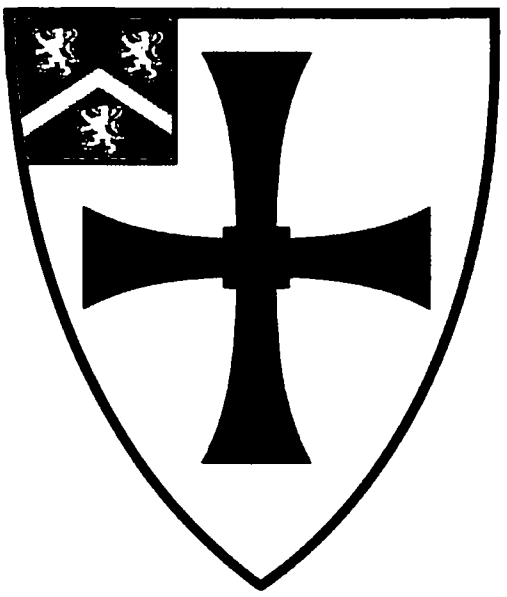
Digital enterprise technology implementation A methodology to facilitate the innovation process in SMEs

Udisien Woy



DIGITAL ENTERPRISE TECHNOLOGY IMPLEMENTATION

A Methodology to Facilitate the Innovation Process in SMEs

A dissertation submitted in partial fulfilment
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Master of Science

Udisien Woy

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ABSTRACT

A technology-led innovation methodology was developed for small-to-medium sized enterprises (SMEs) in the made-to-order (MTO) manufacturing environment. This methodology was used to demonstrate how businesses can be transformed to stimulate innovation, supported by fact-based systems, in a sustainable and flexible approach.

Digital Enterprise Technologies (DET) such as Enterprise resource planning (ERP) and computer aided design (CAD) technologies are used in the vast majority of manufacturing environments and manage data and metadata, which are vital sources of business intelligence. When properly managed, these fact-based systems can lead to technology-led innovation by keeping businesses informed; information leads to insight, which can potentially be transformed to innovation and exploited by businesses to increase efficiency, maintain competitiveness and increase their profit margins. However, managing these DET systems to successfully achieve sustainable innovation requires a number of resources of which, time has been identified as the most critical. Although, the innovative process is a high value added process that requires a lot of time and due attention, MTO SMEs struggle to meet due to the numerous demands on their resources, particularly time. However, due the potential benefits that can be accrued from pursuing innovation, it will be useful to MTO SMEs to prioritise this activity.

Analyzing the ERP and CAD systems used in a typical MTO manufacturing enterprise, the issues faced were highlighted: evaluation and selection of suitable technology; implementation and integration with existing technology; customization and configuration; personnel development and increased proficiency; and the implementation of standardized working procedures. Other issues such as the scope of activities and available management support for technology innovation were also explored. The issue identified were addressed by developing a framework for technology assessment and selection; defining the strategic priorities and actions required to stimulate innovation; integration of overall business strategy with DETs to facilitate technology innovation; and a framework to support technology innovation management in SMEs.

By addressing the main issues identified, it is anticipated that DETs implemented by MTO SMEs where required, will be strategically targeted at managing time-consuming routine tasks thus freeing up valuable creative time that can be dedicated to innovations and the innovative process.

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DECLARATION

I declare that the work presented in this thesis for assessment is original and the result of my own work, except where group project work was involved. In the case of a group project, the work was prepared in collaboration with other members of the group and my contributions suitably indicated. In all other cases, material from the work of others has been acknowledged and quotations and paraphrases suitably indicated.

1. INTRODUCTION

1.1. Background

The face of the UK manufacturing industry has changed drastically due to globalisation; the ability to manufacture goods in countries where labour is significantly cheaper and readily available has made it possible for businesses to accommodate increasingly demanding customer requirements and still realise huge profits. While the current business environment may be favourable to larger corporations that can set-up their operations in such regions and take advantage of global manufacturing opportunities, small-to-medium enterprises (SMEs) are left in an untenable position; they have higher manufacturing costs and have to sell at prices that will match those of their competitors. Although increasing low cost competition is a concern for UK manufacturers, and has been identified in the government's manufacturing strategy report in 2002 [1] as a key area that places UK SMEs at a disadvantage, leading UK manufacturers are turning technological advances and the globalisation of markets to their advantage, having embraced knowledge intensive, highly skilled manufacturing. With a focus on technology and innovation, particularly the utilization of technology for routine and repetitive time-consuming tasks, SMEs should be encouraged to exploit knowledge intensive and highly skilled business strategies that are geared towards improving product or service performance, quality and value. Through an understanding of their global strengths and weaknesses, facilitated by the creation of 'creative time', SMEs can harness their strengths to exploit global opportunities.

A strategy that strengthens manufacturing and gives SMEs in the UK a competitive advantage, in a manner similar to effects of low cost manufacturing solutions for other economies will be beneficial to the manufacturing industry and the UK economy as a whole. Therefore, the focus of this research is aimed at identifying DETs that improve the strategic, operational and processes functions of SMEs to ensure that innovation occurs and that the innovative process is well facilitated and supported. This will be achieved through the identification of the key strategic areas and priorities that SMEs should be focused on to increase their global competitiveness by increasingly engaging in innovative activities.

1.2. Problem Definition

Resources, particularly time, money, skilled personnel, and expert support are required by manufacturing SMEs for the successful acquisition, implementation and management of new technology. However, despite the fact that this is a widely acknowledged problem, SMEs are still faced with the challenge of managing their available and sometimes inadequate resources to meet their business objectives and priorities. Having recognised that SMEs will continuously face this challenge and are vulnerable as a consequence, available resources are priorities based on the present and urgent needs of the business to ensure they can adequately satisfy existing customers. This implies that the planning and implementation of long term strategies are not often prioritized until they become urgent. Thus, they are faced with situations where decisions are taken without a full and clear understanding of the long term implications that may affect their efficiency, responsiveness and agility to changes in their business environment.

Businesses typically exist to satisfying the needs and requirements of their target customers', through their activities and operations therefore, it is important that they understand the fundamental goals and value based stimulations of their customers to balance the demand for and supply of their products and/ or services and be profitable. However, understanding these stimulations in a constantly changing business environment can be challenging for SMEs due especially to limited time available to dedicate to this activity. In Abraham Maslow 'A Theory of Human Motivation' [2, 3], a hierarchy of needs is proposed and widely used, to understand what motivates our actions. The underlying principle of this theory implies that our actions are reactions to internal and external stimulations in a hierarchy of pre-potency. Likewise, it is fair to say that today's customers' are driven by particular fundamental goals from internal and external value based stimulations. For SMEs, understanding and accurately translating the requirements of the manufacturing industry is an urgent business priority that if not adequately addressed will further compound the challenges they face due to limited or lacking resources and low cost competition. When applied in the business context of SMEs, Maslow's theory can help to explain why businesses operate the way they do; they prioritize their activities according to their urgent and pressing needs with a greater emphasis placed on making profits by doing just enough to

meet the needs of the industry. Although Maslow's theory is a popular introductory motivation theory for management, there is little scientific evidence to support its strict hierarchy, which implies that people exclusively satisfy one motivating need at a time, except when needs conflict [3, 4]. In reality, it is possible and indeed so that businesses and customers satisfy their motivating needs simultaneously, often balancing between their main priorities. Therefore, a more fluid hierarchical structure is perhaps more appropriate in this instance to describe the relationship that exists, a structure that is based on a central core that supports the other value based stimulations permitting other motivating needs to be satisfied by balancing priorities. This is more representative of the main value based stimulations that motivates businesses and customers and is illustrated in Figure 1 below. This has been developed by identifying the core or main value based stimulations that are essential to SMEs and their survival, using Maslow's theory [3, 4]. It illustrates the relationship between the industrial markets targeted by SMEs, their core priorities and how they manage this relationship to ensure that their interests are protected while fulfilling the needs of the industry. Managing these relationships, interests and priorities, which can sometimes be conflicting, requires a lot of time and effort with SMEs sometimes putting the needs of the industry ahead of theirs to their detriment. Hence, it is necessary to have core hierarchical priorities or primary needs as a foundation to protect and support the business while secondary and tertiary needs can be satisfied simultaneously based on present motivating needs. With these primary stimulations identified and properly managed, it becomes easier prioritize and balance sometimes conflicting need. Thus, technology can be selected to make more efficient the core business priorities allowing the focus to shift from balancing to sustaining them, which would require less time.

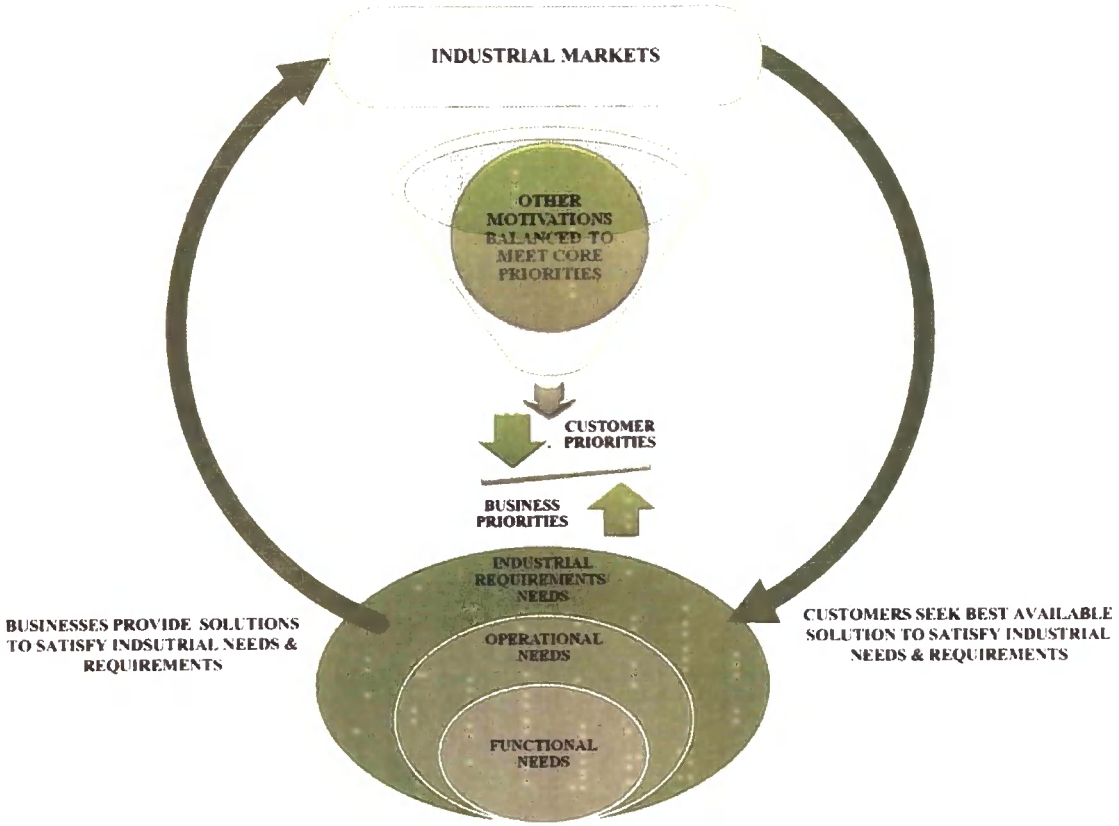

Figure 1: Main Value Based Stimulations

The core priority for businesses and customers' respectively from observation are; profitability, through the provision of solutions to customers problems and for customers, finding the right solutions to meet their requirements. While profitability is crucial to the survival of businesses, customers have the flexibility to pay more or less for available solutions to their problems, highlighting the need for a strict hierarchical primary core, especially for SMEs. Other challenges faced by SMEs stem from their ability to balance immediate and long term needs to ensure profitability and competitiveness while taking into account, changing customer and industrial requirements and global factors including low cost competition, trade, economic, environmental and climate issues are factors that have present and long term implications for SMEs. These factors, which have their own associated issues, have to be accommodated earlier on as they have an impact on the business and its operations and this is an area that would benefit from simultaneously balanced priorities.

By diversifying, SMEs in the UK can create an advantage for themselves in an increasingly competitive business environment. Although there are a number of ways

businesses can diversify, in the modern business environment of low cost competition, technology and innovation have to play a crucial role in any diversification plans. An innovative diversification strategy is new product development and introduction (NPDI), and SMEs are increasingly engaging in NPDI activities to boost their profitability. Although the approach to product development is somewhat lacking due to gaps in the knowledge and skills of personnel involved in the process, this can be improved upon to form the basis for sustainable and innovative product development processes and activities.

The level of product innovation amongst other things differentiates competitors, and this is influenced greatly by the approach to innovation taken. Although there are a number of ways to approach innovation, the most common approaches are; the market pull approach, where innovations are based on the demand for products and services; and the technology push approach, where technology is applied for improvements, or exploited to add value. With the market pull approach, businesses supply products based on the demands and requirements of their customers, thus creating a situation where innovation is driven by the market. However, SMEs have high aspirations when they engage in product development activities and for some, this can distort their view of what is realistically achievable. The success of a product is dependent on a number of factors, including setting goals that are realistic and achievable. New products and services have been categorised, in Figure 2 below, based on a combination of the level of innovativeness and the types of market.

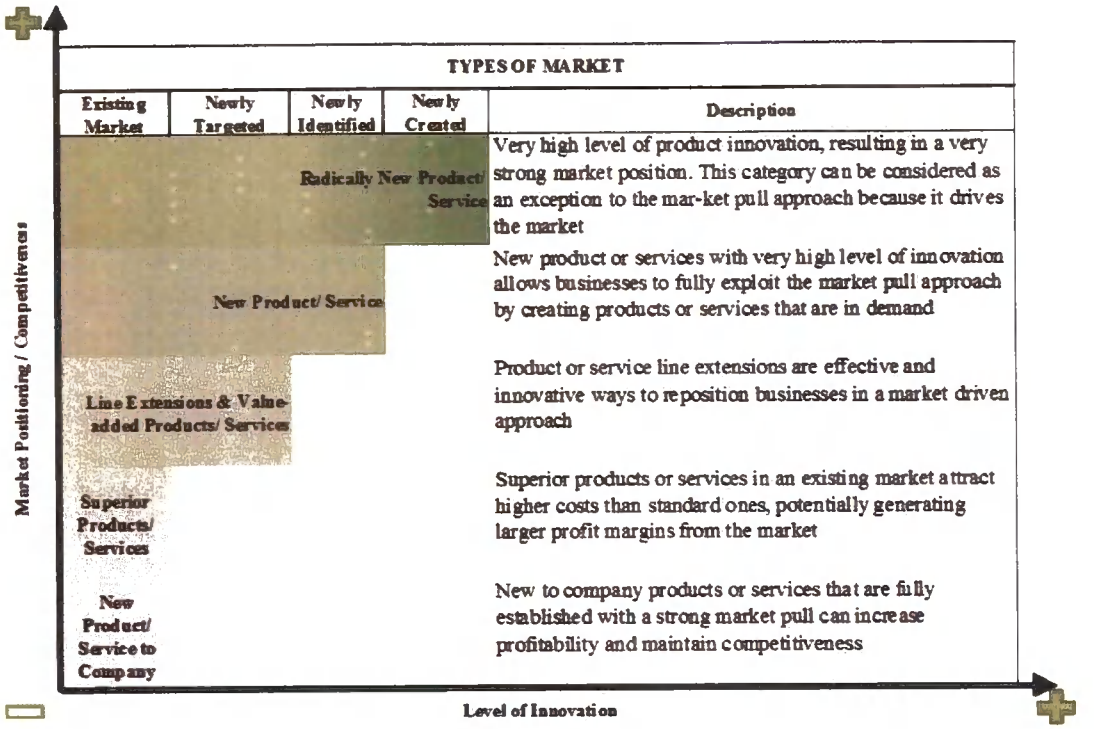

Figure 2: New Product/ Service Categories

SMEs, particularly those that supply made-to-order (MTO) products, adopt a market-pull approach to product development. This provides them with an opportunity to create highly innovative new products or improve their services, which in most cases are customised to the needs of their customers. The ingenuity of their solutions and the techniques they apply to problem solving are not usually exploited primarily because they are designed to solve unique problems. However, even if they recognise the potential of their solutions to create new business opportunities, they do not often have the resources to exploit them. In addition, the market-pull approach is subject to increased competition whereas, utilising a technology push approach gives SMEs greater control of their innovations. Thus, the ability to recognise the significance of technology to the needs of the business and accurately translating them is important to the technology push approach as knowledge, information and skill are essential to unlocking the potential of technology for businesses.

Technology-led innovations can initially strengthen the competitive position of a business providing they keep abreast with technological advancements. However, when competitors are able to achieve similar outcomes and are evenly matched, the business loses its advantage, which can weaken its competitive position. This cycle il-

lustrated in Figure 3 below, can be described as the innovative cycle and has, in recent times, reduced [5] as the pace of technological evolution increases. The S-curve phenomenon used to depict cycles has been used to show how the innovative cycle develops over time. The cycle begins with the introduction of an innovative product or process. Once implemented, businesses can begin to customise and configure innovations to suit their needs and this is known as the growth phase. When innovations are fully established or have attained maturity, businesses settle into a comfortable zone and focus on maintaining their innovations and maximizing the return on their investment while experiencing the full benefits of such innovations. The benefits of an established innovation can last for extended periods of time, but ultimately, a decline occurs and this is evidenced by the fact that there are less benefits experienced

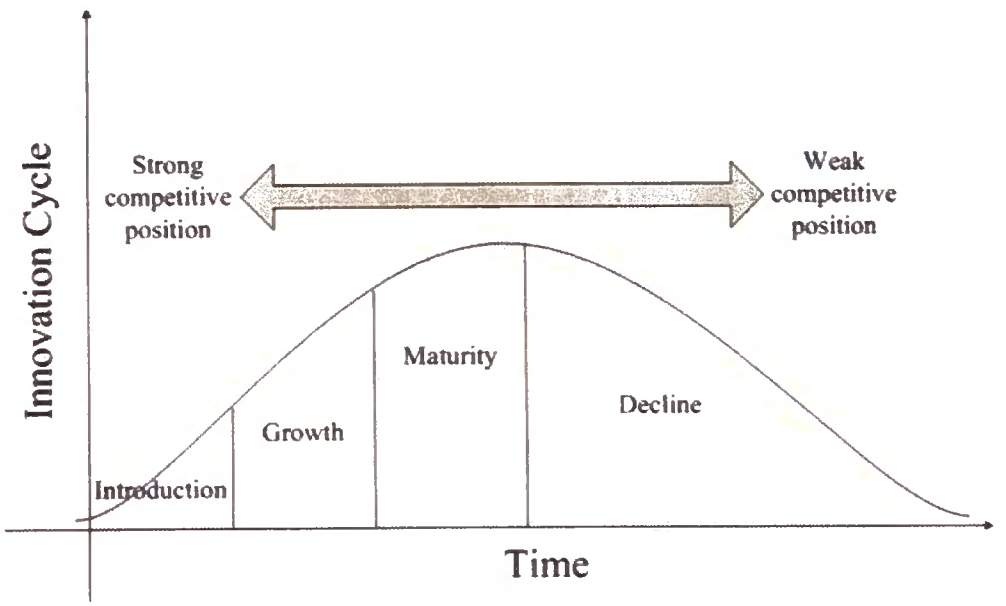

Figure 3: The Innovative Cycle

An innovation strategy combined with advanced manufacturing technologies can potentially transform businesses by increasing their efficiency. But, advanced technologies are developed generically for particular industries; larger enterprises have the resources to maximize the change impact of new technology whereas smaller businesses often struggle to achieve similar result, which can significantly affect the expected outcomes and change impact on the business. With technological advancements and shortened innovation cycle times, businesses will require support to maximise the impact of technological changes to ensure that new knowledge is success-

fully turned into profitable business. With their strengths and the ability to identify opportunities and niches in the market, SMEs can utilise available and affordable advanced technologies to ensure that they can harness the maximum potential from new technologies to facilitate the innovation process. Through this, they can increase their competitiveness and take advantage of global business opportunities. Consequently, an adaptable technology management strategy that supports sustainable innovation will be useful in addressing the uncertainties that will certainly arise from internal and external value based stimulations in the modern, global businesses environment.

1.3. Industrial Significance

Globalisation and low cost manufacturing are two factors that will increasingly have an effect on the competitiveness of Small-to-Medium Enterprises (SMEs) in the UK. While it is important that they have the capability, and are in a position to take advantage of global opportunities, it is even more so that they achieve competitiveness on a global scale. However, there is a lot of pressure on SMEs to manage their available resources, which are allocated to key business priorities while long term strategic management and similar issues are not prioritised until they need to. Having identified technology and innovation as key priority areas [5] for businesses to increase productivity and profitability and achieve a global competitive edge, SMEs require adequate support to develop these areas.

There are a number of anticipated industrial benefits including;

- The ability to identifying available DETs, tools, and systems developed for the manufacturing industry that can impact positively on business operations
- A methodology for strategically selecting and implementing DETs, tools, and systems that are targeted at managing time-consuming routine and core tasks and business activities
- The application and utilization of DETs in the right context to maximize potential and experience the associated benefits
- The development of the knowledge and skills base within the business
- Increased innovativeness and improved innovations as a result of investing more time and effort on the innovative process

1.4. Research Aims and Objectives

This research is intended to provide SMEs with a methodology that can be used to facilitate the innovation process and increase their competitiveness. The main aims and objectives are;

- To provide a methodology to facilitate innovation through the management of advanced technology in manufacturing SMEs, using the principles of Digital Enterprise Technology (DET) as a foundation.
- To identify and synthesizes the main technologies and systems used by industry leaders to facilitate and support the innovation process and activities for SMEs during the product development process.
- To understand the main issues and problems currently faced by SMEs in an MTO environment during the NPDI.
- To identify the critical technology and management needs of SMEs through the definition and management of strategic priorities and actions.

The outcomes described in the following chapters have been generated from the following activities, which were carried out to meet the objectives described above;

- The development of a new product using the typical NPDI process steps identified above.
- The development of a methodology for the identification, assessment and selection of technologies and techniques for innovation at the strategic functional levels of the business.
- The development of a framework for the implementation, management and support of the innovation strategy; and to analyse the critical technological needs and strategic priorities of manufacturing SMEs through a determination of their main global competitive strengths, weakness, opportunities and threats.

1.5. Research Outline

The research topic 'Managing Technology to Underpin Innovation' was used to form the research question, 'How can DETs be managed by manufacturing SMEs with a

made-to-order business model to facilitate the innovation process?' In order to achieve the anticipated outcomes and find a solution to this question, key theories, including technology, innovation, management and strategy will be investigated. The contents of the main chapters of this thesis will be organised as shown in the outline below.

Chapter 2: In this chapter, previously conducted research and established theories and other works on technology, innovation, management and product development will be used to identify critical links to support and validate the main themes in this work. Also, the methods, tools and procedures currently employed in industry will be presented.

Chapter 3: In this chapter, the qualitative research approach, which is the research method selected to meet the primary research aims and objectives is introduced. Also presented is the proposed methodology for managing DETs to facilitate innovation.

Chapter 4: This chapter describes a practical application for the methodology developed to facilitate innovation, during the NPD process. For the case study example, a typical SME with a made-to-order business model is used.

Chapter 5: This chapter presents the main findings, central arguments, challenges and limitations on technology, management and innovation during NPDI in a typical subcontract manufacturing SME. The outcomes of the case study in the previous chapter will be analysed also to determine the level of success of the implementation process, while exploring the suitability of the proposed strategy for use by other SMEs with similar business models. Furthermore, the similarities and differences between established and proposed theories will be discussed.

Chapter 6: The main conclusions drawn from the work carried out, in addition to the issues, challenges and successes will be presented in this section. Particular emphasis will be placed on new ideas stimulated as a result and how it contributes to learning and the knowledge body in the areas of technology, innovation and management in SMEs. Furthermore, recommendations made during the project implementation will be analysed to illuminate issues and shortcomings. Suggested areas for future work are also presented in this chapter.

1.6. Summary

In this chapter, the problems faced by manufacturing SMEs due to a lack of time for the innovative process, globalisation and intense competition faced from low cost manufacturing were introduced and background information about the project and its relevance to industry provided. In addition, the research aims, objectives and deliverables were discussed and an outline of the entire thesis provided.

In the following chapter, previously conducted research on strategy, technology and innovation will be reviewed to provide an insight into the main ideas and criticisms established in these areas and how they apply to the proposed strategy for managing technology to underpin innovation.

2. LITERATURE REVIEW

2.1. Introduction

In this chapter, information and previously conducted research will be critically analysed to identify and highlight established and emerging ideas on technology, management and innovation to support this research in finding a solution to the research question; *how can manufacturing SMEs that operate the made-to-order business model implement and manage DETs to facilitate innovation and the innovation process.*

2.2. SME Statistics

Small-to-medium sized businesses, according to the UK National Statistics [5], are businesses that have between 10 and 249 employees; businesses employing less than 10 or more than 249 are classed respectively as micro and large businesses. However, for the purpose of this research, SMEs will be classed as businesses that have between 0 – 249 employees, as micro businesses can also rely on technology to improve their operations and increase their competitiveness and profitability, equally taking advantage of global opportunities.

According to the latest available figures [5], SMEs in the private sector make up approximately 99% of all UK businesses, employ 59% of the private sector employees and contribute over 50% of the total UK turnover. Businesses in the manufacturing industry make up 50% of these figures, of which over 99% are SMEs. Given the statistics in the present economic climate, innovation has become synonymous with competitive advantage, especially for economies that cannot effectively compete with others that provide increasingly low cost manufacturing to the global market. A top government priority for economic global competitiveness [5], this topic continues to receive widespread attention from industry and academia similarly, aimed at exploring different ways to maintain the competitiveness of the UK economy.

2.3. Technology Management Theories

The study of technology management has received wide-spread attention from industry and academia alike in various subject areas including research and development management; innovation management; technology planning; and strategic management of technology [6-8]. The focus on technology management is one that has far reaching consequences, especially in the application of existing technology and driving technology to new heights. However, the pace of technological advancement is such that it can be extremely challenging for individuals and businesses alike to keep abreast of developments. Furthermore, with increasing global competition, businesses cannot afford to adopt a 'wait and see' approach to new and advanced technology. Instead, they have to be proactive yet discerning with the acquisition and management of technology.

Technology provides a means for businesses to diversify and be innovative, either through the application and/ or utilisation of technology. However, a lack of time can be a major contributing factor in the selection, implementation and proper utilization of technology and businesses would need to address this issue in order to realize the full potential of DETs, which can be used to facilitate the innovative process. In the past, technology management was not given very much attention to ensure that it could be retained and adapted for future generations. 'However, during the last 40-50 years this has changed and, especially during the 1980s...' [8], a time of radical changes and technological innovation. With the dawn of the information age, where data was proven to be a valuable and insightful source of technological innovation for businesses, it has become increasingly important that technology is managed properly to achieve the intended outcomes when implemented by businesses. With this realisation, the collection, storage and protection of data have become increasingly important to businesses as they realize the value this adds to the innovative process. This has also resulted in an increase in the number of practitioners of management and academics involved with the management of technology (MOT).

Studies into management of technology have also expanded greatly, not just in terms of directly managing the technology in question but covering areas such as important concepts and what they mean, how technology management is measured and how

problems related to technology management can be solved. With technology, businesses can underpin innovation, but how can this be achieved, and what type of technologies can facilitate this process? Before delving further into these questions, there are other aspects of technology to consider particularly, a lack of time for the innovative process, increased low cost competition, the globalisation of world markets and its impact on product and innovation life cycles.

Increased competition leads to more research and development (R&D) activities, which in turn shortens product and innovation life cycles. However, R&D is a resource intensive activity, requiring a lot of time and commitment that can strain the already limited resources of SMEs and have an impact on their core priorities. With an increasing number of SMEs now involved in product development activities, which has an element of R&D involved that is vital to the success of the product on the market, SMEs would have to invest more time and effort into this activity. Other issues that need to be addressed stem from the informal approach to R&D that can have a negative impact or the handling, storage and interpretation of R&D data. Consequently, insights that could potentially transform the business could be lost. Additionally, valuable time is wasted through overlapping and/or repetitive R&D activities. Considering the impact this has on the innovative process, it is crucial that DETs are utilized to maximize resources, particularly time, while carrying out research and development work.

2.3.1. Research and Development Management

R&D is an important aspect of technology management that ensures continuous performance improvement or innovation of that technology, to increase competitiveness and profitability. The management of research and development (R&D) is an important aspect of MOT and a top priority for most economies, industries, institutions and so on, across the globe. This is due to proven value of undertaking and managing R&D activities to add value to the businesses and individuals. It is arguably as important as MOT itself because it has the potential to further technological evolution. It supports existing technology and facilitates the sustainable development of technology for future generations. R&D also applies to products, processes and services and through R&D, businesses can discover and explore innovative ways of satisfying the

needs of the manufacturing industry. However, R&D activities require the investment of greater resources in order to achieve high performance levels. Also, Schumpeter, [8, 9] an important contributor to the theory of technology and innovation, recognises the role of the individual in driving innovation through R&D, and that of the government as having the capacity and capability to provide the resources required for this activity. Thus, it is necessary that businesses have a plan to deal with the issue of creating and investing more time for personnel development should occur alongside business development when undertaking R&D. With government support, SMEs can have increased access to the resources they need for R&D, but it is still important that they have the right individuals with the necessary skills within the business to successfully implement and utilize DETs to improve performance.

2.3.2. Innovation Management

Innovation is the aspect of managing technology that deal with how technology is applied to similar tasks by different businesses. Innovation is a process that combines conception, invention and exploitation and is predetermined according to the S-curve phenomenon [8], which is used to depict a growth cycle over a period of time. When a new technology is developed, due to the uncertainties surrounding it, very few businesses are willing to take a risk by implementing it. Although the risks may be high, particularly with time and timing, the potential rewards may be equally high and can be balanced by thorough research and understanding of the technology and how it can transform the business when put in context. Ultimately, risks have to be acceptable or manageable but this decision rests with SMEs, and any support that facilitates the decision making process will go a long way towards understanding the potential risks they face, versus the rewards they can gain from the implementation of DETs. One of the main rewards, especially in the early stages on the growth cycle, is that businesses willing to take the risk can potentially achieve significant performance improvement and gain a competitive advantage. Although it becomes more difficult to sustain this advantage over time, an extension strategy can actually help to extend the benefits for a longer period. All the same, it is their approach to the implementation and utilization of available DETs that can significantly facilitate the innovation process, which sets them apart from competitors.

In a manufacturing environment, businesses are able to meet different needs in the same industry using similar technology but it is their ability to accurately identify or create a need within customers for their product, process or service with this technology that makes them innovative. As businesses become more innovative, "emphasis is placed on systems which simultaneously provide quality, variety, frequency, speed of response and customisation" [5]. These systems or DETs, combined with proper planning, implementation and management of the business strategy, processes, activities and related issues [10], keep businesses competitive. Also, the innovation cycle needs to be properly managed and sustained for businesses to maintain their competitive advantage.

The most innovative businesses are also the most agile and adaptable, keeping up with rapid technological developments and changing customer needs and wants. Although SMEs are positioned in the market such that they can be more agile by fitting into niches that larger businesses are unable to, the reality is that this potential is not exploited as fully as it can be. It is similar to the analogy, where a glass jar full of rocks still has room for pebbles and sand. Although each takes up its own space, the rocks and pebbles will be constrained to their positions by the jar, due to their size and properties. While the pebbles might fit into smaller spaces, the properties and size of the sand particles makes them so much more flexible and agile, fitting into the smallest of spaces. However, despite the fact that SMEs are, like sand particles, able to fit into the smallest of niches, they appear not to be as flexible as they could be. Survival doesn't seem to be proactively prioritized, even though it is a top priority that should be instinctive. Instead, some SMEs seem to be reactively surviving and this could lead to a situation where they get caught up in protecting their niche. On the other hand, competition and survival can be about becoming more agile by protecting what they have while actively seeking ways to expand and filling gaps in the market. Although risky, the current business environment appears to favour the sensible risk takers than it does the businesses that play it safe and wait on the sidelines. Being innovative is risky, but this can be achieved through the implementation and management of innovative processes. However, it is important to note that even though the desire to be increasingly innovative is strong, the time and commitment to follow through makes it challenging to actualize this ambition.

The successful implementation of an innovative process requires the efforts of a cross-functional team, early involvement, advanced technological tools and other internal mechanisms that can be challenging for most SMEs [11 16] but are critical to achieving agility. Furthermore, external mechanisms such as the socio-cultural environment, government support, access to advanced tools, marketing expertise, availability of skilled labour, supplier relations and so on, also influence the process [5]. Advanced technological tools or DETs are capable of integrating both internal and external mechanisms and can facilitate the integration and reconfiguration of innovative process, as well as harness resources and expertise and coordinate the business development activities.

Agility or Agile Manufacturing (AM) is a natural development from the original concept of lean manufacturing, which aims to reduce all wasteful activities. Although SMEs need to be agile, this should be balanced as too much agility results in poor utilisation of resources, which in turn impacts negatively on lean manufacturing [12]. However, it seems that the reduction of wasteful activities is still somewhat of a challenge for SMEs, a potential opportunity to smarten their operations and maximize the use of their limited resources that isn't being utilized. AM itself is a strategy and requires customer-integrated multidisciplinary teams, supply chain partners, flexible manufacturing, computer-integrated information systems, and modular production facilities [5]. Although, it is important to strike a balance between agility and lean manufacturing because while agility facilitates the innovative process, lean helps to sustain it thus providing greater control and management of innovations and the innovative process.

The utilization of enabling technologies to AM can greatly enhance the innovative process for SMEs, and advanced manufacturing technology and related tools such as the Internet, the World Wide Web (WWW), the Electronic Data Interchange (EDI), and Electronic Commerce [5] facilitate lower development cost and speed, in return for high quality products or services [13]. SMEs require these and other global communication and information tools, which are used by the experts and industry leaders to establish global links and networks. Some already have these tools, or access to them but for the rest, there are government support schemes and initiatives aimed at

encourage innovation. Thus, businesses can seek expert opinion and gain access to state-of-the-art technological tools to achieve the desired success.

Stimulating innovation is an important early phase of the innovation management process and SMEs can apply technology to stimulate the creation of innovative products and/or services. Regardless of the application, the underlying aim for innovation management is to create something of value that will result in a radical change for the business, thus sustaining competitiveness.

2.3.3. Strategic Management

The strategic MOT is another aspect that has been affected by globalisation and competition. The competitiveness of the current businesses environment makes the case for strategic MOT due to unpredictability and the progressively shorter time spans between the discovery and application of new technology. Therefore, it is important that SMEs have a short and longer term strategic technology plan. This provides insightful knowledge into what their business requires to be smart and efficient. With this insight, businesses can come up with a technology plan based on an assessment of their needs, the needs of the industry and the technology available to them.

Strategic management can be defined as the process employed by businesses to achieve their organizational objectives, which ultimately, is to realize a profit by providing a product or service that is needed in the market place. In Michael Porter's generic strategies for businesses, [14, 15] he describes three generic strategies; Cost Leadership, Differentiation and Focus that lead to sustainable competitive advantage. Cost leadership strategies are employed in high volume production to increase efficiency by seeking ways to reduce costs in all aspects of the business. Businesses employing the Differentiation strategy seek to sustain their competitiveness by providing customers with a unique, new product or service. With the Focus strategy, business focus on low volume production targeted at a niche market, which commands a high degree of customer loyalty. The implementation of the generic strategies is most effective when businesses capitalise on their internal strengths before application. Table 1 below is a summary of the internal strengths for each generic strategy developed from Porter's generic strategy for businesses [14, 15];

Core Internal Business Strengths		
Cost Leadership	**Differentiation**	**Focus**
Access to the capital required	Access to highly technical research required	Access to accurate and timely data on niche market
High level of expertise in manufacturing process engineering	High level of expertise in marketing and sales	Extensive knowledge of market segment
Highly skilled product design personnel (DFM, CAE, FEA, FMEA)	Highly skilled and creative product development personnel	Personnel with highly skilled and varied product development strengths
Efficient distribution channels	Established reputation for quality and innovation	
*Subject to low cost competition/ competitors	*Subject to imitation and changing customer/ industrial requirements	*Subject to imitation and changing customer/ industrial requirements

Table 1: Internal Strengths of Porter's Generic Business Strategies

With recent global trends, businesses strive to maintain their competitiveness by seeking way to differentiate themselves from their competitors. These three generic strategies provide a defence against Porter's the five industry forces [16] of competitive position, shown in Figure 4 below.

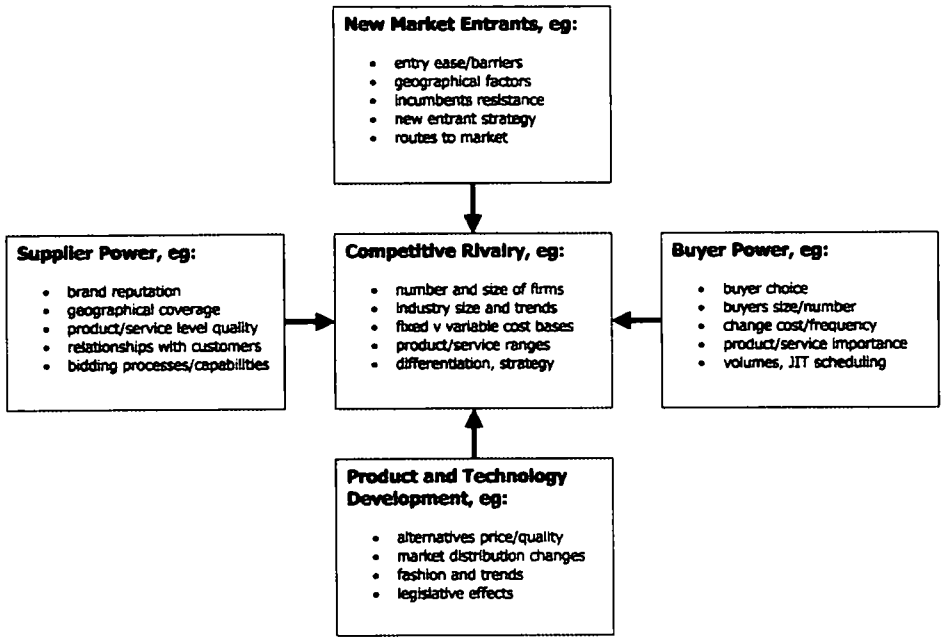

Figure 4: Porter's Five Forces of Competitive Position [16]

Businesses may introduce technology pre-maturely and without a plan, and this is one of the reasons why the introduction and implementation of new technology sometimes fails [17-21]. Nevertheless, with proper technology planning, a business is more aware of what it needs to distinguish it from its competitors. Furthermore, SMEs do not have to get caught up in trying to stay abreast with the latest technology especially if they cannot afford to. Any technology introduced should be relevant to the business, taking into account, its intermediate and long term goals. With strategic planning and management of technology, they can confidently and successful introduce technology at a sustainable pace.

The successful management of technology cannot occur without the training and development of the people involved. As such, the flexibility of personnel in relation to their ability to adapt to continuous changes to products and technologies has to be understood to ensure that personnel development planning is integrated as part of a strategic technology management plan [22]. The continuous development of products and technology in manufacturing affects both the present and future requirements for personnel development therefore the work force has to be adapted to external and internal factors that influence the management of technology.

2.4. Technology for Innovation

The utilization of technology to facilitate innovation can be traced back to the last few decades where globalisation and information technology has transformed the manufacturing industry. Although there is a greater demand on businesses to lower costs, enlarge product assortment, improve product quality, and provide reliable delivery dates through effective and efficient coordination of production and distribution activities, DETs have also been evolving. Thus, achieving these goals can be easier if businesses continuously re-engineer themselves, utilizing strategically selected and implemented, available DETs.

To understand how DETs can facilitate innovation, it is useful to explore the term 'Digital Enterprise Technology'. Digital refers to the representation of information or data as digits thus digital enterprise technologies can be described as the enterprise-wide utilization of technology to manage data or information digitally. This implies that any technology employed by businesses that enables them to manage information or data digitally, can be classed as a digital enterprise technology. A number of DETs are employed by businesses today, to manage engineering and manufacturing information and have now become essential pre-requisites for competitiveness and business success.

As a facilitator to the innovative process, DETs need to be used effectively and this can be supported by a collection of methods or systems. However, due to the fact that DETs are designed for specific purposes and need to be utilized in the proper context as discussed in a previous chapter, the following chapters are dedicated to exploring two types of DETs; Enterprise Resource Planning (ERP) and Computer Aided Design (CAD) that commonly implemented by SMEs in the manufacturing industry.

2.4.1. Enterprise Resource Planning

ERP is a DET used in the management of both manufacturing and business processes. As an integration tool, ERP systems pull data from all processes and provide real time information about a business. There are several factors that influence the management of technology in the manufacturing environment, with real consequences to the technology and its application. The main influences are the technology; implementation

and human resources, specifically, skills, understanding and co-operation. The management of ERP technology is linked closely to the data that is being integrated by the system. Therefore, businesses have to pay close attention to data sources/ input, while being perceptive about data output from business process.

Enterprise resource planning (ERP) is a technology that has evolved over time to accommodate the needs of the manufacturing industry. The technology has proven to be successful for some manufacturing businesses, while not so successful for others; when ERP systems were first introduced, studies on the application and value revealed that a remarkable 65% of executives believe that ERP systems could be harmful, this perception being buttressed by specific examples [20, 21, 23-26] of how poorly implemented ERP systems have contributed to the bankruptcy of businesses (e.g., Appleton, 1997). On the other hand, there is also evidence indicating the numerous tangible and intangible benefits of ERPs [5]. Currently, the global implementation of ERP systems suggests that its value has been widely established, with numerous businesses evidencing the benefits of successfully implemented systems.

ERP is a strategic technological tool, which emerged in the early 1900 [27] as an enabling technology that integrates various functional information systems of a business such as production, marketing and finance, into a seamless suite of business applications across the business. It allowed businesses for the first time to streamline their processing of business data and cross-functional integration within and between business operations without the need for legacy systems, which were used in the pre-ERP era, to collect, store and analyse data. But due to the associated problems they posed, and with ERP systems gaining popularity as complete business solutions for businesses, there was a shift in focus. Thus, ERP systems provide an enticing solution to managers who have struggles with incompatible information systems and inconsistent operations policies. However, successful implementation of ERP systems requires active participation from senior-level managers from various functional areas so as to delineate its impact on the business level as well as functional level strategies.

In the 2000s, technological advances in the areas of Internet and electronic commerce have facilitated the advancement of ERP systems in exploiting the potential of the new opportunities now available in the areas of Internet and electronic commerce thus

requiring businesses to consider changes to take advantage of new opportunities. Nevertheless, there are numerous advantages with the latest advancements in ERP technology, which is focused on making an organization's extended networks of suppliers and distributors more effective by improving the quality of communication and interaction between enterprises. However, the problems with making the supply chain network more effective through the quality of communication and interaction between enterprises is the number of varied ERP systems available today. Suppliers will not always go for the same ERP systems rather, they will choose a system that is suitable to meet their basic requirements, affordable and easy to implement. This could pose problems for businesses when they attempt to achieve enterprise-to-enterprise integration [6, 19, 25, 27-40] on some sort of neutral platform and with the globalisation and the advancement of technology, there is every indication that in the future, SMEs will have to implement such technologies. Also, it raises the issue of confidentiality, where businesses have to decide on the levels of integration they hope to achieve with other enterprises. While sharing is great for fast growth and development, it will have an impact on the agility and competitiveness of businesses that should ideally be considered by SMEs in the early stages of development, hence the importance of R&D activities. Although standardizing ERP systems to facilitate the management and security of internal and external electronic data management is not a present priority, it will have to be considered by ERP vendors in the near future as collaboration is crucial to the future developments and sustainability of this type of technology. In Figure 5 below, a summary of the ERP technology time-line is provided [41].

ERP TIME LINE					
1960s & Earlier	**1970s**	**1980s**	**1990s**	**2000s**	**Future**
Inventory Control Systems	**MRP** *(Early ERP)*	**MRP-II** *(Early ERP systems)*	**JIT + MRP-II Extension**	**Vendor Consolidation** *(Maturity of ERP)*	**Easy configuration, universal standards, etc**

Figure 5: Development of ERP Technology

2.4.1.1. Components of ERP Systems

The components of ERP systems are simply, the constituents/ modules that make up the software systems while the architecture of the system is the structure/ design of the modules of the system and how they behave [41]. Both the components and archi-

tecture of ERP systems are important to the planning and implementation of ERP technology as SMEs have an opportunity to re-organize their operations and processes to achieve a lean structure that is designed around the system. This should facilitate a change in the company culture and create the right environment for increased efficiency. The three key components of most ERP systems[41], summarized in Table 2 below, gives business an idea of how the main system components and their functions.

Key Components		**Description**
1	Client/Server system	Application of technology is via a centralized server to clients in multiple locations in the enterprise.
2	Enterprise-wide database	Consists of a core database that interacts with all system applications/ modules
3	Application modules	Integrated software packages for individual business units/ processes

Table 2: Key components of ERP systems

The client or server system helps business plan for the implementation of a centralized server, if one does not exist. It also helps them determine how many clients or users would be granted access to the system, which is useful for determining licensing issues and associated costs. With a centralized server, the business has the ability to store all of its information on a core database, and would have to make plans to ensure that true integration of all business systems and applications is achieved during the implementation process, while considering future integration/ interaction plans. The application modules link each individual business process/ unit and their activities, and ERP systems are designed generically to fit these processes/ units. It is mainly for this reason that SMEs should take the opportunity to restructure the businesses before implementation to ensure that the generic design of the system is accommodated early on.

There are two commonly implemented ERP architectures[41], which demonstrate the relationship between the three key components of ERP systems. Table 3 below is a summary of the main features of both types of client/ server systems showing how the key components are related.

Two-tier client/server	**Three-tier client/server**
Handles application and database processes	Handles complete corporate ERP deployment
Integrated database and application server	Separate database and application server
Process distribution via server	Process distribution via two or more networks

Table 3: Commonly Implemented ERP Architectures

SMEs tend to implement a two-tier client/ server system because they are easier to manage and mainly, most of their operations tend to be located in one site whereas larger corporations run larger networks and prefer a three-tier client/ server system. These systems are run on operating platforms and the main ERP system platforms are AS/400, Windows NT and UNIX [41]. These systems have different appeals to different user groups and should be assessed before adopting an ERP system. Larger businesses prefer UNIX based systems due to the spread out of their operations across numerous sites, while small-to-medium businesses tend to use Windows NT for ERP implementation. The main reasons for this is that NT is less expandable than UNIX and even though it is not ideal for global corporations, it provides the best solution for single site manufacturers, a category into which most small-to-medium sized enterprises fall. ERP systems are enterprise wide solutions that deliver many benefits such as low operating costs and improved customer service. Other benefits and disadvantages of ERP systems have been summarized below and this provides an insight into the impact ERP technology will have on businesses in the future.

Advantages	Disadvantages
Promotion of integration	High Cost
Adaptation to globalisation	Lack of privacy within an ERP system
Data integration	Implementation process
Utilisation of the latest information technology	System customization
Enabling process improvement	

Table 4: Advantages and Disadvantages ERP Systems

The key principle behind ERP systems 'involves entering the data from a series of modular applications only once. Once stored, the data automatically triggers the update of all related information within the system' [36]. The integration of working practices and the information system ensures that businesses can exploit the data from the implementation of ERP systems, allowing them to gain a competitive advantage such as business process automation, timely access to management information and improvement in the supply chain. Originally, ERP systems were implemented by businesses to automate their business processes but currently, the focus has shifted to 'the quick access of up-to-date and timely management information', which is vital to customer satisfaction and business success.

There are currently more software vendors available and ERP systems are continuously being developed to allow users to be responsible for updating their own information so that ERP management reports can be generated and distributed to managers from data stored on the systems database. However, this process requires skills that can be developed within the business, through training activities, or simply involving experts. The technology is still evolving, but most of the advancements have been made in recent times as summarized in Figure 5. Now, complementary technologies are being developed as extensions to functionality of ERP systems to helps businesses to maintain their competitive advantage.

ERP software consists of a number of modules that link together to form a complete business solution making it important to differentiating between 'functions' and 'modules' when implementing ERP systems (where functions are actual physical tasks and modules are software pieces used to perform the tasks). By understanding

these differences, businesses can select software modules that are best suited to the functions of their business.

2.4.1.2. Implementation of ERP Systems

'ERP implementations have been subject to a number of studies [6, 19, 25, 27-36] aiming to identify critical success factors (CSFs). Consequently, a number of generic success models have been developed for larger businesses with interdepartmental communications. However, SMEs are too small to have such complex communications thus, any such models would have to be put into the organizational context to determine CSFs and new models that closely match the business set-up of a typical SME in the manufacturing industry would have to be created. CSF identified include, top management support, vendor support and a project champion [28, 42]. While top management and vendor support may be readily available, the support of a project champion, competent and dedicated to supporting the innovation process may be more difficult to achieve. The project champion(s) acts as an intermediary between top management and the system users (his colleagues) and has to devote a lot of time and energy consistently promoting ERP to them. The project champion is responsible for supporting the innovation process, to harness the full potential of the system for the business. As it is a slow and often difficult process, the individual(s) should be capable and dedicated to this task. The users may support or resist changes but with the project champion, barrier or knowledge gaps on the application of the system can be addressed, making them more likely to support the change, especially if the champion is a well respected and trusted member of the team. Thus, dynamic and simulation CSF models need to be developed for SMEs to ease their understanding and use of ERP and most importantly, provide vital support for ERP practitioners and users in SMEs. However, it is also important to have an awareness of why ERP implementations fail and the 5 top reasons identified are [19, 27, 28];

- Lacking of proper education and unrealistic expectations to ERP users.
- Lacking of top management support.
- Lacking of formal project status, sufficient personnel, time, and communication.
- Lacking of technical expertise and information system support to solve problems.

- Personnel's resistance to change

2.4.1.3. ERP System Related Issues

There are other issues that can arise with the implementation of ERP systems but these can be classified under 3 main areas; culture, business and technical. Of these issues, cultural issues pose the greatest challenge and result in resistance to change which has a huge impact on the technology and its effects on the business. Cultural problems relate to problems that arise from the business culture and can be resolved by demonstrations, training, seminars, meetings and presentations in the workplace to relay information to all employees about the changes of working practices and illustrate improvements made to the business. One of the main aims of implementing ERP systems by businesses is to link all the internal and external areas of a business, and businesses that have successfully implemented and reaped the benefits of ERP systems, planned, organised and were prepared for the changes involved. There was an awareness that, they needed to adapted their business mainly because it was a lot less expensive and easier to adapt their working practices to the information system than vice versa. However, if the software modules should be adapted to suit the business's functions, it would become like a 'legacy' system where any updates made to the software would have to be adapted to suit the business, resulting in increased costs and a loss of flexibility of the ERP system. The businesses that were not as successful were said to have found the software to be too rigid. Although ERP software is not very malleable and businesses that wish to use them correctly have to change their working practices to fit the software.

The rigidity of most ERP systems is an issue due to the fact that a fairly rigid business structure is required in order for it to work successfully. It is best that businesses considering introducing an ERP system change the way they operate to prevent problems with the utilisation of the system. In the short term, re-engineering the business can be time consuming and resource demanding but provides a means for businesses to map their current processes, identify any problems/ issues and solving them to ensure that the new system will function properly when implemented. In the long term, the business will experience the full benefits of such a system and have little or no need for further modifications to the system.

The main technical problems with ERP systems arise from the retrieval of data and metadata from a previous business system during the implementation. The data has to be analysed and validated before the old system can be gradually phased out. However, this is a process that once completed results in highly organized new system that are flexible and can be configured to keep future operating costs low.

2.4.1.4. Implications of ERP

Over 2000 small, medium and large firms are said to have invested $10 billion in 1997 on ERP systems and this was estimated to increase to $15.8 billion by the year 2008 [17], and re-engineering of business processes and being competitive are described as the main reasons why businesses invest heavily in ERP systems. Businesses expect the system to give them a strategic advantage over their competitors by providing access to up-to-date management information which allows them to adapt and react quickly to a rapidly changing business environment. In other words, it is primed to support agility and sustain the innovative efforts of businesses.

To understand the implications of ERP, current definitions of ERP from different sources [43, 44] were reviewed in order to identify similarities and differences in definitions provided. All three definitions are similar in their classification of ERP as a tool of business process integration. However, they each have a different opinion on the role that ERP plays in business management. These comparisons have lead to the conclusion that ERP is a set of highly integrated applications, which can be used to manage all the business functions within the organization. It is a highly commercial software package with the potential to integrate financial, human resources, production and all such information, flowing throughout the business.

The functions of ERP systems allow it to manage business information for business resources planning. These functions are divided into categories based on the field they are being applied to, including finance, human resources (HR), manufacturing and logistics, supply chain management (SCM), and data analysis with potential benefits for each of these departments for ERP practitioners.

SCM deals with the supply chain processes, while customer relationship management (CRM) allows businesses to improve customer relationships [45]. When linked with

ERP, SCM and CRM allow businesses to be competitive through process automation thus improving the efficiency and effectiveness of the process [29]. Major ERP vendors, having observed the potential revenues and obvious benefits, now integrate SCM and CRM into their software solutions. This is still a development area but should lead to a situation where ultimately, one vendor can offer a fully integrated solution to businesses.

The ability of ERP systems to gather data across organizational and regional boundaries is unrivalled and the focus of ERP is shifting. The future of ERP systems, especially with globalisation and the evolution of information technology, is already being evidenced as the internet is used to extend its capabilities; the internet provides an excellent opportunity for business and the potential market for e-business in terms of its global reach and the opportunities it provides. The implication is that businesses will need to integrate ERP into their intranet and extranet environments to harness the potential of such opportunities.

2.4.1.5. Inter-organisational Systems

Inter-organisational systems (IOS), such as ERP systems enable organizations to share information and to electronically conduct business across organizational boundaries [46]. In the past, computerized information systems were mainly directed to support internal processes, but nowadays technological opportunities enable many businesses to implement electronic networks among suppliers, customers and other business partners. However, businesses in general and SMEs in particular are vulnerable with IOS from being dependent on IOS partners such as suppliers, customers and business partners and this can lead to a competitive disadvantage if businesses are forced into markets where profits are lower and the demands on them are higher. On the other hand, IOS enhance businesses because they are cost effective, time saving, cost reducing and flexible. They contribute to business optimization and can lead to innovation through the partnerships created, and the opportunities presented by the partnership including new customers and markets. SMEs may sometimes implement IOS to accommodate customer demands but this could put them at risk, especially in situations where they have to use IOS even though it may not be in their best interest. This can cause technological problems stemming from lack of awareness, ability/

skills and knowledge. Thus, expert support is required to develop the necessary skills within the business so potential opportunities can be used to their advantage.

2.4.1.6. Legacy Systems

Legacy systems are internal business systems developed for the management of business resource. However, these systems are so unique to the businesses that develop them that they need further development to ensure they can be interfaced with other internal and external business systems. There are a number of issues businesses face with legacy systems, from the development and implementation to functionality, staff training and management, which have the following consequences;

- Time consuming
- Expensive operating costs
- Difficult to maintain
- Data provided is not always accurate, consistent, accessible and timely
- Timely management decisions cannot be taken confidently
- Accurate performance assessments are difficult to make

Although in all fairness, data accuracy can also be affected on a standardized system if data input is not properly managed. Furthermore, departments work in isolation and legacy systems often do not lend themselves fully to a modern business environment. Communication and organization of work activities becomes a problem interdepartmentally and this affects the business's ability to keep up with the constantly changing business environment thus affecting the growth of the business. However, despite these problems, SMEs are still spending valuable resources developing legacy systems. The most obvious reasons for this trend are the flexibility and fit of their system to their operations and process, but perhaps a more appropriate solution will be to accurately identify the present and future needs of a business and map these with any solutions considered to ensure that a business processes re-engineering is required, is minimal. Legacy systems also pose an additional problem; the data from such systems needs to be integrated with the main business systems or linked in some way to the

main business system to ensure the business has full visibility and real time information.

2.4.1.7. Complementary ERP Technologies

Complementary technology for ERP provides new opportunities for businesses. For example, Groupware technology and applications facilitate the collaborative efforts of its users and allows businesses to extend their ERP implementation to the internet and the intranet to make the collaboration process more efficient. Groupware such as calendar sharing, collective writing, e-mail handling, shared database accessing, electronic conferencing, etc allows networked users to have access to and process shared information. Also, data warehousing provides users with critical information about a business and when combined with ERP, it can be used to facilitate the analysis of data from ERP systems and provide insight that can be used to benefit the business. This is a growing trend, as vendors continue to push the boundaries of ERP technology.

ERP is a facilitator to the innovation process, and every effort should be made to ensure this DET is utilized properly to reduce time spent on managing data and information manually. By identifying and establishing routine tasks, the system can be tweaked to handle them, and is capable of doing it much more efficiently.

2.4.2. Design and Manufacturing Technologies

Several modelling, simulation and rapid prototyping tools are now extensively used in the manufacturing industry today, to provide the customer with a realistic and visual appreciation of a product. This is very effective in the reduction of manufacturing costs and process delays as potential problems can be identified and eliminated before the product gets to a critical stage. Although in the initial stages, it can take a longer time to set-up, once a system of working or routine is established, the system is capable of handling such tasks much more efficiently freeing up time for the user to dedicate to the innovative process.

SMEs utilize available technology such as Computer Aided Design (CAD) tools, which are constantly being adapted to the needs of the manufacturing industry, to stay competitive and diversify. Although it appears that these tools are being used as a panacea for existing issues, which takes up valuable time away from innovation the

innovation process due to the fact that inefficiencies are magnified. Instead, such issues need to be properly addressed before implementing these systems so they can serve as true facilitators to the innovating process, which in turn creates a positive change impact for the business. With the evolution of CAD technology, there are now numerous solutions available and the key priority for SMEs when implementing this DET is to ensure they dedicate time to developing the right skills and re-engineering their business in anticipation of the changes that will definitely occur.

The justification, implementation and productivity measurement of CAD systems has been previously studied [18] and several factors, including the evaluation and implementation, have been identified. Of these, the key factors that contribute to the successful use of CAD are a combination of the technology, organization and people. Although, there is often a conflict between application, where the tendency is to get a job done and theory, where the tendency is to ponder why and how things are done [47]. However, both the theory and application of CAD technology are critical to the success and future of CAD systems, and the technology itself. There are numerous benefits to having CAD systems and these are based on the capability and functionality of the system and how it relates to the goals of a business. In order to determine, and thus relate the benefits of the system to a business, they should be conversant with the capabilities, which would ultimately save time when it comes to selecting and implementing the right system. The capabilities of CAD systems are constantly evolving to meet the requirements of the manufacturing industry and current capabilities include but are not limited to those identified in Table 5 below.

Capabilities	Functionality
Advanced Solid and Surface Modelling	
Part Modelling	Allows the user to create a solid / 3D model of a part
Sheet Metal Design	Sheet metal design tools allows the user to create sheet metal design and automatic flat patterns of sheet metal parts
Parametric Modelling	Feature based modelling that allows a user to refer to features instead of the underlying geometry.
Freeform Surface Modelling	For creating the skin/surface of a 3D geometric element such as automotive body panels
Model verification	Validation/verification of designs against specifications and design rules
Express design tools	Designs such as Pipe and Cable routing are created using express tools
Assemblies	
Assembly Design	Allows the user to create assemblies using individual parts and/or other assemblies.
Welding and Fabrication	Welds can be applied to a model in the assembly environment
Advanced Drafting and Detailing	
Wire frame geometry	Allows users to view the underlying geometry of a model
Engineering drawings	Engineering drawings are automatically create from 3D models and/ or assemblies
Associativity between 2D and 3D models	Changes from one part of the design to the next are associative. Useful for automatically creating and maintaining parts, parts list and sub-assembly quantities.
Simulation, Visualisation and Rendering	
Visual analysis	Sophisticated visual analysis routines for drafts, curvature
Rendering	For Photo-quality images

Simulation	Allows the user to simulate designs without building a physical prototype
Product Data Management	
Integrated materials database	Allows user to input real materials for calculating mass properties of parts and assemblies
Standard parts libraries	For the automatic generation of standard design components
Code programming	Allows the inclusion of programming code in a model to control and relate desired attributes of the model
PDM	For the management and sharing of engineering design data
Bi-directional parametric associativity	Modification of any feature is reflected in all information relying on that feature such as properties, assemblies and drawings
Data Exchange - Import /Export Routines	
Collaboration & file sharing	Output of engineering documentation, such as manufacturing drawings, and Bills of Materials to reflect the BOM required to build the product
Neutral data transfer	Import/Export routines to exchange data with other software packages
Free CAD viewer	For sharing product designs with suppliers and customers
Office (OLE) compatibility	Compatible with Microsoft office tools
Engineering Analysis	
Kinematics	Allows the user to constrain assembly and show motion based on constraints
Interference and clearance	Allows the user to check assemblies to determine clearances and interference fits
Stress analysis	Integrated analysis tools for carrying out stress analysis on models

Table 5: Capabilities of Current CAD Systems

The focus on CAD technology is not as extensive as that of ERP in this section, mainly because CAD technology is more established and widely accepted by SMEs in industry than ERP, which is still an emerging in terms of how established and widely implemented it is amongst SMEs. Their functionality is well understood, and CAD systems are more widely implemented than ERP systems. They have become part of the fabric of the manufacturing industry and without them businesses would not function as efficiently and effectively in the provision of complex solutions. Although, there are still issues with CAD technology that can be explored further, such as inaccuracies observed between virtual models and real life problems that can be due to either human involvement or the technology itself, which is continuously evolving.

2.5. Technology Driven Innovation

As stated previously, new products or services are typically created for the market, to fill a gap in the market, or in response to a competitor providing that product or service for the market. This response or reactive strategy may be better suited for SMEs because they can reap the benefit of using proven technology without the burden of developing the technology themselves. Regardless of the strategy employed, every effort should be made to ensure that the timing is right for new product development and introduction especially because it has an impact on the efficiency of the business as well as cost, quality and delivery.

There are four distinct stages identified in any innovative process; the introduction, the growth phase, the maturity and the decline. When a process is mature, it can be described as having almost reached the end of its useful life and may be unable to sustain any competitive advantage the business once had. This can be avoided by seeking new sources of ideas to stimulate innovation, which can be achieved with the right methodology. The allocation of resources is required for this to be most effective, and it is during this time that available technology plays an important role for SMEs.

When employees are motivated, it becomes easier to stimulate innovation, through the implementation of technology. There are a number of motivation theories including Adam's Equity Theory on job motivation [4], illustrated in Figure 6 below. It high-

lights the inputs and outputs, which should be balanced in the work environment to motivate personnel.

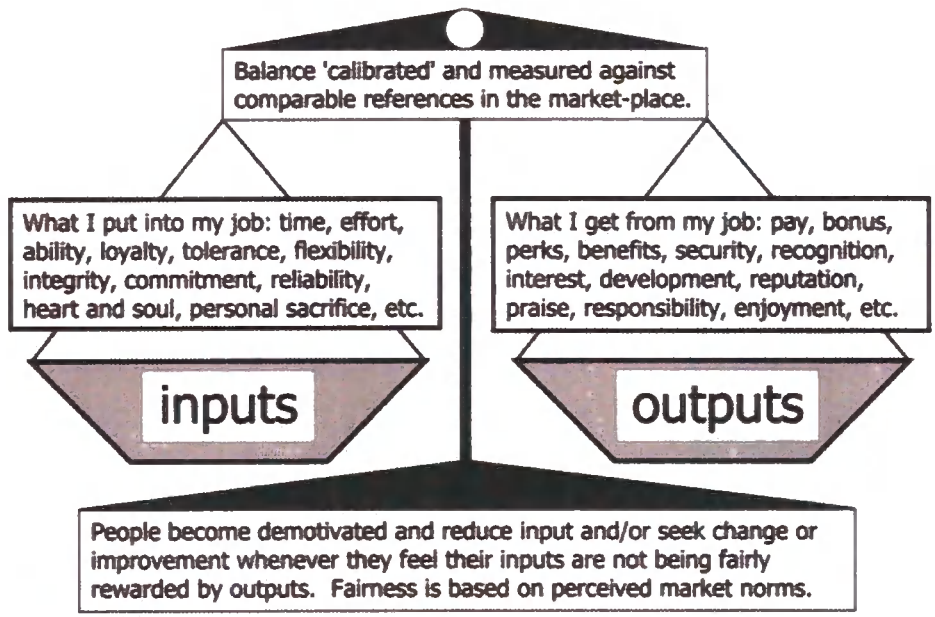

Figure 6: Adams Equity Theory[4]

In reality, it is not often that the inputs and outputs are balanced and this is compounded by the fact that they are subject to human emotions. Thus, it is necessary to have in place, a structured reward scheme that reduces the element of human emotion ensuring that employees, especially the creative ones, are adequately rewarded to keep them motivated.

Technological change mechanisms that result in the transformation of the typical practices of a business, is often the reason for personnel development [48]. However, because personnel training and development is usually reactive to newly implemented strategies or technologies, the work force is often unprepared. Also, there is a tendency for businesses to pay more attention to the utilisation of technology for business innovation than to training personnel to use the same technology effectively. Business innovation works best with cross-functional teams, with each team providing the necessary expertise for the completion of an innovation project. "Research has shown that effective integration of R&D, manufacturing, and marketing can enhance

project performance and firm competitiveness" [49]. This is largely due to the fact that "positive" routine behaviour develops selective attentions, which is responsible for the identification of indications that would be missed by the untrained eye [5]. Positive routines, however, cannot be established if teams are not adequately trained and motivated to become skilled at their tasks, which also encourages them to be innovative. Training, motivation and establishing positive routines can facilitate the innovation process for businesses by harnessing the expertise of an integrated, motivated and innovative team to maximise efforts, increase efficiency and reduce cycle times.

Technological tools that greatly improve business performance and increase competitiveness like Enterprise Resource Planning (ERP), used in the management and integration of business processes, are fast becoming business pre-requisites as they provide greater control, accountability and traceability over internal business influences and the capacity to adapt to external influences in a constantly changing business environment. SMEs can analyse data from such ERP systems in order to gain insight and ideas for the business to and identifying trends and patterns for data classification. Accurate data is required for such analyses to be insightful sources of technological innovation for businesses hence, the emphasis on personnel training and development, as technology by itself does not bring about innovation nor does it give businesses the competitive advantage they seek. It is the combination of the application of suitable technology and personnel skills and expertise to business processes that makes them unique.

When developing new products or services for a target market, businesses should make an effort to understand the requirements of that market by conducting a marketing analysis and obtaining information that can improve product quality. Again, the hierarchy of needs is essential to ensuring that the business is competitive and techniques like the Quality Function Deployment (QFD) can be used to understand the requirements of an industry through a translation of the functions of the particular product for example, and interpreting it into a product specification that accurately captures the voice of the customer. Quality-Cost-Delivery (QCD), unlike QFD, is a business function focused on lean manufacturing practices. It is a measure that businesses

employ to manage internal business processes and activities to identify key performance indicators (KPI) for business improvements and also facilitates competitiveness.

Innovation can be achieved through implementation and incorporation of new technologies to typical business practices. However, successful innovation in this context has little to do with originality, but the level of commitment and dedication of all involved in the implementation and integration process that drives success. Few businesses successfully incorporate new technologies, while the majority reactively attempt to achieve the same level of success using similar strategies. Nevertheless, organizational learning and knowledge management, especially the capture, transfer and absorption of knowledge [50, 51], provides a means for businesses to identify critical success factors (CSFs) and other issues and incorporate it into their business strategy for high levels of success. ERP systems should be implemented using a process oriented framework that includes strategy formulation; process planning and systems design; system evaluation; justification; configuration; implementation and post-implementation audit, to ensure that issues leading to ERP systems implementation failure [41] are suitably addressed.

ERP technology is reliant on personnel involvement for accurate and consistent data input, which requires 'a broader set of business knowledge as well as new technical/system knowledge' [50] and the efforts of a cohesive team with a common goal. Although challenging for SMEs due to resource limitations, 'ERP consultants can act as knowledge links, providing the necessary knowledge to the client when the client's expertise is scarce and organizational learning around the ERP system is burdensome' [51]. Knowledge management and transfer from consultants to team members play a vital role in increasing the potential for increased system integration and assimilation of new knowledge.

'ERP systems impact the content and structure of organizational knowledge at the individual and organization levels'[50], which is essential to stimulating innovation and managing technology. Thus, the implementation of ERP systems should be seen as an opportunity by businesses to introduce new technology that impacts positively on all levels on the business, to achieve the highest levels of technological innovation.

2.6. Summary

SMEs are the backbone of economies globally, and with technology constantly evolving, their definition may change but their basic function will remain the same. In the UK, the current challenges manufacturing SMEs face stem from increased low cost competition from abroad. Therefore, innovation, which is the key to differentiation and maintaining global competitiveness, should be supported. The strategic implementation and utilization of the technology for innovation are vital to the survival of SMEs as these tools combined with the right skills and knowledge will encourage learning which can be applied to bring about changes that enhance business performance.

Sustainability is a key issue for SMEs and constantly swapping old technology for new ones may not always be a viable option, especially if costs play a critical role. Therefore, R&D management should be encouraged and supported from available government funding sources to ensure that businesses can maximise and sustain the benefits of their investment in new technology for a longer period of time.

Digital Enterprise Technology systems and methods assist businesses to increase quality, reduce costs and streamline their business processes. Digital technologies like CAD and ERP are still expanding and increasingly being implemented by more businesses across the globe and this will allow for further reductions in the cost of investing in this type of technology, as well as increased support from vendors, and greater contributions to the knowledge and skills base via the users' group. As businesses start to have a greater requirement for business-to-business (B2B) transactions, and solutions/ applications integrated with the internet, ERP will have to extend further to cater for this growing trend. Therefore, a technology innovation management methodology will have to accommodate the implications of this trend for SMEs to ensure adequate support for business forecasting.

In this chapter, established and emerging theories on technology management and related fields were explored to determine how this work will contribute to previously conducted research. Previous research into technology management theories and the implementation of digital technologies have mostly been on larger corporations, while the focus for SMEs is mostly on implementation and its wider implications. In the

next chapter, the research design and methodology is presented and proposed enterprise innovation strategy for SMEs is developed.

3. TECHNOLOGY MANAGEMENT METHODOLOGY

3.1. Introduction

It was important to define the scope of the methodology to provide structure and a clear focus. To achieve this, the business product development activities were analysed and improved upon by undertaking the development of a new product and implementing product development standards. Also, improvements were made to the design activities of the business through the implementation, customisation and configuration of a new CAD system. Following these activities, the methodology for managing technology to facilitate the innovative process was developed, based on experience, observation and research carried out. However, it was important that the business strategy was considered to ensure that the methodology developed would be relevant and useful in the short and long term business plans. The activities, observations and experiences, which have been captured in the following sections, were documented to ensure that these could be replicated where possible, and also to address the issues and challenges which were encountered and how these could be resolved using the proposed methodology.

Having identified the business strategy as being crucial in the development of a methodology, it was important to ascertain the strategic level and importance of this methodology. Although there are several levels of strategy hierarchies [52], only 3 of them; the corporate; the business unit; and the functional levels of strategy, were considered in the development of the methodology for the management of DETs. Corporate level strategies are more suited to the configuration of larger corporations, while the business and functional levels were considered appropriate, the scope of the project and access to necessary resources only allowed for the development of a functional level strategy, which deals with the departments or functions of the business. The methodology for managing DETs developed in this section is aimed at micro-businesses suitable for application at the functional levels of a business.

3.2. Research Plan and Methodology

The qualitative approach was used to support this work, specifically in carrying out direct observations, collecting and recording relevant textual data and insider accounts for analysis, to achieve the set project aims and objectives. The technologies assessed were ERP and CAD technologies. The ERP system analysed was EFACS, an EXEL system, widely implemented by SMEs due to its affordability and the support available to its users via the users group, a great source of information on issues and developments. The CAD system analysed was Autodesk Inventor, another widely implemented, mid-range CAD system used by SMEs, due to its affordability and the fact that most SMEs start out with an Autodesk product and get deals from vendors. These were considered viable data sources for the assessment of the technology management strategy for innovation.

To determine the level of support required by the business used in the case study example, the current state of practice with regards to the utilisation of available technology to stimulate and support innovation was observed, and the opinions and perspectives of key personnel and management recorded. These were used to guide the development process to ensure the company's needs were accurately captured. As a result of this, the core priorities and actions for the company were determined and presented in the framework in the following sections. It is intended that other SMEs can apply the framework to underpin innovation.

3.3. Development of Technology Management Methodology

Considering the proposed methodology was being developed for possible application by other subcontract manufacturing MTO SMEs, it was necessary to make the framework as generic as possible, while highlight the salient points of such businesses and the environment in which they operate. A crucial and contributing factor to the success of any strategy is the ability of businesses to know and understand themselves in relation to their internal and external value based stimulation. But even more important is gaining an understanding of the value based stimulations of their target and potential customers. For a technology management methodology, the focus for busi-

nesses should be on technology with regards to how it is affected by the internal and external value based stimulation of the business.

3.3.1. Business Model and Architecture

A business model refers to the value offering of the business and its architecture is a representation of how the model is designed to achieve its value offerings. From observation, the model of a business that makes to order and its architecture is not 'designed' per se; it is highly dependent on the business priorities and how these can be achieved at that particular time with its available resources. Although it was observed that with top management support, any changes to the business architecture was usually adhered to.

The business model, which defines the business, its internal stimulations and how it relates to and interacts with its environment and external stimulations typically, remains constant over a period of time. After a period of stable growth for example, businesses may choose to diversify or undergo strategic changes to advance their growth and development or simply for survival. However, the architecture, which supports the functions of the business is more flexible and can be designed so the desired outcomes can be achieved by linking it to a functional strategy.

For subcontract manufacturers that make-to-order, their business model is set-up to provide subcontract manufacturing services. From observation, location is important because businesses that require their services need easy access to ensure they can monitor the progress of their sub-contracted projects. Other important features are the capability to handle a variety of products from a range of industries. However, their productivity is dependent on winning new orders but they have the flexibility to take on different order sizes and turn them around very quickly. Due to this flexibility, SMEs with this model have the potential to fit into identified niches and fill-in positions, a flexibility that larger businesses do not have. Furthermore, size indicates that it should be easier for SMEs to adapt.

It is important to note that due to the influence of their industry sector or principal customers on subcontract manufacturers, the utilization of DET facilitates the digital exchange of information. This is important to customers, as they want to be informed

and with DETs, businesses can make this happen thus by providing secure but limited access to digital information. Thus, time spent on this activity can be reduced by placing more emphasis on improving the way the system works and quality of information provided.

3.3.2. Business Environment Analysis

There are several tools already developed for the analysis of the internal and external environment in which a business operates. An internal analysis, such as the SWOT and Michael Porters analysis techniques can be used to identify the firm's strengths and weaknesses based on its offering to the industry. While an external analysis, such as the PEST can be used to identify opportunities and threats to the business. However, despite the fact that these well established techniques have been proven to be effective, it was observed their application and utilisation is not widely implemented by SMEs. There are other established analytical techniques such as the Six Forces Model, the Gap analysis technique, and the Value, Rarity, Imitability and Organization (VRIO) framework can be utilised to analyse internal and external business environments. However, due to the skills and resources required to conduct a thorough analysis, SMEs without expert support and with little or no experience will struggle during the implementation process.

The current business environment for subcontract manufacturers is very competitive and customer loyalty is based on a number of factors, especially cost and delivery performance. SMEs are also under the threat of increased low cost competition from their external environment. However, their size and flexibility is an opportunity to be increasingly agile and innovative. Utilizing the available tools to thoroughly analyse their business environment, they can fully exploit opportunities and increase their competitiveness.

3.3.3. Strategic Goals and Objectives

When setting short and long term strategic goals and objectives for technology management at the functional level, the business unit strategies should be taken into consideration. The functional strategy should incorporate the specific and measurable strategic objectives business unit level strategy. In addition, the activities, roles and

responsibilities of the team and team members should be taken into account and linked back to business unit level of strategy to provide grass root and top management support, which has been observed to facilitate the implementation and success of methodologies.

It is important to note that these objectives are linked to the competitive position of the business to ensure that realistic and achievable targets can be set and met. However, if a thorough assessment of the internal and external business environment is not conducted, it can have an impact on the company's perception of its opportunities and threats should be considered for true and sustainable innovation. Furthermore, with customers demanding faster turn-around times for product delivery, the main objective for such businesses is to increase performance and productivity thus having the capability and capacity to take on or attract new business.

3.3.4. Technology Assessment

Once the strategic goals and objectives have been set, a technology assessment can be carried out and the right technology selected for the business, based on the functional areas of accountability and the activities of those areas. Thus, technology is strategically selected to meet the desired outcomes. However, selecting the right technology requires a knowledge and understanding of the influencing factors, mainly the technology, process organisation and personnel. Thus, a framework was developed to simplify the evaluation of new technology for company, providing then with an opportunity to acquire new knowledge and develop their skills base. This structured process gives companies an efficient and effective means of understanding all the aspects of the business, technology and personnel related issues, applicable to the evaluation, selection and implementation of new technologies. Furthermore, the steps in the evaluation process are divided into stages, making it easy to monitor the progress of the evaluation.

The framework highlights the most important requirements of a new CAD/CAM system and allows the user to both qualify and quantify the potential benefits of investing in a new system. In figure 7 below, an overview of the technology assessment framework is provided.

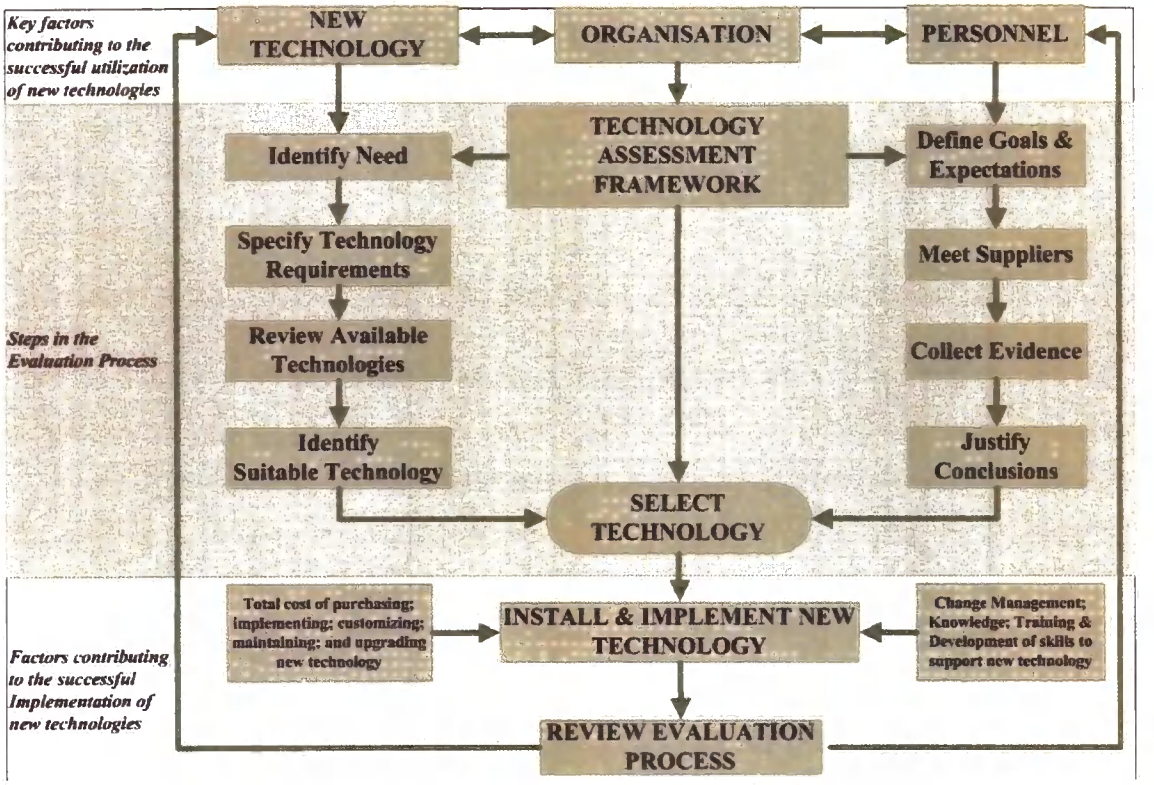

Figure 7: Technology Assessment Framework

There are 8 main steps in the framework shown, which have been summarised below, were considered crucial to the selection process, and the purpose is to encourage a methodical approach to technology selection and implementation. Thus, this increases the like hood that the right technology, which in this case is one that aims to reduce or eliminate routine/ repetitive actions and encourages mass customization, is selected.

- Identification of need - to ensure that due care and attention is given to the technology needs of the business to maintain competitiveness

- Definition of goals and expectations - to ensure that their present and future technology goals and expectations are understood and strategically planned for, proactively.

- Specification of technology requirements - to focus attention on the most important aspects of technology selection, which in this case is to address routine/ repetitive actions

- Identification of suitable, affordable technology - to ensure that the 'right' technology is selected to meet the specified requirements of the business
- Review of a narrow selection of identified suitable technology - to increase the efficiency of the evaluation process as there are now more choices available
- Identifying and meeting suitable suppliers/ vendors - to determine the functionality and capability of the technology through trials and demonstrations
- Evidence gathering - to justify technology selection to meet specified needs, goals and expectations
- Justifying conclusions - to support the recommendations on which technology to purchase for implementation

The technology assessment framework provides a simple way for businesses to determine what they have and what they need technologically, to meet the requirements of their industry and customers, and in comparison to their competitors. The main factors influencing the assessment process and the successful utilization of manufacturing systems are; the technology, the process organisation and personnel. The proposed framework aims to simplify the assessment of manufacturing systems for businesses and provide an opportunity for them to acquire/ increase their knowledge and develop their skills base. The steps in the evaluation process are used to divide the process into stages making it easy to monitor the progress of the evaluation. Thus, giving businesses an efficient and effective means of understanding their technology needs and the knowledge and skills required for the successful management of implemented technology.

3.3.4.1. Priorities and Actions for Technology

With the evolution of advance technologies and the availability of numerous technological solutions, investment in new technology is now more affordable for SMEs. Furthermore, with several government initiatives designed to stimulate innovation, there is now more funding sources and options as well as access to institutes and similar bodies with the technology businesses require.

Customer and industrial requirements, determine to a large extent, the priorities for businesses. The top business priorities, identified through the development of the framework for technology assessment, and the associated actions for achieving them have been summarised in Table 6 below.

Business Priorities		Actions
1	Planning	More resources dedicated to front end strategic planning for new technology based on Business Environmental Assessment, Strategic goals and objectives (short and long term), and Technology Assessment.
2	Management Support	Involvement of experts before, during and after the implementation process for proper integration of technology and to capture and retain best practices
3	Increase Knowledge and Skills	Investment in initial and continued training and development of personnel to increase proficiency and performance

Table 6: Priorities and Actions for Technology

3.3.5. Knowledge and Skills Assessment

The development of the knowledge and skills base within the business was observed to be an underestimated factor in the implementation of certain types of new technology that has far reaching consequences on its success for the business, since it is not the introduction and management of technology by itself that supports innovation but the application of technology. Thus, when it comes to the development of the knowledge and skills base or the implementation of technology, all technology should be considered the same, especially if the management decides it is worth the investment. Any investments made by SMEs should be properly managed and well protected. For performance improvements to be experienced, those involved have to be proficient and knowledgeable about the technology. While formal training is necessary for developing the basic skills and knowledge about the technology, the responsibility lies with the users to advance their knowledge and skills and translate it to the needs of the business. Technology works best when put in the context of the business, and even

though expert support is available, businesses are unique and thus stand a better chance of differentiating themselves this way.

3.3.5.1. Priorities and Actions for Knowledge and Skills Development

Business Priorities		Actions
1	Planning	More resources dedicated to identifying and/ or developing the required skills within the business before, during and after investing in new technology.
2	Support	Selecting a 'champion', a member of the team whose responsibility it is to promote and drive the development the technology and has the support of top management and user's and access to a technology consultant or expert
3	Knowledge and information management	The utilization of digital enterprise technologies to record learning and centralise knowledge and information and the provision of access to knowledge base to personnel that will benefit from it.
4	Training and development	The maximization of resources by team learning and skills development.

Table 7: Priorities and Actions for Knowledge and Skills Development

Personnel motivation, although not a business priority, is an important aspect for stimulating creativity when learning and developing the skills required to encourage proper utilization of DETs. Therefore, this should also be considered when planning for new technology, and getting personnel involved in training and development activities.

3.4. Proposed Technology Management Methodology Framework

The proposed technology management methodology framework to facilitate the innovation process, shown in Figure 8 below, was developed taking into consideration, the nature of the business, it total offering the technology needs of the business.

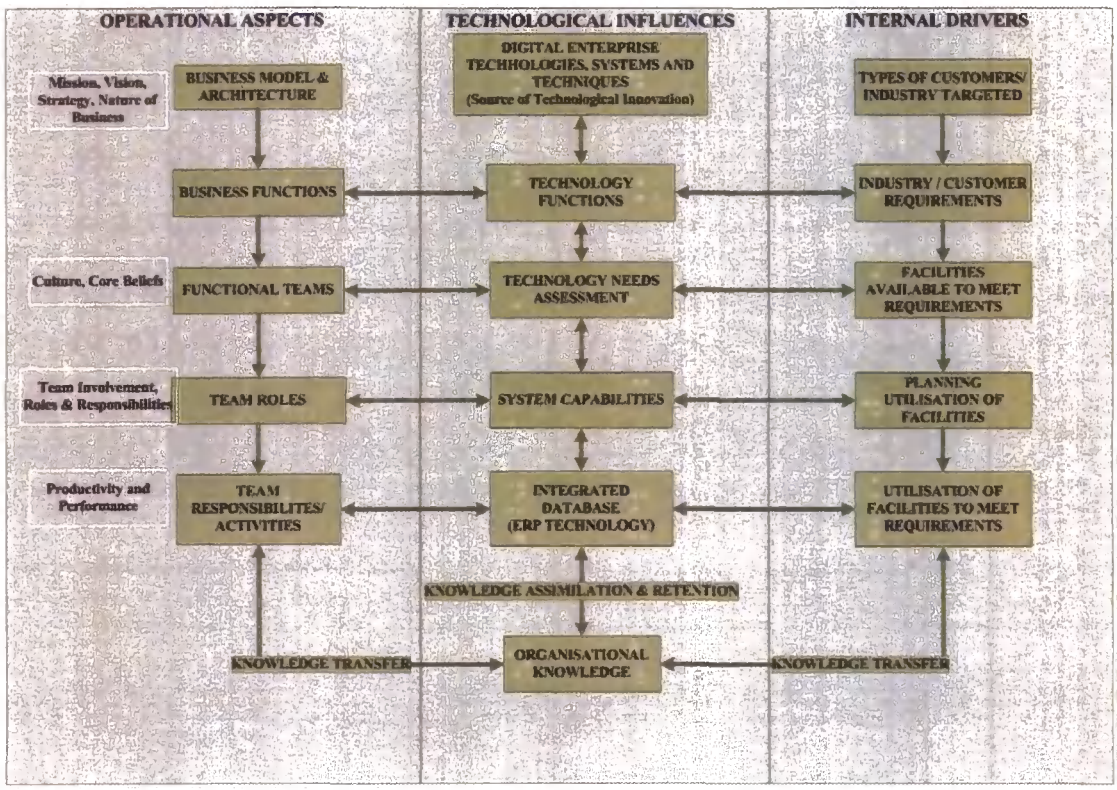

Figure 8: Overview of Methodology for Managing Technology

The framework shows the relationship between the operational and functional aspects of the business, its internal drivers/ motivating factors and the technologies and techniques, which are central to this relationship as it sustains and is sustained by the other two factors. It focuses businesses on important aspects and allows functional teams to be responsible for related functional activities and assimilate and cascade the knowledge to other functions of the business via a centralised database. In this case, an enterprise technology that allows the integration of other technologies. These links are important for businesses in understanding how they can increase efficiency by taking advantage of technology they already have.

3.5. Summary

In this chapter, the proposed technology management methodology for innovation was introduced. In the next chapter, a case study example is presented to demonstrate the practical application of the methodology in a typical subcontract manufacturing SME that provides MTO products.

4. CASE STUDY IMPLEMENTATION

The developed methodology was implemented by means of procedures, in this case, procedures for the development and introduction of a new product. These procedures were developed to suit the particular needs of Dyer Engineering Limited in the first instance.

4.1. Company Introduction

Dyer Engineering is a made-to-order, subcontract engineering business, with over 30years experience in the manufacturing industry, providing services to a range of industries. Located in the North East of England, the business specialises in manufacture of low volume, quick turn-around parts, offering its customers the total engineering service package as its unique selling point. Dyer's main services comprise design and drafting services, complemented by document and quality management; laser cutting; machining; pressing and forming; welding and fabrication; painting; and materials handling. This was mostly achieved through the strategic acquisition of smaller businesses in a similar line of work in the same locality, resulting in an amalgamation of all its business activities on one site, now home to 2 large factories, 2 office buildings and outdoor warehousing. The number of employees, although fluctuate to accommodate peaks and troughs to the manufacturing cycle, currently stands at 85, the majority of which are direct labour personnel.

Being a 'one-stop shop' for low volume high turn-around products is one of Dyer's main strength's and in addition to the its manufacturing technologies, other systems and methods are utilised in the provision of services to the manufacturing industry.

4.2. Implemented Technologies, Systems and Methods

In order to provide the total engineering service package, Dyer's have implemented a variety and combination of technologies, systems and methods to meet its business objectives and priorities. Driven by the growth of the business and customer initiative, the company invested approximately £1 Million in the installation of its ERP system,

EFACS in 1999. EFACS is an integrated manufacturing financial and distribution software, built around the latest database technology. Although implemented several years ago, it is only recently that customer initiative and requirements, and top management drive and support that the system is now truly becoming the functional nerve centre of the business as it has often been described. This implies that the opportunity to facilitate the innovation process through this technology is not being realized, which would obviously have an effect on productivity, efficiency and the business performance. Furthermore, as a result of the time lag between implementation and increased utilization, there is a gap in the skills, knowledge and experience of users, which has implications on resources, particularly time and money. Figure 9 below shows the relationship between the database Files, Records and Fields.

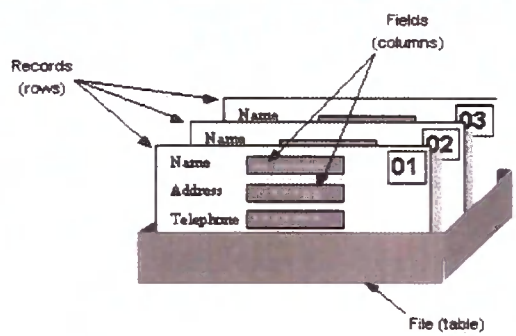

Figure 9: Database File, Record, Field Relationship

The structure of EFACS Graphic User Interface (GUI) menu is a hierarchical, tree like structure comprising four layers shown in Figure 10. There are six main functions within EFACS (Engineering, Sales, Planning, Material Control, Production and Accountancy System) and two additional functions for system management and linkage modules like electronic data interchange (EDI). EFACS has a database query facility, which is used to perform complex searches upon the data associated with a single field or combination of fields and provides businesses with access to system data. Data entry is critical thus, personnel involved require adequate training and motivation to reduce human errors and produce more accurate information to facilitate strategic planning and decision making.

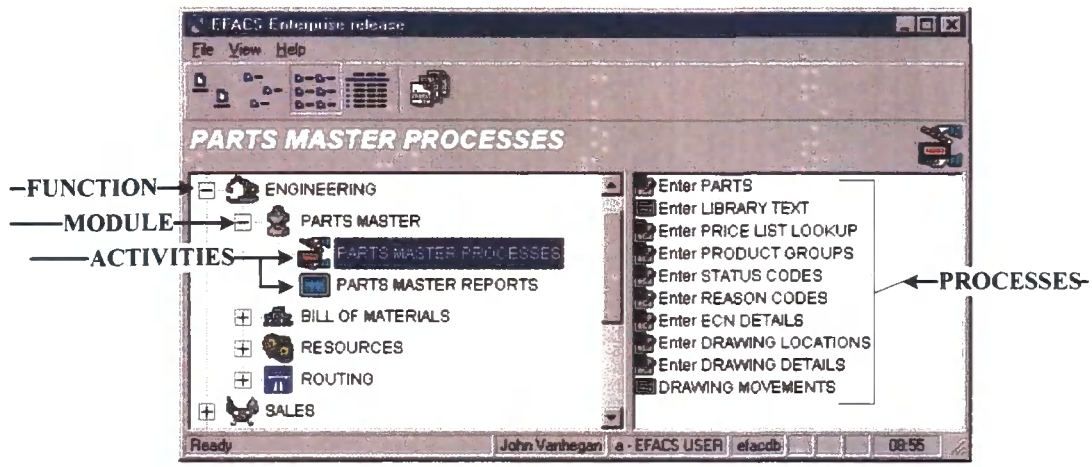

Figure 10: Four layers in EFACS GUI Menu Structure

There are a number of legacy systems used as complementary systems to EFACS because of its rigid structure. 'Job Shop', is a Microsoft Access based application that manages mostly one-off and repair jobs. It is used in the estimation of material costs and manufacturing times in addition to planning jobs and the required resources to successful complete them. With EFACS and JobShop, there is a lot of guesstimation involved in the specification of job process times, in addition to the disparities in guesstimated times, as each engineer using the system may set different process times for similar jobs. For this reason, engineers each take responsibility for dealing with specific customers, providing the sort of personal touch that encourages continuity and familiarity, which commands customer loyalty with the added benefit of consistency.

Another legacy system used is the "laser package to use", which is an Excel spreadsheet based application. It is simply a calculator, used to calculate the cost of the raw material and cost to manufacture sheet metal profiles. Shown in Figure 11 below, it is only set up with the machine times and material sizes and costs and serves as a complementary system to both EFACS, and the two laser cutting machines.

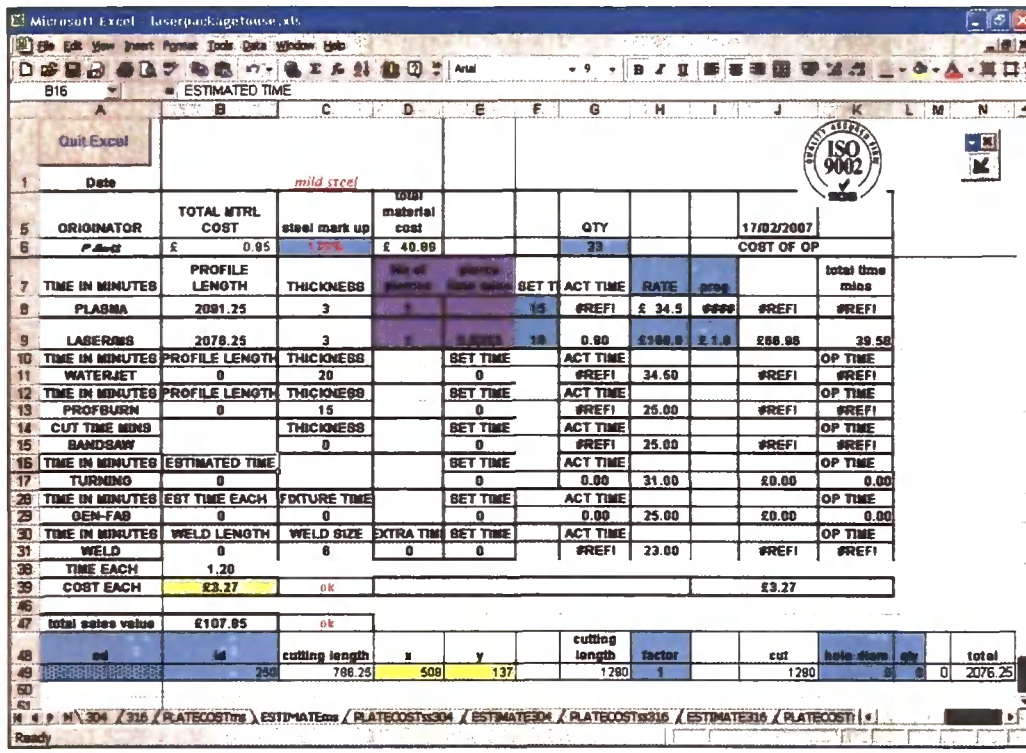

Figure 11: Screen Dump of the "laser package to use" Tables

This system helps to increase the accuracy of guesstimations but does not do much to help should any other process such as machining, fabrication or painting be required for that particular job. Although the engineers are very experienced, they do not often have the opportunity to review changes in their internal and external environments that affect the cost, quality and delivery of jobs. The consequences include a lost opportunity to deliver a more efficient and cost effective solution to the customer, and potential savings from gained from being 'leaner'. The laser cutting of profiles for customers is the most utilised service Dyer's offers to customers. This involves a lot of running and maintenance costs making them the most expensive machine to run. They have their own inbuilt data management systems, to ensure that the cutting time is maximised but this is an issue as EFACS is the main business system through which all processes are managed. For this reason, the company developed an application to link both systems. For other linked systems, EFACS is used to collect, store, manipulate and manage data and metadata to provide visibility on the company's performance. These link-backs and legacy systems are inefficiencies that take-up valuable productive time and other business resources.

Having successfully catered to the needs of its manufacturing industry for several years, the company made the decision to diversify into product development and introduction for survival, and to enter into higher value-added engineering markets to increase its competitiveness.

4.3. The New Product Development Application

The methodology developed in the previous section was applied to the development and introduction of new products. The implementation, described below, has been carried out in 3 stages; the methodology was applied to the assessment and selection of a new technology, to equip the engineers with the techniques and systems for technology assessment; next, it was applied to the NPDI process to demonstrate how the available and implemented technologies in the businesses could be applied to support innovation; finally, its application to personnel for motivation and to stimulate innovation was explored.

4.3.1. Assessing and Selecting Technology for Innovation

The technology assessment framework was used to assess computer aided design (CAD) systems to determine their suitability for the company during the NPDI process. Below are the specified short terms goals and expectations, recorded from conversations with key personnel;

- CAD system to support its product design and development procedures
- Linked to current CAD packages and business system on a basic level
- Capable of handling basic computer aided engineering analysis
- Access to existing drawings in the system
- Read all drawing formats from customers
- Smooth transition between old and new package

In the long term, the company required a CAD software solution for all applications to satisfy design needs of the engineers in the office and the needs of the manufacturing staff and shop floor processes.

For the actual assessment and review process, mid-range CAD packages were researched and the 3 most commonly implemented and affordable packages were se-

lected and reviewed for their suitability to meet the requirements of the business. The selection was based on the specified requirements and other critical issues as agreed and recorded by key personnel involved in the selection process.

An Excel spread sheet was developed and used in conjunction with the framework, to organise the process and ensure consistency in responses from the identified users. Each user was asked to review each package, and assign values to their capability. The main categories listed were broken down into specific functions required and rated based on the importance to the company and how well the package performed/ met the specified requirements. Data on product, functionality and vendors were gathered from internet sources and by speaking to industry experts to ensure that the information provided for the evaluation process was as detailed and thorough as possible to facilitate understanding.

The selection criteria were determined through discussions with the top management team, stakeholders, colleagues and industry experts. Through the responses and feedback provided, the selection criteria were set by the evaluation team. The information provided by key stakeholders during this process was used to determine the importance priority of each criterion, which was used to assign weighting values. Consequently, during the evaluation process, team members scored the functions of each category demonstrated by the software vendors, which was combined with the weighting to determine the overall score for each function and subsequently, each package evaluated. In tables 8 and 9 below, a summary of the evaluation process is provided.

EVALUATION SPREADSHEET NAME OF SOFTWARE: PACKAGE C								
Category	**Importance**	**Rating**					**Average Rating**	**Score**
		User 1	**User 2**	**User 3**	**User 4**	**User 5**		
Part Modelling	10	5	8	5	5	9	6.1	61
Assembly Functionality	10	2	3	1	2	6	2.8	28
Drafting and Detailing	7	7	6	7	5	9	6.7	47
Data Exchange	8	2	1	1	1	2	1.4	11
Visualization and Rendering	7.5	8	4	10	8	10	8	60
Data Manage-ment	7	7	7	8	5	7	6.8	48
Engineering Analysis	8	7	6	7	5	8	6.6	53
CAD	7	9	7	7	3	7	6.6	46
Price	7.25	2	5	3	3	6	3.8	29
Services	7.5	5	8	5	5	7	6	45
							TOTAL SCORE	**429**

Table 8: Summary of Package 'C' Evaluation

COMPARISON OF PACKAGES EVALUATED			
Summary Of Requirements	**Scores**		
	Package A	**Package B**	**Package C**
Part Modelling	51	59	61
Assembly Functionality	63	38	28
Drafting and Detailing	18	53	47
Data Exchange	10	13	11
Visualization & Rendering	47	51	60
Data Management	42	30	48
Engineering Analysis	56	11	53
CAD	51	51	46
Price	19	29	29
Services	14	34	45
TOTAL SCORE	**369**	**368**	**429**

Table 9: Summary of Evaluation Comparing Packages 'A', 'B' and 'C'

The total score for each package shown in Table 8 was used to determine which package had been allocated the highest values and thus best overall performance by the company users based on their understanding of the functions demonstrated and its benefits for them and the company as a whole. The individual score in each category was also reviewed to check that the package with the best overall performance also met/ exceeded the company's requirements for that category.

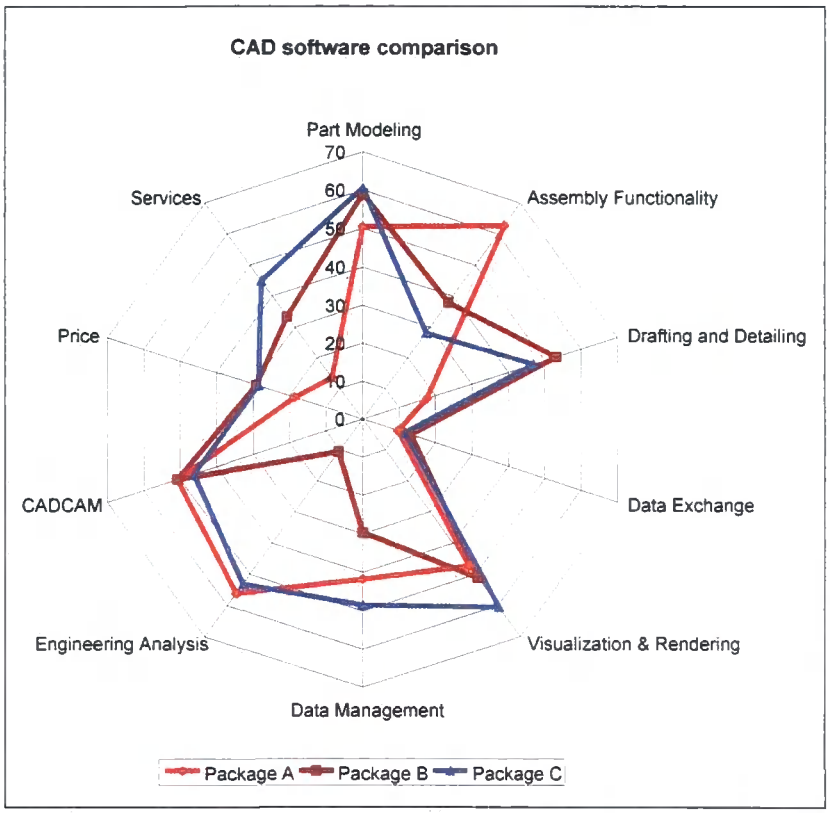

Figure 12: Radar Chart Comparison of Evaluated Packages

The Radar chart in Figure 12 is a plot of the requirements as detailed in Table 8 and was used for its ability to communicate efficiently and effectively, the proportion of the values assigned to each package evaluated. This chart, and the It shows clearly how they each performed against the specified requirements; package 'A' performed better than the 'B' or 'C' in Assembly, Engineering Analysis and CAD; package 'B' performed well in Drafting and Detailing, CAD and Part Modelling, while 'C' came out on top in Part Modelling, Visualization & Rendering and Data Management. It is important to note that the performance of each package was analysed based on the specified system requirements and other evaluation criteria as set by the evaluation team and not necessarily the product offering. The overall performance of each pack-

age was determined by how satisfactory and to what level it met the both the specification and set criteria.

4.3.2. Managing Technology for Innovation

Dyer engineering uses the informal four stage approach to NPD, from idea to concept development to production and commercialisation. This mimic's the company's approach to providing manufacturing services where customer enquiries are reviewed and prepared for production, produced and then despatched to the customer. The company wants to remain a MTO business but incorporate NPD to strengthen its market position and protect its economic future. However, one of the characteristic of MTO businesses is their dependence on maintaining close customer relationships to ensure that there is a steady flow of orders for business continuity. While product development is dependent on the identification of new business opportunities through the recognition of market needs, which the company can fulfil. The risks with NPD are obviously greater as there are no close individual customer relationships but instead, a relationship with a group of customers is formed. There are also risks for SMEs depending on close customer relationships that can affect the profit margins of the business. It is important to note that although some SMEs that MTO also make products to stock (MTS), this is greatly influenced by customer or industry requirements. However, the risks that they face from MTS can be mitigated if DETs are properly utilized and managed to facilitate the innovative process, which should help them take decisions on when and how to MTS thus improving efficiency and management of available resources.

The main challenges faced were in the identification of a suitable method for integrating NPD with the provision of MTO sub-contract engineering services without compromising on product quality; and changing the routine business operations and practices to accommodate the NPD process. Having identified EFACS as the key to any solution developed, an investigation of the system was carried out to determine the relationship between the system, the company's business processes and process teams, which would be central to the implementation of sustainable product development procedures. Figure 13 is a basic overview of EFACS and the relationship that exists between the business functions and the systems offering.

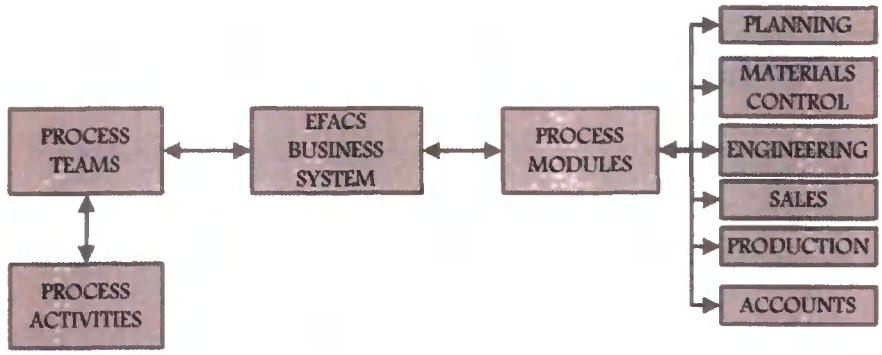

Figure 13: Overview of the ERP business system EFACS

EFACS manages the processes, the process teams who manage the process activities of the business. The process teams input data from process activities into EFACS via process modules, which are integrated internally. In this manner, EFACS supports and sustains the business processes, and process teams efficiently and effectively. Although EFACS does not have a specific NPD module, existing modules can be used to ensure that the process is integrated with other business processes. The existing business processes integrated by EFACS, and the product development processes were mapped in Figure 14 below, to understand the relationship that exists between the company's process and the NPD process.

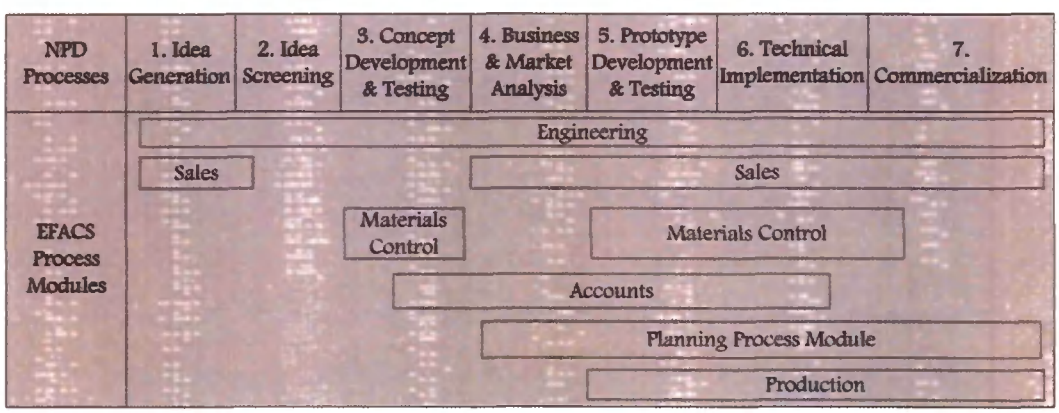

Figure 14: Mapping NPD and EFACS processes

To map the process, the main steps, activities and anticipated outcomes in the product development process were considered. This was used to identify time consuming and/ or routine activities that could be facilitated by the utilization of EFACs. Following this process, the Modules within EFACs were examined to determine exactly how they could increase the efficiency of the NPD process thus, reducing time and resources. The result of the mapping process supports theory that more financial re-

sources are required in the latter stages of product development as opposed to the time consuming nature of the initial stages. Thus, the utilization of DETs such as EFACs makes it possible for businesses to reduce the time spent on the initial stages on NPD. Having established the relationship between EFACS and the NPD processes, teams could be assigned to different stages of the process, reducing the time required to complete the process. Although early involvement is important to the NPD process but the right teams have to be involved at the right time. However, the company has a limited engineering and sales team therefore, it was not just a case of involving the team but ensuring that their time and expertise was maximised. Because EFACS already holds vital information, which has been collected over time, it was useful to begin the process by analysing the sales and engineering databases. From the sales database, the details of over 500 customers were analysed to identify potential industrial sectors to target, shown in Figure 15. The customers were classified into different categories based on total sales generated and services provided. This highlighted the fact that a small percentage of customers, approximately 3% in this case accounted for over 70% of the company's profits hence the need to diversify. This is by no means a unique situation for the company, hence the increasing involvement in NPDI by SMEs. A further classification of the customers' using the UK Standard Industrial Classification (SIC) revealed the industries that the company already had access to through its existing industrial links as a supplier. Following this, enabling technologies such as the internet, were employed to determine the viability of the selected industries.

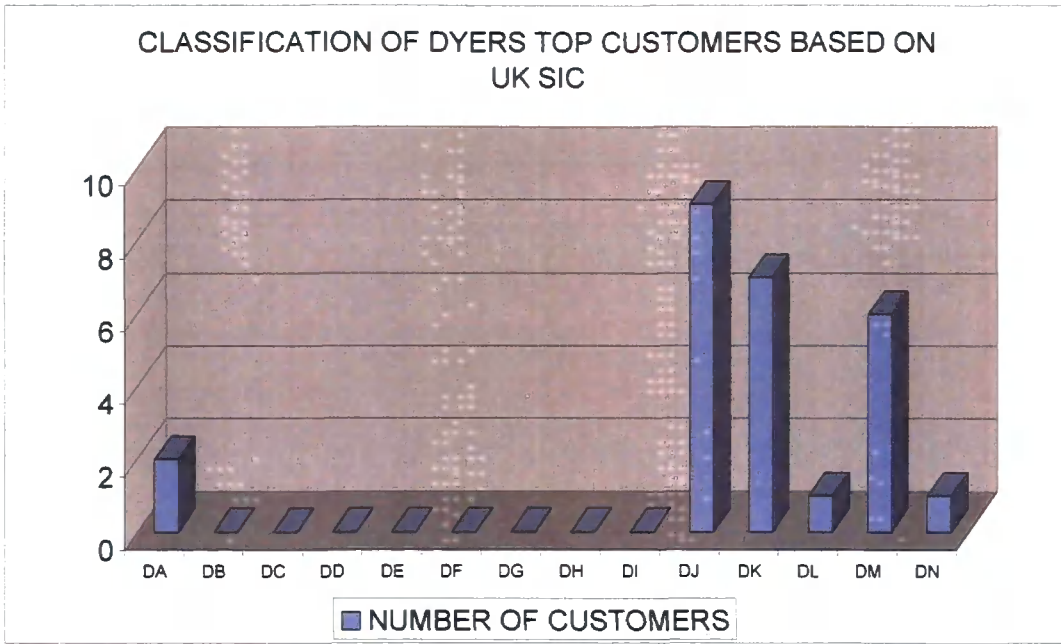

Figure 15: UK SIC Classification of company's customers

The UK SIC for manufacturing is section D, while subsections are prefixed with 'D' and a second alphabet (currently ranging from 'A' to 'N' for the manufacturing sector) to denote the subsection. Analysis of data from selected subsections revealed trends in the manufacturing industry, allowing us to select viable target sectors (Figure 16). This trend was confirmed by the sales team whose task had been simplified to identifying customers within the target sectors. With their knowledge and insight about the fluctuations and the industry in general, identifying target customer for the new product was completed in a fraction of the time it would have taken otherwise. The same method was used at each stage of the NPD process, with the team only meeting when necessary and management taking decisions upon the completion of each stage.

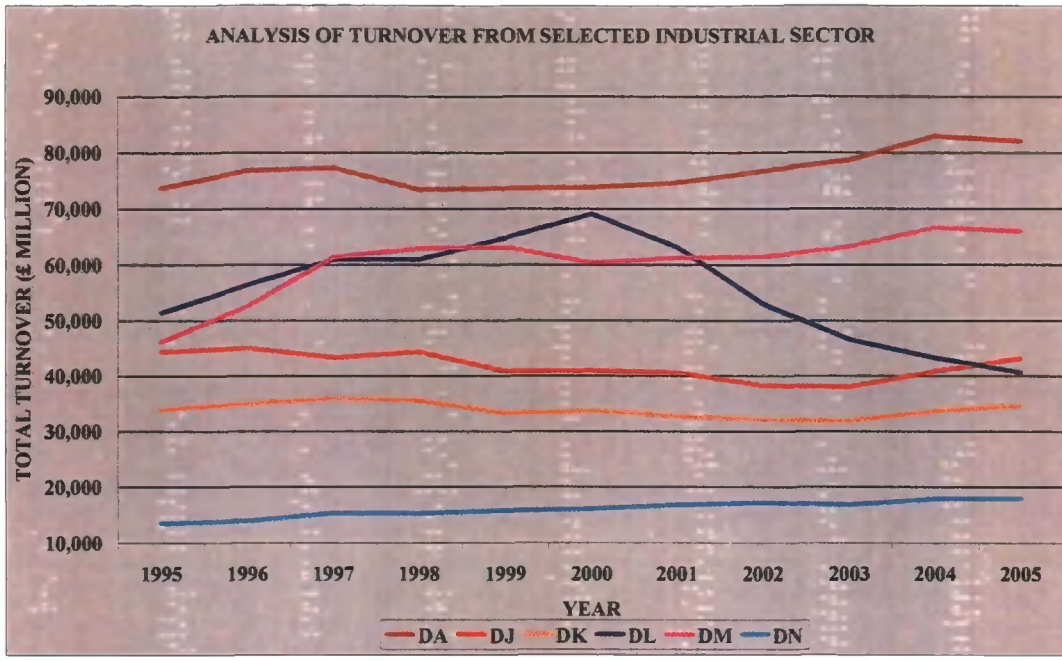

Figure 16: Analysis of turnover from selected industry sectors

EFACS manages the parts bill of materials (BOMs) in addition to controlling the materials resources requirements. With recent developments in CAD technology and the development of the product data management module, CAD system databases are capable of holding information about product BOMs, allowing businesses to successfully integrate their CAD and ERP systems. With the integration of CAD and EFACS, businesses can be more responsive to changes while managing product quality and sustaining NPD activities through the implementation of design and development standards. This impacts manufacturing and other related processes that are sustained by EFACS.

To implement the NPD procedures, a separate document was created for every completed stage, to retain the knowledge for the company. One of the procedures implemented, is the procedure for supplier related activities. During the product development process, materials have to be specified for production during the concept development stage and this is entered into the system via the engineering module. The materials control team with knowledge of materials and suppliers, select the most suitable suppliers and enter them into the system as potential suppliers (Figure 17) and could at this stage, ask them to provide a quotation for the required materials. This information and other factors that affect the cost of production are used when conduct-

ing the business analysis to determine the best supplier based on the stored quotation data and negotiate contracts accordingly.

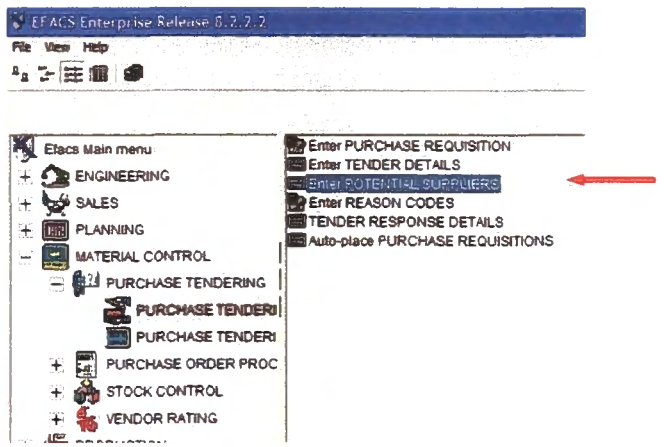

Figure 17: Implementing procedures for supplier activities

The other procedures were implemented similarly by using the existing relationship with EFACS processes to ensure that data was retrieved, analysed and integrated with a related NPD process.

An investigation into the best practices for product development was carried out to determine how experts and industry leaders approached the process, and documented at every stage of the process and recommended to the company. This was to encourage the implementation of quality procedures at the initial stages of NPD. The company already conducts customer satisfaction surveys and uses KPI's to improve its provision of subcontract services but did not feel the need for tools like QFD, FEA and FMEA that help to improve product quality. However, when analysing market needs and competitors products, they were willing to apply enabling technologies for Agile Manufacturing (AM) in the analysis of the market and its competitors. It was especially important as without a formal standard, encouraging staff to adhere to procedures is challenging and there is only so much that can be done to maintain quality in future NPD projects. Nevertheless, the company can demonstrate its commitment to sustainable development of quality products by adding 'Design and Development' activities to its ISO 9001-2000 certification.

4.4. Summary

The successful introduction of a new technology requires knowledge of the technology and an effective evaluation framework that aids the user in defining specific goals and expectations. It allows the user to focus on relevant issues and highlights the most important requirements of the new technology. Businesses can list the potential benefits of investing in a new system as it applies to them, which is more effective than having someone else explain the benefits, which include increased efficiency, reduced lead times, improved quality, reduced costs and the opportunity for new business.

Proper application of the framework ensures that the system and methods applied meet the specified requirements, and is in line with goals and future plans for growth and development of the business. Thus, the use of an evaluation framework for the process may be challenging but is an opportunity to increase awareness and commitment amongst personnel, increase the possibility of achieving set objectives, broadening the business's knowledge base, and most importantly increasing the possibility that the new system will be properly utilized to its full potential.

There are numerous benefits to investing in technology but improper management/ utilization of technology is one of the main reasons why most businesses are not successful in their implementation of technology. The introduction of new technology does not in itself bring about the anticipated benefits. Instead, knowledge, understanding and continuous training/ practise are the keys to unlocking the potential of today's technology. But, the responsibility lies with SMEs to source, obtain and retain the knowledge, skills and expertise required.

The case study though limited in its scope, revealed that even though a collaborative team effort is required during the product development process, this is still a challenge for SMEs due to limited resources, expertise in NPD and a low level of commitment to the process by top management and company staff due to existing customer requirements and other management priorities. However, advanced technologies through several government schemes designed to promote growth and development and stimulate innovation within SMEs is more readily available, and should be taken advantage of. It provides an opportunity for businesses to take advantage of available expertise and technologies they should be willing and ready to fully commit to the

process to experience its benefits in their pursuit of business excellence. Furthermore, there were several changes taking place at the same time and while this was all focused on company improvements, a lack of strategic foresight in the change process meant that already stretched resources didn't have enough elasticity to take on NPD at the same time. This affects the assimilation of new knowledge, skills and expertise during the development process and is compounded by the fact that, changes implemented are not consistently and conscientiously adhered to, a critical factor in developing a culture that facilitates agile manufacturing.

Implementing NPD procedures using an ERP system in this instance provided the best strategy for sustainable development due to its data management capabilities. In general, systems that facilitate knowledge management and reduce the burden on the requirements for resources through the use of virtual manufacturing and other advanced technological tools for AM should be encouraged in SMEs. Also, the right skills and expertise can be developed within the business by transferring new knowledge between available experts and company staff at all stages of the NPD process. Best practices should also be adopted and quality standards implemented at this stage and adhered to till it becomes a part of the company's culture. With proper management of available advanced technologies, the company becomes more innovative and agile in its approach, making it easier to identify opportunities and niches in the market.

In this chapter, two aspects of the technology management methodology were successfully implemented but, the purpose of the methodology is to support innovation at the functional level, taking into consideration, the business unit strategy. In the following chapter, the methodology will be reviewed based on the implementation outcomes. In particular, its usefulness to the business unit level of strategy will be explored.

5. DISCUSSION

Technology management is a field that is still evolving as new technologies emerge thus, studies into technology and the management of technology will still have an impact on businesses and the way they operate, especially when it comes to innovation. In particular, the utilization of technology will increase as business become more knowledgeable, skilled and comfortable with new technology. This will have an impact on the innovative process as more time is created and dedicate to business innovation through the proper implementation of DETs for increased business efficiency and competitiveness.

5.1. Research Limitations

The planning, development and implementation of methodologies, requires experience, which was lacking, although adequate support was provided to ensure there were benefits for the company.

The main limitations to the project were the role and level of daily involvement in the functional area of responsibility, which was limited due to top management concerns about antagonising existing personnel as SMEs are very people-centric. This had an effect on decision making and encouraging staff involvement but was mainly a due to the sheer volume of work and responsibility each member of the team had to shoulder. Ultimately, increased management and staff support and more experience in the development and implementation of methodologies to support functional level strategies would have a greater positive impact on the business.

Previous industrial projects have been carried out in the company and some of the results implemented. However, these are not followed up on, and eventually, the benefits are often lost. The sustainability of implemented industrial projects is important to a company's development and part of the growth phase. Without this, it will be difficult to achieve sustained and continuous growth and previous work cannot be built upon or adapted to changes in circumstances and situations.

5.2. Methodology Evaluation

The methodology developed was implemented to demonstrate how this particular company could manage its ERP technology to underpin innovation during the product development process. However, due to the fact that the company did not have any intentions of re-engineering its process, there were still issues that could have been addresses to make the company leaner that weren't. Hence, these issues, such as the elimination of the routine and time consuming activity of producing engineering drawings by depending on the 2D CAD system due to the comfort levels of the design team rather than embracing the new 3D CAD systems that was more efficient at handling these tasks, were only magnified as expected when new processes are being implemented. Although, new members of the team were trained to, and only used the new CAD system; this goes a long way towards achieving full implementation and integration of the system and the realization of its potential for the business.

By developing EFACs during this process, the efficiency of the system has been increased. This has also been used to demonstrate how scarce resources, particularly time can be maximized using this and other DETs. There are other improvements that can be made, but the focus for businesses should be identifying routine and time consuming business activities and identifying suitable technologies that can be implemented to increase their efficiency and reduce the time spent on such activities. This process of identifying time consuming and routine activities can be improved upon through experience and knowledge about the business, its activities, its vision and industry goals and objectives.

In terms of functionality, the framework developed for the selection of new systems performed as expected, by simplifying the process and engaging the staff to the extent where it was easier to transfer knowledge about the technology. Thus, when the new technology was implemented, developing the basic skills required and shifting operations from the old to the new system was a much smoother transition as there was less resistance to change. There are other tools available, like the PEST and SWOT that were also useful for the business, but requires more involvement on the company's part, meaning they would have to seek the help of experts or train themselves to use these tools effectively. In general, the functionality and usefulness of any tools or

techniques that stimulate or underpin innovation can only be proven when businesses fully commit to using them, and adapting them appropriately to fit their business needs. In order words, they have to be willing to take calculated and acceptable risks once in a while to survive in the current business environment.

By developing the methodologies described, such as the methodology for the selection of a CAD system, and providing a framework to guide the process, it provides an opportunity for businesses to fully engage in a systematic approach to identifying areas for improvements and strategically selecting the right technology to achieve their objectives. Furthermore, it focuses their attention on important issues, while increasing their knowledge, skills and understanding of DETs, their capabilities and how this translates to increased efficiency and competitiveness.

5.2.1. Implementation Outcomes

Through the implementation of techniques to increase efficiency, the methodology to facilitate innovation was developed and enhanced through continuous improvement. Although this was developed as a result of the activities carried out at Dyer Engineering Ltd., by continuously improving the model and making it generically appealing, other SMEs can apply the methodology to their business context. Ultimately, the implementation of the methodology should focus their attention on identifying and eliminating business activities that reduce efficiency and take time away from pursuing innovation. This is particularly important, especially in the current global business environment, for sustainable competitiveness.

5.2.1.1. Selecting Technology for Innovation

Selecting technology for innovation can be both challenging and rewarding if the evaluation team makes the effort. If the technology is worth investing in, then the team should even harder to ensure they select the right fit for the business. With the framework proposed in this work, the selection process should become easier and with practise, SMEs will soon develop the knowledge and skills they need within the business, to forecast their technology needs and select technology that should be able to reduce the need for keeping abreast.

5.2.1.2. Managing Technology for Innovation

The main challenges SMEs face in the management of technology for innovation will be in the areas of developing increased proficiency, sustainability and adaptability. If they are unable or unwilling to spend time learning more about all, and not just some of the technology they invest in, it will become increasingly difficult to increase proficiency and very soon, they will find that their employees are lagging behind, even though they have the 'latest' technology for their industry. If this occurs, sustaining the technology and building on it will also become a problem. Hence, it is important that all of the technology SMEs own is properly and adequately managed and that they adapt as often as is required to stay competitive while maintaining lean practices to ensure they can offer good value to their customers. It is particularly important that they utilize it to maximize efficiency and increase the benefits experienced by identifying and eliminating routine and time consuming business activities. Ultimately, technology as a facilitator to the innovation process would soon become second nature thus making it easier to sustain while increasing competitiveness.

5.3. Summary

Case studies are important to the establishment of proposed theories and methodologies, but businesses often express feelings of being exploited by experts, often left to deal with the consequences if the theories fail to provide the anticipated benefits. However, they are very useful and in most cases, businesses gain new knowledge, skills and experiences from their involvement in industrial projects. While they are encouraged to participate, more can be done to minimize the risks and increase the benefits for SMEs. Hence, the approach taken, by developing a methodology based on making improvements to routine work activities and tweaking them to maximize their benefits for the company, was more effective that it would have been if the methodology was first developed and then implemented.

Conclusions drawn from this work, along with recommendations and suggestions for future work are presented in the next and final chapter.

6. CONCLUSION

The work carried out in this research as a result of routine activities undertaken in an SME, has resulted in an increased understanding of the challenges faced by subcontract MTO SMEs in the provision of services to the manufacturing industry. Through the case study, a number of observations and findings have been made and summarised in the following sections.

6.1. Conclusions

There is no doubt whatsoever, that SMEs can manage technology to underpin innovation. However, the challenges faced stem from the willingness and capacity to learn and the motivation to implement learning and new knowledge to create an advantage. Individuals are motivated by their internal and external value based stimulations, which are equally important, although they can be flexible if they are rewarded for their inputs to the business. Hence, managing personnel is as important to businesses today as the management of technology. because for true innovation, there has to be a strong combination of the right technology and the best, motivated individuals to form a great team capable of transforming knowledge and information to new innovations thus creating new and profitable business.

It was observed that employees were expected to handle their responsibilities independently, thus increasing their skills base. The disadvantage is that existing skills cannot be honed and this will cause the business to miss potential opportunities. Also, it hinders creativity as time cannot be spent developing specific areas of the business.

The management of technology to underpin innovation should be a top priority for businesses as they strive to differentiate themselves. Utilizing the methodology proposed in this work is only the first step towards innovation.

Strategic planning and management of innovation have been identified as key areas that SMEs could do with more support. However, the nature of some SMEs is such that they may not be aware of the expertise and support available and would have to seek it. The information is available, so the greatest challenge for those interested or

involved in solving the problems with or for SMEs, will be ensuring that they are aware of the possibilities.

6.1.1. Future Risks, Responsibilities and Responses

SMEs will always be faced with challenges where resources are concerned due to a number of reasons, but this is not an insurmountable problem. However, the nature of this problem is such that it poses the greatest risk to survival for SMEs. But, rather than focus on their lacking resources, there needs to be a shift in focus. The new focus should be firmly on how they can manage their available resources. And, although there are risks involved, businesses owe it to themselves to take a risk sometimes, while assuming responsibility for the outcomes. In order to do this, the risks they take have to be acceptable or manageable and methodologies such as the methodology for innovation proposed can facilitate the process. If they do not act, then it is possible that inactivity can be the worst response to the threats they face in the current, global, economic climate. However, if they act, this will put them in control of their competitiveness as a consequence of increased efficiency and innovativeness.

6.2. Recommendations

The recommendations made to the company following the technology assessment exercise, were on the available digital CAD technologies; the fit of these technologies with the vision, mission and businesses objectives; compatibility and integration with existing DET; cost versus functionality and return on investment (ROI) as well as suitable vendors; maximizing value of investment; and available funding sources. This ultimately resulted in the implementation of digital design capabilities.

There were other recommendations made, for the management of the existing ERP technology, such as the integration of CAD with ERP were not implemented, due to time constraints. Also, there were risks that had the potential to adversely impact present manufacturing activities. This was a key point as SMEs are encouraged to implement theoretical methodologies, which may not have been fully tested, although they bear the burden and responsibility for such actions. For this reason, they are well within their rights to be cautious or even doubtful of the benefits of following a recommended course of action.

6.3. Summary

Managing technology for underpinning innovation is achievable with the right combination technology, resources, skills, methodologies and conditions. It is not enough for businesses to hire highly skilled individuals or get expert support and invest in expensive technologies or tools. Greater consideration needs to be given to devising a means of extracting the true value of its people, tools and technologies. This should be prioritized as ultimately, specialized tools, applied appropriately and at the right time by skilled individuals or experts, increases efficiency. Thus, businesses are more agile making it easier to innovate, and is more competitive.

Although the methodologies introduced were developed with manufacturing SMEs in mind, DETs are widely implemented by other industry sectors, like the construction industry for example. Therefore, the systematic approach applied to the selection of a CAD system can be utilized by other businesses when selecting, implementing and utilizing DETs. Furthermore, the lessons learned are equally important and applicable to other industry sectors; if businesses focus on reducing wasteful, time consuming and routine activities, they can increase their efficiency, facilitate innovation and become more competitive.

This research was carried out to achieve a number of objectives, whose outcomes are outlined below:

- One of the main objectives was to provide a methodology to facilitate innovation through the management of advanced technology in manufacturing SMEs, using the principles of Digital Enterprise Technology (DET) as a foundation. This was met by undertaking routine and time consuming business activities and developing a methodology, supported by the utilization of appropriate DETs to increase efficiency thus freeing up time to engage in the innovative process.

- The main technologies and systems used by manufacturing industry leaders to facilitate and support the innovation process and activities for SMEs during the product development process were identified and synthesized. The aim was to provide the company with the awareness of available DETs for

NPD. Through this activity, a link was established between a core DET (ERP) that internally integrates business functions, and a functional business area (digital design) to facilitate the innovative process while engaging in NPD. This was utilized to reduce the time spent by the design/ engineering team on overlapping activities during the process, which was then invested in product innovation and customization. This demonstrated the benefits of properly utilizing available technology to facilitate innovation.

- To understand the main issues and problems currently faced by SMEs in an MTO environment during the NPDI, a new product was developed and the process documented. This activity highlighted the challenges SMEs that MTO face as they balance their needs with the needs of the industry. With MTS, it is generally easier to plan and meet the demands of the industry while MTO is a bit more challenging and subject to a lot of peaks and troughs in business activity due to its high dependence on customer orders. However, it also highlighted the fact although time is a critical factor, if properly managed, business can utilize available technologies to 'mass customize' the delivery of their products and services. There are other ways to improve the NPDI process in SMEs that MTO, but the most effective way due to time being a major constraint is through the strategic implementation of DETs that will facilitate the innovative process by increasing efficiency.

Finally, the critical technology and management needs of SMEs were identified through the definition and management of strategic priorities and actions. This was necessary to inform strategic management planning process, taking into account the vision, mission and company objectives. This main purpose of this activity was to ensure that the time, timing and investment in new technology or DETs were carried out as a result of proper planning and consideration of the long and short term business needs. This was to ensure that the company could maximize the potential of new technology, increase their efficiency and experience the benefits of the technology. Furthermore, this would ensure that the needs of the business were met and the right skills/ expertise and knowledge were developed within the business.

6.3.1. Future Work

The work described in this thesis was aimed at addressing the issue of managing the limited resources of SMEs, particularly time, which has an impact on the innovative process. Through the implementation and proper utilization of DETs, SMEs have the opportunity to identify technology that can facilitate the creation of time which can be dedicated to the innovative process. However, the key area that stands out from this work is the development of virtual models or systems for SMEs that can be used to analyse the usefulness of methodologies, thus encouraging businesses to confidently implement recommendations. In general, an investigation into the levels of implementation and utilization of DETs already being used by businesses will be beneficial in understanding the impact this is having on efficiency and technology management, which are two important factors in the management of technology to facilitate the innovative process and thus increase competitiveness.

Agility and Agile manufacturing (AM) would greatly benefit from further research into defining the boundaries of AM with a focus on lean manufacturing and how businesses and SMEs in particular can strike a balance between these two concepts. By exploring this middle ground or balance between these concepts, a new model should emerge but needs to be fully explored to understand the impact it would have on businesses and how they can interact with and influence their environment by applying it. Thus, any future work in this area should aim to define the boundaries, identify the issues and challenges within said boundaries and its applicability to solving the problems businesses face in the modern, global, business environment.

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