ten experts were availed information on the system performance and were asked to make scores of between [0] to [100] percent based on their opinion on each condition. Realistically, experts' opinions were sought. They were required to analyse a list of parameters of proposed lean projects as demonstrated in Table (7.7)

Although the experts were led to believe the information depicted within the table were proposed lean projects within varied companies, in reality, the data were true company results that had been involved in previous lean projects. These datasets were the ones used in the development of the KBAS. Hence, the idea of letting the experts to believe the datasets was for proposals, emanated from the fact that experts would be inclined into making a fair, honest and transparent assessment. Whereas is they knew the datasets were actual, perhaps they might have merely concurred with the results, thus presenting a state of bias within their judgment.

Interpretatively, certain parameters such as the number of years a company has operated, whether it had implemented lean previously and if its personnel had lean expertise; constituted inputs for lean readiness status. Certainly, the estimated cost of lean and the gross value-add figures were interpreted to represent relative cost and forecasted lean benefits (impact), as was deployed within the KBAS discussed previously. The ten experts made respective scores for each particular company represented in Table (7.7). Their scores were averaged and analysed. Analytically, it may be asserted that for the average scores of experts giving advice involving company [1] highlighted in Table (7.7); 83.5 percent average, postulates a [Do It] condition. However, when the range of experts are considered further as exemplified below, an inference may be drawn based on the average scores falling within the [Do It boundaries], although the 80-10 score provides a stronger confidence of [Do It].

In order to test the system's accuracy, a sample of the system scores were averaged as demonstrated in Table (7.8). The system's highest points were selected in each



condition. These were then matched with the expert scoreboard. Conclusively, the system's scores matched most of the experts' scoreboard, save for the "Don't Do It" condition which posted a wider range of 45 against 20 from experts. This may be attributed to a number of reasons. Firstly, as highlighted in Table (7.7), the experts posted their scores based on the information they thought was realistic for a decision to embark on lean project or not. For example, ten experts made their opinion and scored differently on the prospect of Company [1] displayed in Table (7.7). Their average scores amounts to 85 percent, meaning that the company should go ahead and implement lean manufacturing (Do it). When this is counter-checked against the system scores highest point, it is found out that the expert score falls within the systems score of 90 percent; a close match.



**Table 7.7: A determination of the system confidence using real companies Dataset**

Parameters of a proposed Lean Project		Expert Scores: How much confidence do you have (expressed as a percentage) in a recommendation that this Company should proceed with their lean project?																						
Company ID	Nature of business	Main reason for considering of lean project	Years in operation	Annual turnover (£m)	Number of Employees	Estimated number of employees to be involved in lean	(Some of) employees to be involved already	(Some of) employees to be involved have lean	Estimated duration of lean project implementation	Estimated total cost of lean project implementation (£k)	Estimated gross value-add of lean project in pounds	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	average	range	
Company 1	Electronics	Optimisation	28	3.2	65	25	Y	N	10	71	412	85	90	90	90	80	80	80	70	75	100	75	83.5	30
Company 2	Cable assembly	Competition	25	15.0	207	20	Y	N	20	112	289	80	90	90	85	80	75	75	50	60	80	60	75	40
Company 3	Vibrations controls	Clear vision	25	1.4	30	6	Y	N	20	39	70	50	75	75	70	60	60	60	60	55	60	55	62	25
Company 4	Computer recycle	Disparate operations	10	0.8	15	14	N	N	20	76	85	10	20	20	10	10	10	10	0	0	0	0	8	20
Company 5	Framed arts	Competition	23	6.0	102	40	N	N	20	215	1,104	70	75	80	70	75	70	70	60	70	75	80	72.5	20
Company 6	Sheet metals	Competitive advantage	34	3.8	70	20	Y	Y	10	55	803	95	100	90	95	95	95	95	85	90	100	90	93.5	15
Company 7	Plastic materials	Communication	15	2.5	50	8	Y	Y	20	46	100	75	80	85	85	80	85	85	75	75	80	80	80	10
Company 8	Vehicle care products	Cost reduction	30	17.5	120	8	N	N	20	57	147	80	70	75	80	80	80	80	60	60	70	60	71.5	20
Company 9	Passenger & goods lifts	Cost reduction	22	5.0	100	11	N	N	20	63	125	70	65	65	70	60	60	60	50	50	60	50	60	20
Company 10	Furniture	Cost reduction	8	0.4	8	7	N	N	20	37	45	10	20	20	30	25	30	30	0	5	0	0	14	30



**Table 7.8: A comparison of the expert score versus the knowledge based advisory system's**

<b>Company No</b>	<b>Average experts score %</b>	<b>Range</b>	<b>Recommended KBAS advice</b>	<b>Actual KBAS score (highest point) %</b>
1	83.50	30.00	Do It	90.00
2	75.00	40.00	Possibly Do It	65.00
3	62.00	25.00	Possibly Do It	65.00
4	8.00	20.00	Don't Do It	45.00
5	72.50	20.00	Probably Do It	70.00
6	93.50	15.00	Do It	90.00
7	80.00	10.00	Do It	90.00
8	71.50	20.00	Probably Do It	65.00
9	60.00	20.00	Possibly Do It	65.00
10	14.00	30.00	Don't Do It	45.00



## 7.7 Key Observations

- The experts confer that three entry points within the system (the relative cost, readiness and impact) structures, and their membership functions were harder to interpret in terms of KBAS representation from a novice point of view. In their opinion, the surface viewer is a good tool that is much easier to understand and interpret. It also provides a more generic set of membership functions that would work across-board.
- The topography from the surface viewer may be used as a strategic tool where a company views itself from where it is and projects where it wishes to be in a period of time. The changes in level of the topography from orange, green and blue colours are a depiction of how a particular firm may climb the ladder of lean conversion. A firm may opt to move from the blue points blue to orange as highlighted in Figures (7.2) and (7.3) straight away (from bottom to the top) or may take a rather gradual approach in terms of putting certain lean elements together like awareness and training prior to serious involvement.
- The model may also be ideal for a company who has already made up their mind for business improvement. This can be derived from the diagrammatic representation in Figure (7.3) where the steep ramp may be adduced, to such a company having taken up the cost of implementation out of the equation, because one is either ready or not. Hence the inclination of implementing lean manufacturing right away or not at all. This inference may be bolstered by the argument that, one may do the simple bits such as the implementation of 5S approaches or the kanban systems on their own, before seeking to embrace lean at a full scale. However, if a more adventurous intervention such as shifting equipments prevails, then one needs to identify or hire a champion or change agent which in the topographic view illustrate the steep drop, meaning a deferral in doing it later.



- The system may also represent a company with a perfect platform of how to climb the gradient. This may be characterised by employing a rather light but rigorous change projects such as the use of a graduate service or university student projects.
- The ideal usage of the system may lie on the probabilities or possibilities of plotting your journey and checking the points in a non-linear fashion since the KBAS extrapolation is a black-box like pattern. The benefit of the system is its ability of enabling a company to move away from initiatives of the old theory of making suppositions that, “if we do such and such a thing, then we need to accomplish some other ones in order to improve”. The system thus enables a company to view and identify right on, which input parameters to improve on.
- Consultants are identified as the most probable eventual users of the developed system. Academics or experts of some sort may also get involved with companies to aid their usage. Initially, companies in the categories of Rolls Royce and Jaguar may be better suited in comparison to smaller players.
- The developed system may also be envisaged for use by frameworks like the Benchmark Index and the Excellent Framework for Quality Measure (EFQM). The Benchmark Index being regarded as arguably the world’s most extensive benchmarking resource for businesses may appreciate the developed KBAS in improving the competitiveness and profitability of their clientele. The Benchmarking Index could use its comparative analysis of companies’ competitive positions and aid the strategic future planning of a particular company’s direction by deploying the use of the knowledge based advisory system surface view topographic interpretation.

## **7.8 Summary**

This chapter has presented the process of industrial testing and validation of the developed impact assessment framework and the conceptualised knowledge based



advisory system for lean manufacturing within SMEs. The chapter has also provided detailed accounts of the validation case studies and the outcome thereafter. In conclusion, the chapter has proven the functionality, usability, relevance and accuracy of the developed framework and the KBAS. The chapter has also highlighted an in-depth analysis of the results generated in the developed framework and KBAS demonstrated and discussed in Chapters 5 and 6 respectively. Moreover, results obtained from the developed framework and the knowledge based advisory systems were observed and critically analysed in this chapter.

Hence, the chapter has achieved the accomplishment of objective (7) set out in Section 3.1.1; *validating the impact assessment framework and the developed knowledge based system for implementing lean manufacturing within SMEs*. This achievement has encompassed the involvement of real-life case studies, workshops and expert opinions discussed in Sections 7.2-7.5 respectively.



## CHAPTER (8)

### 8 DISCUSSION AND CONCLUSIONS

#### 8.1 Introduction

The literature review presented in Chapter 2 together with the analysis of lean manufacturing utilisation in Chapter 4, synergistically provided some research gaps which facilitated the development of the impact assessment framework and knowledge based advisory system for lean manufacturing within SMEs implemented in Chapters 5 and 6 respectively. Moreover, to test the usability and the effectiveness of the developed framework, and the KBAS, validation sessions were performed with experts both in academia and industry. Observations and learning outcomes have been discussed in Chapter 7. Within this chapter, the overall research findings are presented and discussed against the research aim and objectives. The chapter also provides and clarifies observations obtained from this research study. Contributions to knowledge are discussed and identified research limitations and recommendations for future research direction are stated. The thesis is summarised by the concluding remarks presented in Section 8.6. The main aim of this chapter is to:

#### Chapter aim:

Present, discuss and make final conclusions on the implications of the research findings highlighted in the entire thesis.

#### 8.2 Discussion

In recapitulation it may be stated that, the overall aim of this research study was to develop an impact assessment framework for lean manufacturing within SMEs. In order to achieve the above-stated aim, the research study had to accomplish a number of set objectives as listed below.

(1) Identifying the key drivers for implementing lean manufacturing within SMEs, (2) investigating the operational activities of SMEs in order to understand their manufacturing issues, (3) exploring the current level of lean manufacturing usage within



SMEs so as to categorise users based on their levels of involvement, (4) identifying factors that determine the assessment of lean manufacturing, (5) developing an impact assessment framework for lean manufacturing within SMEs, (6) developing a KBAS and (7) validating the impact assessment framework and the developed knowledge based advisory system through real-life case studies, workshops, and expert opinions.

### **8.2.1 Achievements of the Set Research Objectives**

The first objective set out to identify the key drivers for implementing lean manufacturing within SMEs. To achieve this desire, the research study conducted a critical analysis of published work within the subject of lean manufacturing and its related attributes, presented in Chapter 2. These encompassed the background theories on lean manufacturing concepts and the benefits organisations derive from implementing lean manufacturing within their business. The literature review also sought to identify various industrial contexts where lean manufacturing has been utilised to fruition.

The different lean manufacturing techniques/methods and their applicability was included in the identification process of the key drivers for lean implementation. This idea stemmed from the fact that implementation requirements on the usage of lean techniques were necessary in providing an understanding of their capability. Nevertheless, the literature review presented a number of fundamental issues such as cost of lean deployment and the complexity in manufacturing processes as amongst the most pertinent factors that propel the drivers of its implementation. Moreover, these findings have been supported by several authors who maintain that the application of lean philosophy within an organisation is not simple and attracts enormous resources (Womack *et al.*, 1990; 1996); Schonberger 1982; Hall 1983; Goldratt and Cox (1984).

Moreover, the literature review exercise perused several other impact assessment frameworks within lean manufacturing domain. However, most of these frameworks provided insignificant accounts to actual impact assessment of lean manufacturing implementation. They did not take into consideration the cost, readiness and benefit



factors of lean implementation at an early stage. This scenario therefore suggests that that, many SMEs practitioners are still in dire need of a more robust system capable of providing them with the mechanisms of decision-making process of lean adoption.

The second objective entailed the investigation of the operational activities of a number of SMEs, with a view of understanding the manufacturing challenges they encounter. This task required the engagement of a sample of carefully selected SMEs who had implemented lean manufacturing within their premises. Analytical assessment thereafter yielded an AS-IS scenario of how most of these companies utilise the practices of lean implementation. These results were validated through the use of case studies that involved a number of experts drawn from both the academia and industry.

The research therefore classified these companies in accordance with their lean classes. A gap analysis from the current practice (AS-IS) demonstrated in Chapter 4 necessitated a need for a better technique for addressing the problem of lean impact assessment at the conceptual implementation stage. Hence, an impact assessment framework for justifying lean manufacturing within SMES was designed, as discussed in chapter 5. The developed impact assessment framework for lean manufacturing was further conceptualised in a KBAS as a means of enhancing its robustness. These two developments were then validated through real-life case studies, workshops and expert opinions, as presented in Chapters 6 and 7 respectively.

### **8.2.2 Developing an Impact Assessment Framework for Lean Manufacturing within SMEs**

The research has identified a decision-making process for lean manufacturing implementation within SMEs. The developed impact assessment framework comprises of three main parameters. They include; relative cost of lean implementation, a company lean readiness and the projected benefits to be achieved (impact). Moreover, the framework is conceptualised in a knowledge based advisory system that generates heuristic rules in order to create value-advice conditions. These rules are a combination of the membership functions of the input variables (relative cost, lean readiness and lean



impact). The developed knowledge based advisory system converts the ranges of the desired membership functions into linguistic variables, consequently generating the heuristic rules. Furthermore, the research outcomes presented in this thesis has demonstrated the possibility of quantitative and qualitative assessment of the lean manufacturing impact at the conceptual implementation stage. The developed framework uses flowcharts to illustrate the activities involved in the entire impact assessment process.

### **8.2.3 Validation of the Developed Knowledge Based advisory System**

This research project has validated the developed impact assessment framework and the developed KBAS for lean manufacturing within SMEs. This thesis presents and discusses the validation process of the developed framework and its conceptualised knowledge based advisory system. Validation sessions involving several expert opinions both in academia and industry have demonstrated that the developed system accurately highlights the lean manufacturing implementation conditions (Do it, Probably do it, Possibly do it and Don't do it). The validation case studies have also proven that the developed framework and its conceptualised knowledge based advisory system have been built based on accurate company reported data. Furthermore, the validation case studies tested the developed framework and its conceptualised knowledge based advisory systems' authenticity, by verifying their accuracy, usability and relevance in the assessment of lean impact.

Moreover, the linguistic variables adopted by the developed system (Relative Cost: verysmall, small, high, veryhigh; Lean Readiness: notready, somewhatready, justaboutready and ready; and Lean Impact: awareness, piecemeal constrained and widespread), provide logical and easy to understand inferences. Additionally, the benefit of developing such a framework is cited as, its ability to integrate the insights of different stakeholders (businesses and other users) at various levels. The validation process engaged four carefully chosen case studies with different layers. These layers included the expertise of both academic and industrial practitioners. The validation exercises provided an impetus for analysing the developed system's usability in terms of



its interface and accuracy. Drawbacks were also observed, thus enabling the research to make recommendations for further improvements. Further details of the developed framework and the systems' functionalities and validity are contained in Chapters 5, 6 and 7 respectively.

#### **8.2.4 Strengths and Weaknesses of the Research Work**

The developed impact assessment framework for lean manufacturing that has been realised in this thesis was achieved through a structured and rigorous academic process. The developed framework performs impact assessment of lean manufacturing within SMEs at the conceptual stage. The framework aims to aid decision-making process of potential lean users on its economic viability. Additionally, the developed framework was conceptualised through the use of a KBAS. Hence, the developed knowledge based advisory system's authenticity was industrially tested and validated through a number of sessions as stated in Section 8.2.3. Thus, the main strengths of this research outcome are its provision of the following capabilities.

- A rare opportunity to convert quantitative numbers into qualitative assumptions using the developed knowledge based advisory system.
- Potential lean manufacturing users can make informed decisions on the overall economic viability of its adoption at an early stage.
- Companies may also strategise lean manufacturing adoption based on factors such as cost, readiness, benefit analysis and risk assessment.
- Expert inference reiterated that the model can be better used in the facilitation of a step change given a competent pair of hands, young or seasoned, to help implement lean; this would be a catalyst in a given company.

However, validation exercises highlighted some weaknesses in the system usability. For example, the experts had reservations on the developed system's usage by many managers in average manufacturing companies, as most would not have enough time to take a look, or rather interest in understanding the interpretation of the overall system. Furthermore, as is evident in most research projects, one challenge this research



encounters is that of bias, that may be generated through respondents and researcher's own opinion. Attempts have been made to reduce this drawback by initiating the following contingencies.

- In terms of data collection and validation, the researcher engaged several collaborating partners in both a professional and to a good extent, personal manner. This involvement is believed to have promoted conducive atmosphere where parties on both sides developed a good degree of confidence to talk in a honest, transparent and free modes.
- The deployment of several research sources (triangulation) that involved the use of literature survey, industrial engagements and academic inferences in the entire research investigation, yielded several research gaps. Analytical previews enabled the development of an AS-IS Model depicting clear and realistic problem definition. This testimony justifies that the identified problems within this research work, was not based on mere assumptions.
- The involvement of the entire stakeholders in the research project (sponsors, academic and industrial supervisor and company practitioners), enabled the research to set-up iterative forums that allowed for on timely brainstorming sessions to iron out any anomalies.
- Furthermore, the use of electronic resources in capturing, analysing and storing collected data also provided a perfect platform for consistency, since audit trails of all the processes and occurrences could easily be retrieved. Moreover, the concepts and constructs derived from the study, provides a platform that is relevant for drawing generalisability to settings.

### **8.3 Research Contribution**

The research study has made a number of contributions to knowledge. Specifically, the novelty of the research contributions can be categorised into 4 main themes; the research



findings in terms of data and results, research method pursued, knowledge transferability and the developed impact assessment framework's capability.

### **8.3.1 Novelty in terms of Research Findings**

In terms of data and results, the research has provided an understanding of how to generate company data relevant for performing lean impact assessment within SMEs. This is important because the obtained data listed in Table 5.1, provided the research with a unique opportunity for defining the key drivers for lean manufacturing within SMEs. For example, by understanding the nature of a particular business, it is possible to assess a company's manufacturing process in terms of its complexity. In turn, this allows one to analyse the impact of lean manufacturing within SMEs. Moreover, company reported data such as; annual turnover, number of years in operation and their employees' skills level, were also significant in making analysis on company lean readiness. A further contribution to knowledge in terms of research findings is the classification of SMEs in lean usage. Initial investigation of some SMEs within the identified dataset discussed in Chapter 4, enabled the categorisation of their lean involvement within three classes; Receptive, Interested and Less-interested. The classification exercise of SMEs in lean categorises has provided this research with valuable knowledge of how they are viewed. This is because; the categorisation promotes an understanding of how to improve the cost-effectiveness of these companies. Moreover, these findings have been published in peer reviewed journals and internationally recognised conference proceedings presented in pages (v-vi).

### **8.3.2 Novelty in terms of Research Method Pursued**

The second research contribution stems from the selected research method adopted while developing the impact assessment framework. A hybrid research method was used in the overall development of the impact assessment framework for lean manufacturing within SMEs. This choice of approach was novel in that it allowed the researcher the opportunity to work both within the academic and industrial contexts. This is important because; real-world engineering problems contain discrete design variables which can create complexity both in the identification and problem definition. Hence, the research



method allowed the researcher to contain both the inside and outside knowledge of the problem domain. This was demonstrated by the systematic designed of the research method pursued that enabled the research investigation to achieve targeted milestones. This was good in that the researcher could take-stock of the overall research progress and impact, at each and every milestone researched. It was possible for analytical assessments to be made as to whether the course of action was the right move for that particular problem solving process. For example, the research was contained within an academics setting while attempts were being made to define the specific research problem. This was done through literature review exercises that were obtained from both electronic and off-the-shelf sources. Thus, the accomplishment of a literature review exercise was an important milestone since findings from the literature provided research gaps that eventually influenced the course of the research process and findings.

### **8.3.3 Novelty in terms of Knowledge Transfer**

The developed impact assessment framework for lean manufacturing within SMEs provides company practitioners with a good tool for aiding decision-making process of lean uptake. Hence, it may be fair to assert that the tool may also facilitate companies to solve other problems within their manufacturing environments. This inference may be derived from the developed framework's capability in making a cost-benefit analysis. Equally, the framework may be used within other business contexts such as large sized manufacturing firms. This is because; large sized enterprises also embrace certain similar parameters like; finance, employees and manufacturing processes. Therefore, the developed lean impact assessment framework may also aid such companies in analysing their resources and manpower capacities. However, to achieve this objective, it should be realised that certain characteristics within the framework need to be readjusted in order to accommodate the robustness of a larger organisation. An example would be in the context of the framework ability to assess cost impact within an SME. Here, the original design maintained that implementation of lean manufacturing within SMEs absorbs minimal cost values. Thus, for the developed impact assessment framework to achieve the objective of conducting similar tasks within a large sized organisation, it



would require a calibration of the cost assessment features to consider larger amount of data.

#### **8.3.4 Novelty in terms of the developed Framework's Capability**

The research study has provided a novel framework for assessing the impact of lean manufacturing within SMEs. The developed framework is conceptualised in a knowledge based advisory system. Moreover, the framework is intended to aid SMEs practitioners in carrying out impact assessment of lean manufacturing implementation at the early implementation stage. Companies can assess their business needs in terms of lean usability. SMEs can also assess their eligibility in terms of lean readiness. This is important because the degree of a company lean readiness determines whether it succeeds in implementing it. The level of readiness may also determine the amount of resource needs for the lean project. SMEs are also able to analyse the likely impact of lean manufacturing to their business in terms of the cost benefits. This is a major knowledge contribution since the framework provides an effective tool for decision-making, for a business case in a potential lean user. In the researcher's opinion, no significant literature substantiates similar work elsewhere. The contribution will therefore be beneficial to the business community in several ways. This assertion can be deduced because of the developed system's capability to perform the following.

- It can enable an organisation to make forecast on the probable cost of implementing lean manufacturing within its business.
- A company can also project upfront what it anticipates to achieve as the return on investments (ROI) from implementing lean manufacturing.
- The framework is a precursor for implementing the concept of lean manufacturing. It allows a potential lean using company to make assessments on its capabilities and the capacity of its resource for the intended project.
- Organisations are able to realise its degree of lean need, since the framework conducts test-case scenarios of the affected business drivers as a qualification for lean embracement.
- Identification of area of need is conducted by carrying out analysis on factors



such as resource availability visa-vie the extent of the problem to be solved.

- Companies can also evaluate the strengths and weaknesses of their manufacturing processes based on the impact assessment results.
- The framework can also be used as a standard business tool for assessing an organisation's status.

### **8.3.5 Solutions to the Identified Research Gaps**

Preliminary studies discussed in Chapters 2 and 4 had generated a number of research gaps summarised below.

- Non-clarity as to what is the best fit for lean implementation within SMEs. Do companies need lean wholesome or piecemeal?
- SMEs unawareness in conducting their eligibility of lean uptake.
- Lack of structured framework to aid organisations in determining the lean impact at the conceptual stage.
- Few reasons supporting why SMEs have not bought into the idea of lean manufacturing whole-heartedly.
- Why many SMEs fail to sustain lean manufacturing
- How to determine the expected benefits of using lean manufacturing within organisations.
- Non existence of a model capable of expressing lean impact results both qualitatively and quantitatively to potential users.

The research study has therefore provided some solutions to the gaps identified above by; developing an impact assessment framework for lean manufacturing implementation within SMEs. Furthermore, the developed impact assessment framework was conceptualised in a knowledge based advisory system that performs a number of functions. The developed framework realises the aforementioned achievements, by enhancing a number of relationships between itself and the identified gaps as presented



in Section 8.3. Conversely, the research study had set a hypothesis and research questions as summarised below.

### **8.3.6 Accomplishment of the Research Hypothesis:**

Whether developing a novel framework for assessing the impact of implementing lean manufacturing would motivate SMEs adoption.

In order to accomplish the above desire, a number of research questions were initially asked, and have been addressed thus follows.

- The first question asked the possibility to assess the impact of implementing lean manufacturing within SMEs. The research has proven through the development of an impact assessment framework that it is possible to assess the impact of implementing lean manufacturing within SMEs at the conceptual stage as demonstrated in Chapter 5.
- The next question rippled through two other questions since it inquired on how the impact of implementing lean manufacturing could be assessed, how the factors of lean impact assessment could be identified and what the most suitable delivery medium for the impact assessment framework could be. The three listed questions have been achieved through the deployment of a KBAS that utilises relative cost, lean readiness and lean impact to generate heuristic rules that set-up four conditions for making advice on implementing lean manufacturing presented and discussed in Chapters 5 and 6 respectively.
- The next question concerned itself with the challenge as to whether the assessment of lean manufacturing impact would reassure SMEs about its benefits. This question is treated with another question which also concerned itself as to whether developing a framework for assessing the impact of implementing lean manufacturing would motivate SMEs to adopt the concept of lean. In addressing these aforementioned questions, preliminary exercises to evaluate, test and apply the developed impact assessment framework for lean



manufacturing within SMEs concluded that practitioners have confidence in the lean benefits generated by the developed framework. This is appreciated by expert views presented in Chapter 7.

#### **8.4 Research Limitations**

A further drawback of this research study has been its inability to quantify the lean needs parameters in tangible numerical values. The research was not able to extract from companies, their real-time data of manufacturing operations like; lead-times, delivery-time, inventory days and value-add figures. Given this lack of valuable data, the research was therefore able to shift towards qualitative assessment. Hence, the impact assessment framework presented in this thesis was developed using strong qualitative inputs highlighted in the preceding chapters.

However, as is evident in most knowledge base systems, guaranteeing a desired solution to a given problem might not be an easy task, although results achieved might be consistent. Similarly, the developed KBAS does not provide a launch-pad facility capable of initiating user interface for instructing the system, on a real-time basis. A further drawback of the developed system is its inability to provide a simulation of plotting exact points calculated by the KBAS.

Moreover, the prototype system does not provide an easy to understand readiness parameter as is the case with the relative cost and impact parameters. This drawback may present users with problems more so, at the level of SMEs. This is because; SMEs may take the view of the KBAS operation as a black-box, where SMEs, who are the intended audience, may not have the technical expertise to operationalise its usage resource wise.

The definition of the value-add statements such as [Do not do it], may also present some ambiguity while making conclusive judgments. This in the experts' opinion, stems from the fact that, [Do not do it] may imply a company has not reached the benchmark of implementing lean due to its lack of resources and other necessary ingredients such as



awareness. However, in reality, such statements are linear logics that all it does best is representing the results from the fuzzy logic system. Therefore, the aid of an expert may be desired in such instances.

## **8.5 Future Research Directions**

Expert inference obtained during the entire research validation process provided useful insights for future research leads. For example, one issue raised during the framework and system development session, centered on the interpretative mechanisms for a common user. Specifically, it was pointed out the difficulty that smaller firms may face in understanding the system at its current status. It is therefore recommended that future work should seek to refine the system interface with easy-friendly features. These are sought to include devising mechanisms of pinpointing the different points identified within the system and then use these to compare how one goes from one point to the next in terms of visualisation and also as a measure of testing a step change.

The usability of the developed impact assessment framework should also be practically applied through a number of existing companies to draw conclusive judgement on SMEs' reassurance about lean benefits. Moreover, the author suggests further research investigation be carried out within the confines of larger size manufacturing firms, with a view of identifying their current lean impact assessment techniques. This assertion stems from the fact that the research conducts of developing impact assessment framework for lean manufacturing within SMEs, concentrated mainly on small-to-medium manufacturing firms. Although there were some research engagements to a number of large size manufacturers, it may be fair to assume that, investigation involving a wider sample of larger size manufacturing firms may provide a good platform for better understanding of how to conduct impact assessment of lean manufacturing within SMEs at an early implementation stage.

The other interesting area of potential investigation is the notion of how to make the framework and the developed system more generic across other industrial sectors. The research may opt to identify further case studies that involve completely different



industrial settings to validate the usability of the developed system. This approach may also provide a new angle of thought process in that, expert opinion sought in the validation process may gauge new leads of how best to apply the framework within a given environment.

Hence, to address the issue of guaranteeing problem solution raised in the opening paragraphs of this section, the framework could further be improved by enhancing the system features that enable a user to directly instruct it through the available interfaces. Such interactions would allow the user to solve a given or specific problem on-timely, as opposed to the current system's performance where conversion of natural language generates rules for interpretation in the final decision-making process. For example, in the current system, many rules are fired simultaneously while the system generates expected results. This current scenario makes it difficult to adjust the visualisation interfaces to the required specification since a user may not know which exact rule to modify. The author also recommends further work in evaluating the developed framework's cost-benefit analysis. This exercise should include issues such as; cost of training and the level of education, a user should possess.

## **8.6 Conclusions**

In conclusion, it may be asserted that this research study has achieved the main aim and its set objectives of developing an impact assessment framework for justifying lean manufacturing within SMEs. Moreover, this thesis has conducted the following;

- The thesis has presented a review of techniques, tools and methodologies of lean manufacturing implementation and its impact assessment.
- The literature review exercise identified a number of research gaps. Significantly, the review exercise generated a need for further work in the area of lean impact assessment.



- Additionally, the research has outlined a systematic problem solution for addressing the identified gaps. In particular, the research has developed an impact assessment framework that uses KBAS to advice lean manufacturing practitioners within SMEs.
- The developed knowledge based advisory system generates heuristic rules capable of setting conditions for advice on implementing lean manufacturing. Furthermore, the system provides a more generic set of membership functions that may work across-board.
- The visualisation facility embedded within the developed system is perceived to be a useful tool that provides ease of understanding and interpretation.
- The topographic viewers are essential part of the system and may be used as a strategic tool. Companies may use it to plot their lean development over a period of time.
- The thesis highlights that the model may be used by companies in different states. One such example is a company that has already made up its mind on business improvement. In this instance, the model can enable such a company to plot the improvement journey visualised as a pathway across the topography.



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# **APPENDIX A: RESEARCH QUESTIONNAIRE-1**

## **Questionnaire-1**

### **Research Topic:**

**‘Development of an Impact Assessment Framework for Lean  
Manufacturing within SMEs**

#### **Pius Coxwell Achanga**

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## Introduction

The aim of this questionnaire is to gather knowledge for the purposes of understanding how SMEs employ lean manufacturing approach within their organisations. The interview exercise is intended to include a number of key personnel within the company who were involved in implementing the technique. The main objective of the interview is to enable the researcher obtain information that should assist in assessing the cost-benefit analysis that are involved in lean manufacturing implementation in a company.

**NB:** *(Some of these questions may not be relevant to you. Please ignore as appropriate)*

**Date... ..Questionnaire No.....**

**Company Name.....**

**Employee Name (optional)... ..**

**Department.....**

**Job Title.....**



## **Lean Manufacturing**

1. What is your job description?
2. What kind of products do you manufacture?
3. How would you classify the volume level of the products you make? (Please tick)
  - (a) Low
  - (b) Medium
  - (c) High
  - (d) Other: Please specify
4. Who are your customers?
  - (a) Retailers
  - (b) End users
  - (c) Other: Please specify
5. What is your current lead-time?
6. How many people do you employ?
7. What is your annual turnover?
8. How long has the company existed?
9. What are the major drivers of your business?



10. What is your definition of lean manufacturing? (Please tick).

- (a) A production model whose coordinated manufacturing system is designed to drive closer linkages between all functions within the organization in order to ensure quality compliance (Cook & Graser 2001). [  ]
- (b) A manufacturing system that uses techniques such as the Kanban, Kaizen, JIT, to ensure continuous improvement (Bicheno 2000). [  ]
- (c) The goal of lean manufacturing is to reduce the waste in human effort, inventory, time to market and manufacturing space to become highly responsive to customer demand while producing world-class quality products in the most efficient and economical manner (Todd 2000). [  ]
- (d) Lean production is a secret weapon that welds the activities of everyone in an organisation; from top management to line workers, to suppliers so production and quality is doubled while keeping costs down. (Womack et al 1990). [  ]
- (e) Other: [  ] Please specify.

11. What has motivated the company to implement lean manufacturing?

12. Where has lean been implemented in your organisation (piecemeal or whole)?

13. What were the criteria for choosing that specific area?

14. Briefly could you explain how the whole process started?

15. How many People were involved in the exercise?

16. How were they selected?

17. What training, if any, did the staff undertake?

18. How long did the training take?

19. What were the difficulties encountered in training?

20. How were they overcome?



21. How was the concept received by the employees?
22. How long did it take to implement lean manufacturing? (Please circle).
- (a) 1 week [ ]
  - (b) 2 weeks [ ]
  - (c) 1 month []
  - (d) 3 months [ ]
  - (e) 6 months [ ]
  - (f) 1 year [ ]
  - (g) Other (please specify)
23. What were the **direct** costs involved in the implementation lean manufacturing?  
(e.g. labour costs, consultancy fees, etc)
24. What were the **indirect** costs involved in implementation of lean manufacturing? (e.g. disruption to business, etc)
25. Overall, how much did the company spend on lean implementation?
26. What **tangible** benefits has lean brought to your company? (e.g. Financial returns in figures, etc)
27. What **intangible** benefits has lean brought to your company? (e.g. process improvement, staff motivation level, etc)
28. How have you determined (measured) these benefits?
29. Did you get value for money on these benefits?
- (b) Why?
30. At the time of implementing lean, did the company have any other projects running in parallel?
- (b) If yes, how did this affect the decision to go lean?
31. How would you advice a potential company wishing to implement lean manufacturing?



32. Any other comments on implementation of lean?

.....  
.....

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# APPENDIX: B DATA COLLECTION SHEET

## Observation data collection sheet

### Observation Technique for Lean Needs Elicitation

Date..... Sheet No.....

Company Name.....

Start Time.....End Time.....

Department (area being observed e.g. shop-floor.....

No of people in the vicinity.....

Job Type.....

Process being observed.....

No of Operations.....

No of Persons involved.....

Summary of discursive interaction with people in the vicinity.....

.....  
.....

Relevance of the discussion e.g. rapport building with the employee.....

.....  
.....

Intended person/s to evaluate findings... ..



# APPENDIX: C RESEARCH QUESTIONNAIRE-2

## Questionnaire-2

### Identifying factors that affect lean manufacturing implementation within SMEs

The main purpose of this questionnaire is to aid the provision of information that can enable the identification of relevant factors that affect lean manufacturing drives within SMEs. The questionnaire should also aid the research in obtaining relevant information for defining the relative contribution of each factor in terms of cost of lean manufacturing implementation. E.g. if a company has asserted that manpower factor was the major contributory factor in its lean manufacturing implementation drive, then to what extent has manpower contributed to the overall cost of lean implementation within that particular company.

**Company name:**.....

**Name of Interviewee (optional):**.....

**Position within the company:**.....

**How long position held:**.....

**Brief job description:**.....

.....  
.....  
.....  
.....  
.....  
.....

1. What was the main aim of your company bringing in lean manufacturing?
2. How many personnel were involved at the inception?
3. Were they from a particular department or else they were drawn from different departments such as engineering, design and materials control?



4. What were their job roles within the company?

5. What was the constituent of the personnel in terms of their job roles within the company (How many)?

(i) Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

5. What is their wage structure within the company?

(i) Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

6. How long were they engaged in the initiation process of lean manufacturing implementation?

Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

7. What was the constituent of the eventual personnel used in the actual lean manufacturing implementation in terms of their job roles within the company (How many)?

Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

8. What is their wage structure within the company?

(i) Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

8. How long were they engaged in the actual implementation of lean manufacturing within the company?

Shop-floor personnel (ii) Supervisors (iii) Managers (iv) Senior managers

9. What effect did the **product/process** complexity have on the implementation of lean manufacturing within your company?

10. Was the implementation process of lean manufacturing continuous?



11. Is this the first lean manufacturing project the company has invested in?

(b) If no, please state the previous ones

(c) What impact if any did the previous projects have on the latest lean project in terms of ease of absorption of ideas and winning the minds of the employees?

(d) Would you consider your company as **good** or **bad** on lean manufacturing principles?

(e) If bad, how did this affect the ease of lean manufacturing implementation?

(f) If good, how did this influence the ease of lean manufacturing implementation?

12. How would you define the market condition that your company experienced while trying to bring in lean manufacturing? E.g. **little** market/cost pressure or **intense** market/cost pressure?

(b) What effect if any did the market condition impact on the implementation drive of lean manufacturing?

(c) How did the market condition impact on the level of value-add activities?

13. Why did the company achieve so much lean benefits within a short period of time?

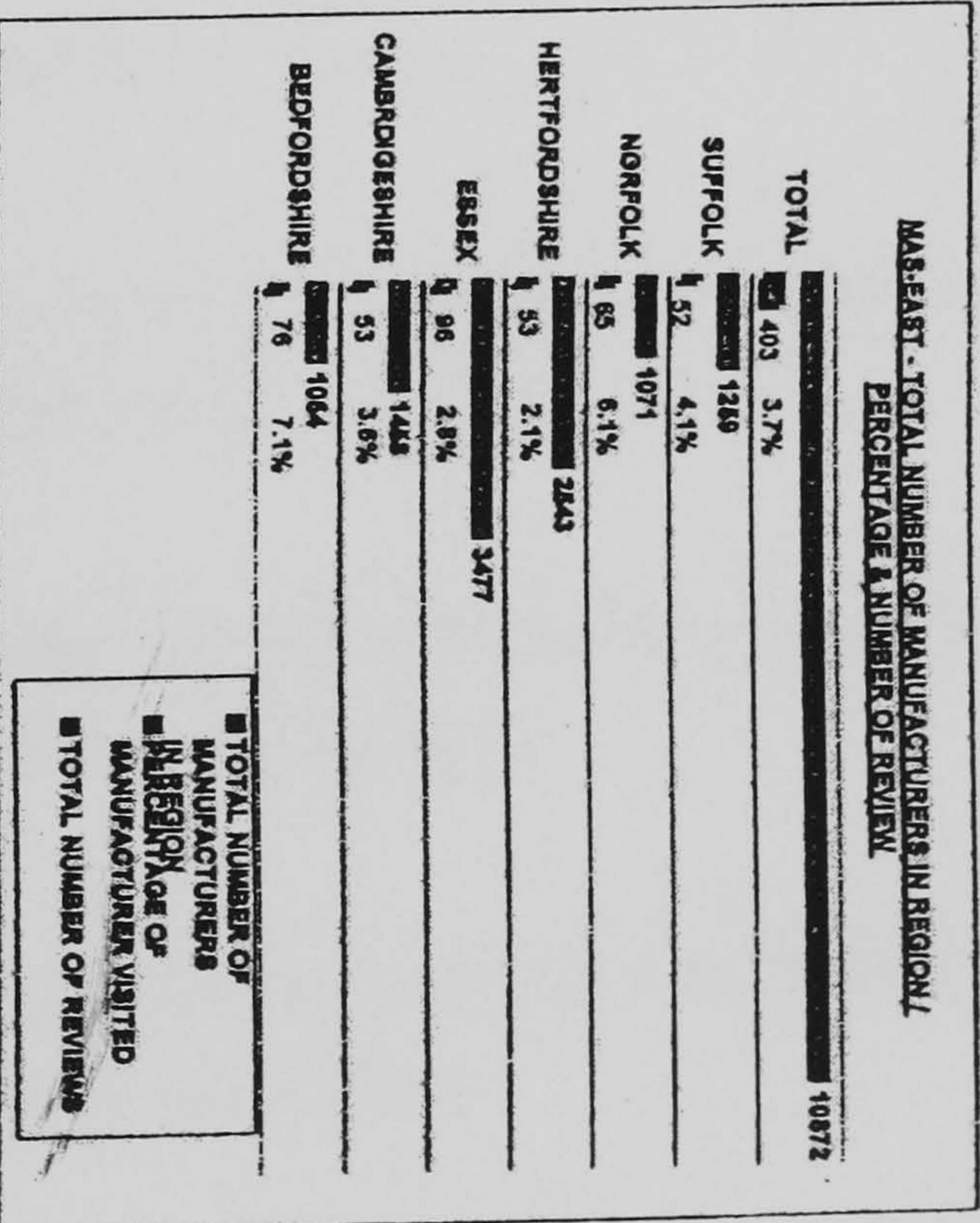
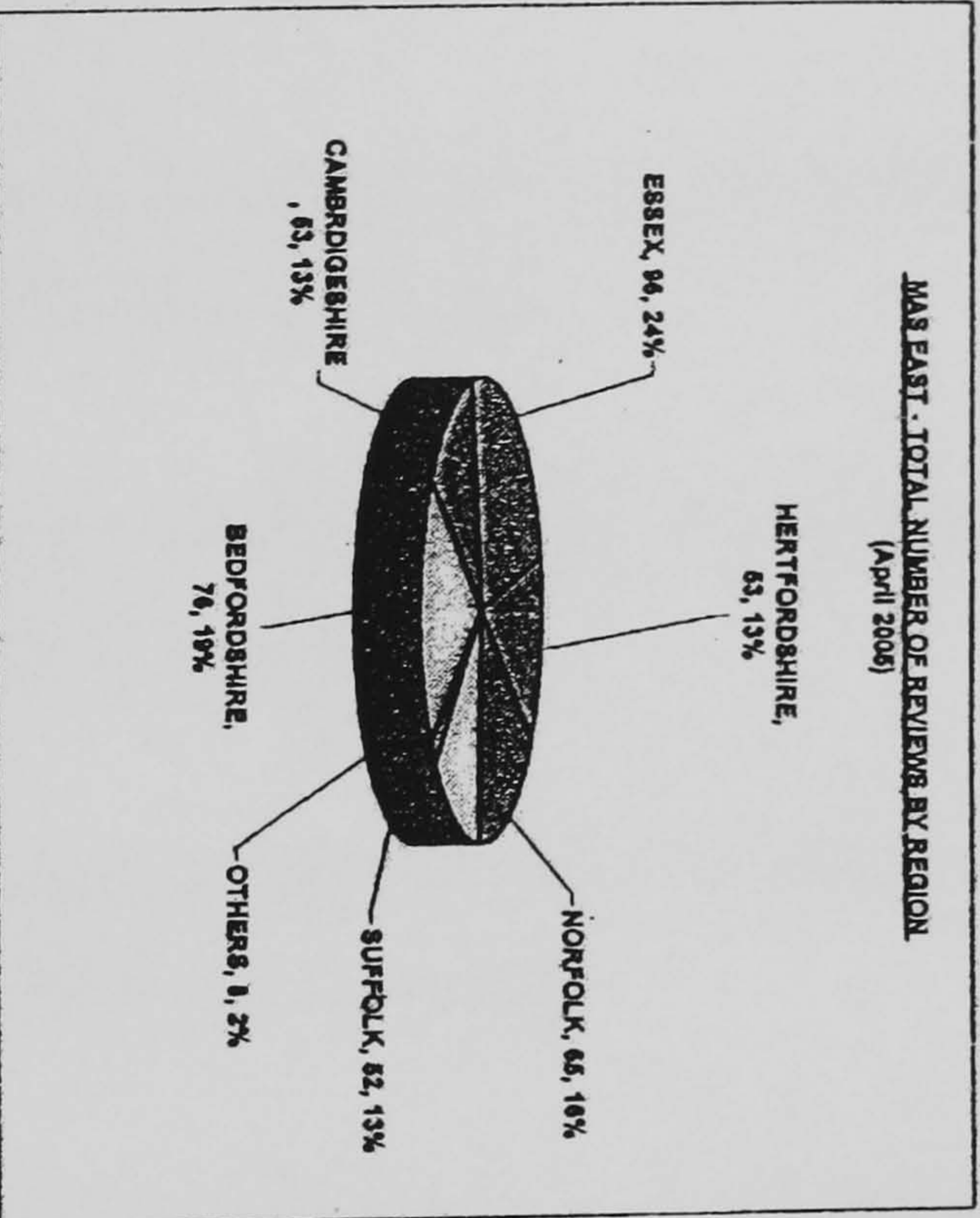


14. What were the factors responsible for the high returns of value-add on lean manufacturing within your company?

15. Any other comments?



APPENDIX: D MAS DATASET



A.

COUNTY	NUMBER OF REVIEWS	PERCENTAGE
BEDFORDSHIRE	76	19%
CAMBRIDGESHIRE	63	13%
ESSEX	96	24%
HERTFORDSHIRE	63	13%
NORFOLK	65	16%
SUFFOLK	62	13%
OTHERS	8	2%
<b>TOTAL</b>	<b>403</b>	<b>100%</b>

COUNTY	TOTAL NUMBER OF REVIEWS	PERCENTAGE OF MANUFACTURER VISITED	TOTAL NUMBER OF MANUFACTURERS IN REGION
BEDFORDSHIRE	76	7.1%	1064
CAMBRIDGESHIRE	63	3.6%	1458
ESSEX	96	2.8%	3477
HERTFORDSHIRE	63	2.1%	2643
NORFOLK	65	6.1%	1071
SUFFOLK	62	4.1%	1269
<b>TOTAL</b>	<b>403</b>	<b>3.7%</b>	<b>10872</b>



## **APPENDIX: E The SUB-SYSTEMS' HEURISTIC RULES**

### **Cost Rules**

1. IF CompanySize is nil THEN cost is nil
2. IF CompanySize is small AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is Awareness THEN cost is very small
3. IF CompanySize is small AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is PieceMeal THEN cost is Large
4. IF CompanySize is small AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is WideSpread THEN cost is VeryLarge
5. IF CompanySize is small AND CompanyExperience is RepeatUser AND LeanImpactArea is PieceMeal THEN cost is Small
6. IF CompanySize is small AND CompanyLeanExperience is RepeatUser AND LeanImpactArea is WideSpread THEN cost is Large
7. IF CompanySize is small AND CompanyLeanExperience is ContinualUser AND LeanImpactArea is PieceMeal THEN cost is VerySmall
8. IF CompanySize is small AND CompanyLeanExperience is RepeatUser AND LeanImpactArea is WideSpread THEN cost is Small
9. IF CompanySize is medium AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is Awareness THEN cost is very small



10. IF CompanySize is medium AND CompanyExperience is FirsttimeUser AND LeanImpactArea is PieceMeal THEN cost is Large
11. IF CompanySize is medium AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is WideSpread THEN cost is VeryLarge
12. IF CompanySize is medium AND CompanyLeanExperience is RepeatUser AND LeanImpactArea is PieceMeal THEN cost is Small
13. IF CompanySize is medium AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is WideSpread THEN cost is large
14. IF CompanySize is Large AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is Awareness THEN cost is VerySmall
15. IF CompanySize is Large AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is PieceMeal THEN cost is Large
16. IF CompanySize is Large AND CompanyLeanExperience is FirsttimeUser AND LeanImpactArea is WideSpread THEN cost is VeryLarge
17. IF CompanySize is Large AND CompanyLeanExperience is RepeatUser AND LeanImpactArea is PieceMeal THEN cost is Small
18. IF CompanySize is Large AND CompanyLeanExperience is RepeatUser AND LeanImpactArea is WideSpread THEN cost is Large
19. IF CompanySize is Large AND CompanyLeanExperience is ContinualUser AND LeanImpactArea is PieceMeal THEN cost is verysmall



20. IF CompanySize is Large AND CompanyLeanExperience is ContinualUser AND LeanImpactArea is WideSpread THEN cost is small

### **Lean Readiness Rules**

1. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is Ready
2. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is good and EmployeesEducationalLevel is fair then LeanReadiness is JustaboutReady
3. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is good and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
4. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is SomewhatReady
5. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is fair and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
6. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is poor and EmployeesEducationalLevel is Poor then LeanReadiness is NotReady



7. IF ManagementSupport is good and FinancialAvailability is good and corporateStaregy is fair and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
8. IF ManagementSupport is good and FinancialAvailability is fair and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is JustaboutReady
9. IF ManagementSupport is good and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is good then LeanReadiness is SomewhatReady
10. IF ManagementSupport is good and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is SomewhatReady
11. IF ManagementSupport is good and FinancialAvailability is fair and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
12. IF ManagementSupport is good and FinancialAvailability is poor and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
13. IF ManagementSupport is good and FinancialAvailability is fair and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
14. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is SomewhatReady



15. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is good then LeanReadiness is SomewhatReady
16. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
17. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is SomewhatReady
18. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
19. IF ManagementSupport is fair and FinancialAvailability is poor and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
20. IF ManagementSupport is fair and FinancialAvailability is good and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is JustaboutReady
21. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
22. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is good and EmployeesEducationalLevel is fair then LeanReadiness is SomewhatReady



23. IF ManagementSupport is fair and FinancialAvailability is good and corporateStaregy is poor and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
24. IF ManagementSupport is fair and FinancialAvailability is poor and corporateStaregy is good and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
25. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
26. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is poor and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
27. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is poor and EmployeesEducationalLevel is good then LeanReadiness is NotReady
28. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is NotReady
29. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is good and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
30. IF ManagementSupport is poor and FinancialAvailability is poor and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is NotReady



31. IF ManagementSupport is poor and FinancialAvailability is good and corporateStaregy is good and EmployeesEducationalLevel is good then LeanReadiness is NotReady
32. IF ManagementSupport is fair and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
33. IF ManagementSupport is poor and FinancialAvailability is good and corporateStaregy is poor and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
34. IF ManagementSupport is poor and FinancialAvailability is good and corporateStaregy is fair and EmployeesEducationalLevel is poor then LeanReadiness is NotReady
35. IF ManagementSupport is poor and FinancialAvailability is fair and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is NotReady
36. IF ManagementSupport is poor and FinancialAvailability is good and corporateStaregy is fair and EmployeesEducationalLevel is fair then LeanReadiness is NotReady

### **Lean Benefit/Impact Rules**

1. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is High and LeadTime is Short then Productivity is High
2. IF InventoryLevel is High and ManufacturingProcess is Complex and StaffMotivationLevel is Low and LeadTime is Long then Productivity is Low



3. IF InventoryLevel is Medium and ManufacturingProcess is Moderate and StaffMotivationLevel is Medium and LeadTime is Medium then Productivity is Medium
4. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
5. IF InventoryLevel is Low and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
6. IF InventoryLevel is Low and ManufacturingProcess is Complex and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
7. IF InventoryLevel is Medium and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
8. IF InventoryLevel is Medium and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
9. IF InventoryLevel is Medium and ManufacturingProcess is Complex and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
10. IF InventoryLevel is High and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
11. IF InventoryLevel is High and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
12. IF InventoryLevel is High and ManufacturingProcess is Complex and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low



13. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is Medium and LeadTime is Short then Productivity is Low
14. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
15. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Medium then Productivity is Low
16. IF InventoryLevel is Low and ManufacturingProcess is Simple and StaffMotivationLevel is High and LeadTime is Long then Productivity is Low
17. IF InventoryLevel is Medium and ManufacturingProcess is Simple and StaffMotivationLevel is Medium and LeadTime is Long then Productivity is Low
18. IF InventoryLevel is Medium and ManufacturingProcess is Simple and StaffMotivationLevel is High and LeadTime is Short then Productivity is Medium
19. IF InventoryLevel is Medium and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Short then Productivity is Low
20. IF InventoryLevel is Medium and ManufacturingProcess is Complex and StaffMotivationLevel is Medium and LeadTime is Short then Productivity is Low
21. IF InventoryLevel is Medium and ManufacturingProcess is Complex and StaffMotivationLevel is Medium and LeadTime is Medium then Productivity is Low



22. IF InventoryLevel is High and ManufacturingProcess is Moderate and StaffMotivationLevel is Medium and LeadTime is Long then Productivity is Low
23. IF InventoryLevel is High and ManufacturingProcess is Complex and StaffMotivationLevel is Low and LeadTime is Long then Productivity is Low
24. IF InventoryLevel is High and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Long then Productivity is Low
25. IF InventoryLevel is High and ManufacturingProcess is Simple and StaffMotivationLevel is Low and LeadTime is Long then Productivity is Low
26. IF InventoryLevel is High and ManufacturingProcess is Simple and StaffMotivationLevel is Medium and LeadTime is Long then Productivity is Low
27. IF InventoryLevel is High and ManufacturingProcess is Simple and StaffMotivationLevel is High and LeadTime is Long then Productivity is Low
28. IF InventoryLevel is Medium and ManufacturingProcess is Moderate and StaffMotivationLevel is Low and LeadTime is Medium then Productivity is Low
29. IF InventoryLevel is High and ManufacturingProcess is Complex and StaffMotivationLevel is Medium and LeadTime is Long then Productivity is Low



# **APPENDIX: F RESEARCH QUESTIONNAIRE-3**

## **Questionnaire-3**

### **Experts' Feedback**

#### **INTRODUCTION:**

The developed framework is intended to aid SMEs practitioners in carrying out impact assessment of lean manufacturing implementation within SME at the early implementation stages. Companies can assess their business needs in terms of lean usability. In other words, is lean the right thing for them? SMEs can also assess their eligibility in terms of lean readiness. This is important because the degree of a company lean readiness determines whether it succeeds in implementing it. The level of readiness may also determine the amount of resource needs for the lean project. SMEs are also able to forecast the likely impact of lean manufacturing to their business in terms of the cost benefits. Hence, a KBAS has been designed to aid the robustness of the main framework. The KBAS provides heuristic rules for determining the probable outcomes in terms of lean costs, readiness and benefits.

#### **Aim of questionnaire**

The aim of this questionnaire is to obtain feedback from the participating organisations in determining the systems capability in terms of;

- Performance
- Accuracy
- Relevance
- Completeness
- Observations

#### **Benefits to your organisation**

The framework should benefit participating companies by recommending key issues that determine a successful lean project. The feedback report from the participating organisations will provide the research project with useful information which will enable the researcher to tailor a better and improved system.

**NB: To preserve anonymity the names of participating organisations/interviewees are not required. This will also help to reduce bias in the response of interviewees.**



## Questions

1. Job title, main role and years of experience

2. Were the above experiences acquired from more than one organisation

3. Approximately how often are you involved in the productivity improvement initiatives in your company ?(**daily, weekly, monthly, not at all**)

4. Does the KBAS perform cost assessment of lean impact as you would expect?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:

5. Do you agree with the approach to the cost-benefit assessment of lean impact?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:



6. Do you agree with the results of the KBAS?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:

7. Is the KBAS easy to use?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:

8. Is the KBAS easy to understand?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:

9. Would you consider the KBAS to be relevant to the SMEs Community?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:

10. Does the KBAS completely capture all possible scenarios of lean manufacturing readiness, cost and benefits?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6

Explain the reason for your choice:



11. Do you think the KBAS can be easily integrated into your current business philosophy, or (any business philosophy)?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6
Explain the reason for your choice:					

12. Do the presented rules make logic to the cost impact of lean manufacturing implementation within SMEs?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6
Explain the reason for your choice:					

13. Do the presented rules make logic to the readiness impact of lean manufacturing implementation within SMEs?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6
Explain the reason for your choice:					

14. Do the presented rules make logic to the benefit impact of lean manufacturing implementation within SMEs?

Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1	2	3	4	5	6
Explain the reason for your choice:					




15. What are your general observations relative to the proposed benefits of the system?

16. Any other comments

Thank you for your time!



## APPENDIX G: ACHIEVEMENT

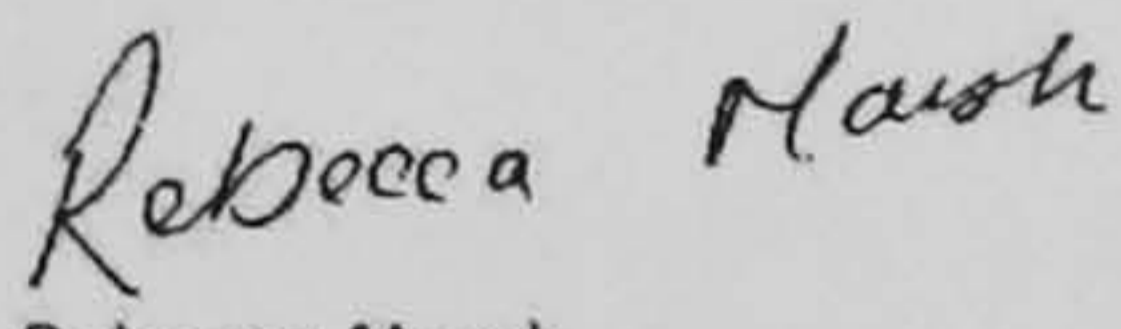
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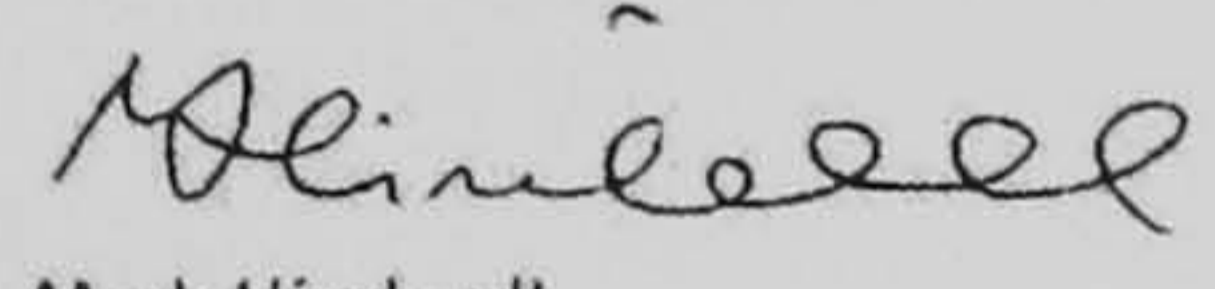
2007

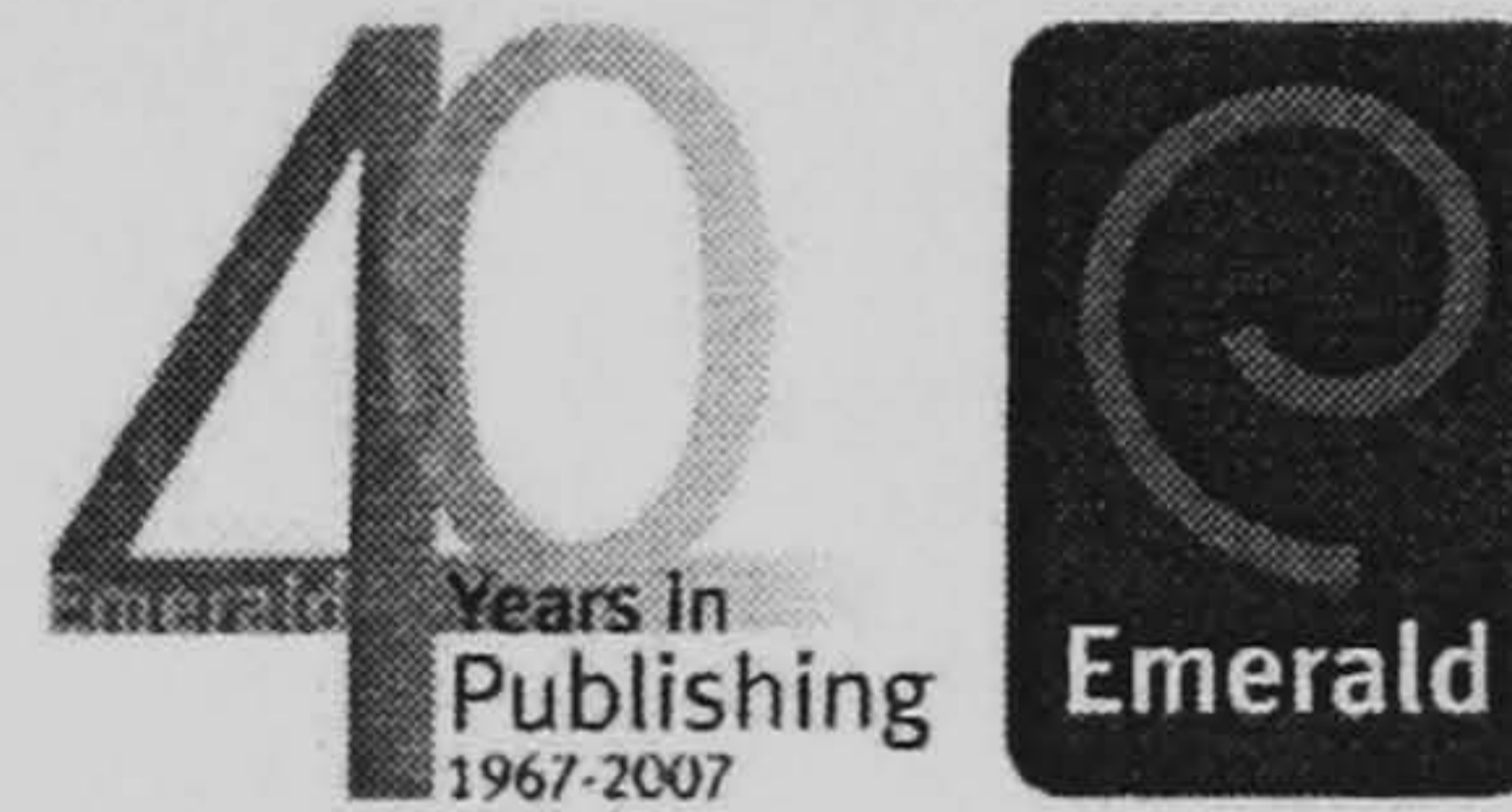
Highly Commended Award

Presented for:

“Critical success factors  
for lean implementation within SMEs”  
Pius Achanga, Esam Shehab, Rajkumar Roy, Geoff Nelder  
*Journal of Manufacturing Technology Management*, Volume  
17, Issue 4, 2007

  
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*Journal of*

# Manufacturing Technology Management

## **Critical success factors for lean implementation within SMEs**

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17,4

## Critical success factors for lean implementation within SMEs

Pius Achanga, Esam Shehab, Rajkumar Roy and Geoff Nelder  
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460

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### Abstract

**Purpose** – The aim of this research paper is to present the critical factors that constitute a successful implementation of lean manufacturing within manufacturing SMEs.

**Design/methodology/approach** – A combination of comprehensive literature review and visits to ten SMEs based in the East of the UK were employed in the study. The companies' practices were observed to highlight the degree of lean manufacturing utilisation within these companies. This was followed by interviewing of the relevant and key personnel involved in lean implementation. Results were analysed and validated through workshops, case studies and Delphi techniques.

**Findings** – Several critical factors that determine the success of implementing the concept of lean manufacturing within SMEs are identified. Leadership, management, finance organisational culture and skills and expertise, amongst other factors, are classified as the most pertinent issues critical for the successful adoption of lean manufacturing within SMEs environment.

**Research limitations/implications** – Continued scepticism within SMEs about the benefits of lean to their business is one of the fundamental limitations this research faces. SMEs are, therefore, not very willing to provide useful information and data, timely for further investigation.

**Originality/value** – The novelty of this research project stems from the realisation of critical factors determining a successful implementation of lean manufacturing within SMEs environment. The results would provide SMEs with indicators and guidelines for a successful implementation of lean principles.

**Keywords** Lean production, Small to medium-sized enterprises, Critical success factors

**Paper type** Research paper

### Introduction

Globalisation and emerging technologies are having enormous impacts on the manufacturing industry around the world. This scenario has seen the exponential upsurge in new entrants to the market environment, prompting stiff competition in the market place (Umble *et al.*, 2003). Many SMEs are vulnerable in that they operate in sectors where there are few barriers to new entrants and where they have little power to dictate to suppliers their needs as shown in Figure 1.

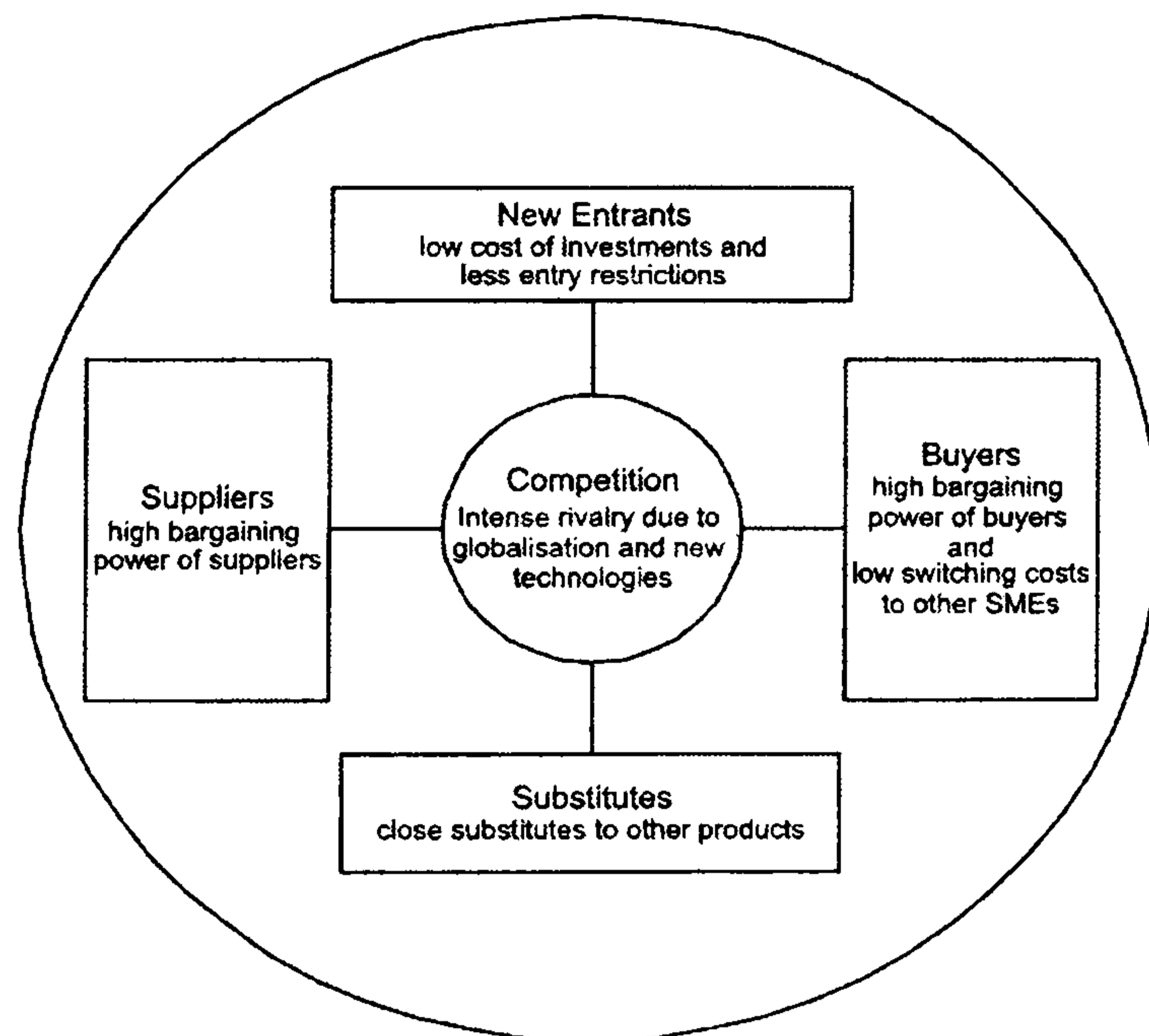
This scenario puts SMEs in a very precarious position since they must operate in a very reactive manner to ever changing circumstances. As a result, the manufacturing environment in the UK is witnessing a decline in the number of manufacturing SMEs, as work is transferred to far east and elsewhere, in search of cheaper operating costs. However, SMEs are valued as part of the business ecology



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Source: Porter (1985)

Figure 1.  
Porter's five forces

for their role in the sustenance of most national economies, and are an important element of governmental strategies (Achanga *et al.*, 2005a, b; Denton and Hodgson, 1997; Levy, 1993).

The Department of Trade and Industry (DTI) in the UK commissioned a productivity improvement initiative known as the Manufacturing Advisory Service (MAS), to promote the use of lean manufacturing within the SMEs. This is because lean manufacturing is hailed as a cost reduction mechanism, hence the need for its applicability within the SMEs (Achanga *et al.*, 2004, 2005a, b; Bicheno, 2000, 2004; Creese, 2000; Phillips, 2000; Womack *et al.*, 1990; Womack and Jones, 1996). Several authors have reiterated the importance of cost factors and their reduction strategies in the current production process (Kulmala *et al.*, 2001; Roy *et al.*, 2001; Roy, 2003; Shehab and Abdalla, 2002). They assert that, cost factors are crucial, therefore, fundamental to the survivability of most organisations.

Unfortunately, the idea of applying lean manufacturing has not been adopted by meaningful numbers of SMEs with any conviction. These companies require that the implementation costs and the subsequent benefits of lean manufacturing adoption, be projected upfront before they are able to commit. Therefore, this research paper aims to outline some of the factors that are perceived to be critical in the successful application of lean manufacturing within SMEs community. The main objectives of the research were to:



- explore the operational activities of SMEs in order to identify their cost drivers;
- investigate the dimensions of lean manufacturing applications within SMEs; and
- outline critical factors that determine its successful application within SMEs.

#### Literature review

The implementation of lean manufacturing like any other productivity improvement initiative is believed to harbour enormous difficulties (Denton and Hodgson, 1997). For example, Safayeni *et al.* (1991) highlighted the difficulties and controversies in implementing one of the many lean manufacturing techniques known as just-in-time. This problem may further be compounded by a lack of standardised mechanism of analysis and measure of value-adding capabilities within organisations, such as the lean concept (Baker, 1996; Iyer and Jha, 2004).

Moreover, SMEs by virtue of their size are constrained by a number of key factors that include a lack of adequate funding and leadership deficiencies (Achanga *et al.*, 2004, 2005a, b). Hayes (2000) discussed that successful corporate initiatives like lean manufacturing, should be properly planned prior to implementation. Management involvement and commitment are perhaps the most essential prerequisites in aiding any of the desired productivity improvement initiatives (Antony and Banuelas, 2001; Coronado and Antony, 2002; Eckes, 2000; Henderson and Evans, 2000).

Several authors have also emphasised on the need for examining and executing such significant factors deemed critical for the success of implementing any new productivity initiative in an organisation. Holland and Light (1999) asserted that in attempting to implement any productivity improvement drive in any organisation, a business should have a clear vision and strategy in forecasting a project's likely costs and duration. Their inference is derived from ERP case studies where approximately 90 per cent of its implementations are late or over budgeted. The authors maintain these occurrences are a consequence of poor cost and schedule estimation and planning. Their argument is supported by Al-Mashari *et al.* (2003) and Volkoff (1999) who confer that despite the significant benefits any productivity improvement packages provide to the business community, they often cost millions of dollars to acquire and implement, and more awkwardly, they end up disrupting organisational framework. Most times, changes brought about by new productivity like lean manufacturing may cause disruptions in the very process it is meant to improve. This is because employee in some cases, derive fear of infringements and job losses and are, therefore, prepared to cause sabotage.

Irrespective of how it is perceived, the concept of lean manufacturing has unarguably been discussed extensively in the past decade or so. However, there appears to be little empirical evidence in publications on the implementation of lean practices and the factors that might influence them in SMEs (Bruun and Mefford, 2004). With the notable exception of White (1999) and Conner (2001), most of these publications have tended to focus on the premise of large sized enterprises only (Bozdogan *et al.*, 2000; Cook and Graser, 2001; Murman *et al.*, 2002).

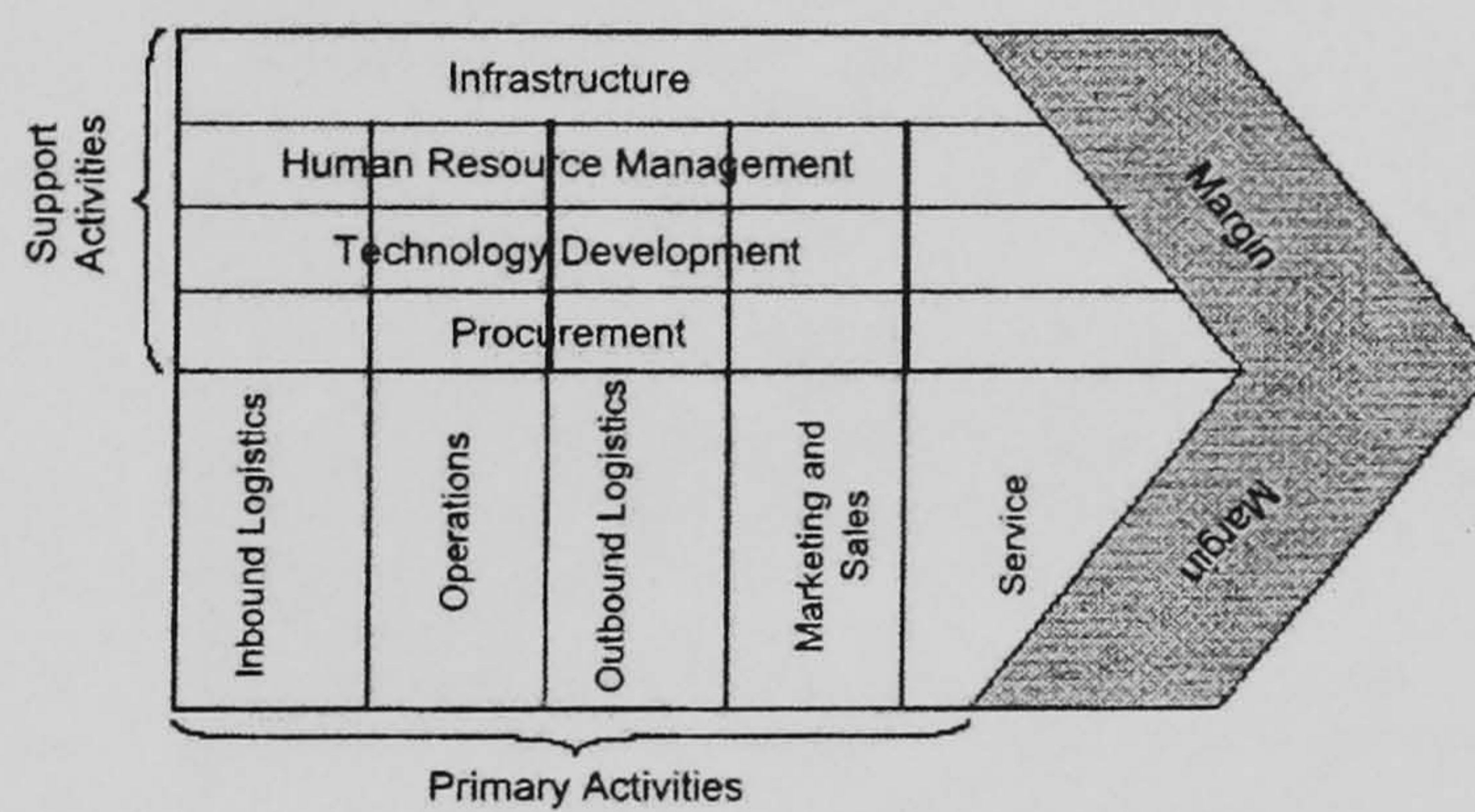
#### Problem definition

Although lean manufacturing is becoming a popular technique for productivity improvement, SMEs are still not certain of the cost of its implementation and the likely tangible and intangible benefits they may achieve. Most of these companies fear that



implementing lean manufacturing is costly and time consuming. Moreover, the implementation of lean manufacturing is a strategic activity within a given organisation as shown in Figure 2. These encompass both the primary and support activities such as a firm's infrastructure, human resources management and technology development. The linkages between the primary and support activities enable an organisation to minimise all its operating costs, inclusive of the execution of any productivity improvement initiative such as lean manufacturing.

This research investigated ten SMEs in the East of the UK which had implemented lean manufacturing in their firms. The research underpinned the issues that were fundamental to their successes in implementing the concept. A number of issues were taken into consideration during the study. These included the companies' characteristics as illustrated in Table I. In particular, the research carried out a critical assessment of the size of the companies in terms of employability and the rate



Source: Porter (1985)

Figure 2. The value chain analysis

Characteristics	Investigated SMEs									
	1	2	3	4	5	6	7	8	9	10
Management type	IM	IM	OM	IM	IM	OM	IM	IM	IM	IM
Annual turnover (£) millions	3.50	4.00	0.75	5.00	3.50	2.00	2.10	4.00	5.85	1.00
Volume of production	L-H	L-H	L	L-H	M	L-H	M	M	H	M
Area lean applied	P	P	W	P	P	P	P	P	P	P
Duration in days	10	15	10	10	18	12	10	10	15	10
Number of employees	65	98	15	65	200	9	36	25	80	30
Number of employees involved	13	50	12	20	25	5	10	8	15	12
Total spend (£) thousands	5.0	4.0	2.5	10.0	4.0	2.0	2.7	1.5	3.5	1.5
Return on investment (ROI) (%)	0.12	0.50	0.05	0.40	0.55	0.01	0.30	0.17	0.25	0.19
Reduction in lead-times (weeks)	6-2	4-2	8-3	4-2	6-2	5-2	6-3	6-2	6-2	4-2

Notes: IM, independently managed; OM, owner-managed; L, low; M, medium; H, high; P, piecemeal; and W, whole

Table I. Characteristics of the investigated SMES



of their annual turnover. In addition, the type of management style was the other focus of study, since the research needed to verify to what extent such factors enhance, or rather impede the success of lean implementation.

**Research methodology**

A combination of research methodology approaches has been employed in this research project. This comprises literature review, observation of companies' practices and personal interviews. The literature review conducted extensively at the initial stages of this research, demonstrated the existence of gaps in knowledge. The review has not provided sufficient information on issues that affect the successful implementation of lean manufacturing within companies. Therefore, there is a need for further research within the existing SMEs that had implemented the lean concept previously. The idea behind this move was to investigate further, so as to determine such factors deemed critical for lean implementation.

The data collection process involved ten SMEs listed in Table I and visits to three large sized manufacturers based within the locality. Visitations to the three large size manufacturers were to allow for comparison between the two sectors. It was also to facilitate the emulation of best practices from such large size manufacturers which had implemented lean before.

As shown in Figure 3, companies were contacted by telephone, e-mail, fax and letter. After the initial contacts were made, a review meeting was arranged between the researcher and the SME concerned. The review meeting enabled the researcher to carry-out direct observation of the activities within a particular company. The observatory exercise has enabled a visual assessment of the general manufacturing issues at stake.

Results obtained were noted in a specially improvised document known as the observation data collection sheet. For example, observations were focused on both

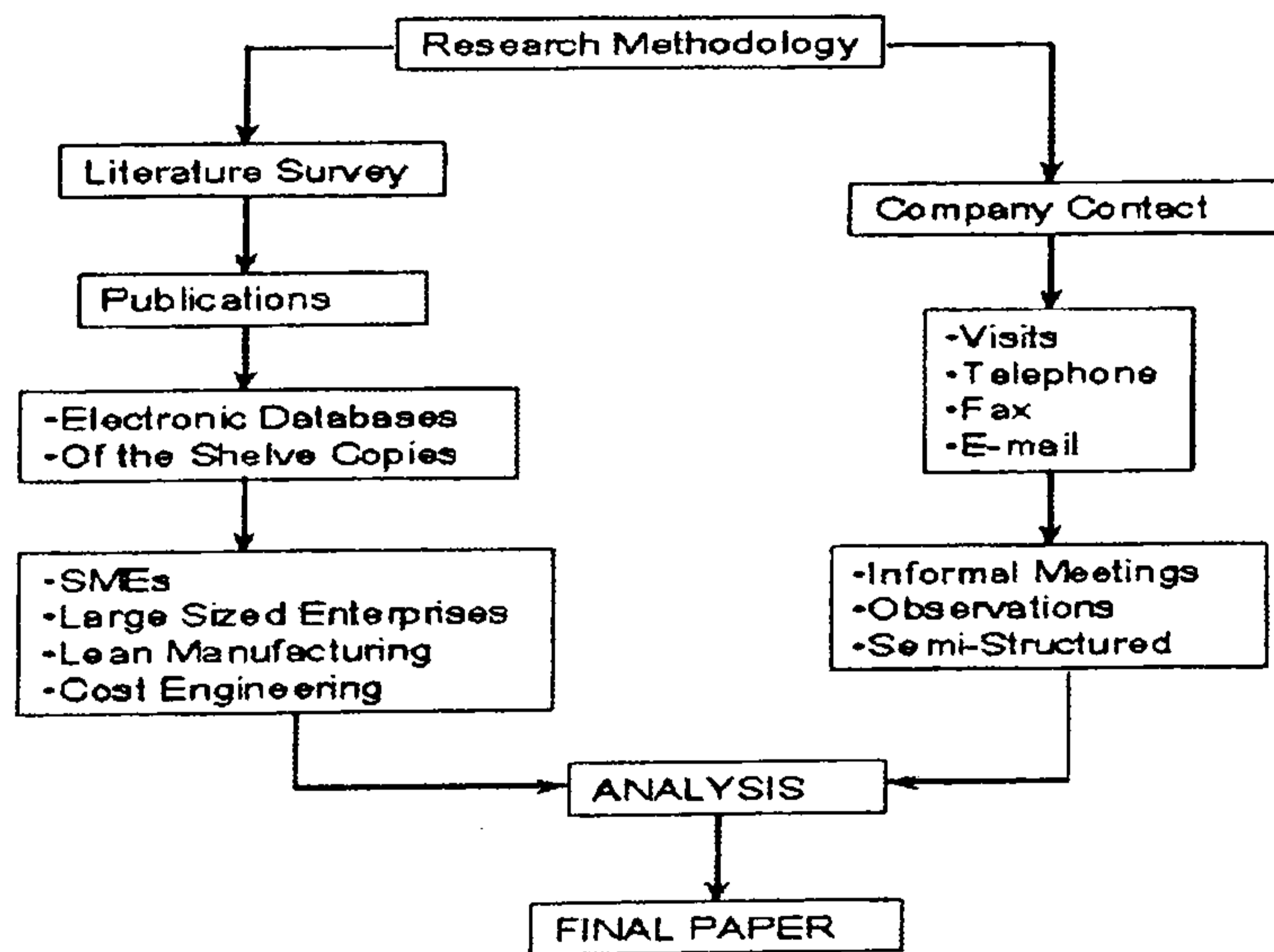


Figure 3.  
Scenario of the research methodology



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performance of work force during their daily tasks and the time frame to carry out these activities. The observation exercise was conducted for approximately 30 minutes at each particular point of observation. Eventually, information from the observation data collection sheet was analysed and used for the preparation of the interviewing process. Personal interviews were conducted through prepared semi-structured questionnaires. They involved a number of key personnel in the company that included the general workforce of the companies concerned. This selection criterion was used as a means of acquiring information in a blanket format so as to make the study more representative.

In order to succinctly find out from these companies their perspectives on the factors that are critical for lean implementation, a number of questions were tailored to enable the extraction of ideas that give a true reflection on the interviewee's perception on these factors. The research, therefore, set a number of questions that embodied the companies' definition of lean manufacturing and whether that company had implemented lean before. For example, the key questions asked in the semi-structured questionnaires were as follow:

- Is this company independently managed or it is owner-managed? What are the major drivers of your business?
- What is your definition of lean manufacturing?
- What has motivated the company to implement lean manufacturing?
- Where has lean been implemented in your organisation (piecemeal or whole)?
- What were the criteria for choosing that specific area?
- How many people were involved in the exercise?
- What training if any, did the staff undertake?
- What were the difficulties encountered in training and how were they overcome?
- What were the direct and indirect costs involved in the implementation lean manufacturing? (E.g. labour costs and consultancy fees.)

The above questions were significant for enabling the retrieval of the relevant and accurate information on lean manufacturing utilisation within these companies. For instance, by asking questions about a company's major business drivers, how such a company views and perceives the concept of lean manufacturing and where lean has been implemented, and at whatever cost; the study was able to deduce a number of things. First and foremost, it could be verified instantly based on information provided as to whether such a firm understood and was actually practising lean or not. This was significant for the retrieval of information on the factors that are critical to lean implementation due to the following. By knowing about the management type of such a company, it was found to be useful in determining its motives to adopt the lean concept. The study wanted to find out relationships between lean adoption and the management style in these SMEs. Again it wanted to determine as to whether the type of management style actually influenced or deterred the absorption of the lean concept.

The interviews were structured to last not more than 15 minutes. The intention was to gather as much information as possible in a limited time without demoralizing the



interviewee. It was believed that way; answers to pertinent questions could be provided resolutely. Finally, the overall information obtained from the interviews, and summaries of both the informal meetings and observations, were compared with that from the literature survey in way of analysis. Results were validated through workshops in the companies concerned. At the same time, expert opinions were sought to verify and validate the actual findings.

**Research results and discussions**

This research investigation has realised four key main factors that are fundamental, hence critical for the implementation of lean manufacturing within SMEs. They include; leadership and management, finance, skills and expertise, and culture of the recipient organisation (Figure 4).

Of these identified factors, it has been hypothesised that leadership and management commitment are the most critical ones in determining the success of a lean project within the SMEs premise as shown in Figure 5. Strong leadership ethos and committed management support is the cornerstone to the success of implementing any idea within an organisation. These factors have been discussed in detail in the following sections.

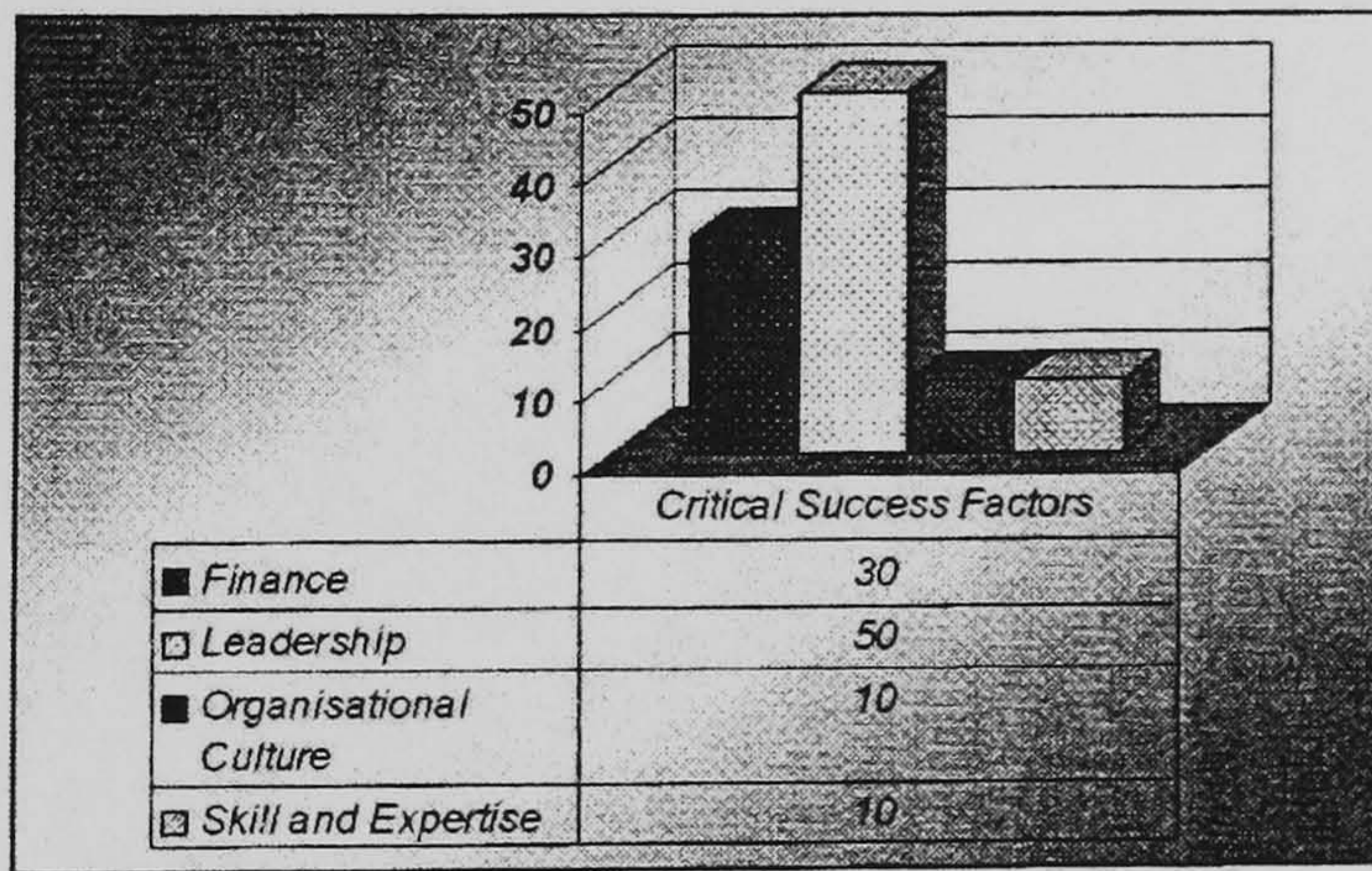


Figure 4. The proportions of critical factors from interviews

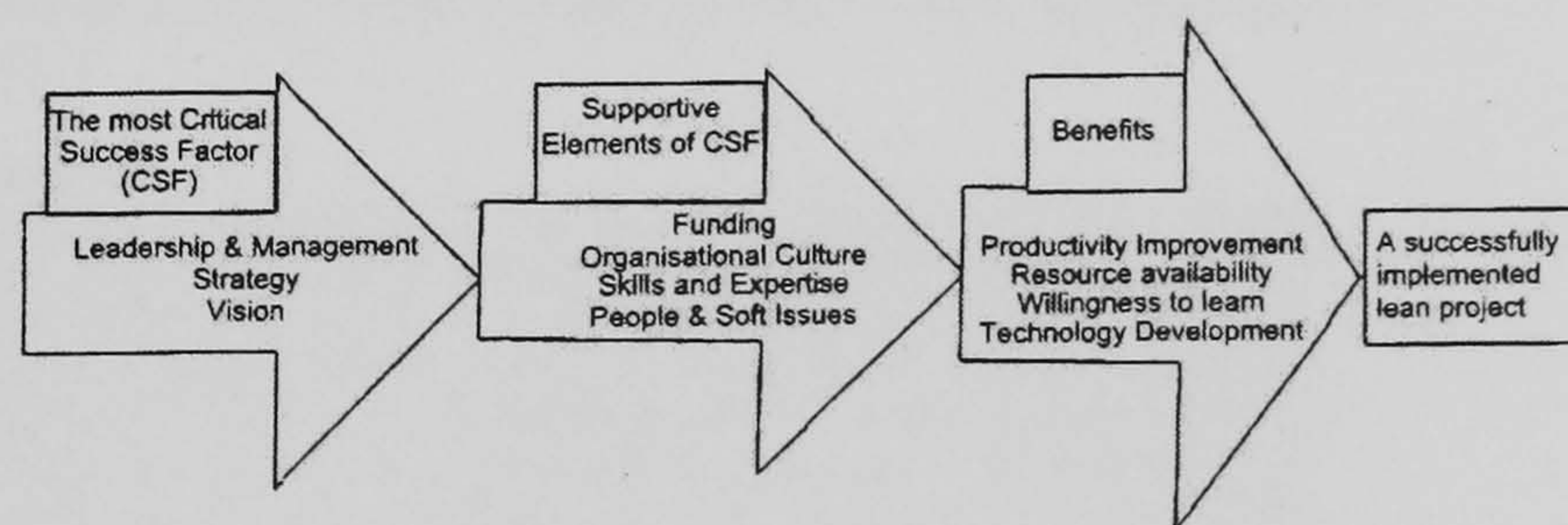


Figure 5. Elements of critical factors for a successful lean implementation



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#### **Leadership and management**

Thus, in order to succinctly implement the concept of lean manufacturing successfully within SMEs, the recipient companies should harbour strong leadership traits capable of exhibiting excellent project management styles. In essence, these qualities would facilitate the integration of all infrastructures within an organisation, since strong leadership and management permeates a vision and strategy for generating, while permitting a flexible organisational structure. Good leadership ultimately fosters effective skills and knowledge enhancement amongst its workforce. The supportive elements which shown in Figure 4, therefore, benefit the potential SMEs intending to implement the lean concept by the provision of resource availability, willingness to learn and acquire new ideas and technologies for its corporate competitiveness. SMEs would then be able to implement the concept of lean manufacturing successfully. Unfortunately, this study has found most SMEs to be by default, owner managers who may not have the tactful management know-how. Consequently, a large number of SMEs are hampered strategically due to a lack of quality strategic drives from good leadership traits. Moreover, this research investigation has established that strategic improvement initiatives are now the norm for most organisations throughout the world today. Leadership behaviour and rewards are then too easily focused on the management of a continuous series of short-term crises, whilst the implementation of lean manufacturing that could create a firmer base for success by reducing costs and improving use of resources can be subject to continuous postponements "until better times".

#### **Financial capabilities**

Financial capacity is a crucial factor in the determination of any successful project. This is due to the fact that finance covers the avenues through which other useful provisions like consultancy and training can be made. The study has also realised that SMEs are financially inept and harbour poor financing arrangements. Financial inadequacy is thus a major hindrance to the adoption and subsequent implementation of successful lean manufacturing within SMEs. They fear that the application of lean manufacturing, like any other productivity improvement initiative within any organisation, could require financial resources to hire consultants, as well as to aid the actual implementation of such ideas. Training of people to utilise the techniques also requires financial resources. In some instances, production of firms may be ceased temporarily in order for the workforce to embrace such knowledge; a fact that SMEs view as an unnecessary loss of resources, more especially if they do not anticipate immediate returns.

#### **Skills and expertise**

The financial incapacitation discussed above ripples through the SMEs strategic framework, hampering critical success factors such as skills and expertise. The future of manufacturing in the UK also lies in the use of intellectual capital and ability to innovate and differentiate. Most SMEs employ people with low skills levels, and they do not foster the ideology of skill enhancement. This in the final analysis derails the very basic core of improvement strategies such as lean manufacturing, since some technicalities in the application process require employee skills and expertise. Moreover, low level employee skills would not harness the desire for technology development.



#### **Organisational culture**

The creation of a supportive organisational culture is an essential platform for the implementation of lean manufacturing. High-performing companies are those with a culture of sustainable and proactive improvement. Manufacturing, almost more than any other sector, is a global industry. The study further confers that the ability to operate in diverse environments is a pre-requisite for managers. The investigation has clearly indicated that it is highly desirable to have some degree of communication skills, long-term focus and strategic team while intending to implement any new initiative. Most large organisations are conscious of this, regardless of their choice of cultural models or success in using them, but many SMEs by default, reflect in their culture the personality of the owner/manager and are constrained by this in terms of the changes they may be able to undertake.

The four issues listed above can be regarded as the top level critical factors that may determine the success of a lean project. Responses from various interviewees indicate that these four factors can be broken down further into detail as follows. Under the leadership factor, management should have clear vision and strategic initiatives, good level of education and the willingness to support productivity improvement initiatives like lean manufacturing. The organisational culture criterion includes; management ability to operate in diverse environment, easy acceptance of change and long-term focus on their roles. Financially, the criterion includes the availability of funds to enable capital investment and strong financial management. Skills and expertise criterion includes the recruitment and enhancement of capable workforce and provision of training and innovation.

#### **Conclusions**

This paper has described the realisation of critical success factors determining a successful implementation of lean manufacturing within SMEs environment. The identified critical success factors have provided a useful insight for the enhancement of critical decision-making process, needed for the delivery of corporate strategic ambitions towards the implementation of lean manufacturing. The study maintains that lack of adequate funding denies many SMEs the opportunity to hire their ideal management team, and that they, therefore, suffer from lack of astute leadership and planning. This factor prevents SMEs from implementing good productivity improvement strategies such as lean manufacturing. The funding and leadership deficiencies inhibit other productivity initiatives such as workforce training, denying SMEs the benefits of improvement in knowledge, skills and cultural awareness. Inevitably, effective application and utilisation of lean manufacturing within SMEs will be delayed or may not be achieved at all unless SMEs restructure their focus to become more receptive and capable of absorbing new ideas.

Equally crucial to this study, is also the outcome derived from the analysis of the behavioural patterns of certain characteristics of the investigated SMEs. There exists a correlation between the SMEs management styles and several outputs such as lead-time, number of employees and the return on investments (ROIs). It is fair to assert, based on observations obtained from this study so far, that the independently managed SMEs in the investigated sample have demonstrated a feasibility of enormous increases in the level of ROI as compared to those of the owner-managed SMEs. More so, independently managed SMEs provided easier access to their

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companies for this research investigation as opposed to owner-managed ones. Hence, although the rate at which output like lead-time have been reduced favours the owner-managed companies, yet the disparity between the two variables do not provide much difference. Perhaps this has resulted from the line of operatives in the owner-managed SMEs who are constantly on the watch, hence shorter lead-times.

Finally, it should be pointed out that a further limitation to this study is continued scepticism within SMEs about the benefits of lean to their business. SMEs are, therefore, not very willing to provide useful information and data for timely, further investigation. Furthermore, results obtained from these investigated SMEs should be treated with caution as indicative, but far from conclusive since observations involved a limited number of both independently and owner-managed SMEs. Future work should lead to a wider spectrum of SMEs in order to derive a more concrete multi-variant analysis on the relations between the two variables.

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**Further reading**

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Critical success  
factors for lean  
implementation

**About the authors**

Pius Achanga obtained his BSc degree in Information Technology at the University of Hull and an MSc in the Management Of Manufacturing Systems from Cranfield University. Currently, he is pursuing a three-year doctorate degree in Decision Engineering, with a collaborative effort of Cranfield University and the MAS in the East of the UK (MAS-East). His research is titled: developing a framework for assessing the impacts of lean manufacturing implementation within SMEs. Pius Achanga is the corresponding author and can be contacted at: [p.c.achanga@cranfield.ac.uk](mailto:p.c.achanga@cranfield.ac.uk)

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## **APPENDIX: H INTRODUCTORY LETTER**

### **A Sample of Introductory Letter to Research Partners**

Dear (name),

I am writing to seek your support in conducting a lean manufacturing case study at (Company). This is based on advice from (*Name of contact person*) to my supervisor Dr Essam Shehab.

I am a PhD researcher at the School of Applied Science in Cranfield University. My research project focuses on developing a framework for assessing the impact of lean manufacturing within small-to-medium manufacturing enterprises (SMEs) at the conceptual implementation stage.

At the moment, I am trying to identify a number of SME firms for the purposes of studying best practices of lean applicability. Therefore, I earnestly request your utmost kindness to guide me to the relevant people within your organisation, so I can carry out my research successfully.

I would like to take this opportunity to thank you in advance, for your kind consideration in this matter and look forward to an expedited response at the earliest available opportunity.

Best Wishes,

Pius Achanga