A FRAMEWORK FOR EMBEDDING SIMULATION

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Abstract

Although exemplars of successful outcomes from using simulation are readily available, little has been published outlining how simulation can be implemented in an organisation.

This study examines on an experimental approach on how discrete event simulation (DES) can be implemented in an organisation and the various success and failure factors associated with it. The importance of factors like organisational culture, information management, and human resource management was investigated. To understand the general challenges faced by organisations in implementing simulation and other business process improvement techniques, various case studies were discussed. A questionnaire was also formulated to invite some of the well-known organisations that use simulation technology to evaluate the current methods and strategies in implementing simulation.

The primary outcome was to create a framework for embedding simulation based on the research from the successful case studies and the findings and outcomes from the literature survey and questionnaire. The framework was validated using examples of various cases during the research experience in the collaborating organisation. The importance of creating a structural framework and its collaboration and co-existence with the current organisational framework and required project outcome(s) were highlighted. In creating a relevant and workable framework and validating the same, this study has contributed significantly to the research gap established within the existing simulation integration studies.

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1 Introduction

1.1 Introduction

Despite huge investments in information technology, new systems, and equipment, many companies have not improved their market responsiveness and operational efficiency. Still there are many companies within Europe, where the on time deliveries are under 95% and the inventory turn is under 10%. (Greene, 1999). The new manufacturing processes including lean manufacturing largely focus on reducing the operating costs primarily by reducing the level of inventory. This concept may not work always from the supplier relationship point of view.

It is apparent that suppliers will give the most attention to their biggest clients. If a new manufacturing concept means reduction in inventory level, through, say a just in time planning system, that would mean that you are making fewer orders for inventory and emphasising on on-time delivery from your supplier. Hence, it's vital that while the production line is streamlined and lean, a level of compromise has to be set when it comes to inventory, orders and management.

In a large manufacturing organisation, it would be a prodigious task to ensure all these factors gel together, thereby maintaining the most effective supply chain system for organisation, both financially and non financially.

Many companies have established flow lines for certain products or for certain components, while maintaining batch production for lower-level items (Motwani and Mohamed, 2002). The key aspect is to identify the current supply chain processes within an organisation and identify the best possible manufacturing methodology to suit the system. In a large organisation, where managing the inventory levels are critical to the smooth flow of the system and any kind of experiments to improve the costs could prove vital, tools like simulation would be a key application.

Using Simulation tools, one can create a virtual model of a supply chain and manufacturing processes and using the simulated model of the processes run various experiments and scenarios.

Experimenting with the actual system is usually not cost-effective and often not feasible. A simulation model is a substitute for experimenting with the actual system. Therefore, if the simulation model doesn't completely represent the actual system, it cannot be classified as *"valid"*, and any decisions made with the model are likely to be of limited value.

The collaborating organisation chosen for the validation of the proposed framework is no different in this respect to other organisations. The organisation specialises in manufacturing Industrial turbines. They are one of the largest turbine manufacturers in the world. The company has decided to adopt the Lean Manufacturing methodology as the framework for driving change with simulation used as a tool for quantifying the likely benefits for the organisation. As part of improving the current system a great deal of time and money was spent on new machines and improving current systems and methodologies.

Before adopting any of these changes, these new measures had to be justified before being implemented. Simulation was seen as an ideal tool but has been used on an ad hock basis by the organisation. The use of a simulation model can help managers determine the effects of change before implementation: the impact of layout changes, resource reallocation, etc. on the key performance indicators before and after lean transformation without huge investment (R Van and De Buf, 1997).

1.2 Current status of simulation

Exemplars of where modelling and simulation is used can be found in almost all areas of commerce. Ranging from production facilities, (Ashby, 2005), through the supply chain, (Petrovic, Rajat and Radivoj, 1998), to sales (Kleijnen, 1999).

Even in manufacturing, where historically simulation has been applied it remains at the periphery of the tools used to solve complex operational problems. Even though simulation can be extremely beneficial it is difficult to convert "*the recognition of value into an embrace of the technology*" (Knoll and Heim, 2000).

Research undertaken by (Greasley, 2004) reported that there was a perception among industrial engineers and management involved in the simulation study that it was a *"one-off project."* With the benefits gained through undertaking a simulation project attained then the model and the findings shelved.

1.3 Background of the study

For many organisations, the use of simulation as a tool in designing, evaluating and managing their business processes have proved to be hugely successful. Although the concept of simulation has only started to gain popularity in the early 1990s, the advancement of technology, and gradual migration from a rather prescriptive strategy to evolutionary strategy meant that today's organisations are more comfortable experimenting with new tools and techniques to enhance the overall business performance.

The importance of saving costs and streamlining business processes in a globalised and highly competitive business environment has become paramount. Companies can take little risk by making a wrong call when developing a service or a product, as there are more competitors out there with very similar product. A sound business or product strategy is necessary to ensure the sustainability and competitiveness in business. Evaluation of the chosen business or product strategies before or during its various stages of implementation has hence become more significant than ever before.

The requirement for an organisation to enhance its business processes within time constraints has also increased. Since there is a constant development in technologies and increased availability of business process tools and techniques, often organisations tend to migrate from tool to the other.

Moreover, some of the business process tools even have to compete with each other for mainly three reasons: (i) they cross organisational boundaries by involving customers, partners, suppliers and sometimes competitors, (ii) they comprehend organisational structures by involving different kinds of business processes, activities and information, and (iii) they have to share limited resources of time, money, equipment and people (Holst, 2001).

Studies show that simulation as a tool, much like industrial information technology and computer integration in general, is not always successfully integrated within the practising organisations. (Murphy and Perera, 2001); (Jägstam and Klingstam, 2002).

Williams (1996) states that few companies have managed to make simulation a *"corporate norm"* to achieve the on-going, long-term benefits from using the technique.

Given the above, the purpose of this study is to evaluate the current practice of embedding simulation in organisations and assessing the various contributing factors to the successes and failures of these attempts. The author strongly supports the view that simulation is a technique that should be made an integral part of an organisation, which deals with multiple, and complex business processes.

1.4 Justification of research

Although many authors have suggested using simulation as a long-term strategic tool (Murphy and Perera, 2002); (Holst, 2001), research has proven that the long-term implementation of simulation as a tool in businesses is very limited. Despite the obvious increase in the use of simulation, many organisations have used simulation only in exceptional situations. Very few companies have managed to fully integrate simulation into their business processes (Stanger and Robinson, 1998); (Holst, 2001); (Jägstam and Klingstam, 2002); (Greasley, 2004)

Mtaawa and Basher (2007) summarised the reasons for this lack of continuous use of simulation as the following:

- There is a lack of clear guidelines for adopting simulation.
- Many organisations cannot devote the necessary resources, competence, and organisational support over enough time to reap the benefits of simulation integration.
- There is little knowledge of simulation and its capabilities among the industries. This results in very little commitment and effort in simulation projects.
- Lack of clear objective and scope.

In order to achieve the full potential of simulation technology, it is important to embed simulation into the core philosophy of the organisation and let it develop as a business process tool. Ad-hoc projects can only really lead to ad-hoc results. The current approach to using simulation as a piecemeal tool can only be changed if the organisations begin to believe that this technology can reap long-term benefits and it can be used and developed within the walls of the organisation itself. The main aim of this research is to develop a framework for embedding simulation. The literature survey and the findings from the questionnaire and case studies detailing examples of similar exercises and real life experiences will act as a foundation and knowledge base to the development of the proposed framework for this research. The validation of the framework will detail the challenges faced by the researcher during the due course of the implementation of the proposed framework in the collaborating organisation.

1.5 Aims & Objectives

The aim of the research is to examine how to embed the practice of using Discrete Event Simulation (DES), create a framework for introducing simulation as a day-to-day tool, and to integrating it within an organisation. The research also aims to validate the proposed framework by implementing the same in the collaborating organisation and documenting the validation approach in detail. The research will be performed over a period of 24 months in the organisation by the author. This aim will be accomplished through the following four objectives:

1.5.1 Conduct a literature survey to review the current success factors in implementing simulation

A literature survey will be conducted to identify some of the latest business process techniques and tools available in the industries today. For most cases, the introduction of new business process techniques has paved the way for the introduction of simulation into businesses. This survey will attempt to identify some of the most popular business process tools and look into how these tools are currently being embedded in organisations.

Examples of success stories in embedding simulation technologies and other business process implementations in organisations will be explored in detail through case studies.

1.5.2 Conduct a questionnaire survey to review the current practices in simulation and its limited implementation of within industry.

A questionnaire will also be formulated to invite some of the well-known organisations using simulation technology to share their views and opinions. The key objective behind conducting the survey is to understand from existing simulation practitioners in various organisations about the challenges they have faced over the due course of implementation of simulation projects. The survey will help in evaluating the right methods and strategies in implementing simulation technology.

1.5.3 Develop a framework to embed simulation in an organisation.

A refined and systematic approach will be created based on the information collected from the literature survey, questionnaire and case studies to develop a framework that will help enable companies to integrate simulation technologies into their business processes. Each of the relevant stages of the proposed framework will be explained in detail. It is expected that this framework will act as the blueprint to guide companies to embed simulation technologies in their business processes.

1.5.4 Validate the proposed framework through implementation at the collaborating organisation.

The proposed framework shall be validated by implementation of the proposed framework at the collaborating organisation. While implementing the proposed approach at the collaborating organisation, the author will be using examples of various real life situations during the research experience at the organisation, to validate the approach.

The importance of creating a structural framework and its co-relation to the current organisational framework and required project outcome(s) will be highlighted.

In creating a relevant and workable framework, and examining the various factors influencing in achieving the same, the author hopes that this study will contribute significantly to the research gap established within the existing simulation integration studies.

1.6 Structure

This thesis is broadly divided into eight parts, structured into chapters as follows:

Chapter 1 – **Introduction** presents with the chosen field of research, background of the study and provides with the motive in the chosen field. This chapter also summarises the aims and objectives of this thesis.

Chapter 2 – **Literature Review** explores the current business process techniques and tools available today. The chapter also discuss simulation as a distinctive tool for process modelling and the various factors influencing successful integration of simulation in organisations.

Chapter 3 – **Case Studies** reports on three case studies, two of them analysing the introduction to implementation process of simulation within their businesses. One case study analyses how a change philosophy and change management was introduced and implemented within an organisation. These studies are analysed and later concluded at the end of Chapter 3.

Chapter 4 – **Research Design & Methodology** explains the design and methodology used in this study. This chapter seeks to develop and deploy the research methodology for collecting all the data and information for the contribution to this research objective.

Chapter 5 – **Questionnaire** examines the practice of simulation technologies in organisations through a questionnaire survey. This chapter explores how the participating organisations have come across various challenges at different stages in integration of simulation and what future they see for simulation.

Chapter 6 – **Proposed Framework** presents the first part of the main contributions to this thesis: a methodological approach to embed simulation in organisations.

Chapter 7 – **Validation of the proposed framework** presents the experience and the results learned from the validation of the framework: embedding simulation in the collaborating organisation. This chapter also discusses the modifications to the proposed framework and the key contributing factors that requires to be considered while applying modifications.

Chapter 8 – **Conclusions & Recommendations** closes this thesis with a discussion on the key contribution from the study.

1.7 Summary

This chapter presented the background of this study, justification and the objectives of the research. Chapter 2 presents the literature review, which aims to examine the current status of simulation as a business process modelling tool and the various factors surrounding its implementation in business processes.

2 Literature Review

2.1 Introduction

Over the past few decades the use of simulation techniques and tools have gained popularity. With the advancement of computing, power simulation is becoming more affordable. A great deal of information can be found on the achievements of using simulation in a wide range of areas in various organisations. While emphasis has been given on the results and the achievements of using simulation, seldom does anyone document about how they incorporated simulation methodologies and established a simulation team within the organisation.

This Chapter provides a review on some of the most popular, commonly used Business Process Re-Engineering techniques and tools used widely by organisations. The proportion of organisations using some of these regular business process tools is high. Hence, examining how these techniques and tools are incorporated into the daily business provides a good insight into the methodologies followed by some of the organisations in integrating these tools into their businesses. The review also sites examples on how increased use of some of the static business process-modelling tools has paved the way for the arrival of simulation into these businesses.

This Chapter further explores the current status of simulation projects and evaluates the current behaviour using simulation on an Adhoc basis. Fundamental factors behind successful integration of simulation in business processes and the importance of creating a framework for integration of simulation are specially looked upon. Further research is conducted to identify the key challenges behind successful implementing simulation in business processes.

Figure 2.1-1 provides the structure and overview of chapter 2 and chapter 3.

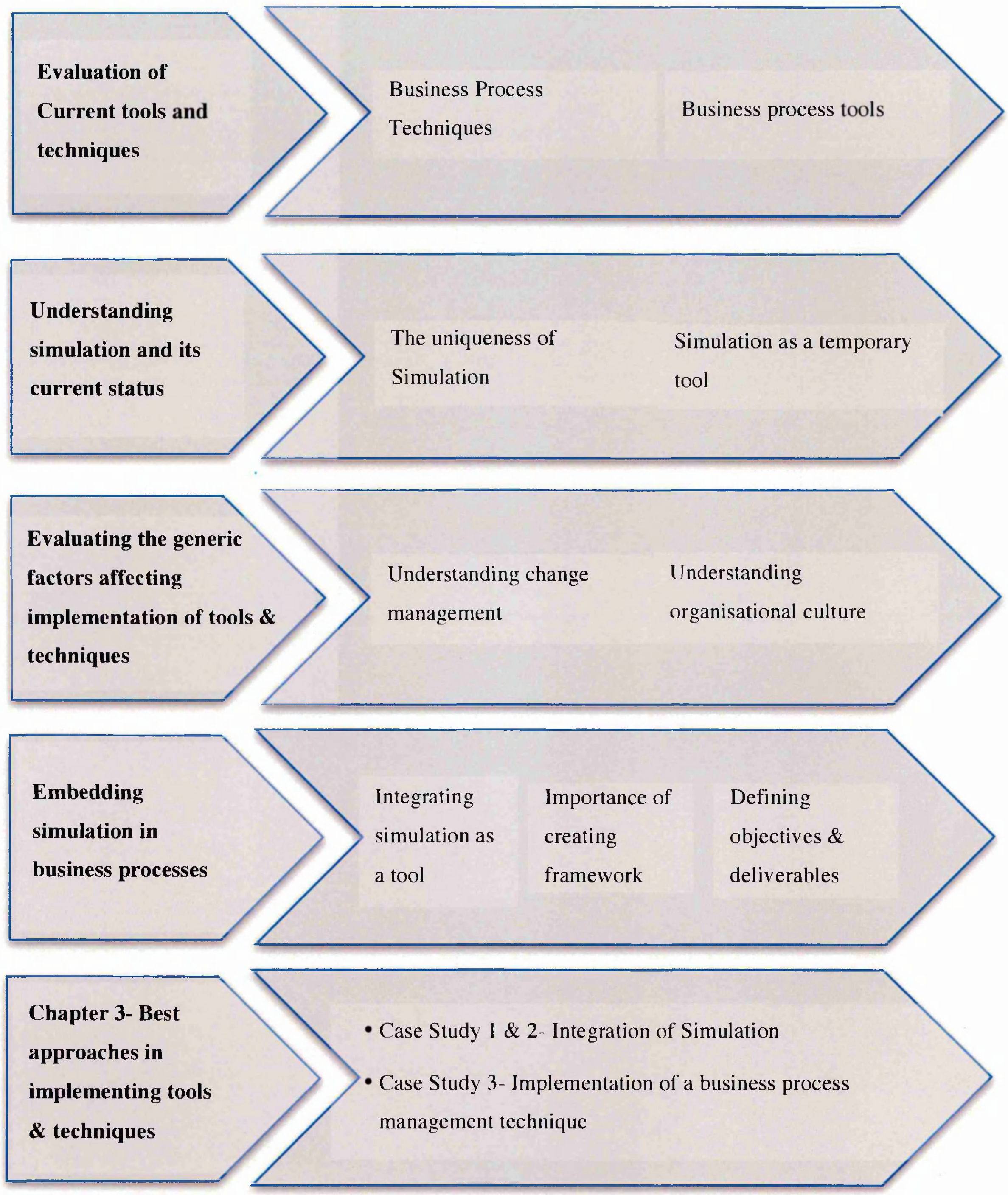

Figure 2.1-1: Structure and overview of Chapter 2 (Literature Survey) and Chapter 3 (Case Study)

2.2 Evaluation of current business process tools & techniques

2.2.1 Business process techniques

The subject of managing innovation and change has been widely discussed over the past few decades. Every few years, a new management philosophy, method or technique is developed which is believed to enhance business performance (Hlupic and Currie, 2003). Many of them originate from North America and are developed by practising management consultants.

Ferrie (1995) defines processes as being *"a definable set of activities which from a known starting-point"*. Although there are a great number of tools and methods developed to measure and manage change within a given system, choosing the right tool or set of tools is quite an intricate task to achieve. Perhaps, failure to understand what needs to be measured and managed would be the underlining reason to this. Most of all, it is also about how one tends to implement and embed these tools and methodologies within the organisation. Lack of a strong foundation can lead to the tools not been implemented properly.

2.2.2 Business process tools

Gladwin and Tumay (1994) discovered that over 80% of BPR projects used static flowcharting tools for business process modelling. Prosci (1997) analysed over 60 large international organisations that went through a BPR exercise. It was interesting to note that only 10% of the organisations used simulation software as a modelling tool. The most prominent tools used include flowcharting tools, spreadsheet modelling, and project management tools like Gantt chart, word processors and database management tools.

Gladwin and Tumay (1994) argues that one of the major problems that contribute to the failure of business process change projects is a lack of tools for evaluating the effects of designed solutions before implementation.

2.3 Integration of current tools and techniques

Although there are many popular business process tools and techniques being increasingly used in many organisations across the globe, there are only a few documented applications that emphasise or at least explain about the steps taken by the businesses to incorporate these tools into the business units. Rightly so, other industrialists and businesses that are aspiring users of business process reengineering techniques would be keen to know how these businesses have achieved successful implementation and the methodology followed. Although information on implementation and integration of simulation as a technique was scarce, the same cannot be said about some of the more commonly used business processes engineering tools and techniques.

Hence, it was important to shift the attention to similar engineering and management tools and the methods used to incorporate them into various businesses.

2.3.1 Six sigma

Six Sigma, a tool that dates back to mid 1980s, helps many organisations to sustain their competitive advantage by integrating their knowledge of the process with statistics, engineering, and project management (Laureani and Antony, 2004) (Antony and Banuelas, 2002).

Wyper and Harrison (2000) presented the key ingredients for the effective introduction and implementation of six sigma within manufacturing and services organisations in the UK as the following.

- Management commitment and involvement.
- Understanding of six sigma methodology, tools, and techniques.
- Linking six sigma to business strategy.
- Linking six sigma to customers.
- Project selection, reviews and tracking.
- Organisational infrastructure.
- Cultural change.
- Project management skills.
- Linking six sigma to suppliers.
- Training programs
- Linking six sigma to human resources

Source: (Wyper and Harrison, 2000)

2.3.2 VSM (Value Stream Mapping)

A value stream is a collection of all actions (value added as well as non-value-added) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer (Shook and Rother, 2003).

In many organisations VSM is introduced as part of a tool supporting Lean philosophy along with Total Quality Management (TQM), Just In Time (JIT) and 5s (Sort, Set In Order, Standardise, Shine, Sustain). What distinguishes VSM from all the other supply chain operations tools is its capability of visualising the processes and the material and information flow. Taking the value stream means working on the big picture, not individual process. (Abdulmalek and Rajgopal, 2006)

The VSA exercise in BT (Jones et al., 2000) was based around the company's process for providing a basic telephony service. BT has an Operational Research and Design team who work within the company as internal consultants, who work on various projects throughout the BT organisation. To implement VSMs, the team initially interviewed people working in each step of the process and observed them doing their jobs. Each step was then broken down to a series of activities and the time taken to complete each activity was recorded. These times were then classifies in to value added or non-value added times.

The project was deemed successful and it later on paved the way for Discrete Event Simulation to be used as the tool for further analysis, which is discussed further in Case Study 2.

2.4 Generic factors affecting the implementation of business process tools & techniques

2.4.1 Understanding change management

When implementing a new change, whether it is in the form of a technique, tool or philosophy, it is important to consider how the change process directly or indirectly affects the people working in the organisation. People are generally the most critical resource, supporter, barrier and risk when managing change. It was important to plan and cater the awareness program(s) and initiatives to tackle these psychological barriers from the start.

Depending on the size (workforce) of the organisation, and the depth of its organisational culture, these difficulties and challenges in achieving change may vary. Research has shown some of the common reasons for disinterested in change, which include:

- Employees may not be aware of the reasons why change is necessary
- They feel that there are other more important issues to be dealt with
- They not agree with the proposed change, or feel that there is a better way to achieve the outcome or may disagree about how the change should be implemented
- They feel there is a criticism about the way they do things implied in the change process
- Feel that they have done this before and nothing changed
- Feel that there will be extra work for them as a result of the changes.

Source: (NHS, 2005)

2.4.2 Understanding organisational culture

One of the most fundamental elements before creating and incorporating a new framework is to understand the psychology and culture of the current framework in the organisation. A roadmap to successful implementation of structural change programs, such as TQM or re-engineering, is the vulnerability of such initiatives to powerful, yet poorly understood, cultural influences (Dooley, 2003).

To the extent that change initiatives are values-based, they may clash with cultural patterns of values, thought, and action already in place. In spite of many advances in business process technologies, their adoption by the business analyst community has been primarily limited to specialists (Ramachandran et al., 2006). These effects can powerfully inhibit an organisation's ability to implement successful, durable systemic change.

2.5 Understanding simulation and its current status

2.5.1 The uniqueness of a simulation study

Page (1994) observes that at least until the late 1970s, there actually was such a thing as a typical simulation study, and it could be easily described as involving *"systems analysis using a single model generated by a relatively small group of modellers, analysts, users, and decision makers."*

Fishwick (1995) describes a simulation study in three stages:

1. Model design,

2. Model execution

3. Model analysis.

Page and Nance (1994) explains that in a discrete event simulation possess there are several characteristics that distinguish them from most software-intensive efforts. Some of the major factors that distinguish simulation from other software applications are time, correctness, efficiency in execution and varied approaches.

Umeda and Jones (1998) highlights the advantages of using simulation for optimisation of supply chain after analysing results from multiple simulation runs which produced slightly varied results.

2.5.2 Use of simulation as a temporary tool

Despite the obvious increase in the use of simulation, many companies have used simulation only in exceptional situations. There is enough evidence on the diverse environments where simulation can be used. Giaglis et al. (1999) suggests that simulation can also be useful for focusing *"brainstorming"* meetings, where various new ideas can be tested using a simulation model, and informed decisions can be made on the basis of model results.

Many organisations have seen the use of simulation evolve, often in something of a piecemeal fashion (Stanger and Robinson, 1998). The majority of companies are still using simulation technologies and techniques as a *"One Off"* tool. It is not easy to find companies, which use simulation as a day-to-day tool. Hlupic, Vreede and Orsoni (2005) state that there is no doubt that simulation is a powerful tool for scenario testing in business process re-engineering projects.

Mclean and Riddick (2000) suggest that companies have to develop their own simulation models, which replicates their own operational processes and use these models regularly. Jägstam and Klingstam (2002) highlight the fact that many companies have failed to reap the long-term benefits of using simulation techniques due to lack of integration of simulation in their business processes.

Verdanat (2002) emphasised on the importance of integration of simulation as a tool deep enough into the organisational framework so that it will play an integral role in shaping the permanent process of change within the organisation. Sarawgi, Gupta and Sivakumar (2002) highlight the benefits of simulation being used as a pro-active decision maker tool which can operate as a "*what now*" tool instead of a "*what if*" tool. They demonstrated this by making simulation online and offering the sales and marketing functions the capability to reliably predict order completion times for customers and support to real time scheduling decisions. Hughes and Perera (2009) suggest that integrating simulation into the existing Enterprise Resource Planning (ERP) system can accelerate the development of simulation.

In order to examine good approaches for embedding simulation technologies into business processes, the following section will look at some major factors for successful development and integration of simulation.

2.6 Embedding simulation into business processes

2.6.1 Fundamentals for integration of simulation

Jägstam and Klingstam (2002) looks at three aspects of the prerequisites: technological, operational, and organisational and summarise the main challenges connected to each one of the aspects. Hughes and Perera (2009) consider these three aspects as the main input elements and explains a framework for implementing simulation in 5 stages; Foundation, Introduction, Infrastructure, Deployment & Embedding. A significant level of planning and change is necessary to incorporate the concept and usage of simulation technologies for the purpose of decision making into the management framework.

Holst (2001) suggested to address the simulation integration situation by following three actions;

1. Focused research in selected simulation areas,
2. Learning from other disciplines, and
3. Developing holistic, generic, and structured approaches to integration.

However, it also has to be noted that the integration of simulation is a never-ending process. Verdanat (2002) emphasises that behind successful integration and development of the use of simulation is a carefully considered and documented master plan that executes each stages: from Introduction to integration.

2.6.2 Defining the objectives and deliverables of a simulation project

Page and Nance (1994) emphasises setting the objectives of a simulation project early to avoid a catastrophic failure of the project and the credentials of the simulation tool later on. Ernest Page & Richard Nance state that:

"Essentially, a simulation is the basis for making some decision – this decision being based on the answers provided by the simulation. Arriving at the correct decision is the singular overriding objective of simulation."

Figure 2.6-1 examines the key factors affecting the correctness of a simulation model, there by influencing the success of a simulation project.

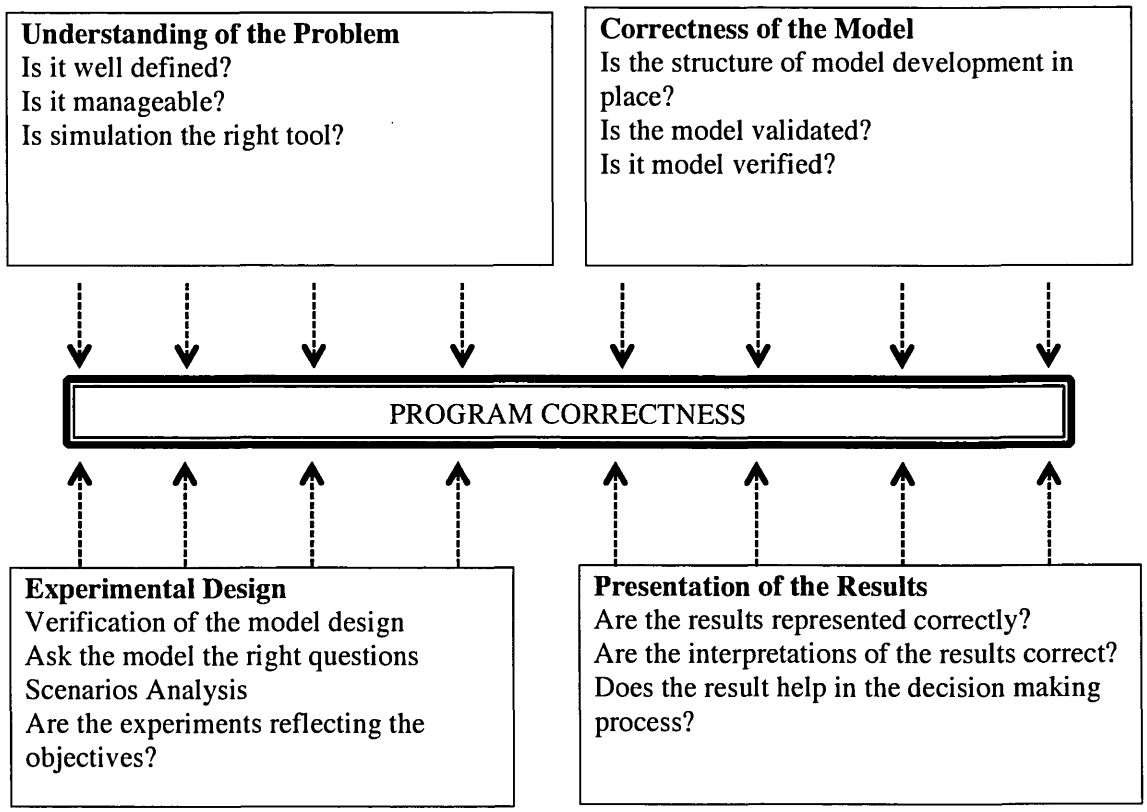

Figure 2.6-1: Factors affecting the correctness of a simulation model

Essentially if simulation as a tool fails to contribute to making the right decision to the process owner or the responsible personnel, it may be deemed as a failure. Due to the ad-hoc nature of simulation projects, and depending on the size or the project, amount of time spent and costs, the project could collapse and the damage done can be irreparable. Murphy and Perera (2002) emphasis on the importance of successful simulation projects initially to increase the possibilities of developments of more simulation projects in the organisation.

2.6.3 The importance of creating a framework for integration of simulation

Discrete event simulation (DES) has evolved over a few decades now and is moving into a mature state in which standardisation is a relevant part (Banks et al., 2003). A considerable amount of time will be utilised to accomplish various stages of the simulation modelling process like data collection, model building and so on. Not so often, the developers or the people responsible will be concentrating on physical or organisational structure they have put together in accomplishing the project.

In large organisations, a structural framework is necessary to ensure that the project accomplishes all its objectives in an orderly fashion. Now, here comes a question; Most of the time simulation models are used as a problem-solving tool rather than a day-to-day development tool. So, why is there such a huge need of structure in place to ensure that the project goes smoothly? The answer to this question depends entirely on how much success you want to achieve from this exercise. If you were purely looking for an answer to a problem, then as the owner of the process, you wouldn't be too bothered with calculating your success on anything more than from finding the answers to the particular problem. However, a more business oriented and structured approach to project management can help achieve better results. Murphy and Perera (2001) explained the best practises of integrating simulation in US companies in four stages:

- Introducing Simulation
- Establishing Simulation
- Practising Simulation
- Developing Simulation

Murphy and Perera (2001) also emphasises the *"people dimension"*, *"technological dimension"* and the *"organisational dimension"* when designing a framework for better understanding on the possible challenges related to embedding simulation in an organisation. They identified the success factors in building a successful simulation project.

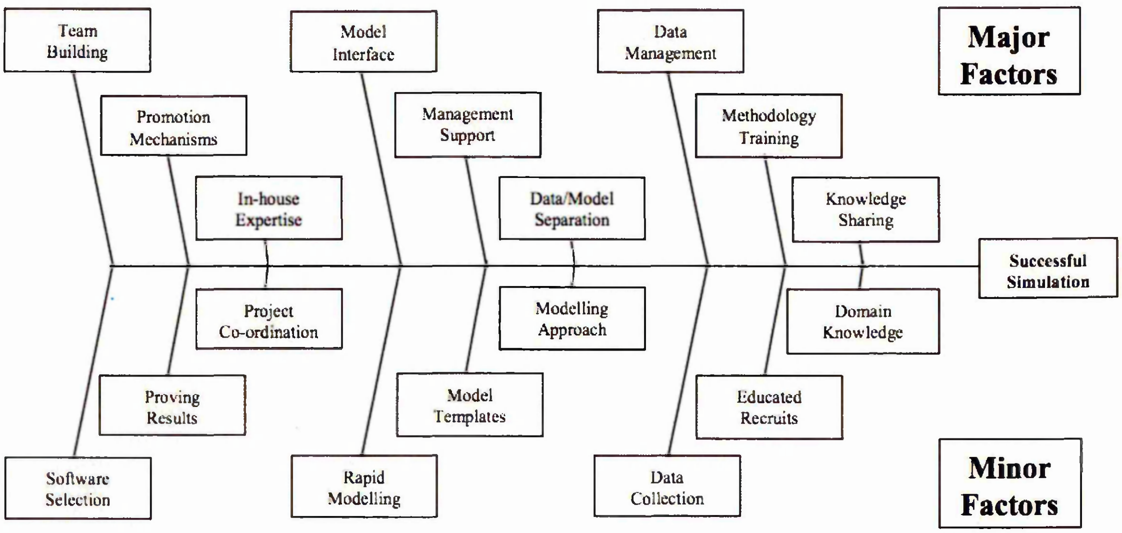

Figure 2.6-2 Major and minor factors influencing successful simulation (source: Key enablers in the development of simulation, Proceedings of the Winter Simulation Conference, Murphy & Perera, 2001)

Furthermore groups distributed throughout a company, or across continents may develop simulation models. Model analysis may be the purview of an entirely separate group, or groups. And the model users may represent yet another diverse collective. Clearly, each of these uses and development paths has unique criteria that determine the credibility of the simulation. Thus methods to apply parallelism must be reconciled with a given approach (Page and Nance, 1994).

2.6.4 Challenges in implementing simulation

A simulation model is not a good representation of reality if whatever drives the underlying system is not properly represented. Successful simulation projects in business are those, which are implemented, generate measurable results, and impact positively the organisation's financial picture. To achieve these goals, simulation professionals must put as much emphasis and work in finding the best way to reach the future state as they already put on defining it.

Vidal (2002) suggests that the main reason for needing an implementation management tool is that organisations undergoing process improvement (supported by a simulation project) can reach the to-be following multiple paths, some of which will lead to success and others to failure, and that the choice of one such path must depend on the analysis of the current situation of the business and the impact of internal and external factors over time. Yücesan et al., (2002) also argues that the job gets more difficult in the case of larger organisations, as they require powerful direction tools that go beyond typical assessment and interpretation techniques.

Vidal (2002) argues that developers should look into the Complete Simulation Project scope rather than just concentrating on the traditional way of just designing and achieving the deliverables set out by running the experiments in the model. Vidal (2002) also suggests once a current state model is designed, that this future state model should act as the blueprint for the successful implementation a new system.

2.7 Summary

The aim of this chapter was to review the available literature to identify some of the most popular business process tools and techniques and look into how they are currently being integrated in organisations. This chapter began with an introduction to business process techniques and tools. The most commonly used business process tools and techniques were chosen and examples of integration of these techniques were further explored in detail. The literature review also outlined the current practice of using simulation largely as a temporary tool on ad-hoc basis and the need of integrating simulation to reap the most benefits out of this tool. The chapter further explores the need to embed simulation in business processes and some of the generic factors affecting the implementation of business process tools and techniques.

This chapter emphasised the need for setting clear objectives and deliverables when executing a simulation project. The importance of creating a framework for integrating simulation and the various challenges associate with it has been explored in detail.

The literature survey further referred to some valuable studies conducted in the past and experiences shared by authors on some of the major and minor factors that needed to be addressed and looked upon when implementing a framework for simulation integration.

In continuation to this chapter, the following chapter looks at two case studies of success stories in implementing simulation technologies in business processes in detail. Additionally, one case study also looks into successful business process implementations in an organisation. It examines the factors and decisions that have influenced the organisations in implementing or not implementing simulation technologies within their business.

3 Case Study

3.1 Manufacturing process modelling of Boeing 747 moving line concepts

3.1.1 Introduction

As part of their Business Process Re-Engineering plans, Boeing decided to streamline their final Assembly line by introducing a Flow Line system. The goal of the project was to complete the final assembly stages of the 747 manufacturing process while the Aircraft is on a continuous moving line. During the first two years, the moving line will achieve four major milestones, the first of which was completed on December 10, 2001 when the plane moved for the final 64 feet of assembly. At the conclusion of the project the 747 will be on a moving line from the time of final body join (the joining of the three major sections of the plane) until the plane exits the factory.

3.1.2 Flow line concept

The moving assembly line is considered Henry Ford's greatest contribution to manufacturing, (Lau and Sundaram, 2002). Since Henry Ford first created the model T, in 1914, the benefits of moving assembly line have gradually created the awareness in mass production companies and many have gradually started to follow the concept.

Over the years, many companies adopted this Flow Line concept across the globe. A Lean Flow Line final manufacturing line became the norm of the Automobile industries. It is worth pointing out that many additions were made to this concept as it evolved through the past decades.

3.1.3 Integration of simulation objectives and direction

According to Boeing, the gaining popularity of Discrete Event Simulation in the airline industry prompted them to implement simulation modelling as a key tool to help with Line balancing. The idea was to analyse the effect of moving the aircraft through the line on head counts and shift patterns. Multiple scenarios were modelled for each situation to provide the flow line team with various situations to analyse and plan proactively. All processes are defined and documented by the responsible process owners and stored in a repository maintained by the Process Management Integration group that manages the *"Integrate and Deploy Processes and Procedures"* process. This group maintains a complete picture of all the processes within Boeing.

3.1.4 Creating a project team for simulation

A process owner was not always the manager. The owners of some lower-level or technical processes were *"Subject Matter Experts"*. The owner is familiar with the working of the process and is responsible for the planning, modelling, measurement, and improvement of the process if it is determined that the process was to progress to the measurement step. The process owner most often worked with a team of individuals to model, measure, and improve the process. The process owner was responsible for ensuring that the process adheres to all requirements and that the output meets the quality agreed to with the process.

3.1.5 Justifying and promoting the use of simulation

Before producing a simulation model, the team at Boeing had to justify the need for using simulation tools to their management. Hence, before starting the model creation, the team put together the objectives and the overall benefits of the project were determined. One of the key objectives was to conduct scenarios analysis.

The team at Boeing were well aware of the benefits of using Simulation Tools. They called this method *"Virtual Prototyping"*, a concept developed at the University of Michigan in early 1990s, which uses computer programs to create design iterations for prototype without the need to build a physical model. The key objectives from the project and the supposed benefits from using a simulation model matched and the project got the go ahead. The benefits from modelling were served as the modelling objectives throughout the modelling course.

The benefits of the projects were outlined as the following:

- Providing multiple scenario analysis to aid decision making process
- Minimising material flow
- Minimising flow times
- Minimise resource costs
- Maximise efficiency

3.1.6 Summary

The Boeing team successfully completed the production of the simulation model for the Final assembly line. One of the early findings showed the necessity to relocate one of their test stations. This task did not seem to be feasible initially as there were too many tasks being completed in the test bed; it was practically impossible to move the stations around. But, having done further work analysis using the simulation model, the team realised that most of the work could be separated from the gear and could be done in the moving line. This simplified the list of tasks to a point were they could comfortably move around the stations, to have a better flow line in the Assembly.

Additional Line balancing ideas and techniques were further tested and analysed using the simulation model. This work initiated the realisation of the usefulness of discrete event simulation modelling and the benefits to optimising manufacturing processes on the 747 final assembly floors. The project has given Boeing great confidence in the use of simulation modelling as a direct support tool in an intense manufacturing/production environment. As the moving line continues to improve in the future, so will the simulation modelling practices. Findings of this simulation work are just the tip of the iceberg (Boeing, 2002).

Lau (2002), an Associate Technical Fellow in Simulation states that they didn't use any particular recipe to embed simulation into their culture. *"It took a lot of educational communications and meetings. We have several internal teams and we use outside talents also."*

It has to be emphasised here that simulation was only used initially to analyse line balancing. However, the success from the initial project, was then used as the driving force to spur the use Simulation techniques across the Boeing manufacturing line. A dedicated team of Process Simulation Engineers were set up internally within the Commercial Airplane Manufacturing Research and Development department within Boeing. The team was created from a group of manufacturing engineers within the organisation itself, which meant that they now had the manufacturing experience and the expertise of the new tool.

3.2 Application Of Business Process Simulation and Lean Techniques In British Telecommunications PLC.

3.2.1 Introduction

Improving Business Processes is paramount for businesses to stay competitive in today's market place. The level of competency has increased over the past 3 or 4 decades, as customers now have the choice of manufacturers or products to choose from. Companies are now forced to improve their business processes to keep on track with the ever-changing customer demands. Organisations have gone into two different routes to achieve this aim.

One of the main routes is introducing the concept of Business Process Re-Engineering within the businesses. Business process reengineering (BPR) is the main way in which organisations become more efficient and modernise. BPR transforms an organisation in ways that directly affect performance (Carter, 2005). In the extreme, Re-engineering assumes that the current processes is irrelevant, and hence, start over.

The second method is to follow the route of Business Process Improvement, which relies on a different school of thought than BPR. The purpose of Business Process Improvement is to look at the current processes within the system with the help of a series of tools and methods and analyse different ways to improve them. Once the current system is analysed using the data collated from the existing system, improvements will be suggested with the help of the process improvement tools. Data will be collected and measured from the new system. This loop repeats all over again and it is called Continuous Improvement. (Prosci, 2002).

British Telecommunications PLC (BT) faces increasing competitive pressure triggered by the continuing globalisation and development of new technologies in the telecommunications sector. This has lead to a need to minimise inefficiencies and waste while at the same time maximising the flexibility and speed of processes and systems to deliver new services to customers. In order to meet this challenge a variety of business process modelling techniques has been used to identify strategies for improvement. Among them were Value Stream Analyses (VSA) and Simulation.

3.2.2 Evolution of business process techniques

The Operational Design Group, part of BT's Advanced Communications Technology Centre, has for some years been designing processes and support systems for use in the operational side of the company. Over the past few years they have began to implement many techniques including Operations Management, Lean techniques, Process Mapping and Discrete Event Simulation. The Group works on projects throughout the BT Organisation acting as internal consultants. They are involved in a number of research activities based around these subjects. Their first approach was to use Value Stream Analysis (VSA). Although it helped identifying issues and potential solutions, it was not able to test the effectiveness of alternative courses of action.

3.2.3 Simulation as part of business transformation

The operations group included Simulation as part of a large program put in place to transform the way BT Customer Service operates. The project had a number of streams all targeting the efficiency and cost reduction throughout the business. Initially, simulation was used as a tool along side with VSM to test the Business Improvement initiatives set out by the programme team. Using the model, the team was able to predict the effects of the proposed solutions would have on such things like resourcing, quality of service, costs and overall efficiency. Soon, the limitations of using a VSM became evident to the team. VSM is largely known to be a *"pencil and paper"* based model. It is often created by physically walking down the shop floor and drawing a layout of the office or factory and mapping the processes. In short, it's very one-dimensional.

Using simulation, the team were able to represent both the processes and the links between them. The simulation was constructed using Arena® software from Systems Modelling Corporation. The team chose Arena due to the features it offers in changing the resource levels, volumes, costs etc. by a non-simulation expert before running the model. This was important as once the model(s) were constructed, and verified and validated, they were then given to the client(s) who used them to perform a wide range of analyses.

3.2.4 Knowledge sharing platform for Simulation practitioners

BT already had a data repository in place for the project management and operational research teams. This common platform enabled various project teams to share the information and data they have collected over the due course of their project period. This system helped them to minimise duplication of data collection and information management. Since simulation starting gaining attention across the organisation, the same data repository was used to share the knowledge on various simulation projects across the organisation.

3.2.5 Summary

The operational research team in BT soon reaped the rewards of using static modelling approach (VSM) combined with dynamic modelling approach (simulation). The former enabled problems and potential solutions to be identified rapidly, while the latter focused on testing the effectiveness of proposed solutions. Having identified the fact that simulation can be effortlessly combined with VSM, the team decided to integrate simulation into all the other areas where VSM tools were used. Due to the shier size of the organisation and their wide range or unique processes, the organisation used different tools for different areas.

For example, in a different project, where analyses on end-to-end process for provision of digital point to point services were conducted, a different simulation tool called Promodel® was used. The objective of the simulation model was to effectively manage resources over a given geographical area do that the Quality of Service (QOS) measures never fell below the BT requirements. In other words, the model was primarily used as a resource allocation and monitoring tool. It is clear that the team has also experimented using more than one simulation tool for the same purposes to evaluate flexibility and the features in these tools.

Regardless of what simulation tools and techniques they use, the key factor is its application in the key areas across the business. BT claims that simulation is currently under development both in terms of a model and its use in whole of BT. The operational framework department within BT focuses on value added transformations within the business and plays a key role in various Business Process Re-engineering and Continuous Improvement initiatives within the organisation. The simulation team is positioned within the Operational Research and Design Group.

When a project is formulated, the team decides whether simulation would be a requirement for the analyses in the project. If so, the team delegates members to support the project and construct simulation models for the support of the project. In essence, the process of using simulation is exactly like how one request for the use or support of Six Sigma or Lean implementer(s) for a particular project.

3.3 A Foundation to Continuous Improvement in Solectron Corporation

3.3.1 Introduction

Solectron Corporation, founded in 1977, is a leading global provider of electronics manufacturing services (EMS) and integrated supply chain solutions. The company serves the world's most innovative companies in industries that rely on high-tech electronics. Our over 50,000 employees have a hand in designing, making and servicing products that people around the world rely on every day.

A recent study conducted by the Aberdeen Group (Lean Supply Chain Report – Aberdeen Group) suggested that 90% of the 308 manufacturers surveyed reported a commitment in Lean. Yet, only about 10% of these companies where considered the Best in Class – practicing Lean manufacturing principles within and beyond the production floor. This triggered the thought of creating a Lean Production System and methodology by Solectron for their customers.

In 2003, Solectron dedicated itself to becoming the Toyota of the EMS Industry. Combining Lean Manufacturing principles from Toyota, along with the quality rigours Six Sigma, Solectron created a trademark Production System (Solectron Corp, 2007).

3.3.2 Establishing the culture & philosophy

To deploy a new Lean Production System, the organisation focussed on five key areas; Establishing the Lean Culture, Establishing Poke Yoke (Error Proofing), Combining Lean and Six Sigma, Kaizen (Improving work Processes), and Leaning out Supply Chain.

For a new manufacturing methodology like Lean to be successfully implemented, it's absolutely vital that the philosophy should be embedded in the company culture from senior management to the shop floor. With strong support from the senior management a Kaizen Promotion Office (KPO) was formed within the organisation. The team was assigned with the function of facilitating Kaizen workshops across the organisation. Later on, smaller teams consisting 8 to 12 workers were formed to conduct various Kaizen events through out the Organisation. The Change Management team conducts various training sessions and seminars to promote the concept of Change Management. They also conducted Lean tools and application techniques across the organisation.

3.3.3 External support & expertise

Often companies fail to recognise the need for expert help to develop indigenous processes and solutions. At some point, almost every growing organisation would benefit from the expertise a consultant can offer. Most companies do not have internal staff with the specialised skills needed to solve every problem. Others will find that their existing internal resources are overburdened with existing work. Consultants can help with strategic planning, business process improvement, information technology, engineering design, and many other specialised areas to provide expertise and extra help to overcome short-term problems.

A key function of KPO is to facilitate Kaizen workshops at sites, supported by Shingijutsu Senseis, a world leader in Lean manufacturing, founded by members of the original Toyota Autonomous Study Group, who provide hands on training on ways to reduce muda[1], mura[2] and muri[3].

This was an integral factor to the development and commissioning of Lean Production System.

3.3.4 Summary

Solectron took the success it gained from lean implementation to its suppliers. The company identified the need to rely on its suppliers to support its lean framework. Solectron has already done more than 1,000 kaizen events with suppliers to identify areas of waste that can be eliminated in Solectron's or the supplier's business processes. Eliminating waste is a key part of Lean manufacturing."

Solectron's lean manufacturing initiatives changed how suppliers interacted with the contract manufacturer. Suppliers must now deliver in smaller quantities at greater frequency than in the past: A few years ago, Solectron had warehouses, which took delivery of large volumes of parts from suppliers. Today, as a result of Lean, Solectron has closed many warehouses and has a "supermarket" on its manufacturing floor where parts are now stored.

The key reason for success in implementing the new philosophy in Solectron was the level of awareness created by the company. The organisation realised early on in the importance of empowering and educating its people, and they brought in some of the best external consultants available for their lean workshops. The KPO acted as the central point to all Lean awareness and promotion activities and they organisation formed sub-groups to further promote its awareness activities. Solectron's lean program has eventually increased productivity by 13% and lead times by 68% (Agarwal, 2005).

3.4 Summary of case study findings

This Chapter referred to the success stories of implementing new business process modelling tools into the respective organisation. Summaries of the key benefits of findings drawn from each case study are shown below;

Case Study 1 gives an insight on how simulation was introduced as a support tool to lean and line balancing and how the success of the project has helped the simulation as a tool to be used in one of the largest aircraft manufacturers in the world. The case study also refers to the structure of standard simulation project team within the organisation, and the importance of creating a data repository for future model building and analysis. Finally the case study also suggests that when a simulation project gets its objectives right and fulfil them, it can take the simulation tool a long way forward. The author believes that this Case study has helped him understanding the following factors, which he would need to consider while developing his proposed framework;

- Increasing awareness through systematic internal training can help in the participation in simulation.

- Rather than rolling out simulation as a new technique and offering solutions to many projects, concentrate on one simulation project at the start and use the success to spur more developments in simulation.
- It is imperative to set out key objectives and deliverables from each simulation projects to ensure clarity on what the project can contribute to the business.
- Where possible, try to train and use the current pool of resources, so that their experience and knowledge in current processes can be utilised when developing simulation projects.

Case Study 2 refers to how simulation was implemented as part of evolution of business process techniques. The organisation already had a platform and framework in place with a history of using static process modelling tools. The organisation went through a gradual transformation or evolution from using the static modelling tools to more dynamic modelling tools like simulation. This Case study has helped understanding the following factors, which would need to consider while developing his proposed framework;

- Simulation can be introduced into existing projects as an upgradation to the current tools.
- It is important to consider the end user experience when designing the user interface of simulation models. Often the use of a particular simulation model can go beyond the boundary of a simulation project. A simple user interface can help increase generic usage.
- Tap into the existing knowledge sharing platforms and data repositories within the organisation to share knowledge on creating and using simulation models.

- For the long-term sustainability of simulation, it's important to set up a dedicated simulation group in the organisation. The group has to be positioned within or closely knit with the core team in-charge of business re-engineering and change management initiatives in the organisation.

Case Study 3 refers to an organisation's effort to integrate a new philosophy and culture into their business. It gives fundamental insight to how the organisation uses external expertise to train their key staff to instil the new ideas and philosophies and change the mind-set of its work force. The case study also refers to the creation and participation of a change management team within the company and the methods and practices used by them to promote the new culture within the organisation. The change management team was also in charge of suggesting and implementing any process management tools within the business units. This Case study has contributed to the knowledge on how a new philosophy and change management was implemented in an organisation.

- This case study analyses how a change philosophy and change management was introduced and implemented within an organization.
- Education & higher management support is key to promoting a new culture within an organization.
- It is important to ensure that the individuals in charge of change management and process reengineering are directly involved in the development and implementation of process management tools.

4 Research Design & Methodology

4.1 Introduction

The purpose of this chapter is to define the methodology used in this study. The aims and objectives of this research were identified in Chapter 1.

This chapter is divided into two sections, which are as follows:

4.2 Research Methodology

This section defines the methodology used in the study and the motivation for the use of these methods to achieve the objective.

4.3 Research Design

This section highlights the experimental approach taken to validate the proposed framework which is derived from each stages identified in the research methodology.

4.2 Research Methodology

Stage 1: *Preliminary Research & Data Collection*

- Conduct a **Literature Review** to analyse the critical success factors in implementing simulation.
- Identify and analyse success stories in implementing simulation and other business process implementations through **Case Studies**.
- Collect information from the **Questionnaire** to analyse current practices in simulation

Stage 2: *Development of the Framework*

- Process and analyse the data collected from Stage 1
- Develop a **framework** to embed simulation technologies in an organisation.

Stage 3: *Validate the proposed framework*

- **Validate** the proposed framework through implementation in the collaborating organisation
- Present the **outcome** of the **implementation** process judging the credibility and validity of the proposed framework in context of the experience within the collaborating organisation.

Stage 4: *Modifications to the Framework*

- Highlight and **summarise** the key issues and challenges endured during the process of validating the proposed framework.
- Suggest areas of **modifications** required in the proposed framework.

Figure 4.2-1: Overview of the research process & methodology

In order to do justice to the framework proposed, it was important that it was validated. The questionnaire was considered indicative in the research and the collaborating organisation corroborating or refuting the findings. By combining both these methods, this research has followed a mixed methods research.

4.3 Research Design

This study uses mixed research approaches to fulfil its key objectives, which is to develop a framework for embedding simulation in organisations. The following sections discuss how the Questionnaire was created and validated.

4.3.1 Questionnaire Survey

The questionnaire survey was designed to understand the current practices in simulation and its limited implementation within industry. The key objective behind conducting the survey was to understand from the existing simulation practitioners in various organisations the challenges they have faced over the due course of implementation of simulation projects. In order to maximise the response from the survey, the questionnaire was created and posted online. In order to encourage the participant's response, each participant was also offered a copy of the survey results. A sample of the invitation sent for questionnaire along with the actual survey is attached in the thesis as Appendix B.

The survey was divided into four sections:

- General information on the business area
- Introduction to Simulation

- Initialisation and deployment of simulation
- Simulation for the future

The questions were kept simple and easy to answer. Most of the questions consisted of a choice of answers for easy selection. If the participants wished to elaborate on a certain question, the opportunity was given. The intention of the questionnaire was not just to analyse and process the data received, but to also develop a communication platform if possible with one or more participants to share more information in the future. One of the participating organisations showed willingness to creating a technical partnership and knowledge-sharing platform to improve simulation between the participating organisation and the collaborating organisation where the research was based at. An example of a similar communication regarding sharing a platform for technology and knowledge management can be seen in Appendix A.

4.3.2 Develop a framework for embedding simulation

This section aims to collate all the information from the literature survey, case studies and questionnaire survey to create a systematic approach to embedding simulation in organisations. The main objective is to develop a generic, holistic and organised approach, which covers all the fundamental stages in integrating simulation in business processes. This proposed framework has been explained in detail in Chapter 6.

4.3.3 Validation of the proposed framework

The purpose of this exercise was to validate the proposed framework described in Chapter 6, by implementing the proposed framework. The validation process was conducted over a period of 24 months in the collaborating organisation. During this period, each stage of the proposed framework was put into practice.

Additionally, this section also reviews the implementation process of each stage in the proposed framework. The purpose of this review was to connect real life experiences when implementing the proposed framework. Lessons learned from this implementation process are further explained in the same Chapter under modification of the proposed framework.

5 Questionnaire

5.1 Introduction

This chapter presents the findings and outcomes of the questionnaire survey and is intended to evaluate the behaviours and approaches taken by simulation practitioners in embedding simulation and analyse its implementations. Since the majority of these efforts were largely not documented, it was decided to conduct a survey inviting the most prominent organisations and teams who are currently implementing simulation technologies in their business processes or have had a history of implementing simulation technologies.

The idea was to prepare a set of questions, which will help identify the fundamental reasons behind implementation of simulation, the various possible challenges they faced during the pre and post implementation phases.

The survey was divided into four major sections and each question within each section was specifically selected to match the requirements:

- General information on the business area
- Introduction to Simulation
- Initialisation and deployment of simulation
- Simulation for the future

Research was conducted identifying the types of questions employee can answer without compromising their position.

Finally, Table 5.6-1 summarises the key factors in embedding simulation technologies in an organisation, which were discussed in the Literature review, Case studies and in the findings and outcomes of the questionnaire survey.

Around eighteen participants from various organisations across Europe and the Americas were chosen to answer the questionnaire. Various levels of discussions were already held with many of these participants prior to sending them the questionnaire. The main intention of the researcher was to get as many responses as possible. As mentioned earlier, the questions were prepared in such a manner that the participants should find them easy to answer without a worry that they are disclosing any details of their internal processes which may require approval from senior management.

In order to allow participants to remain anonymous, it was optional whether participants provided contact details. However, they were given the option that if they require the results of the survey, then may specify their email addresses to which the results can be send to.

All the questions were posted online and emails were sent to each participant requesting them to take part in the survey. The survey was posted online for a period of 1 month. Within the first two weeks there were 6 respondents and by the end of the survey a total of 10 sets of answers were received. This meant that more than more than 55% of the invitees participated in the survey. More than half of the participants requested the results of the survey, which demonstrated their own level of interest in understanding the issues and challenging other organisations face.

5.2 Business area

Section 1 of the questionnaire was designed to ask some basic information about the company. Since the questionnaire was distributed to organisations with diverse business backgrounds, the purpose was to collect the basic information on:

- Primary area of Business
- Size of Organisation (workforce)
- Age of the organisation

Table 5.2-1 shows the total number of responses based on nature of the industry.

Primary Area of Business	Invitations	Responses
Aerospace	5	5
Automotive	2	1
Biotech	1	0
Chemical	0	0
Pharmaceutical	0	0
Business Services	1	1
F&B	1	0
General Manufacturing	3	1
Other	5	2

Table 5.2-1: Summary of business areas of participating organisations

Out of the 10 sets of survey results, only one company was less than 5 years old. There was one company which was between 25-50 years old and the rest of the 8 companies were 50 years or above.

Even though the idea from this question was to understand the age of the organisation, it identified an interesting pattern in the use of simulation technologies.

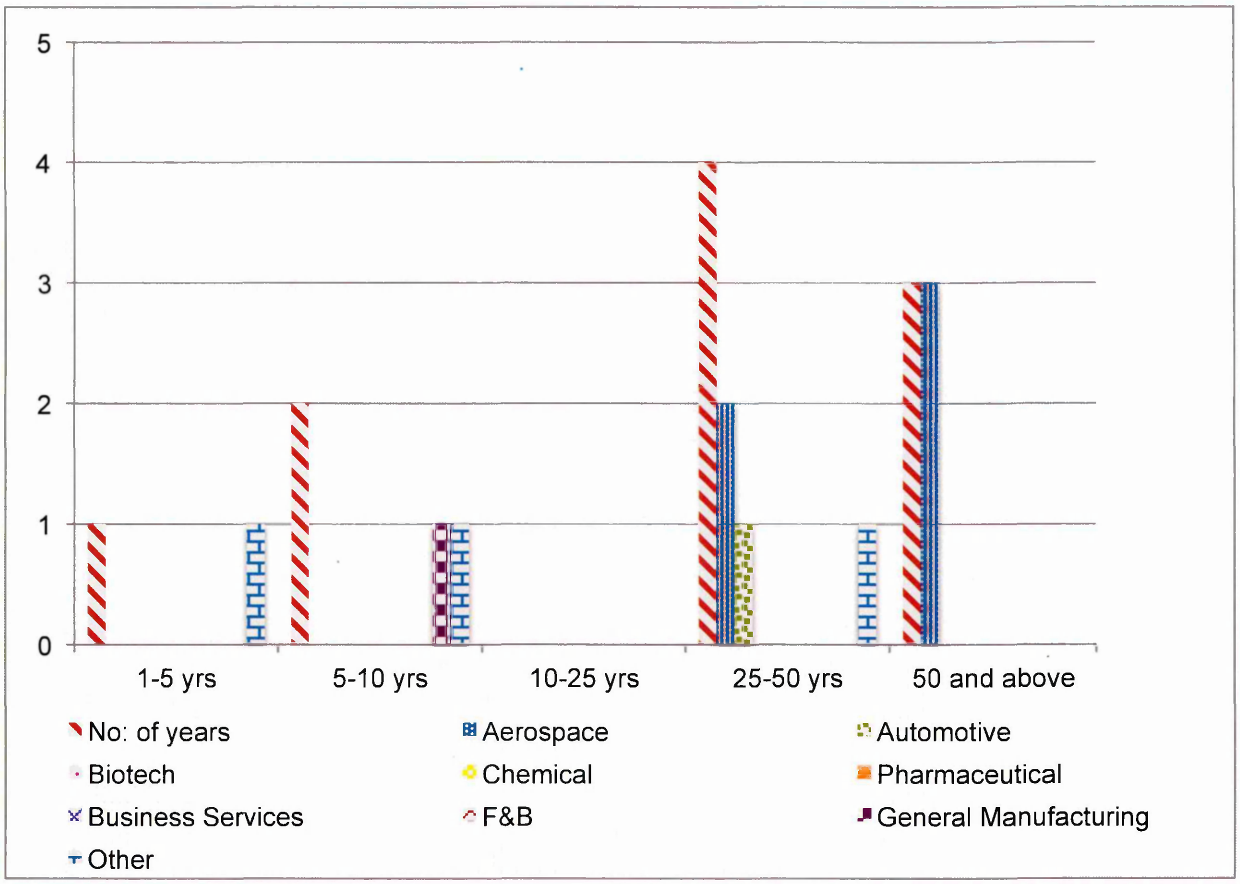

Figure 5.2-1: Classification of organisations based on their business area(s) and number of years in establishment

50% of the organisations were more than 50 years old. These are multi national companies, with billions in turnover and yet, they are still open to new technologies and systems. This may help to disregard the notion that new technologies are not welcome in companies with longer history. Many of these companies have largely moved away from the prescriptive strategy thinking to a more of emergent strategy thinking. As a result, refinements and continuous improvements were high in the business agenda. This may have helped the new technologies to get access into these organisations.

There were no companies within the age group of 10-25 years. Although there may be organisations out there, which are implementing simulation and also falls under the same age bracket, with respect to the results of this survey, they were none that have shown interest in simulation.

In addition to the business area and the age of the organisation, the size of workforce in the organisation was the third question. Interestingly enough, the companies with a larger workforce seem to be more experienced with simulation. More than 60% of the companies responded had a size of more than 500 employees. There were two companies with a large workforce, one with over 10,000 employees, and the other over 48,000.

5.3 Introduction to simulation

Section 2 of this questionnaire is designed to evaluate how the philosophy of simulation was introduced in the respective organisations and how the concept evolved in the business. The section also asked questions regarding the level of external support sought (if any) and the type of support provided.

5.3.1 Evolution of Simulation

The findings in Figure 5.3-1 illustrates that around 17% of the organisations came across the concept of simulation from external consultants.

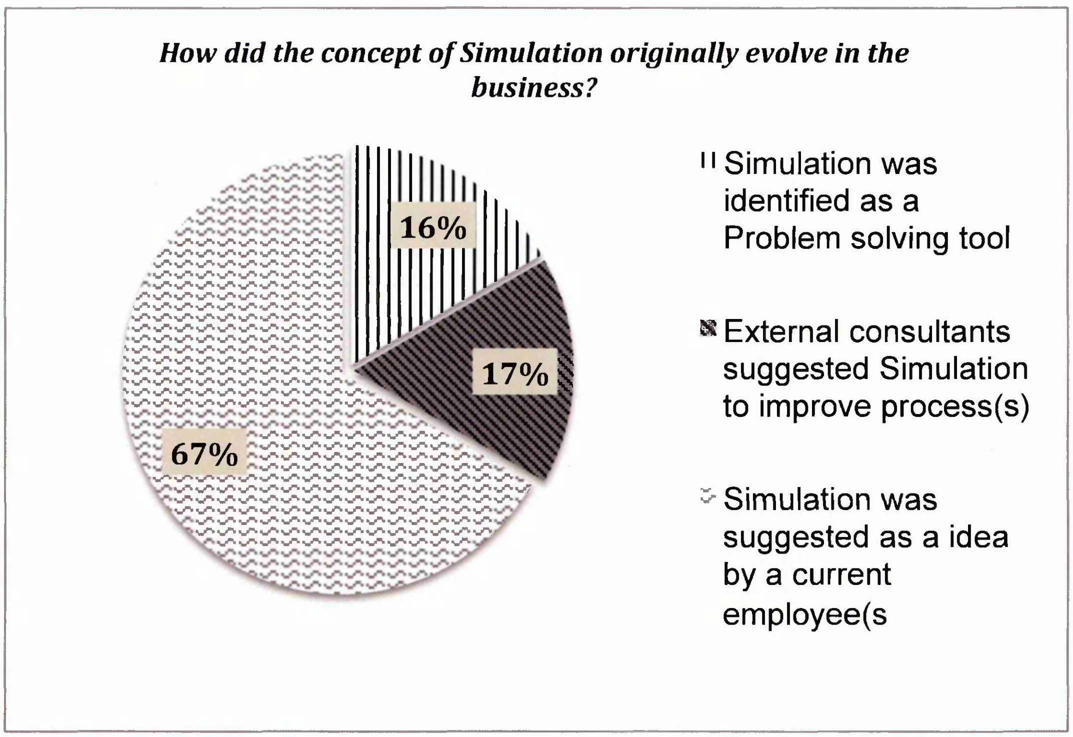

Figure 5.3-1: Evolution of simulation in participating organisations

The most interesting finding however is that over 65% of the companies investigated into simulation as per the suggestion of one of its employees. Perhaps, this shows a high interest in simulation from personnel who are already aware, learned or practised using the tool. One important factor to consider here is that some of these employees must have learned or heard about the tool from their previous work experience and found the tool useful in their new working environments.

Nevertheless, it sure points out to the popularity simulation have to people who have come across it at any point during their work. Around 16% of companies chose simulation purely as a problem-solving tool to start of with.

5.3.2 Collaborating to introduce simulation

The findings illustrated in Figure 5.3-2 suggests that a combined effort between the external and internal team was the main factor to introducing simulation in over 45% of the organisations.

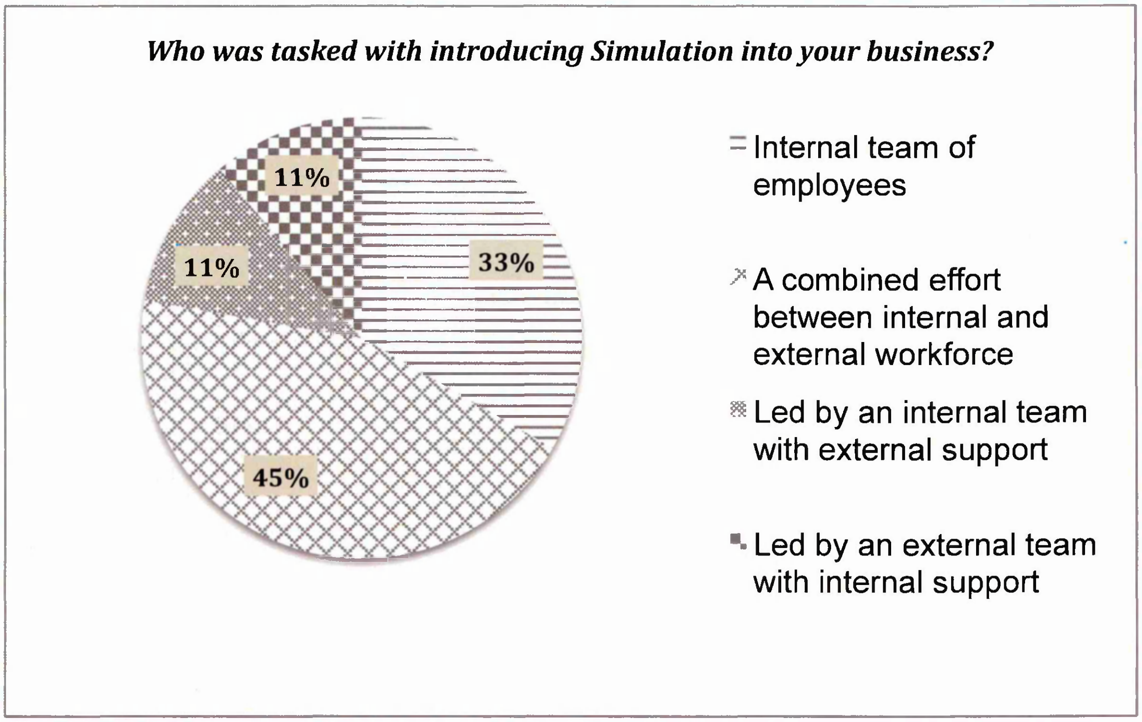

Figure 5.3-2: Internal and external collaboration for introducing simulation

Where as, 33% of companies relied on an internal team of employees to introduce simulation in their businesses. These employees may be experts in simulation already or may have been trained by the organisation in using simulation. Since a large part of the participants of the survey were large organisations, the assumption is that some of these organisations might have had the resource that had some degree of knowledge in simulation already.

Only around 11% of the companies tried to develop simulation in-house with their internal team leading the process.

5.3.3 Engagement of external resources

This question examines the main purpose behind engaging external consultants for the development of simulation projects.

The findings from Figure 5.3-3 illustrates that external resources where used for training and on-going support purposes by around 34% of companies. Around 22% of companies used external resources to build their simulation models with the active support of internal resources.

Around 33% of the organisations have used both of the above approaches during the development of simulation projects. The presence and active involvement of external resources for the development of simulation is clear from these answers.

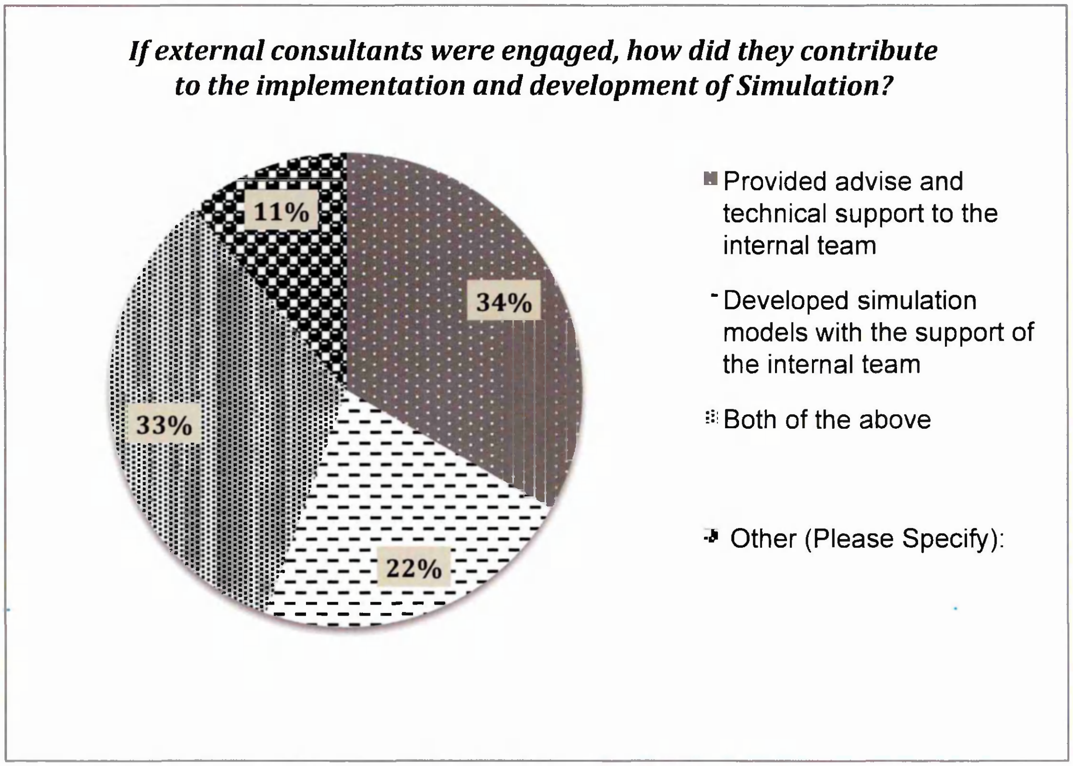

Figure 5.3-3: The engagement of external consultants

5.4 Initialisation and deployment of simulation

This section of the questionnaire is designed to focus the various contributing factors affecting the development and implementation of simulation within organisations. Three questions were designed to evaluate the following;

- Level of Interest in simulation
- Acceptance of simulation
- General awareness in simulation
- Analysing the common challenges in promoting simulation

5.4.1 Level of Interest in simulation

This question intends to evaluate the level of interest received by the simulation implementers from their top management. As Figure 5.4-1 illustrates, that almost 50% of the management were interested in the idea of simulation.

One contributing factor to this level of interest may be the level of awareness generated in the businesses initially. This factor is further analysed in the next question. Interestingly enough, there were none who suggested that any of their managers were totally disinterested.

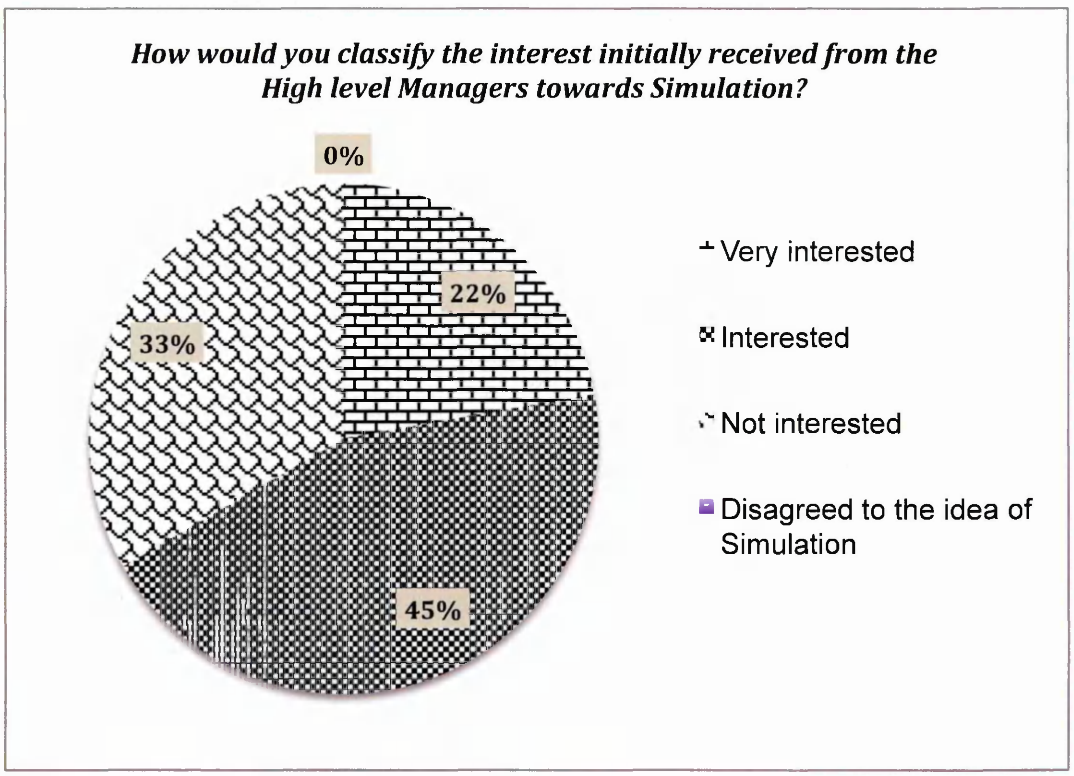

Figure 5.4-1: Level of interest in simulation from higher management

5.4.2 Acceptance of simulation

The participants were asked whether the concept of simulation was well received initially. If not, what were the contributing factors to this. Some of the common possible reasons where provided for the participants to choose from. The participants were also given the opportunity to select Option: 'Other' where they were requested to specify any other possible reason.

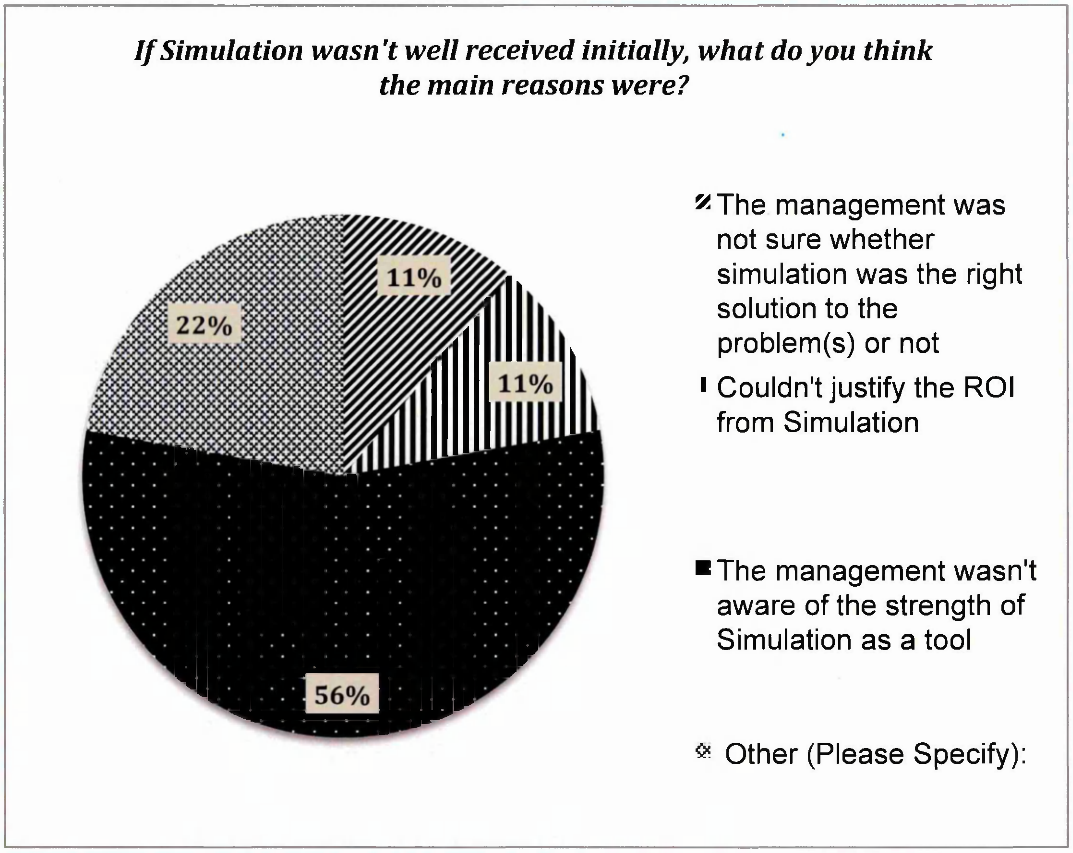

Figure 5.4-2: Reasons behind low appreciation in simulation

Two participants chose Option 'Other'. One participant stated that the key reason why simulation wasn't well received initially in their organisation was that only some of the management were aware of simulation and others didn't and found it as a waste of time. This reason illustrates the importance of having an awareness program, which can cater to all layers of workforce in the organisation.

5.4.3 General awareness in simulation

To understand the contributing factors to the first and second question in this section regarding level of interest in simulation and common challenges in promoting simulation, the next question focuses of the level of awareness among the majority of employees in the company.

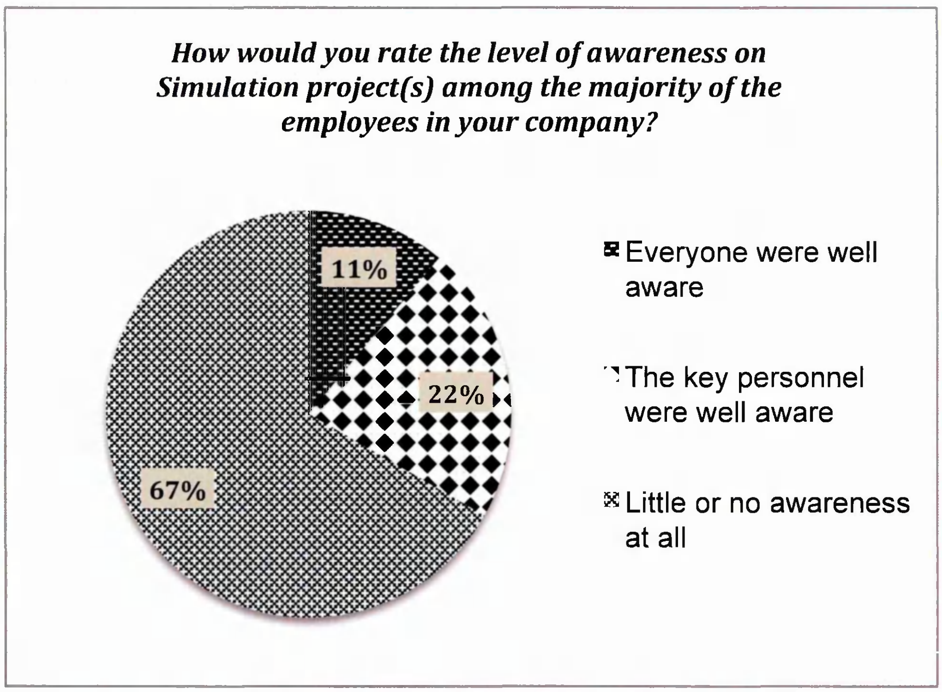

Figure 5.4-3: Level of awareness in simulation

More than 65% of results suggested that the majority of the employees in their organisations had little or no awareness to simulation. Only a mere 11% suggested that there was a complete awareness in simulation technologies across their organisations. A combination of the results from all the three questions in this section has helped to identify the importance of having a well-structured awareness campaign within organisations to ensuring the success of simulation.

5.4.4 Analysing the common challenges in promoting simulation

As illustrated in Figure 5.4-4 a set of common challenges were provided for the participants to rank these challenges based on the level of their severity.

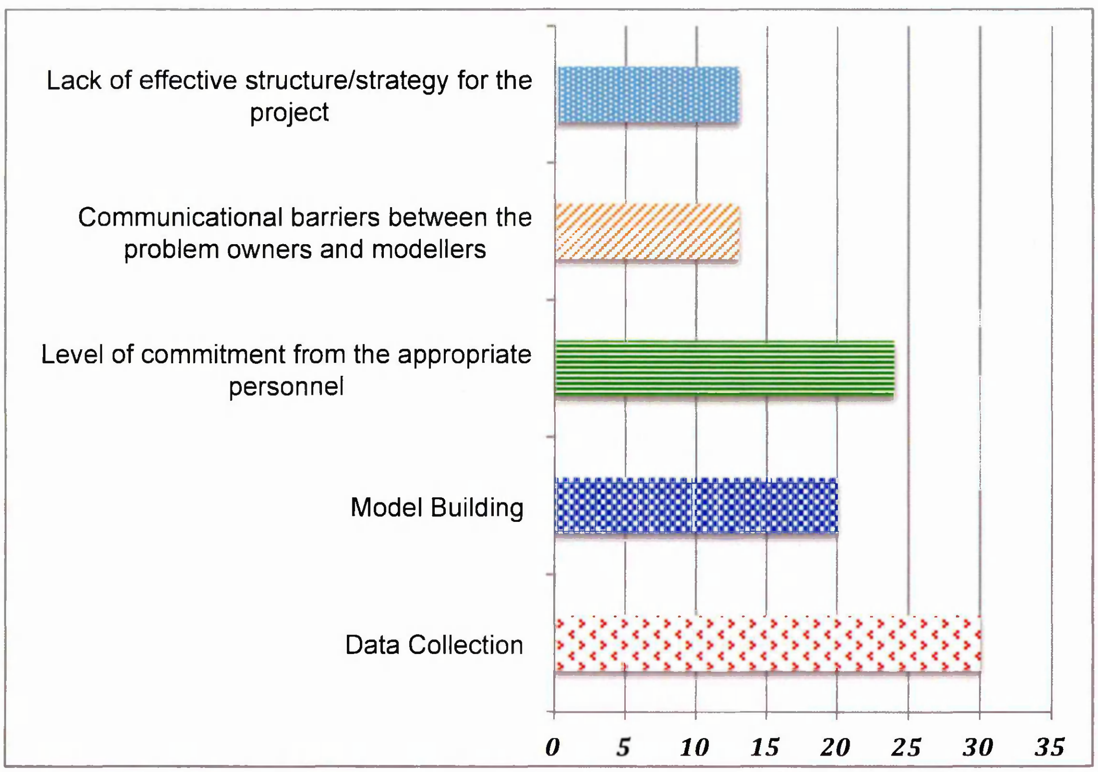

Figure 5.4-4: Ranking of common challenges in promoting simulation

Almost 30% of the organisations chose data collection as the biggest of their challenges. Given the extensive amount of data collection required for simulation modelling and data validation, this choice is no surprise. But, the second biggest challenge seems to be from a human point of view. At almost 25%, the second biggest challenge has been from the lack of commitment from the appropriate personnel.

5.5 Simulation for the future

This section of the questionnaire is intended to evaluate what the current status of simulation and evaluate the rate of success the participating organisations had in simulation projects. A set of four questions was devised to analyse the current role of simulation in terms the number of models developed since the introduction of simulation.

This section also asks questions on how the tool is currently being deployed within the organisation. The four major areas covered in this section are:

- Rate of success of simulation
- Development of simulation project
- Current deployment of simulation
- Scope of more simulation projects

5.5.1 Rate of success of simulation

Figure 5.5-1 illustrates that almost 90% of the organisations found simulation project successful or neutral. 60% of the participating companies chose simulation to be a success story in their businesses.

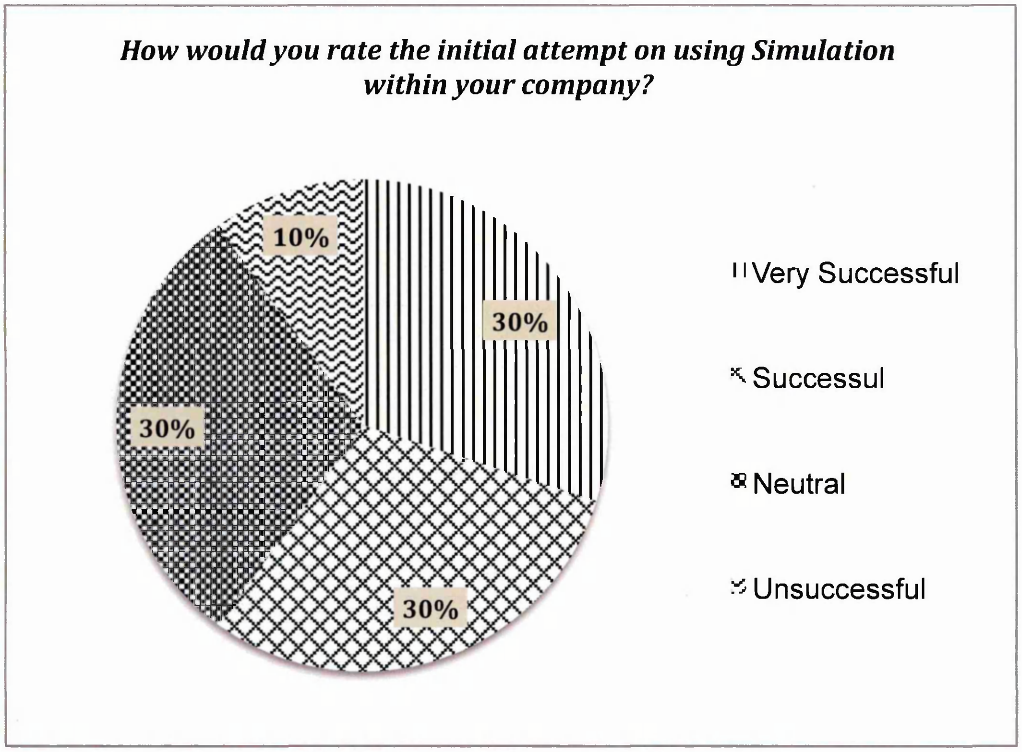

Figure 5.5-1: Ratings on initial attempt in simulation

5.5.2 Development of simulation project

Figure 5.5-2 illustrates the total number of simulation projects developed in the participating organisations since the commencement of the first simulation project.

This gives an indication on the level of development of simulation within these organisations.

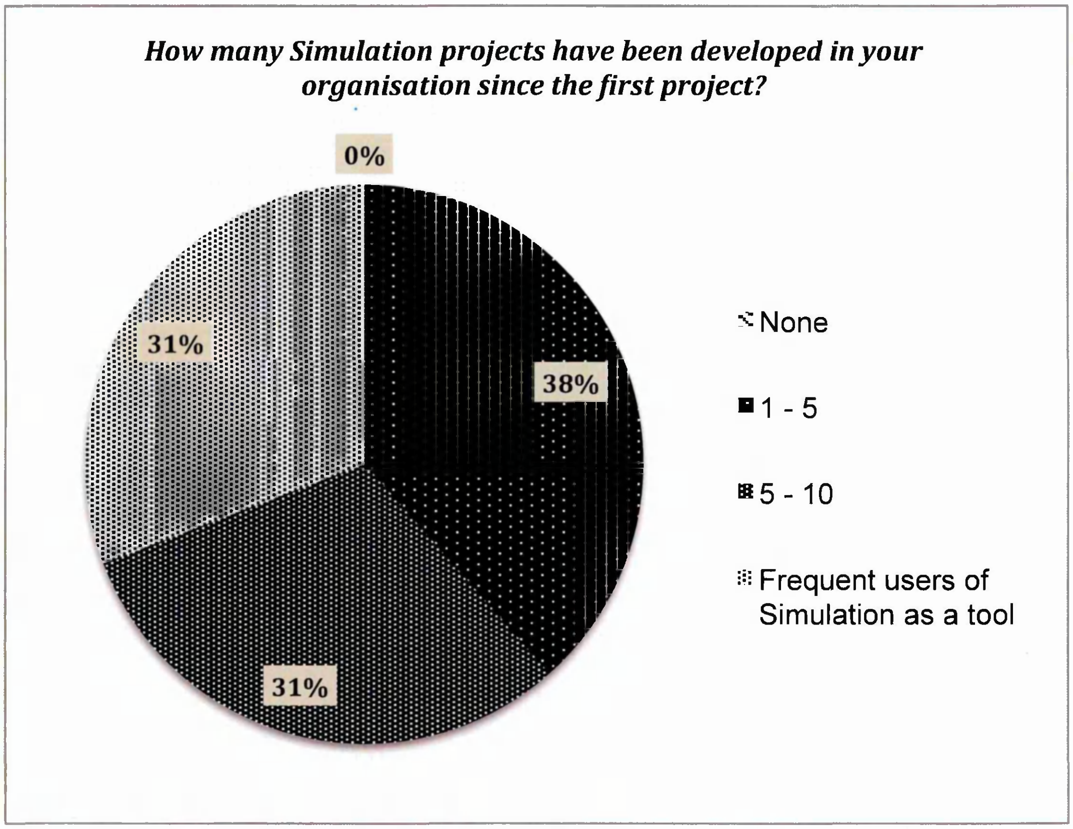

Figure 5.5-2: Development of simulation projects since time first project

Every participating organisation has developed more than one simulation model since the implementation of the first simulation project. This can be seen, as a good sign as if the first project didn't generate good results, then there would be a high chance for not having a second project.

5.5.3 Current deployment of simulation

This question is to understand and analyse the current mechanism followed by organisation in developing simulation models within their businesses. Figure 5.5-3 illustrates the results from this question.

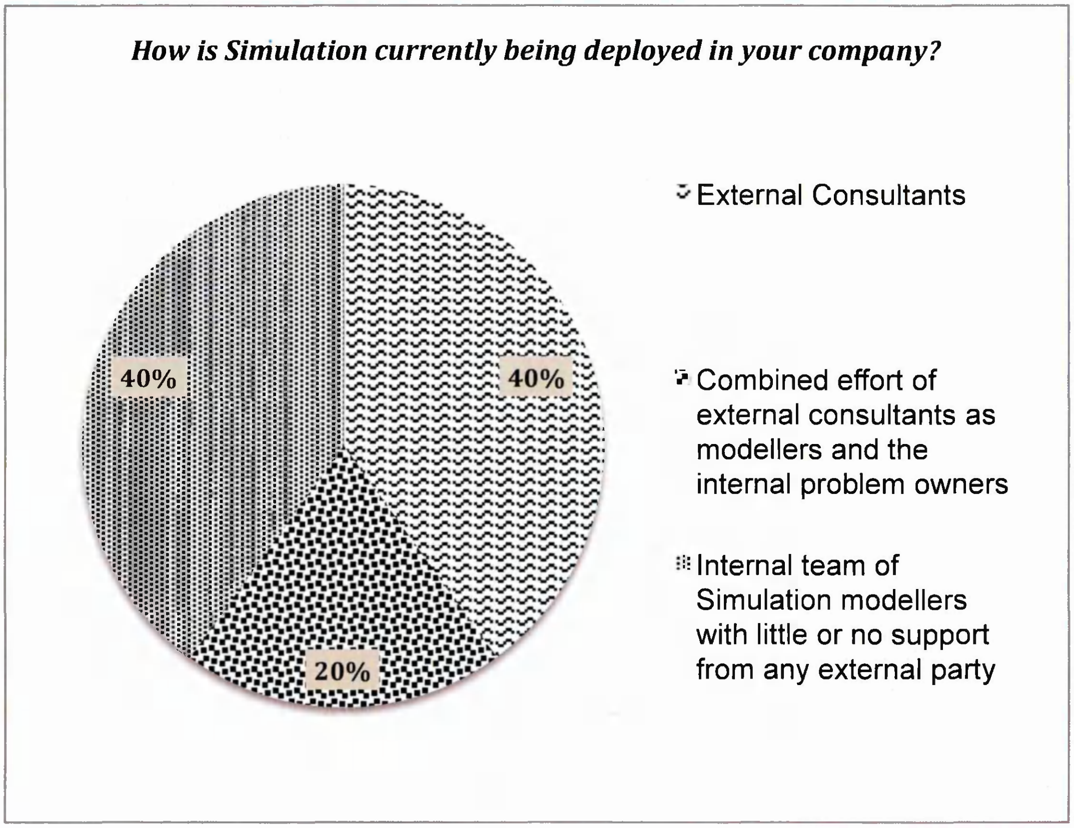

Figure 5.5-3: Current use of resource for deployment of simulation

Almost 40% of the participating organisations use an internal team of simulation modellers to develop their simulation models with little or no help from any external party. This shows that there are organisations, which have successfully developed an internal team and successfully integrated simulation within their business processes.

Around 20% of the companies develop simulation models as a combined effort between external and internal workforce. These organisations could be going through a transitional phase from external support to independent in-house development. Also, 40% of the companies are still relying on external consultants to develop simulation projects.

5.5.4 Scope of more simulation projects

Figure 5.5-4 illustrates that 30% of the organisations found simulation to be a valuable tool and suggests that they will definitely use for the future. 40% of the organisations suggested that they probably would use simulation in the future.

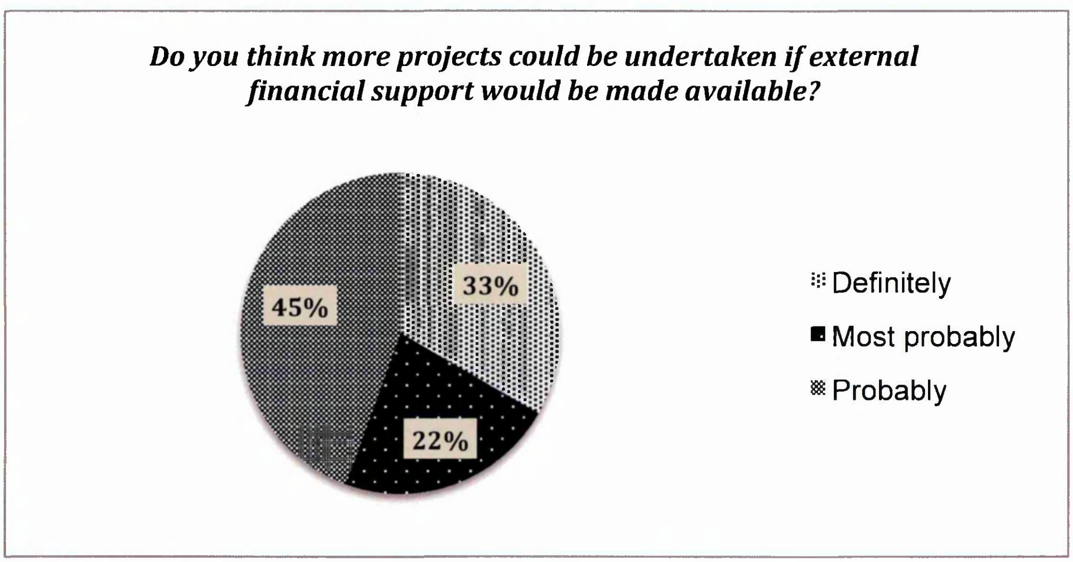

Figure 5.5-4: Scope for more simulation projects

5.6 Summary

The survey has satisfied its objective, which was to review the current practices in simulation and its limited implementation of within industry. The survey was of tremendous help in evaluating the right methods and strategies in implementing simulation technology. The level of insight received from some of the results helped to realise that some areas required more consideration before proposing a framework for embedding simulation.

Many of the answers relate and compliment to each other. The importance of clear and strong awareness sessions were evident from just these results itself. The author believes that the questionnaire and the research conducted through case studies has helped to understand the current status of simulation and how it's being deployed, and valuable information on the various factors influencing the embedding of simulation. The author also suggests that while the results of the survey is of valuable help; the samples may not be representative enough.

Table 5.6-1 summarises the key factors in embedding simulation technologies in an organisation, which were discussed in the Literature survey, Case studies and the findings and outcomes of the questionnaire survey. These key factors, along with the best practices will contribute to the development of the proposed framework for embedding simulation techniques in the following chapter.

Key Topics	Sub-topics	Identified in literature survey	Identified in Case Study	Identified in Questionnaire
Evaluation of Current business process techniques & tools	Understanding current tools & techniques	✓	✓	
	Integration of tools & techniques	✓	✓	✓
	Limitation of current tools	✓	✓	
Introduction to Simulation	Introduction and general awareness	✓	✓	✓
	Uniqueness of simulation study	✓		
	Current uses of simulation	✓	✓	✓
	Evolution of simulation	✓	✓	✓
Initialisation & Development of Simulation Projects	Creating project team		✓	✓
	Setting objectives & deliverables	✓	✓	✓
	Collaboration of internal & external resources	✓	✓	✓
	Promoting use of simulation		✓	✓
Embedding simulation	Acceptance of simulation project	✓	✓	✓
	Change management	✓	✓	✓
	Organisational culture	✓	✓	✓
	Integration of simulation in current framework	✓	✓	✓

Table 5.6-1: Key topics influencing the successful embedding of simulation practices, reviewed in the case studies and literature review

6 Proposed framework

6.1 Introduction

This chapter seeks to develop a framework that will help enable companies to integrate simulation technologies into their business processes. This chapter was devised from the following key areas of this research:

- Literature surveys conducted over the due course of this research.
- Findings from the case studies, which demonstrate exemplars of successful integration of simulation and business process management strategies.
- Questionnaire survey, which helped to identify the fundamental reasons behind implementation of simulation the various possible challenges they faced during the pre and post implementation phases.

The chapter is divided into two integral parts.

- The first part of this chapter discusses about the key concept of the proposed framework, which were drawn from the above steps.
- The second part of this chapter provides an overview of the proposed framework.

Each stage of the framework has been designed by keeping the following factors in mind. The framework and its guidelines should be:

- Easy to follow.
- Generic & flexible for adaptation

6.2 Easy to Follow

Jägstam and Klingstam (2002) suggest that one of the main reasons behind the lack of enough simulation integration is absence of well-defined simulation strategies and working procedures. Hlupic and Currie (2003); Holst (2001) suggest that the availability of a holistic, structured approach will enable more companies to integrate simulation into their core business structure. The proposed framework is divided into four major categories; Introduction, Guided Support, Integration and Embedding. Various factors contributing to the development of each framework is discussed in detail. The framework elaborates specific guidelines set for each of the stages.

6.3 Generic & flexible for adaptation

Jägstam and Klingstam (2002) looks at three aspects of the pre- requisites: technological, operational, and organisational and summarises the main challenges connected to each one of the aspects and emphasises on the requirement of extensive efforts in each of these aspects in order to successfully integrate simulation. The proposed framework will explore integration of simulation from all aspects. In addition to this, in order to provide a holistic view of each category, the framework also defines the key challenges at each stage into three different aspects: technological, operational and organisational. The framework explains the key objectives to be achieved for each stage. After examining the key objective and the key challenges, a strategy is devised which is explained as the guidelines.

6.4 **Stage 1 - Introduction**

This stage aims to provide the right awareness regarding simulation as a tool within the various departments of the organisation. Murphy and Perera (2002) emphasises on the importance of having a successful introduction to simulation, as the first fundamental step to the successful implementation of simulation in an organisation. For ease of understanding, the awareness section is divided into two sections:

- Awareness
- Education

The key components of each section is shown in Figure 6.4-1

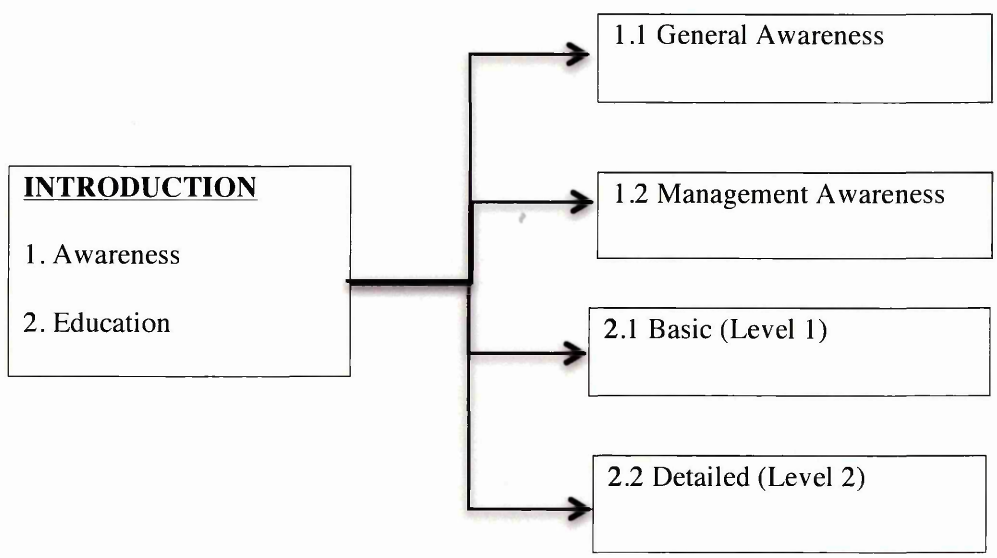

Figure 6.4-1: Classification of Introduction section

6.4.1 Awareness

Murphy and Perera (2002) emphasises on the need for development and use effective mechanisms of promotion to spread the awareness, visibility and benefits of simulation as an important business tool, across the company. Greasley (2004) highlights the diverse perceptions about simulation in the same organisation depending on the background of the employee and his designation in the organisation. Depending on the size of the organisation, introduction of simulation can be conducted in 1 or 2 phases. The primary reason behind this is the desired outputs expected are different depending on the audience.

In phase 1, the target is to make anyone and everyone aware of simulation as a business tool. This session shall hence be called as '*General Awareness*' sessions. The awareness session in Phase 2 has a different purpose. In phase 2, the target audience is the high level management, who can play a major role in the technical, operational and organisational challenges related to implementing each stage of this framework. Since the target audience here is purely the high level management, the phase 2 sessions shall be called as '*Management Awareness*' sessions.

Phase 1 can be a General Awareness session.

- The general awareness session only covers the basic elements of simulation as a tool. What is simulation for? What are its uses? Highlight some success stories of simulation from similar industries as reference.
- Keep the session short and brief
- Use the existing awareness platforms if any (training sessions for any tools or techniques, graduate training sessions, weekly workshops, newsletters etc.)
- Invite the interested participants to the '*Education*' session.

- Allow natural selection of people; encourage anybody interested to come forward. The sessions shouldn't focus on any particular area(s) of departments. The background of attendees shouldn't matter.
- Know your audience; keep the awareness sessions as basic and generic in nature. Consider the diverse background of audience when designing the presentation material.

Phase 2 can concentrate on providing awareness to higher level of management.

- Highlight less about the simulation as a tool and emphasis more on the benefits of simulation.
- Use more relevant examples of simulation and explain each success story in relevance to the time taken and cost savings achieved from the project.

6.4.2 Education

Murphy and Perera (2001) identify the importance of creating a pool of simulation practitioners in-house to retain the simulation experience within the organisation. The process of Education should be conducted in a phase-by-phase manner.

Some of the key guidelines to follow in the first stage are:

Education: Level 1 (Basic)

- By using the material from the awareness session as the foundation, elaborate on simulation in detail. Ensure that there is a smooth transition in learning from the awareness session to the training sessions.
- When building the first models, try using real life examples, so that the audience can relate more too each scenario.
- Keep the session between 45min to 1hour. Allow enough time for the audience at the end to absorb the information.
- Collect opinions about the session. Factors such as ease of understanding should be sought from the attendees by using a simple questionnaire at the end of the session. This will provide some valuable information on how to improve the sessions.

The main intention behind a phase-by-phase structure is to filter out the interest in people. Greasley (2004) suggests that it's important to give a new simulation trainee the time to evaluate his level of interest in simulation. Considerable amount of time will be spent during the education sessions. And since the pupil here are regular employees who are sparing their time to learn something new, the 1st level of the Education session should help them answer many questions:

- How interested am I in this subject?
- How is my understanding on the subject?
- Has my opinion(s) changed from the awareness session? Is this a good tool for me to learn?
- Should I learn further?

The candidates who wish to learn further about simulation can be invited to the Level 2 Education sessions. Some of the key guidelines to follow in the first stage are:

Education: Level 2 (Detailed)

- At this level the process of model building can be explained in detail.
- While educating on model building follow a structure approach of model building. Instil the benefits and advantages following a structured approach in model building early on itself.
- Elaborate various elements of the model building stages from the structured model building sessions in level 1.
- Promote general discussion on what they have learned. Allow one ore two training sessions to purely concentrate on discussions.
- Encourage the participants to suggest areas and examples within organisation where they can use simulation.

6.5 Stage 2- Guided Support

Murphy and Perera (2001) states that for the successful implementation of simulation as a business process tool, a generic support framework has to be in place which will encourage development of more simulation projects and encourage communication across all simulation project platforms. This stage of the framework works in transition with the Education: Level 2. The primary objective of this stage is to ensure that the development of simulation practitioners is supported throughout. It can be argued that this is an on-going process. Following are some of the guidelines aimed at this stage:

- Create an internal team of practitioners from the new pool of practitioners of the Education phase.
- Encourage a structured means of communication between the simulation teams and practitioners. The general discussions sessions initiated during the Education phase can be further expanded to simulation workshops, or self directed learning sessions, etc.
- Introduce a step-by-step strategy to design and manage a simulation project. The strategy should be generic, so that the right adaptations and changes can be made while validating the approach.
- Create a common language in the form of easy to use tools to explain the fundamentals of simulation project and its objectives to any members in the team who may not be familiar with simulation.
- Create a knowledge-sharing program at the discussion sessions/workshops, which will enable the new practitioners have a common data repository from which they could learn.
- Promote pilot projects. Create a team around the pilot project, not a project around a team.

- The model(s) built for the pilot project should only remain on an experimental level. The status of the model and its results should and must remain within its experimental boundary. The model(s) should go thorough verification and validation procedures (ensure model building stages are thoroughly followed) before its results are presented to the higher management or for decision-making.

6.6 Stage 3- Integration

Jägstam and Klingstam (2002) has highlighted that while simulation integration is a never ending process, it is paramount to have well defined simulation strategies and working procedures in place for ensuring successful integration of simulation in business processes. Additionally, Jägstam and Klingstam (2002) also argue that it is important to identify where the simulation tool fits in within the organisation's technological and organisational framework. It could be that by this stage some of the critical capabilities of the tool is not yet fully utilised in the guided support stages. However, some key questions regarding simulation as a business process tool within the organisation may arise at this stage:

- How successful was simulation in the organisation?
- What role can this tool play within the organisation (to what extent)?
- What it its possibilities?
- What are its limitations?
- Is it conflicting with any of our current business process tools within our outside our IT framework?

Following are some of the guidelines aimed at this stage:

- Eliminate scepticism through efficient and accurate delivery of results from simulation.
- Ensure that the success of simulation is well known and documented within the organisation.
- Have an overview and understanding of the various business processes in the organisation. Identify key areas where simulation can be used as a tool even if there is no request from the process owners.
- Evaluate other tools and systems currently existing in the organisation's framework.
- Develop top management support for using simulation as a mandatory tool for any major projects.
- Evaluate possibilities of integrating with existing tools and systems to avoid conflict in future.
- Establish a level of communication with the software vendor to ensure prompt support with software integration and any other potential problems.
- Source help for programming language experts if necessary to link multiple IT tools in business processes to improve the use of simulation.
- Effective use of the data repository and knowledgebase created during the Guided Support stages to build a template for simple model building.

6.7 Stage 4- Embedding

Murphy and Perera (2001) emphasise on promoting success stories of simulation to encourage interests from other departments in the organisation. Johansson, Leong and Klingstam (2007) suggest that having a common, reusable, neutral, standardised simulation template could reduce the overall lead times in building simulation models, there by encouraging more simulation models being built in less time frames. It is important to note that a good data repository with models of real-life examples and a sound knowledge sharing program will accelerate the growth of simulation in the organisation the most (Jones et al., 2000).

The key objective of this final stage of the framework is to successfully incorporate simulation into the core of the organisation. It should be noted here that the meaning of the process of embedding simulation into the core of organisation is from an organisational perspective, rather than an IT perspective. The Integration phase will support the fundamental foundation from an IT and systems point of view for this stage.

- Promote the success of simulation projects in the organisation by cascading the information via means of communication in existence within the organisation. It should be noted that at this time, the information on what the simulation teams have done with the tool will be read by people who may have not heard about simulation at all. It's important for the news material to have a story like overview and limited technical information for ease of understanding.
- Include information about times and venues of simulation training programmes and awareness sessions along with the news on success stories.
- Promote the current simulation practitioners. Name the team members who were part of the said successful simulation project.
- Ensure that the knowledgebase and data repository is shared between departments and not just confined to within an area or department.
- Effective use of data repository to build a template for simple model building.

- The template should contain modules of existing machines and processes used within the organisation. (Cutting and welding machines, process sequences etc.). This will help to reduce the model developing time (lead time) of simulation projects and allow less experienced practitioners to experiment with simulation. It will also encourage re-using existing models.
- Avoid duplication of model building. Create a standard operating procedure.
- Create a knowledge-sharing platform with other branches of the company (if any) to demonstrate the use and success of simulation in the organisation.

6.8 Summary

This chapter developed a framework aimed towards aiding organisations to embed simulation technologies into their business processes. The key stages identified and adopted for this proposed framework were presented and explained. A set of guidelines was identified to follow during each of the stages of the proposed framework. The overview of the proposed framework is shown in Figure 6.9-1.

Following this, deploying the various stages into practice in the collaborating organisation where the research was undertaken will validate the proposed framework. The validation process will help to understand the credibility of the proposed framework. While not all the elements included in the proposed framework may not be applied in the specific collaborating organisation, the author intends to document the process along with real life challenges faced in the due course of validation and implementation of the proposed framework.

6.9 Overview of the proposed framework

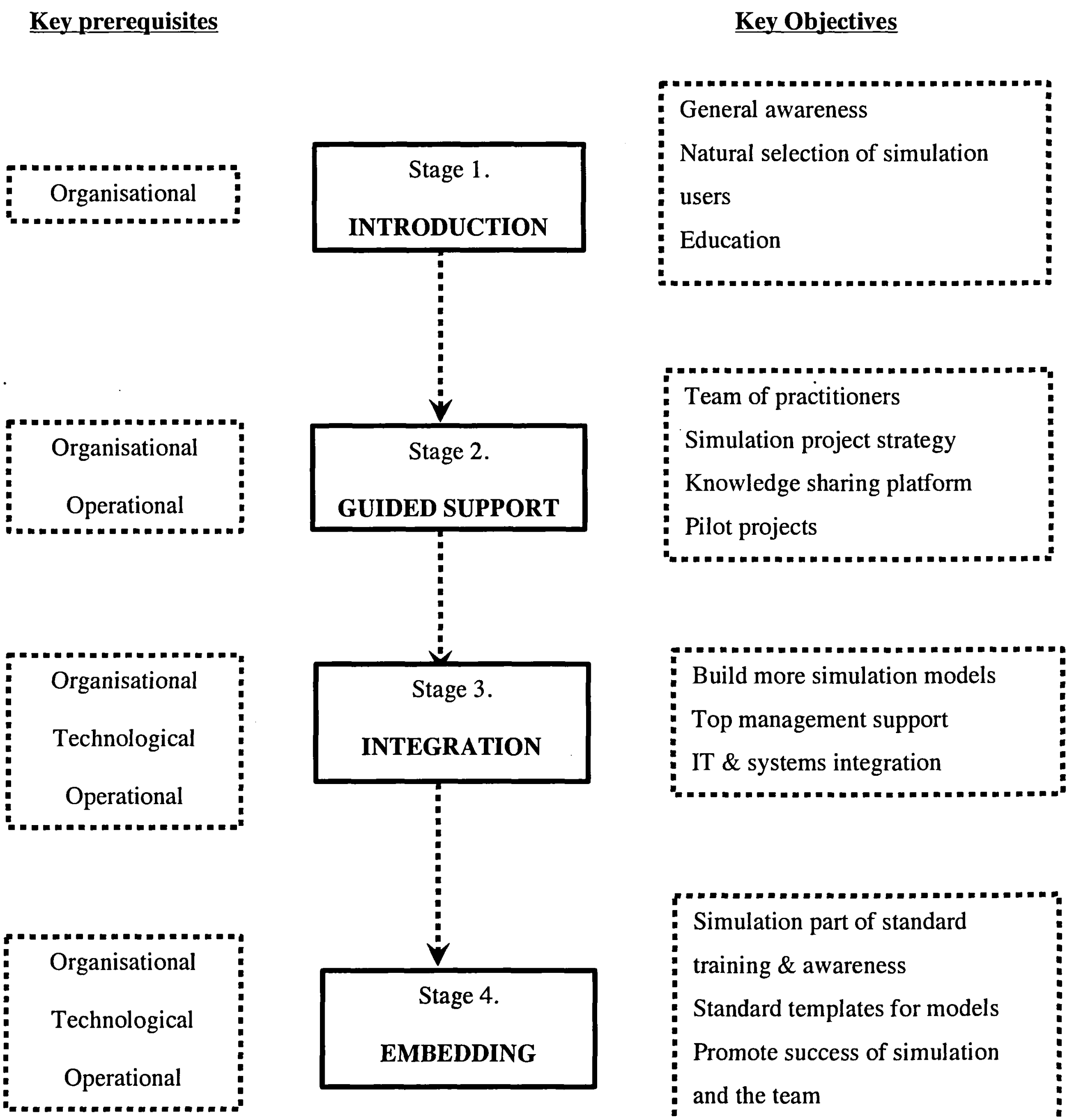

Figure 6.9-1: Overview of the proposed framework

7 Validation of the proposed framework

7.1 Background

For the purpose of validating the proposed framework, embedding simulation in an organisation, Siemens Industrial Turbo machinery (here after referred to as "SIT") was considered as the collaborating organisation. Formerly known as Alstom Power, the company has an unprecedented experience in manufacturing Industrial Gas Turbines all over the world. One of the biggest advantages of Siemens Gas Turbines were the fact that all the individual components, including the I/O units where made in-house, which improved the product's reliability and efficiency.

Manufacturing and assembling all the components in-house means a large logistical and operational exercise of planning and scheduling the production of over 3000 individual components. The manufacturing facility consisted of over 1400 workforce, spanning over 100,000m2 of land area. On an average, 60-70 turbines were required to be built on an annual basis. Given the heavy market demand and added complication of all-in-one manufacturing and assembly, streamlining the operations coupled with acute planning was paramount to reduce any lead times in manufacturing.

7.2 Introduction of business process re-engineering

At the time of the commencement of the research, the organisation had just initiated the practice of Business Process Re-engineering within their business. Talwar (1993) defines a process as *"any sequence of pre-defined activities executed to achieve a pre-specified type or range of outcomes."* Saxena (1995) defines a business process as *"a set of inter related work activities characterised by specific inputs and value added tasks that produce specific outputs"*. The collaborating organisation has identified Lean manufacturing as one of the core philosophies to be established within their supply chain and manufacturing lines. In order to achieve this in an organisation with a large pool of workforce and numerous manufacturing processes, it was paramount to establish a team within the organisation to initiate and facilitate the changes.

A Business Development (BD) team was already operational in the organisation. However, the BD team members were largely concentrating on improving the business activities of the company handling the public relations aspect of the organisation in many ways. Early 2003, the shift in focus occurred within the team to concentrate more on the internal business processes. As a result, a new team was formed to work closely with the Business Development team, known as the Business Improvement (BI) team. The responsibilities of the new team included analysing and collecting information of each phase of the design and manufacturing of the Gas Turbine. The team consisted of 4-5 members, all of them primarily dealing with the task of collection and collation of information. Sets of data were collected over the period of 6 months to analyse existing manufacturing processes and discussions began taking place at high level of management on how the current manufacturing practices can be improved.

The organisation's primary motto was to reduce the lead times on the product manufacturing cycle and also reduce the production costs. Out of these, reducing the lead times of the product manufacturing cycle was considered the most important

7.3 Evaluation of existing tools & techniques

The organisation chose to implement lean manufacturing principles and decided to introduce new business process tools in its manufacturing processes. Some team members received special training in using static process modelling tools. One of the most commonly used business management and analysis tools were Six Sigma and Lean. Both of these business process management techniques were supported using VSM flow charts and Static modelling tools like Microsoft Excel.

7.3.1 Limitation of static modelling tools

Each manufacturing and assembly line of SIT was working independently and physically located in various shop floors. Once the order was placed for a new product, the estimated lead-time for the engine largely varied depending on the specification required and availability of inventory and parts that fed into the main line from other manufacturing lines. Since the individual components were really expensive to make to stock, they were all manufactured upon order. This stretched the lead-time even further. Static modelling tools produced models, which were deterministic and did not enable evaluation of alternative re-designed processes.

Static modelling tools were largely used as part of lean standard production planning systems. As a result, the team decided to adopt the same mechanisms in house. However, they soon realised that the task was much more complicated than they actually estimated it to be. There was also a lack of confidence in applying new changes and philosophies into an organisation, which was over four decades in place, and a highly experienced work force. Hence, the team decided to largely experiment the new philosophies and methodologies on new process lines.

7.3.2 Introduction of simulation as part of business process re-engineering

Primary data regarding the manufacturing processes were accumulated and illustrated using flow charts and pool diagrams. The attention of the team then turned to the fundamental aspect of the task, which was to improve the existing business processes. Traditional process modelling tools and manufacturing philosophies were still considered at this stage. In some areas Lean Manufacturing and Just-In-Time philosophies were researched and even introduced. T-Card systems (Kanbans) to facilitate Lean Manufacturing were introduced.

"We were in the phase of trying various manufacturing philosophies to identify whether there is a best-fit solution for our manufacturing processes", (BI Manager.2004). Members in the BI team were sent for specific training courses catered to understand the ergonomics and benefits of Lean Manufacturing techniques.

In order to measure and plan the process flow on one of their new machines the BI team along with the manufacturing engineers decided to use static modelling. However, the machine included large amount of scheduling and real time changes in the process flows according to various scenario changes over a set period of time.

"We found this extremely challenging as we were only using Excel and charts to plan our model. Multiple scenarios had to be handled by the model in a real time environment. Even the positioning of the machine in the shop floor largely depended on these factors" (Site Manufacturing Engineer, 2004).

The attention switched to a much more powerful modelling system. External expertise in the field of Dynamic Simulation was sourced, to help the BI team developing a comprehensive model to simulate the environment of the process(s) involving the new machine. Since the process was new with fewer inputs, and didn't have any live-time information, the data collection was achieved with relative ease and the expertise and experience of the consultants helped the work to be complete on time. The BI team were very satisfied with the results from the model.

"We initially did it largely as an experiment, but once we began to use the model for planning our output schedules and patterns, we began to see the real benefit of the system" (Business Development Manager, 2004).

This led to a fundamental shift in process modelling within the organisation. An initiative was put forward to promote simulation techniques and use them more within the various business processes in the company. The requirement for creating and managing simulation models in-house became apparent to the management. The researcher was appointed within the BI team of the organisation, which primarily consisted of Six Sigma and Lean practitioners.

7.4 Stage 1- Introduction

As part of the first phase of the Introduction stage, Awareness sessions into simulation were introduced in the organisation. Since there were Lean awareness campaigns running within the organisation, the idea was to use the same platform and audience to initialise the simulation awareness program. Also, the participants in the lean awareness campaign were familiar with various business process tools available.

7.4.1 Awareness

The lean awareness session were mandatory, to be attended by at least one individual from each department. Hence, using the same platform helped to spread presence of simulation awareness in the organisation. The lean awareness sessions were conducted twice a month. The Participants at the Lean awareness session were shown a 2-minute introduction of a working simulation model. The presentation largely concentrated on the model in running form (with sufficient amount of graphics to detail the process). The idea was to keep it simple and straightforward and see the level of interest from the audience.

Overall, positive feedback was received regarding simulation from the awareness sessions, especially from the six-sigma and lean practitioners. A couple of simulation models demonstrating actual processes occurring inside the organisation were constructed for the second and third awareness sessions. The models build here were very simple and the only intention was to demonstrate the *"as-is"* status of a current process. A couple of common scenarios were modelled in the software along with graphics to show the motion of the parts and raw materials within an *"as-is"* process along with the model time frames. A total of two simulation awareness sessions were run at the end of two lean awareness sessions. The first awareness session lasted around 7 minutes and the second and third awareness session lasted around 15 minutes.

Since the BI team was responsible and acting as the agents to change management for the whole organisation, their ideas and opinions played an important factor in the decision making of the higher management. The higher management had delegated all the authority to the BI team to introduce and change any new technologies or systems to improve their business processes. Hence, the second phase of the Introduction stage, Management awareness, did not require to be implemented in the organisation.

"These Lean sessions largely have a lot of engineers and plant line supervisors attending them quite often. So, we thought this would serve the right launch pad for gathering some interest using simulation techniques." (Lean Implementation Supervisor, 2003).

A total of 3 awareness sessions on simulation was conducted over the period of 2 months. Opportunities were given to the participants to attend a full 1-hour education session on simulation. The education session was scheduled on the following week and the attendee list was kept open.

7.4.2 Education

These sessions were conducted in two phases: Basic (Level 1) and Detailed (level 2). Since a brief introduction on Simulation was given to everyone during the awareness session, the first level of the education session involved explaining the benefits of simulation modelling. The concepts of dynamic simulation and static simulation modelling were focused on as some of the trainees had basic to intermediate level of experience in using static modelling tools.

The presentation materials for the education session also concentrated on the various possible implications of discrete event simulation in the current business processes. More detailed simulation models of a couple of in-house manufacturing lines were created and ran during the session. This time, the demonstration went even further highlighting the benefits of inputs and outputs in the model. Since most of the engineers were largely relying on complicated excel files to input, monitor and report their lead times and bottlenecks, the purpose was to show just how variable information can be generated with just the existing information they currently have.

Around 25 employees, both from engineering and shop floor background participated in the first education session. At the end of each session, a questionnaire was distributed to each attendee to evaluate the level of success the researcher had from the session. The purpose was to understand how many of the attendees were willing to dedicate more time and effort to learn. A sample of the questionnaire is attached in Appendix C.

Around 60% of the employees showed definite interest in pursuing learning about the technology and its applicability within their daily jobs. Around 15% of the employees expressed their interest in the technology and willingness to learn about simulation, but only in future. Around 25% of the employees expressed interest in the technology and its potential uses, but declined to the idea of learning more about the technology. Most of them sited the reasons as lack of available time at work.

Given the fact that around 25 employees attended the session and around 75% expressed their interest to learn more about the technology definitely helped the session to be successful. Since there were already more than 12 attendees interested in pursuing their interest in simulation, the researcher decided not to proceed with another beginner's session. However, any employees interested in the beginner's sessions were always welcome for a one-to-one session with the researcher where the same presentation materials were used to explain about simulation and its benefits.

Splitting the education sessions into two phases as per proposed framework helped the trainees evaluate their real interest in simulation and decide on their commitment to learn more about simulation. It also reduced the number of participants from a total of 25 to around 12 participants who showed complete interest to pursue learning further about simulation.

In Level 2 of education, the primary focus of attention was on how a simulation model is constructed. A training module was designed to educate the Level 2 participants on the fundamentals of model building, which is detailed below:

7.4.2.1 Model Building stages

The model building stages of the training session were split into three major components, namely:

1. Static Modelling
2. Dynamic Modelling
    a. Fundamentals of model building
    b. Introduction to Arena Simulation (Chosen software platform for dynamic simulation)
    c. Modules & Templates
    d. Flowchart Model Development
    e. Animation & Graphical representation.
3. Scenario Modelling

1. **Static Modelling**: The purpose of introducing static simulation into the training modules was to familiarise modelling operations and processes for beginners. There were participants who had no experience even in static modelling who were participating in the training. Hence, it was vital to start the education from the base.

A very common and well-known process by everyone in the company was chosen as the first example. A static model was created using Microsoft Excel and its in built support of pivot table and a simulation model was also created explaining the same process. The participants started of with the step-by-step guide on creating the static model. Once the model was created, its results and usage was assessed. Subsequently, the dynamic model was run and its results and usage were presented. Once the trainees understood the difference between static and dynamic simulation, the next step was to take them through the Introduction of Dynamic simulation.

The primary reason behind this training philosophy was to literate the trainees on the difference between static and dynamic modelling. Since everyone was in a working environment, where they are getting paid for the hours they spent in the organisation and their time is valuable, presenting the results from running a static model and a dynamic model helps them distinguish between them instantly. So, the question was, were they happy with the performance and results they are getting from the static model? If so, they could continue with what they learned about static modelling. If not, they could come back and learn more about dynamic simulation.

2. **Dynamic Modelling**

(a). Fundamentals of Model building: The primary purpose of adding this module into the training course was to give the trainees some theories and commonly practised methods on model building. Since all the participants where employees of the organisation with their own individual responsibilities it would be difficult for them to spare their time to gather any literature material on simulation modelling.

Hence the idea was to give them some literature, along with a brief overview of the various and generally preferred stages on model building. The research and analysis of various simulation project case studies using Modelling & Simulation (M&S) Life Cycle (Balci, 1998), paved the way to create a simple and structured approach to build the model. This approach provides clear guidelines to follow and it also enables others to understand the problems more easily. Figure 7.4-1 illustrates the approach devised.

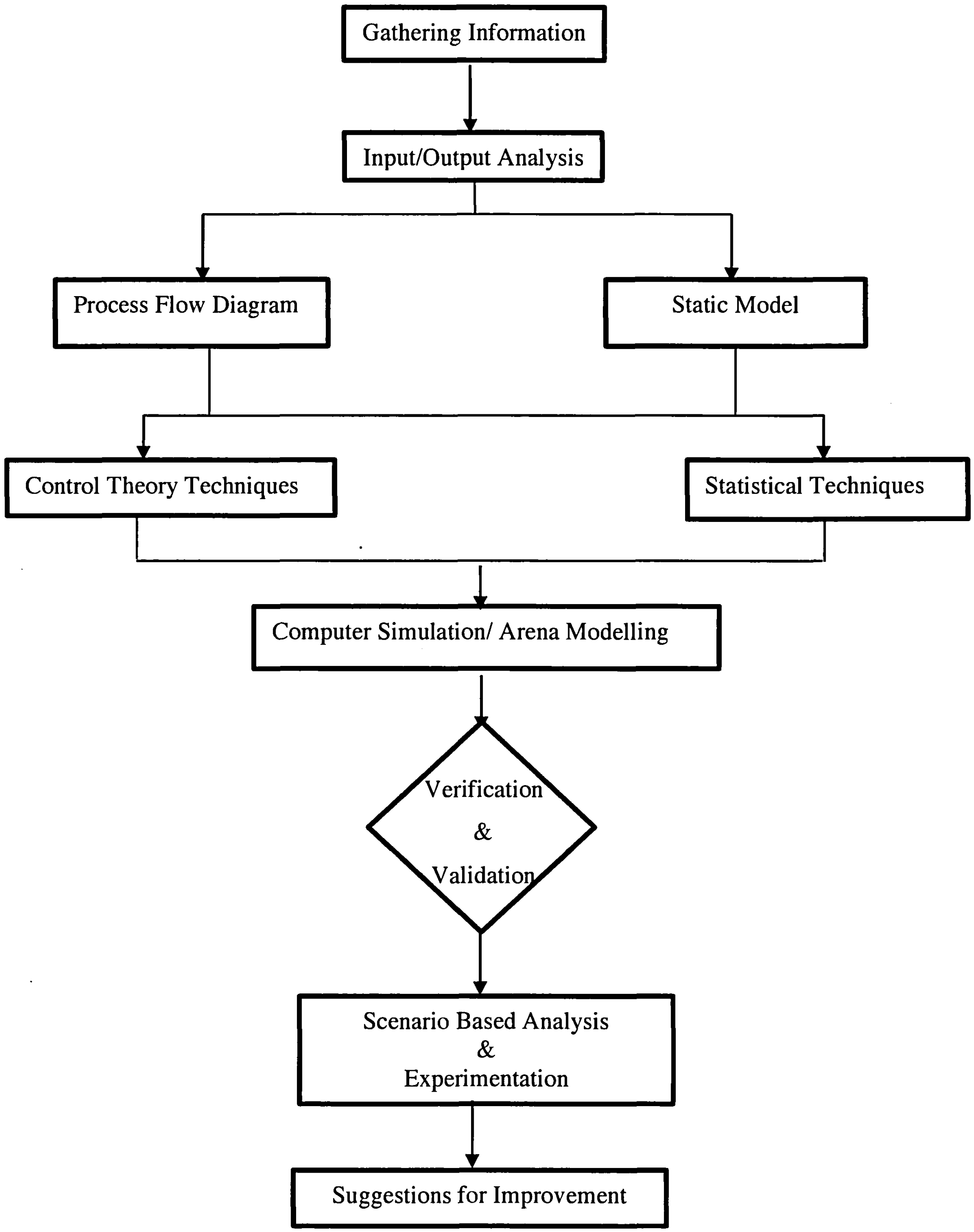

Figure 7.4-1: Fundamentals of model building

A brief discussion of each step in the flow diagram, along with some of the topics covered on each of the steps during the training session are outlined below;

- *Gathering Information* – The first major step in this framework is to gather as much as information as possible to understand the task concisely. Simulation designers call this stage simply as *"Data Collection"*. This is not only limited to the assignment of resources to each phases, but also other factors like the scheduled time for each process etc. Also, there were other issues such as the predefined constraints, which have to be taken into account when building the model. If these factors are not taken into consideration and modelled at first stage, the model should then be least open enough to implement them at the later stages.

- *Input-Output Analysis* – The Input Output Analysis provides a guideline for the data provided. It helps to focus on important data, which is required for the creation and analysis of the model, which must be monitored.

- *Static Model* – An introduction to Static Modelling was already given at the earlier stages of the training. The Static Model is more or less a paper model, which will look in more detail into the Information gathered during the first phase. During this stage, the resource availability and the time schedule is given less importance.

- *Process Flow Diagram* - The Process Flow Diagram covers the workflow in the system. It translates the findings of the static model into a Flow Diagram. Special attention was given to explain the affinity of the process.

- *Control Theory Techniques* – Before starting building the model, the theory behind the building process has to be evaluated. This approach uncovers possible mistakes made at the earlier stages and helps to resolve them.

- *Computer Simulation/Arena Model* – The information provided by the earlier phases helped to develop a sound model, covering all the important aspects. The model should be the translation of the static model and the Process Flow/Block Diagram formation into the Arena Syntax. This model also takes into account the needs of the inputs as well as the requested outputs.

- *Statistical Techniques* – In order to get the full advantage of the outputs, various statistical methods and techniques have to be considered to aid the evaluation of the Output. It has to be ensured that the right measurements are taken so that it could lead to the right conclusions.

- *Verify and Validate Model* – After the initial model is ready, it has to be then validated. This means that it has to be tested for error free running. Special care has to be given to ensure that the process flow is flawless. Furthermore, the model has to be evaluated and comparisons have to be made with the real world. This ensures that there is a reality, which covers al the aspects of the actual production line. In order for the model to generate the correct outputs, it is vital to get the verification and validation spot on.

- *Scenario Based Analysis on the Dynamic Model* - A set of Scenarios, selected on basis of the likelihood of occurrences and risk level has to be identified and run using the model. This will not only help the users to look into each scenario in detail, but will also help them to get a good understanding of the dynamics of the model.

- *Suggestions of Improvement* – From the Analysis of the Dynamic model using the various Scenarios created, suggestions can be drawn to help improve the process. These improvements can further be analysed with the aid of the Dynamic model.

(b). **Introduction to Arena Simulation**: For the purpose of Dynamic simulation, Arena from Rockwell Automation was chosen as the software platform. The Arena modelling system from Rockwell Systems Modelling Corporation is a flexible and powerful tool that allows analysts to create animated simulation models that accurately represent virtually any system.

(c). **Modules & Templates**: This stage of the training primarily concentrated on the core collection of features on Arena. There are over 60 different collections of modules under various templates. The first session on the modules and templates concentrated on the 'Common' panel, the 'Support' panel and the 'Transfer' panel, which are the three primary modules in the software platform. These templates control three fundamental elements in Arena: arrivals; process or service; departure or transfer. Each phase of the training session was incorporated with creating basic simulation models based on what was learned on the day. The large array of help files in Arena (smart files) was extremely useful during these stages.

(d). **Flowchart Model Development**: Gladwin and Tumay (1994) discovered that over

80% of BPR projects used static flowcharting tools for business process modelling. Flow charts are one of the most common and extremely useful methodologies to represent process and work flows. During these sessions, the trainees were given an introduction to system flow charts to familiarise with the algorithms of process flow. Sterneckert (2003) suggested that flowcharts can be modelled from the perspective of different user groups (such as managers, system analysts and clerks) and that there are four general types:

- *Document flowcharts*, showing controls over a document-flow through a system
- *Data flowcharts*, showing controls over a data flows in a system
- *System flowcharts* showing controls at a physical or resource level
- *Program flowchart*, showing the controls in a program within a system

(e). **Animation & Graphical Representation**: In an environment which is not familiar with modelling and system dynamics, it was important to find and learn the right tool which can help the designer present the process and its results in a graphical format. In large organisations, developers get very little time to convince the senior management on their theories and findings. Hence a great emphasis had to be put on presenting the work one has done. In Arena, animations can be run either concurrently with the executing simulation model or in post-process mode. Animations can be created in several ways. They can be created entirely using Arena's graphics and drawing tools or from AutoCAD or other .DXF file using modules from the Arena template or other AST's outside of the wizard itself.

3. **Scenario Modelling***:* A simulation model is pointless if it's not used to its full potential. Abken (2000) states that key feature of this scenario modelling are the separation

of revaluation and simulation. One of the main pros of virtual simulation modelling is that it can imitate what is happening in real life, by also giving you the control of various parameters, a culmination of which, leads to defining the whole process. For example, once a valid model has been developed accurately representing the user's system, it is often useful to find out what the effects are on that system various factors, including entity flows, resource allocations.

7.5 Stage 2- Guided Support

As a result of the awareness sessions and extensive education sessions, small pilot projects started evolving in various parts of the organisation. The primary area where the most interest was generated was in the manufacturing lines.

In order to improve on the foundation built on and to further develop simulation as a tool within the organisation, it was vital to set a structure and system in place for on-going support and development for the simulation team. Having a few pilot projects in various parts of the organisation at one point meant that there was a risk in experimental models used for decision-making purpose. As discussed in the proposed framework, it had to be ensured that the models have gone through thorough validation and verification exercises before the results where presented to the decision makers.

7.5.1 Ensuring the credibility in simulation models

Ryan (2006) emphasises on the difficulties of establishing model credibility due to the lack of good development practices and documentation. Ensuring the credibility of these models meant ensuring the reliability and development of simulation as a tool within the organisation.

Since the major area recognised for using simulation was in the field of manufacturing, the focus was on setting up a team of engineers who can act as the "*Simulation Champions*". These individuals have to oversee each simulation project and part of the standard operating procedure was to ensure that these simulation champions tested the credibility of the models before they were presented. Two engineers who had prior knowledge in simulation techniques and who were also active members in the training session were chosen for this purpose.

7.5.2 Formation of a simulation project

The business improvement and development team were there to support all the business departments and evaluate their business processes. First of all, the major focus or attention into many of these business process analysis tools and philosophies occurred when there was a 'problem'. An individual or a team raises the problem to the management. The management conducts an initial review of the situation and decides to take remedial actions. If they feel like the particular problem will persist or reoccur, then would in turn contact the support teams (BI) to look into the situation.

Henceforth, the Business Improvement team had the right opportunity to decide whether simulation should be used as a tool to evaluate/solve the particular problem. This support framework ensured there was a team of individuals, who were aware of and trained in simulation making the call on whether simulation was the best tool to solve the problem at hand.

If simulation was chosen as the tool, then step-by-step strategy was devised needed to in forming the simulation project:

1. Define the objectives of the project
2. Decide on Modelling Boundaries
3. Define the stakeholder (Process Owner)
4. Create the team along with the individual and group strands
5. Model building: Follow the stages of model building (Fundamentals of model building in section 7.4.2.1)
6. Presentation of findings and results

1. **Define the objectives of the project**: Every simulation project originates from a requirement, which in basic definition is the 'problem' that needs to be solved. Most often, simulation is considered as the last option or in a very late stage of the overall project to analyse a process and evaluate the outcome and various possibilities.

2. **Deciding on Modelling Boundaries**: It has to be decided which processes (or parts of a large process) should be incorporated in the model. This is to be determined on the basis of the importance of certain processes or a need to redesign inefficient processes, and on the basis of the suitability of particular processes to be captured in a simulation model.

3. **Define a stakeholder**: Any request for external help is generally sought through the upper management in most organisations. Once the request for help is accepted, when the support

teams sit together to understand the problem, it is vital that the process owner understands the exact objective of the problem, let alone the problem itself. In most cases, since there is a time pressure and potential loss of money involved, the senior management within the team where the problems arouse, directly assumes the role of project owner or stakeholder. Now, there is nothing wrong with this, providing that the top management is well aware of the issue and has the right time, skills and information in supporting the various stages of the project.

4. **Create the team along with the individual and group strands:** Depending on the nature of the project and the requirement of personnel from various groups, a team was formed. The simulation project team had minimum one individual from the manufacturing background (technical) and at least one individual from the business improvement team. Depending on the requirements and complexity of the project there might be more engineers joining the simulation team or more support from the BI team. However, a minimum number of one people from each support group were suggested as the most ideal option.

The objectives of the project will be discussed between the process owner(s) and the simulation modellers (manufacturing engineers) in the presence of the one or more simulation modeller from the Business Improvement team.

"Having our engineering team to be a major part of framework was a great move. We had to ensure that these guys could answer the queries and doubts from various engineers and

there was no better choice as they speak a different language altogether from the Business development teams" (Chief Assembly Line Manager.2004).

5. **Building of the Simulation model:** Once the team is put together and the project objectives are clear, its time to build the simulation model. Detailed step-by-step information is provided in Section 7.4.2.1. At each stage of the model building process the developers have to undergo on-going data validation and data verification to ensure that the information is up to date.

6. **Presentation of the findings and model results**: Law and Arthur (1999) states that an animation, which shows the short-term dynamic behaviour of a system, is useful for communicating the essence of a model to decision-makers and other people who do not understand or care about the technical details of the model. Hence, it is a great way to enhance the credibility of a model. Animations are also useful for verification of the simulation computer program, for suggesting improved operational procedures, and for training.

The following section (Example: failure in good presentation of simulation results) details an example of a situation in the collaborating organisation, where one ore many factors in the Guided Support stages failed and led to the cancellation of a simulation project.

Example of failure in good presentation of simulation results: During the designing stages of a simulation model within the organisation, there was a change in the stakeholder (process owner) as he got transferred to another department. The new stakeholder came in with the complete intention of delivery solutions to problems as soon as possible. Since the previous stakeholder wasn't very well aware of the advantages of using simulation, he didn't give a good reference on the project to the new stakeholder. The primary reason to this was that the stakeholder wasn't too involved in the technicalities of the project and was largely results oriented. The new stakeholder advised the simulation project team to give him a presentation on what the project is all about. Although the technical team who conducted the presentation had a good degree of knowledge in simulation, they failed to highlight its benefits in a easier manner to the new stakeholder.

The new person, in turn identified the simulation project as a time consuming and needless exercise, and halted the project in between.

A ten-step guideline was prepared for presenters to refer to when preparing and conducting a presentation for simulation project. Although some of the steps in the guideline are fairly generic, from the researcher's experience in the collaborating organisation, often the simulation presenter lacked general experience in conducting presentations and the primary purpose was to help the presenter refer to some common practices followed when presenting a simulation project.

7.5.3 Guidelines for presenting simulation model results

The ten-step approach is outlined below:

1. Understanding your audience.

2. Preparation of the presentation content:

- Adequate input of graphics and animations to convey the results and message
- Run a trial on the results using the output analyser tools if necessary if the presentation requires the same.
- Allocation of speaker (chief speakers and others if any)
- Validation of graphics and animation analyse whether the information is you are intending to convey is presented adequately by the animation.

3. Identifying the meeting venue and facilities (availability of time, resources like projector screen, network connections etc.)
4. Identify the target audience for the meeting. ie; who will be likely to be present for the meeting? Are there members of the audience who are new to the project? How can the project objectives be easily conveyed to them? How should you explain the simulation project in a nutshell?
5. At the meeting, recap or walkthrough (depending on your audience) on the project objectives
6. A brief statement on the various stages the developers went through to design the model (flow chart, building static model, data collection & validation etc.)
7. Conduct a brief walkthrough on the Conceptual model.
8. Allow the audience enough time to be involved in your presentation. Depending on the target audience and their experience in simulation technologies, they might take some time to absorb the content of your material.
9. Every model has a specific set of factors, which one can showcase on. Ensure that you emphasis on the real flexibility and advantage(s) you got from using the model for the

selected project. Modelling and evaluation of these factor(s) in a dynamic environment could be the reason why you got the desired output or solution to your problem (for example; depending on the project, it could be resource scheduling, machine WIP, Lead time, calculating machine utilisation).

10. Leave enough time to allow the target audience for asking questions and raising their opinions.

7.5.4 Managing a simulation project

The right structure within the simulation project team ensured that all the communication and correspondence are done in a systematic manner. General project management tools and techniques were used to manage the time frame and individual task management of each of the individuals in the team along with the model developers alike. The technical member/team representing the project department was indulging in the static model design phase and creating the flow diagram to ensure that any early confusion and possible mistakes are covered.

For the purpose of understanding the process and problem completely, along with its fine details and various intricacies involved, the researcher requested to have an individual from a technical background to be the stakeholder of the process. The chief manager was the overall stakeholder or the process owner of the parent project and technical personnel as the process owner of the child project (simulation). Now, depending on the project and the type of project, the technical background of the person varied.

From the researcher's experience in working in simulation project groups with members from various areas of the business, there was always a lack of a common language for communication in the beginning. Flow diagrams were initially used as the best mode of language between the project members to convey their knowledge and information across. Even though a flow diagram is part of building a simulation model, there is no reason why this tool cannot be used at the very early stages of the project to break the ice and to ensure that everybody is on the same page. The initial flow chart was just an outline and was further refined in the later stages.

The Input Output Analysis provided a guideline for the data provided. It helped to focus on important data, which is required for the creation and analysis of the model, which must be monitored. Depending on the size of the project, the complexity and the required output, the project timescale varied. But, all during the while, it is vital to keep the structure of the team intact.

This stage; Guided support, enabled the successful development of simulation projects across many business areas within the organisation. Ensuring the successful development of simulation projects and ensuring the credibility of the simulation projects helped the promotion of simulation within the organisation. Around seven simulation models were built primarily in the manufacturing lines; three of them were large-scale models that were used to largely for the purpose of scenario modelling.

Data was fed into the simulation models from Microsoft Excel input files and process sequences and routing were created and executed using the help of Visual Basic (VB). An example of such a VB sequence creation can be found in Appendix D.

However, the inputs were still fed into the simulation models from excel output files from the existing ERP systems like Maximo and SAP. This meant that in some areas, the simulation project team had to wait till they received the outputs from the ERP systems, which had to be requested, and at times, took longer than expected. These technical shortcomings in between the initial and continuous success in simulation projects highlighted that it was time for need integrating simulation into the existing business processes. Also, the use and development of simulation models largely focused in an around the key assembly and manufacturing lines. To spread the use of simulation into the business processes within the organisation, it was important to integrate simulation further into the various business processes.

7.6 Stage 3- Integration

As there were various simulation projects undertaken within the organisation, key attention was given how the tool could be integrated within the IT & Systems framework and operational framework of the organisation.

Since the members of the BI team were the change managers, and were overseeing the simulation projects, it was very much integrated into the change management philosophy of the organisation. Whenever there was a new issue, which required the attention of the BI team, simulation was discussed as a possible tool. This ensured that simulation got the right attention as a possible tool for the evaluation and decision making of any business processes.

7.6.1 Promoting simulation success stories

The results of simulation projects were conveyed at all lean workshops and top management meetings. It was mandatory for the change managers in the BI team to be part of high-level meetings and discussions, especially the weekly Assembly line meetings, which included the top management of each sub assembly lines. Simulation was also in fact used as one of the tools to assess the current work in progress (WIP) of the Final Assembly Line. The management used simulation to assess whether a fixed line concept or a flow line concept was the most beneficial for the final assembly line.

7.6.2 Integrating simulation with the existing IT and systems framework

There were many tools that were used by the large part of the organisation's business processes. SAP (Systems Applications and Products in Data Processing) was introduced into the organisation by the head office and it was slowly beginning to be introduced as mandatory software for business management. Data stored in the current ERP systems like Maximo and standard data collection and management tools like excel sheets were made to covert into SAP.

By following the guidelines stated in the proposed framework of evaluating an integrating simulation and existing software packages, a meeting was set up with the head of the SAP integration team to discuss on the possibilities of integrating the systems together. During the meeting, initially the SAP team wanted to ensure that simulation wouldn't be conflicting with the objectives of SAP. There were many areas, where the use simulation was already playing a big role in decision-making. One of the key areas was in the area of inventory management. SAP had inbuilt modules for inventory management, and they believed that the successful use of this modules will reduce much issues in inventory control. However, the SAP team expressed willingness integrating the new system.

The summary of the meeting is detailed below;

- Currently SAP is at its early stages in the organisation.
- The current version of SAP allows export of data into MS Excel format, but is still under testing stage and very much objected by the management as they believe the employees will just export the data and continue working with the more familiar platform of Excel.
- However, this can be changed in future once the employees are used to the SAP modules.

Both the SAP team and the Simulation team agreed on the following:

- In future, an automated tool can be implemented to export reports directly from SAP to a format suggested for simulation like Excel.
- The simulation practitioners will build a VBA routine to read this excel file and load the data into the model(s). This configuration will allow an automatic link between SAP and the simulation tool.

- The model can then generate the output, which can then be fed back to the SAP system (if required) using a similar configuration or any other suggestion as per the choice of the SAP team.

Since SAP was chosen as the future management software, it was not worthwhile investing the time and effort to integrate Simulation into the current ERP frameworks like Maximo. Hence, integrating of simulation tool from an IT and software systems point of view was not possible. However, through successful meetings with the SAP team, a good foundation was set up to enable the process integration in future.

The SAP team began cooperating with the simulation team by creating automated reports every day for a couple of manufacturing lines which had their own dedicated simulation models for experimentation and scenario based analysis. These automated reports helped the simulation practitioners to develop a routine run of simulation model without having to engage in data collection exercises regularly. An example of an automated model run routine can be found in Appendix E. Microsoft Excel was used as the data platform with VB coding which enabled to run the model from Excel itself. This enabled even the non-simulation users to run the simulation model and analyse the results.

7.6.3 Identifying more opportunities in simulation

Although pilot projects in simulation were executed during the guided support stage, a set of areas was identified within the organisation where simulation could be used for improving their business processes. Some of the areas found in the organisation where simulation can be used were:

- Flow in Assembly Line
- Tool to determine a change in philosophy (Lean implementation)
- Managing WIP (Work in Progress)
- Managing Lead times
- Calculating Machine utilisation
- Scheduler for processes

The main purpose behind this exercise was to look into areas within the company where simulation can be used as a support tool. They might not be any necessary issues or problems with the way the operations run currently. As the old saying goes *"If it not broken, there's no need to fix it"*, Hence there was little interest shown from the management or the process owners in assisting you with your model work. From the researcher's experience of implementation simulation systems across this organisation, these kinds of opportunities helped a lot to really showcase the strength of using simulation.

The following section (Example of successful experimentation of simulation) details an example of a situation in the collaborating organisation, where simulation was used on an experimentation level and provided successful results.

Example of successful experimentation of simulation: One of the service bays, which handled all the repairs, maintenance and service of the engines where quite busy with their workload most of the time of the year. An average of 30 engines had to be arranged to pick up from sites that are both onshore and offshore, from around the world. Since a large amount of time was spending on shipping and logistics planning and there was always a degree of uncertainty, the service bay always had tight set of deliverables to achieve.

One of the fundamental stages of operation during the service of the turbine engines was the coating of the blades. The coating process was a very intricate process, which was also done by an external supplier in this scenario. Although the company was doing its best and meeting the tight deadlines, it still meant that the engines were waiting at the service bay waiting for the coated blades to arrive from the external company for over a week. This also meant that the engine bay was occupied during that time and they couldn't accept new repairs due to the lack of engine bays.

A process flow of the current situation is shown in Figure 7.6-1

[redacted]

Figure 7.6-1 Flow chart detailing the process of coating of blades

The average time scale taken to complete the process was an estimated 5 weeks. Of which, one to one and half weeks were taken for coating of the blades.

With the help of the service bay in-charge and the business improvement team, the simulation personnel looked into the issue to see how the existing process can be improved. Although they were facing delays here due to the coating process, the system was largely familiar with this. Hence they scheduled the arrivals of next engines accordingly and there was no immediate need to change or improve anything. This meant that any successful analysis and ideas using simulation any tool would be deemed as an improvement to the existing process. Hence, the pressure to come out with something successful within a short period of time didn't exist in this case.

The simulation team first gathered all the necessary data sufficient enough to build the model. The team also set up meetings with the external company to identify their workload, average WIP and also any issues or opinions they would like to share on this process. This was a critical step in simulation modelling. Research suggests that it is difficult to model any process which involves an external entity as this means, sharing a considerable amount of information, which at times, is not something the external entities are willing to do.

Gan et al., (2000) emphasises on the difficulties faced by organisations when collecting and detailing information when the scope of work expands beyond the four walls of the organisation. Lendermann (2009) states that extending the boundaries of simulation as one of the first steps to an even more grand vision of distributed simulation.

However, in this case, due to the long history with between these organisations and their history in cooperation, they made it clear that they can complete the coating process quicker providing that they get ample of time to be ready for the arrival of the blades. This meant that the service centre to inform them prior on the schedules of engines arriving. This method had its own risks, as although they could predict the schedule of general services, they couldn't predict the repairs and maintenance. And, generally the rule of thumb was that the engine arriving for repairs and maintenance gets precedence over the service engines.

The idea was to build a simulation model showing the current situation, by incorporating the arrivals and movements of engines as entities and movement and processing of various parts in the engine. The model did not concentrate on all the work happening in the bay. Instead it purely concentrated on the blade coating process, as at the end of the day, 99% of the time, most of the other work were completed at least a week before the coating process is complete. Hence, there was no need to look into those operations for the time being.

Thorough analysis using the simulation model helped the team understand that there was good opportunity to improve the current system by adding buffer blades into the service bay. Slowly, some members in the management got more interested in the study and brought in many constructive ideas to run on the scenario manager in the virtual discrete event simulation model. After a considerable amount of scenario modelling, research and co-operation between various teams and individuals, the simulation model was able to establish two ways in which the process can be improved.

- Arranging service schedules of similar batches (age, type, model etc.) around the same time and
- Improving the lead times of the external company by introducing Lean principles in their shop floor.

Within a period of two months, the management was able to reduce the time frame required for coating to 25%. By saving 25% of time from the service process, this added up to one less spare engine at the end of the year to sent as replacement to the customer while their engine was away for repair or service. More over, the simulation model was also used as the tool by the schedulers (service) to decide on arranging the service schedules for the following year.

7.7 Stage 4- Embedding

The primary objective of this stage was to incorporate simulation within the core of the organisation. The successful execution of the guidelines in the first three stages of the proposed framework: Introduction, Guided Support & Integration will help provide a good foundation in embedding simulation as a tool into the core of the organisation.

In many ways, the process of embedding simulation is a culmination to all of the first three stages in the proposed framework. The success generated from executing the first four stages of the proposed framework has helped achieve the following:

- A good reputation and credibility for simulation as a tool within the company

- Good respect and appreciation in the pro-activeness shown by the Simulation and Business improvement team
- A good success portfolio for the team to be proud of.
- Encouragement from other departments to look into their processes for improvement.
- Reputation of model developers.
- Trust and support from the senior management in encouraging the use of simulation as a process analysis and planning tool across all engineering departments.

Simulation implementations often result in numerous intangible benefits that translate into tangible savings in costs and increased revenues in the long run. Intangible benefits range from improved processes, better quality, higher employee morale and better decision-making.

In many business process areas, including final assembly line, blade-manufacturing units, etc. concurrent use of simulation meant that the simulation practitioners created standard templates for each machine and modules. One of the most common examples was in the final assembly line. Each bay in the assembly line had a set of machines and tools that had a specific lead-time and sequence of process. Creating a template for each bay meant that the users were able to successfully add and manage engine bays to study the balancing of lines.

These templates, sequences and general information on model building were made available on a dedicated company intranet space. A database server was already in place within the organisation with an intranet site as the front face for controlled access.

Presentations of each training sessions regarding simulation were posted online and had access granted to all. The models, templates other information were given a controlled access.

As part of the intention of creating more simulation practitioners in future, a section regarding awareness in simulation was added as a module in graduate training programmes. These training programmes were conducted annually as part of welcoming new graduates.

7.8 Modifications to the proposed framework

From the validation exercise conducted at the collaborating organisation, it is considered that the proposed framework needs to be reviewed to accommodate the lessons learned from the validation exercise. Although, the element of technical, operational and organisational factors were discussed in designing the proposed framework, the author considers that some key elements under each of these factors has to be discussed in more detail, especially during the integration and embedding stages of the proposed framework.

From the experience of this validation process in the collaborating organisation, there were many challenges faced which were a combination of Technological, Operational & Organisational challenges. Hence, for the purpose of describing these challenges adequately, the author considers adding a different dimension to the way the various factors are analysed.

The author trusts that although many of these challenges may fall under one of the three categories, sometimes, they can even be a combination of one or more of these factors. Hence the author has decided to categorise these factors as Internal & External.

The internal factors are elements that contribute and confined within the boundaries of simulation project team or group. The External factors are elements that are outside the boundaries of the simulation project, but have a profound effect in the successful execution of the simulation project.

Each of these factors influenced two major areas of the simulation implementation project. The two major areas are detailed below:

- The overall time taken to achieve the task of implementing simulation in the organisation.
- The determination of success level of the implementation process.

The author considers that these challenges need to be addressed in detail and the proposed framework has to be modified to accommodate guidelines to handle these possible challenges. Figure 7.8-1 illustrates some of the key internal and external factors affecting the development and integration process of simulation within the organisation. The inner dotted lines in the figure represents the simulation project team boundaries and the external circle represents the organisational boundary.

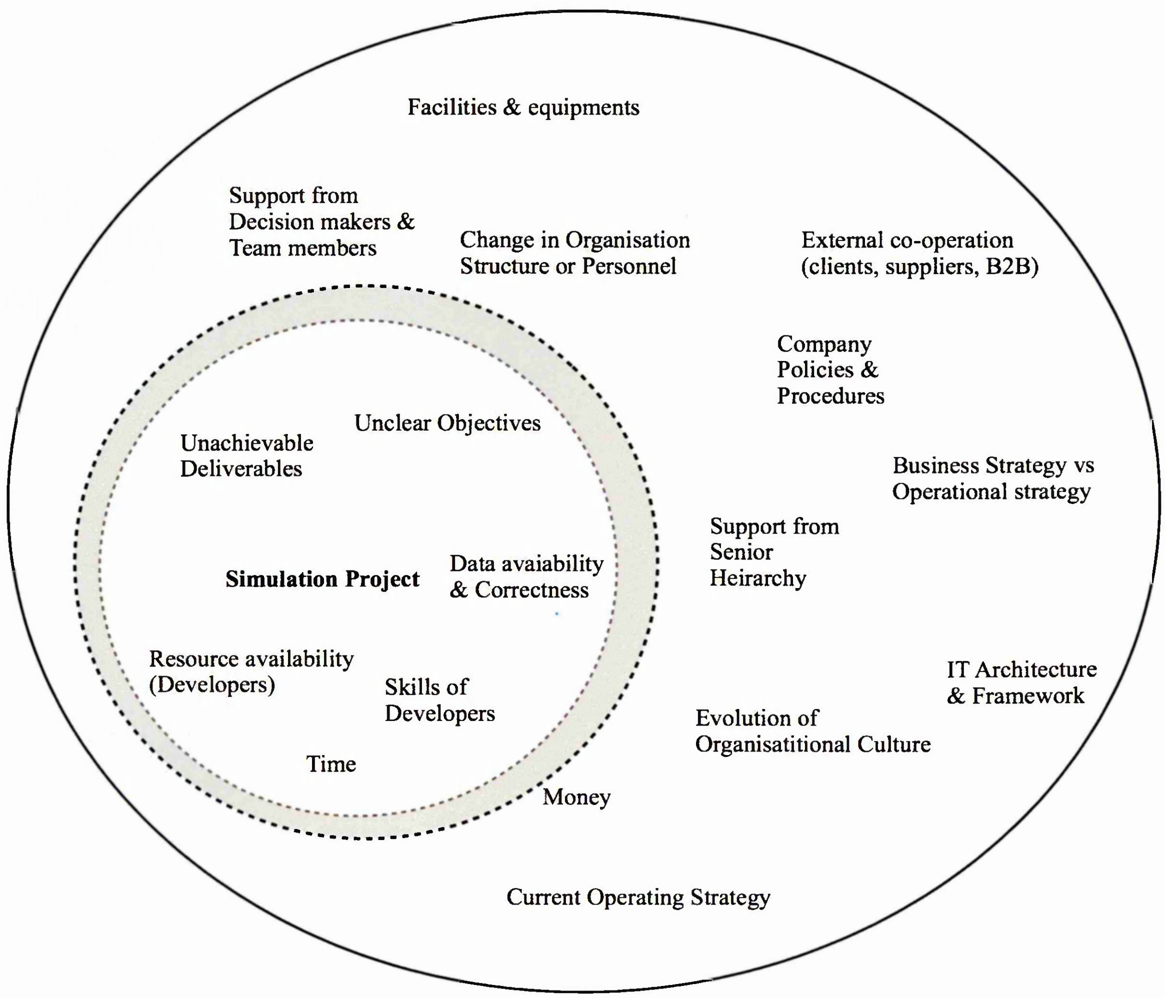

Figure 7.8-1: Internal and external factors affecting the development and integration of simulation within an organisation.

7.8.1 Internal factors

Some of the Internal factors are explained in detail below:

7.8.1.1 Resource Availability

Since the simulation technology and the projects associated with it were largely on an experimental basis, there was no specific department or focus group that were solely involved in achieving the task. As mentioned earlier, existing personnel within the organisation were used to do simulation projects. They were devoting their time and effort due to the willingness to learn more about simulation and its benefits and the same time to learn a new skill set.

For the purpose of explanation, lets call these resources 'shared resources'. They are working in various areas within their company, but also supporting simulation projects during their available time. These kinds of resource sharing and personnel arrangements take a lot of time and patience. It is important that the time spent working on simulation projects doesn't adversely affect their existing working schedules and structures. At times, the extensive time spent for simulation in return of no financial benefit can also act as a de-motivating factor.

7.8.1.2 Time

Time and resource constraints are in many ways interlinked. Since the request for the help in using simulation is coming from many areas within the business, the individual project owners have to be made aware of the fact the dedicated team fully appointed for simulation doesn't physically exist. Many times, where projects which are behind the schedule or have strict time constraints this news would put the process owners off from deciding against using simulation as a support tool for their project.

Although the project would be one of the best-fit scenarios to use simulation, the time and resource constraints can impact the stakeholder's decision to opt out of using simulation.

These kinds of missed opportunities can adversely affect the development of simulation projects.

7.8.1.3 Unachievable and Overambitious targets

Every simulation project has set of objectives and deliverables. From the initial stage of the project itself this has to be made clear. However, it is also important to make the process owners aware what your simulation model can do and what it can't do. Many at time the results a simulation study can give to an operation is very impressive and then the process owners tend to get carried away and expect that simulation is the answer to all their problems. Following the guidelines in the Model Building stages will help to reduce this risk to a great level. However, it is important to define and state the clear objective of the project to the senior management and ensure that these targets are reviewed periodically.

7.8.2 External factors

The factors outside the boundaries of the simulation project, but within the boundaries of the organisation are elements, which the simulation personnel have little influence on, but indirectly change the course of the overall objective of the project, which is successfully embedding simulation technology within the whole organisation.

7.8.2.1 Evolution of Organisational Culture

Although all organisations have cultures, some appear to have stronger, more deeply rooted cultures than others. Initially, a strong culture was conceptualised as a coherent set of beliefs, values, assumptions, and practices embraced by most members of the organisation.

The emphasis was on (1) the degree of consistency of beliefs, values, assumptions, and practice across organisational members; and (2) the pervasiveness (number) of consistent beliefs, values, assumptions, and practices (Baker, 2002).

The subject of organisational culture has been in discussion in the literature survey and also a major contributing factor in setting up the guidelines of the proposed framework. For a successful BPM implementation, organisations should look beyond the technology of the project and focus on the *"human-side"* of the project as well.

Sometimes, even for individual simulation projects to work, you will need to look into changing the culture and mentality of the individuals in charge. One thing, which has to come to the attention while trying to implement simulation projects within the collaborating organisation, was the large amount of resistance from employees in the shop floor. There was a fundamental reason to this. The majority of the shop floor employees where near to their retirement age. When a simulation project intended to improve the processes, where primarily reduce the lead times, or WIP, it translated as possible redundancy to the shop floor employees.

This in turn translated to them as reduced working hours, which meant the new system could jeopardise their chance to complete the remainder of the working years within the company. So, deep beneath the fine layers of organisational culture, there could also be some hidden factors, which may impact your implementation of a change or new technology. Some elements of an organisation's culture may have little impact on its functioning, and the leader must distinguish which elements are important, and focus on those.

The author also believes that depending on the experience and lessons learned during each stages of the proposed framework, a strategy has to be devised in order to prepare a time based plan for embedding simulation within the organisation. In many organisations, systemic change requires a transition period of at least three to five years.

7.8.2.2 Company Policies & Procedures

Every organisation has its own clear set of values, policies and procedures which has been inbuilt in the company over the period of time, which is based on its core values, principles and operational strategies. When implementing a business process change, depending on circumstances, various elements of complications may arise due to various policies set up with in an organisation. One of the most common issues was the change in Human Resource policies. Often simulation developers were shared resources. At times the departments or groups under which the employees were working, debated on how much time of their human resource is being shared by the other departments for simulation projects. Since each department had individual budgets, which also included salaries spend on employees for the respective departments, the question arouse on who will share the cost of 'shared time'.

One way the organisation can work around this problem is by monitoring the hours of work the shared resources are putting into for a particular simulation project and distributing the costs for that time spent towards the particular department, which owns the main project. In return, the departments that share their resources for the simulation project can also in turn receive the share and appreciate of the benefits made from the simulation project.

When they realise that running a simulation project can impact on their financial budget, they tend to back out from the idea. One can say that the financial constraints here play a big role in determining the use of simulation tool and thereby producing a decremented effect in the success of the project.

Depending on the success of simulation projects and the amount of time and usage of simulation team, the organisation can allocate a separate 'budget pool' set out for business improvement initiatives, from which each department can share their required funding for running the simulation project.

Another option is for the project teams to support themselves based on the share of the savings made from the success of the simulation project. The project team in this case can fund for its own expenses. This will help the simulation project team to be more independent.

7.8.2.3 Operational vs. Business Strategy

Operations strategy specifies the policies and plans for using the organisation's resources to support its long-term competitive strategy. Operations strategy specifies the design and use of resources to support the business strategy.

However, the challenge here is the implementation of operations strategy, based on the analysis and results obtained by performing an efficiency analysis on the current business process. But altering the operations strategy can make a profound impact in the overall business strategy of the organisation. The operational strategy of an organisation is shaped from the business strategy of the organisation.

Most businesses improve their operational efficiency or reduce costs tend to do so using simulation technologies to improve its processes. However, the business strategy of the organisation may require the current operational strategy to be intact. Operational efficiency and strategy must be aligned; otherwise you may be very efficiently performing the wrong task. The role of operations strategy is to make sure that all the tasks performed by the operations function are the right tasks.

The standard example of such a scenario would be in the area of improving a certain process within a manufacturing line. The department head sees a good reason to use simulation modelling to improve the process. However, half way through the process, they realise that there is a long-term business strategy already in place to outsource that particular process. An organisation's mission and vision can constantly change too. One year, they would like to be the cheapest in the market, the next year; quality is the main driving force.

When mission values change, new business strategies will shape its form, subsequently changing the operational strategy of the organisation. When this happens all the business improvement projects currently run within that company will come to a halt or have to alter their objectives. The finance, operations, marketing and sales strategies of the business are fundamentally derived from the core business strategy of the organisation. All of these elements are interconnected too. Hence a change in any of these elements can alter the other.

The key factor here is that the operational strategy is defined and modelled based on the core business strategy of the organisation. By creating and running a simulation model, it may become evident that the strategy followed in the operations of the business is not the most efficient way of getting things done or there are areas for improvement.

In many ways, the biggest issue here is that the people in charge of the operations feel and believe that they have to continue what they are doing in the current form to ensure that it is aligned with the core business strategy of the organisation. The fear to improve things due to the perception that experimentation can go wrong can be evident.

For simulation modellers, this will be a very challenging job to effectively ensure that the operational strategy of the organisation or any of its business unit is preserved, while at the same time the operational efficiency of the overall system will be improved by using simulation modelling. Key emphasis should be put on the ability on running virtual experimentations using simulation, and hence it can be an effective tool in deciding the right operational strategy.

8 Conclusions & Recommendations

8.1 Conclusions

This thesis is intended to facilitate embedding simulation within a business. The literature review investigated the various business process tools available today and how some organisations have managed to integrate these tools within their business processes. The importance for integrating simulation within an organisation's business process framework was discussed. The use of simulation and the various important factors surrounding embedding simulation within business processes were investigated. The case studies provided examples of success stories on integration of simulation in businesses and the critical success factors in achieving this aim. The case study also illustrated an example of how an organisation went through the cycle of culture and change in philosophy to accommodate a new manufacturing concept.

Additionally, a questionnaire survey was conducted and its results analysed to identify the main challenges faced by organisations while embedding simulation in their business processes.

8.2 Developing a framework for embedding simulation

After studying the general challenges faced during implementing these business process tools and philosophies and the knowledge drawn from the literature reviews were used as the key reference and benchmark in identifying and developing the best fit approach for embedding Simulation as a tool into the manufacturing groups. Using the knowledge gained from the literature review and the findings and outcomes gathered from the Questionnaire Survey and Case Studies, a set of guidelines were designed for implementing each stage of the proposed framework.

Significant stages on building and implementing simulation modelling within the business were identified, defined and documented.

8.3 Validation of the proposed framework

By conducting the validation of the proposed framework within the collaborating organisation for a period of more than 24 months, it helped the researcher analyse various complications involved and situations, which an external simulation consultant would have been unable to evaluate.

By validating the framework proposed within the collaborating organisation, it was possible to further assess and validate the capability of the proposed framework in the real world. The lessons learned from the validation exercise and the modifications required to the proposed framework are also documented with real life examples to support the need for modification.

The importance of understanding that integration of simulation is a never ending process and accepting that the best methodology is to follow a systematic approach to implement, develop and promote simulation technologies within an organisation has been highlighted in the modification of proposed framework.

8.4 Contribution to Knowledge

This study has made a contribution to reduce the research gap in the existing simulation embedding studies, with a four-stage framework, namely: Introduction; Guided support; Integration; Embedding.

The framework proposed and validated in this thesis, provides a best practice approach to embed simulation as a tool in an organisation. The author considers this research work to be new research knowledge in the existing simulation integration studies. The author also suggests that future researches could use the framework as a reference for guideline and generalise the framework to determine its applicability in other industries and sectors.

9 References

Abdulmalek, F. and Rajgopal, J. (2006) 'Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study', *International Journal on production economics*, September, pp. 1-14.

Abken, P.A. (2000) *OCC Economics working paper 2000-3*, March, pp. 3-15.

Agarwal, A. (2005) 'Fat Results for Lean Times', *Circuit Assemblies*, pp. 26-29.

Antony, F. and Banuelas, R. (2002) 'Critical success factors for the successful implementation of six sigma projects in organisations', *The TQM Journal*, vol. 14, no. 2, pp. 92-99, Available: HYPERLINK "http://www.emeraldinsight.com/0954-478X.htm" http://www.emeraldinsight.com/0954-478X.htm .

Ashby, J.R. (2005) 'How General Motors Used Simulators to Save Time and Money Creating Value for Our Customers', *Proceedings of the 37th conference on Winter simulation (WSC '05)*. Winter Simulation Conference, Orlando.

Baker, K. (2002) 'Organizational culture', Washington DC, 1-10.

Balci, O. (1998) 'Verification, Validation & Accrediation', *Proceedings of the 1998 Winter Simulation Conference* , pp. 41-48.

Banks, J. (2000) 'Getting started with Automod', vol. Edition S, no. 801.

Banks, J., Hugan, J., Lendermann, P., McLean, C., Page, E., Pegden, D., Ulgen, O. and Wilson, J. (2003) 'The future of simulation industry', *Proceedings of the 2003 Winter Simulation Conference* , pp. 2033-2043.

Boeing (2002) *Boeing Commercial initiatives*, [Online], Available: HYPERLINK "http://www.boeing.com/commercial/initiatives/lean/movingline.html." http://www.boeing.com/commercial/initiatives/lean/movingline.html. [September 2006].

Carter, P. (2005) *Business Process Reengineering (BPR) An introductory guide*, [Online], Available: HYPERLINK "http://www.teamtechnology.co.uk/business-process-reengineering.html" http://www.teamtechnology.co.uk/business-process-reengineering.html [September 2006].

Dooley, J. (2003) 'Cultural aspects of systemic change management'.

Ferrie, J. (1995) *Business process - a natural approach*, [Online], Available: HYPERLINK "http://bprc.warwick.ac.uk/forum1.html" http://bprc.warwick.ac.uk/forum1.html [2006].

Fishwick, P.A. (1995) 'Simulation Model Design and Execution: Building Digital Worlds', vol. 1.

Gan, B.P., Liu, L., Jain, S., Turner, S.J., Wentong, C. and Jing, H.W. (2000) 'Distributed Supply Chain Simulation Across Enterprise Boundaries', Manufacturing Planning and Scheduling Group, Manufacturing Information Technology Division, 1-8.

Giaglis, G.M., Hlupic, V. and Paul, R.J. (1999) 'Simulation modelling of business processes'.

Gladwin and Tumay (1994) 'Modeling business processes with simulation tools', *Proceedings of the 26th conference on Winter simulation*, p. 8.

Greasley, A. (2004) 'The case for the organisational use of simulation ', *Journal of Manufacturing Technology Management*, vol. 15, pp. 560-566.

Greene, A.H. (1999) 'A flow manufacturing white paper', *Flow Manufacturing Report*, May, pp. 7-10.

Hlupic, V. and Currie, W.L. (2003) 'Simulation Modelling: The Link Between Change Management Approaches', *Knowledge and business process management*, Hershey: Idea group publishing.

Hlupic, V., Vreede, G.-J.d. and Orsoni, A. (2005) 'Modelling and simulation techniques for business process analysis and re-engineering', *I J of Simulation*, vol. 7, no. 4-5, pp. 1-8.

Holst, L. (2001) *Integrating Discrete-Event Simulation into the Manufacturing System Development Process*, Division of Robotics.

Hughes, R. and Perera, T. (2009) 'Embedding simulation technologies into business processes: challenges and solutions ', *International Journal of Simulation and Process Modelling*, vol. 5, no. 2, pp. 78-85.

Jägstam, M. and Klingstam, P. (2002) 'A handbook for integrating discrete event simulation as an aid in conceptual design of manufacturing systems', *Proceedings of the 2002 Winter Simulation Conference*.

Johansson, M., Leong, S. and Klingstam, P. (2007) 'A test implementation of the core manufacturing simulation data specification', *Proceedings of the 2007 Winter Simulation Conference*, Gothenburg, 1673-1681.

Jones, C., Dennis, S., King, B., Hind, M. and Robinson, S. (2000) 'Applications of business process techniques in British Telecom PLC', *Proceedings of the 2000 Winter Simulation Conference*.

Kleijnen, J.P.C. (1999) 'Validation of models: statistical techniques and data availability', *Proceedings of the 31st conference on Winter simulation*, pp. 647-654.

Knoll, M. and Heim, J. (2000) 'Ensuring the successful adoption of discrete event simulation in a manufacturing environment', *Proceedings of the 32nd conference on Winter simulation*, pp. 1297-1304.

Lau, R.F. and Sundaram, S. (2002) 'Manufacturing process modelling or Boeing 747 moving line concepts', *Proceedings of the 2002 Winter Simulation Conference*.

Laureani, A. and Antony, J. (2004) 'Reducing employees' turnover in transactional services: a Lean Six Sigma case study', *International Journal of Productivity and Performance Management* , pp. 688-700.

Law, A.M. and Arthur, J.D. (1999) 'Verification and validation: what impact should project size and complexity have on attendant v&v activities and supporting infrastructure?', *Proceedings of the 1999 Winter Simulation Conference*, 148-155.

Lendermann, P. (2009) 'How modelling limits Analysis - The long way from distributed simulation to reality', *Proceedings of the 2009 INFORMS Simulation Society Research Workshop*, 9-18.

Mclean, C. and Riddick, F. (2000) 'The IMS mission architecture for distributed manufacturing simulation', *Proceedings of the 2000 Winter Simulation Conference* , pp. 1539-1548.

Motwani, J. and Mohamed, Z. (2002) 'Flow manufacturing necessity, benefits, and implementation: a case study', *Industrial Management & Data Systems*, pp. 73-79.

Mtaawa, J. and Basher, Z. (2007) 'Integrating Manufacturing System Simulation Development A Methodological Framework', *In Proceedings of ISTA'2007*, pp. 234-241.

Murphy, C.A. and Perera, T.D. (2001) 'The definition and potential role of simulation within an aerospace company', *Proceedings of the Winter Simulation Conference*, vol. 2, pp. 829-837.

Murphy, S.P. and Perera, T. (2002) 'Successes and failures in UK/US development of simulation ', *Simulation Practice and Theory*, vol. 9, March.

NHS (2005) 'Managing the human dimensions of change', pp. 11-50.

Page, E. (1994) *Simulation modeling methodology: principles and etiology of decision support*, Virginia.

Page, E.A. and Nance, R. (1994) 'Parallel discrete event simulation: a modeling methodological perspective', *Proceedings of the ACM/IEEE/SCS 8th Workshop on Parallel and Distributed Simulation* , July, pp. 88-93.

Petrovic, D., Rajat, R. and Radivoj, P. (1998) 'Modelling and simulation of a supply chain in an uncertain environment', *European Journal of Operational Research*, vol. 109, March, pp. 299-309.

Prosci (1997) 'Benchmarking study', in Prosci *Best Practices in Business Process Reengineering and Process Design* .

Prosci (2002) 'BPR online learning centre', in *New series on change management*, Prosci, Available: http://www.prosci.com/intro.htm.

R Van, L. and De Buf, M. (1997) 'Supply Chain characterisation through Monte Carlo Simulation', *International Federation of Operational Research Societies (IFORS)*, June, p. 7.

Ramachandran, B., Fujiwara, K., Benayon, J., Kano, M. and Koide, A. (2006) 'Business process transformation patterns & the business process transormation wizard', *Proceedings of the 2006 Winter Simulation Conference* , 636-641.

Ryan, J. (2006) 'Requirements gathering for simulation', *Proceedings of the 2006 OR Society Simulation Workshop*, pp. 1-9.

Sarawgi, S., Gupta, A. and Sivakumar, A.I. (2002) 'Shop floor scheduling with simulation based proactive decision support', *Proceedings of the 2002 Winter Simulation Conference* , pp. 1897-1902.

Saxena, K.B.C. (1995) 'framework, Information technology support for reengineering public administration: A conceptual', *International Journal of Information Management (1995)* , vol. 15, no. 4, pp. 271-293.

Sherrod, C. (2000) 'ViaSim Solutions' pmBLOXTM Project Planning Modeling and Simulation Tool', *Support for Realistic Project Planning, Evaluation, and Re-Planning throughout the Project Lifecycle*., pp. 5-9.

Shook, J. and Rother, M. (2003) Learning to see: value stream mapping to create value and eliminate muda, Lean Enterprise Institute.

Solectron Corp (2007) 'A foundation for continuous lean improvement', *Getting Lean*, pp. 50-58.

Stanger, M. and Robinson, S. (1998) 'Developing a simulation strategy for British Airways OR', *Proceedings of the 1998 Winter simulation conference*, vol. 2, december, pp. 1183-1189.

Sterneckert, A.B. (2003), in *Critical Incident Management*, Auerbach Publications.

Talwar, R. (1993) 'Business Re-engineering - a Strategy driven Approach', *Long Range Planning*, vol. 26, no. 6, pp. 22-40.

Umeda, S. and Jones, A. (1998) 'An integration test-bed system for supply chain management', *Proceedings of the 1998 Winter Simulation Conference* , pp. 1377-1385.

Verdanat, F.B. (2002) 'Enterprise modelling and integration: Current status and research perspectives', *Annual Reviews in Control*, vol. 26, pp. 15-25.

Vidal, F.p. (2002) 'How-to simulation: when knowing what to do is not enough ', *Proceedings of the 2002 Winter Simulation Conference* , pp. 1459-1464.

Williams, E.J. (1996) 'Making simulation a corporate norm', *Proceedings of the 1996 Summer Computer Simulation Conference*, pp. 1-6.

Wyper, B. and Harrison, A. (2000) 'Deployment of Six Sigma methodology in Human Resource function: A case study', in Wyper, B.&.H.A. *Total Quality Management & Business Excellence*.

Yücesan, E., Ferrin, D., Miller, M. and Muthler, D. (2002) 'Six Sigma and simulation, so whats the correlation?', *Proceedings of the 2002 Winter Simulation Conference*.

10 Bibliography

Buss, P. and Ivey, N. (2001) 'Dow Chemical design for Six Sigma rail delivery project', *Proceedings of 2001 Winter simulation conference*, Arlington, U.S.A, 1248-1251.

B Haquea, K.S Pawarb and R.J Barson (2003) 'The application of business process modelling to organisational analysis of concurrent engineering environments', *Technovation*, vol. 23, no. 2, pp. 147-162.

Balci, O. (1990) 'Guidelines for successful simluation studies', *Proceedings of the 22th Winter Simulation Conference*, Louisiana, 25-32.

Chew, M.M.M., Cheng, J.S.L. and Petrovic-Lazarevic1, S. (2006) 'Manager's role in implementing organisational change', *Journal of Global Business and Technology*, vol. 2, no. 1, pp. 58-67.

Ferrin, D.M., Miller, J., M. and Muthler, D. (2005) 'Lean sigma and simulation, so what's the correlation', *Proceedings of the 37th conference on Winter simulation*, Orlando, Florida}, 2011-2015.

Hunter, S.L., Bullard, S.H., Steele, P.H., Motsenbocker, W.D. and Schuler, A. (2004) 'Parallel Pull Flow: A New Lean Production Design', *Case studies of lean manufacturing in furniture and supplying industries*, pp. 1-12.

Hunt, K.L., Madigan, E.F., Hansen, G.A. and Phelps, R.A. (1997) 'Simulation Success Stories: Business Process Reengineering ', *Proceedings of the 1997 Winter Simulation Conference*, 1275-1279.

Heginbotham, B., W. and Ltd., I.(. (1985) 'Simulation in Manufacturing', *Proceedings of the 1st International Conference on Simulation in Manufacturing*, Bedford, 384.

Kelton, David, W., Sadowski, P., R., Sadowski and A., D. (2002) *Simulation with Arena*, 2nd edition, New York: McGraw-Hill, Inc.

Krishnamurthy, A., Suri, R. and Vernon, M. (2000) *Push Can Perform Better than Pull for Flexible Manufacturing Systems with Multiple Products*.

Lendermann, P. (2006) 'About the need for distributed simulation technology for the resolution of real-world manufacturing and logistics problems', *Proceedings of the 38th conference on Winter simulation*, Monterey, California, 10.

Nomura, J. and Takakuwa, S. (2004) 'Module-based modeling of flow-type multistage manufacturing systems adopting dual-card Kanban system', *Proceedings of the 36th conference on Winter simulation*, Washington, D.C, 1065-1072.

Pidd, M. (1989) *Computer modelling for discrete simulation*, New York: John Wiley & Sons, Inc.

Standridge, C.R., Centeno, M.A., Johansson, B. and Stahl, I. (2005) 'Introducing simulation across the disciplines ', *Proceedings of the Winter 2005 Simulation Conference*, Orlando, Florida, 2274-2279.

Robinson, S. (2004) *The Practice of Model Development and Use*, Chicester, UK: John Willey & Sons.

Robinson, S.M., Davies, R., Hoad, K., Pidd, M., Edwards, J.S. and Taylor, S. (2004) ' Simulation model reuse: definitions, benefits and obstacles', *Simulation Modelling Practice and Theory*, pp. 479-494.

Tarumi, Hiroyuki, Matsuyama, Tetsuya, Kambayashi and Yahiko (n.d) 'Evolution of Business Processes and a Process Simulation Tool', *Proceedings of the Sixth Asia Pacific Software Engineering Conference*, 1999, 180.

11 APPENDIX

11.1 APPENDIX A: Communication regarding platform for technology and information exchange

From: Joseph, Lionel PG [mailto:lionel.joseph.ext@pg.siemens.com]
Sent: Tuesday, January 02, 2007 8:44 AM
To: Lu, Roberto F; Sundaram, Shankar
Subject: MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

Hello Roberto/Sundaram,

My name is Lionel Joseph. I'm currently doing MPhil in Applying Simulation Techniques in a Modern Organisation.

I happened to read your journal on the using Simulation for Process Modeling.I'm conducting a review of Literature on identifying organisations which have embeded simulation within their businesses. Eventhough a large number of organisations use simulation models often as a tool for decision making, companies seldom have a group of modellers within their system internally.

The emphasis of my research is on the companies which have accomplished the task of integrating simulation techniques into their systems and also have a team of personnel or modellers within the organisation and the critical success factors in achieving this aim.

I would be very grateful if you could send me some information or source of information on how you've managed to achieve the integration of Simulation into your system.

Thanks & Best Regards,

Lionel Joseph

Researcher (Simulation Engineering)
Business Improvement, MW13
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From: Lu, Roberto F [mailto:roberto.f.lu@boeing.com]
Sent: 03 January 2007 18:20
To: Joseph, Lionel PG
Cc: Sundaram, Shankar
Subject: RE: MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

Greetings Lionel,

Thanks for asking us about simulation. We are humbly honored!

We do use simulation to support our production processes. It is not possible for us to disclose details of our internal processes to any external entity without full approval from our company. What you could do is to search our publications in the public domain.

In case we have enough common interests, on non-competitive basis, we can pursue some levels of technology exchange after appropriate non-disclosure agreement has established among all parties.

Another possible manner of exchanging technical information in the public domain is to co-host a forum and/or session in an international conference where we will have our presentation materials pre-approved to publish.

How do you think?

Thanks again for your interests.

Best Regards,
Roberto

Roberto F. Lu, PE
Associate Technical Fellow
Material & Process Technology - Simulation
Boeing Commercial Airplanes
(206) 655-0575 phone
(425) 830-4715 cell

Email:- lionel.joseph.ext@pg.siemens.com
From: Joseph, Lionel PG
Sent: 04 January 2007 13:55
To: 'Lu, Roberto F'
Cc: 'shankar.sundaram@boeing.com'
Subject: RE: MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

Hello Roberto,

Thanks for your prompt reply.

I did have a look at the difference journals and publications about Lean manufacturing and Simulation within Boeing. However, despite finding a lot of information about using Simulation and Lean tools within different areas in the company, I couldnt find any information on how you achieved that task.

I'm looking at aspects which the business Process had to change to accomodate Simulation as a tool. A few questions I would like to raise are;

How did the concept of Simulation originally evolve within the business?
Did you follow a step by step procedure to integrate Simulation as a tool into the business?
How are Simulation models created or managed within the system currently? (External contractors working as modellers, or an internal team of simulation modellers?) etc
I hope the above questions would come under the public interest domain, rather than undisclosed information.

The emphasis or my research is on the general issues Simulation Engineers or the business personnel come across when they had to integrate Simulation in to the business.

I hope you would be able to provide me with some information on the above, if not point me to the right direction. And, once again, thanks a lot for your help. I would be speaking to the appropriate personnel here at some point with regards to pursuing some sort of mutual technology exchange.

Best Regards,

Lionel Joseph

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From: Lu, Roberto F [mailto:roberto.f.lu@boeing.com]
Sent: 15 January 2007 22:43
To: Joseph, Lionel PG
Cc: Sundaram, Shankar
Subject: RE: MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

Greetings Lionel,

Thank you very much for your interest in this subject.

Again, it's not easy for us to answer your questions in details. I'll try to answer them in general,

1. It took a lot of meetings and educational communications.
2. We did not really follow any particular recipe to use simulation as a tool. We do have some methods that will need clearance to disclose.
3. We have several internal teams in different business units. We do use outside talents also.

Meanwhile, I've been trying to organize a session in a conference. If I were successful in acquiring a session, I really would like to invite you to participate in it.

Thanks again!

Best Regards,
Roberto

From: Joseph, Lionel PG
Sent: 16 January 2007 17:14
To: 'Lu, Roberto F'
Subject: RE: MANUFACTURING PROCESS MODELING OF BOEING 747 MOVING LINE CONCEPTS

Thanks Roberto,

I would very much like to attend the session. Thanks for your invitation and your answers. I understand the limitations in providing all the information. I want to appreciate your time and effort in this matter.

Thanks & Best Regards,

Lionel Joseph

11.2 APPENDIX B: Questionnaire Survey

From: Joseph, Lionel PG
Sent: 19 March 2007 11:50
Subject: Embedding Simulation Techniques within a Modern Organisation

Dear Sir/Madam,

My name is Lionel Joseph. I'm a research student (MPhil) at Sheffield Hallam University. One of the primary aims of my research is to conduct a review of Literature identifying organisations which have embedded simulation techniques within their businesses and the critical success factors in achieving their aim.

As part of this research work, I'm conducting the following survey to understand the introduction, initialisation, deployment and further development of Simulation techniques within your company/organisation.

The following questionnaire consists of 14 questions and would take no longer than 2 - 5 minutes of your time. I would like to assure you that all the information received would be kept confidential and will only be reported in the form of a summary.

Please click on the link below to access the survey.

http://FreeOnlineSurveys.com/rendersurvey.asp?sid=2s4k2dmb4lcg9x9258831

If you have any queries regarding this questionnaire, please do not hesitate to contact me. Should you wish to receive a brief outline of the results from the survey, you may enter your address details at the end of the survey.

I would like to take this opportunity to thank you for allotting your valuable time for this exercise.

You are welcome to forward this link to any of your contacts whom you think could contribute to by taking part in the survey.

Thanks & Best Regards,

Lionel Joseph

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Business Improvement, MW13
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PO Box 1, Waterside South

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Tel:- +44(0)1522 58 6549
Fax:-+44(0)1522 58 4923
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Email:- lionel.joseph.ext@pg.siemens.com

From: "Joseph, Lionel PG" <lionel.joseph.ext@pg.siemens.com>
To: "Mark Treadwell" <mark@thetreadwells.com>, <catrina.randan@duomatic.co.uk>, <katy.harrington@corusgroup.com>, <pares@trellisys.com>, <rwdvanzek@transystems.com>, <phillipe.bunce@csc.com>, <jwh2@umd.edu>, <martin.hind@bt.com>, <simon.dennis@bt.com>, <stewart.robinson@warwick.ac.uk>, <fpulgarvidal@bizproto.biz>, "Ruby W. Lau(ACES)" <Ruby.W.Lau@student.shu.ac.uk>, <rienk.bijlsma@systemsnavigator.com>, <edwin.valentin@systemsnavigator.com>, <shankar.sundaram@boeing.com>, <roberto.f.lu@boeing.com>, <catrina.randan@dumatic.co.uk>, <phillipe.buncc@csc.com>
Date: Mon, 23 Apr 2007 13:50:27 +0100
Subject: Reminder - Embedding Simulation Techniques within a Modern Organisation
Dear Sir/Madam,

I would like to thank all of you who have taken part in the survey so far. Those who haven't taken part in the survey yet, I would appreciate if you could allot a couple of minutes of your time answering a few questions listed on the link below.

http://FreeOnlineSurveys.com/rendersurvey.asp?sid=2s4k2dmb4lcg9x9258831

I would like to take this opportunity to thank you for allotting your valuable time for this exercise.

You are welcome to forward this link to any of your contacts whom you think could contribute to by taking part in the survey.

Thanks & Best Regards,

Lionel Joseph

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Embedding Simulation Technologies within a Modern Organisation

Free Online Surveys .com

Online Surveys

The following questionnaire consists of 15 questions and would take no longer than 2-5 minutes of your time. I would like to assure you that all the information received would be kept confidential and will only be reported in the form of a summary.

If you have any queries regarding this questionnaire, please do not hesitate to contact me. Should you wish to receive a brief outline of the results from the survey, you may enter your address details at the end of the survey.

I would like to take this opportunity to thank you for allotting your valuable time for this survey.

Thanks & Best Regards,

Lionel Joseph

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1) **YOUR BUSINESS AREA**

Please indicate the primary area of your Business.

- ○ Aerospace
- ○ Automotive
- ○ Biotech
- ○ Chemical
- ○ Pharmaceutical
- ○ Business Services
- ○ Food & Beverages
- ○ General Manufacturing
- ○ Other (Please Specify):

2) What is the size of your Business?

- ○ < 100 employees
- ○ 100 - 500 employees
- ○ 500 > employees
- ○ Other (Please Specify):

3) How old is your Business/Organisation?

- ○ 1 - 5 years
- ○ 5 - 10 years

○ 10 - 25 years ○ 25 - 50 years
○ 50 and above

4) **INTRODUCTION TO SIMULATION**

How did the concept of Simulation originally evolve in the business?

○ Simulation was identified as a Problem solving tool
○ External consultants suggested Simulation to improve process(s)
○ Simulation was suggested as a idea by a current employee(s)
○ Other (Please Specify):

5) Who was tasked with introducing Simulation into your business?

○ Internal team of employees
○ A combined effort between internal and external workforce
○ Led by an internal team with external support
○ Led by an external team with internal support

6) If external consultants were engaged, how did they contribute to the implementation and development of Simulation?

○ Provided advise and technical support to the internal team
○ Developed simulation models with the support of the internal team
○ Both of the above
○ Other (Please Specify):

7) **INITIALISATION AND DEPLOYMENT OF SIMULATION**

How would you classify the interest initially received from the High level Managers towards Simulation?

○ Very interested ○ Interested
○ Not interested ○ Disagreed to the idea of Simulation

8) If Simulation wasn't well received initially, what do you think the main reasons were?

○ The management was not sure whether simulation was the right solution to the problem(s) or not
○ Couldn't justify the ROI from Simulation
○ The management wasn't aware of the strength of Simulation as a tool
○ Other (Please Specify):

9) How would you rate the level of awareness on Simulation project(s) among the majority of the employees in your company?

- Everyone were well aware
- The key personnel were well aware
- Little or no awareness at all

10) Please rank the following issues/challenges during the development stages of your Simulation project(s)
One a scale of 1 - 5 (1 = Least challenging, 5 = Most challenging)

	1	2	3	4	5
Data Collection	○	○	○	○	○
Model Building	○	○	○	○	○
Level of commitment from the appropriate personnel	○	○	○	○	○
Communicational barriers between the problem owners and modellers	○	○	○	○	○
Lack of effective structure/strategy for the project	○	○	○	○	○

11) **SIMULATION FOR THE FUTURE**

How would you rate the initial attempt on using Simulation within your company?

- Very Successful
- Successul
- Neutral
- Unsuccessful

12) How many Simulation projects have been developed in your organisation since the first project?

- None
- 1 - 5
- 5 - 10
- Frequent users of Simulation as a tool

13) How is Simulation currently being deployed in your company?

- External Consultants
- Combined effort of external consultants as modellers and the internal problem owners

○ Internal team of Simulation modellers with little or no support from any external party

○ Other (Please Specify): [ ]

14) Do you think more projects could be undertaken if external financial support would be made available?

○ Definitely ○ Most probably
○ Probably ○ Highly unlikely

15) If you would like to receive the results of this survey, then Please enter your contact details below.

First Name [ ]
Last Name [ ]
Address Line 1 [ ]
Address Line 2 [ ]
Address Line 3 [ ]
Address Line 4 [ ]
Post Code [ ]
Other contact details (Phone, Fax etc:) [ ]

Finish Survey

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11.3 APPENDIX C: Simulation Education Session Questionnaire (Evaluation of session standards and interests from participants)

* Name:	*Department:

(*):- Optional

How did you find the Simulation Awareness Session in general?

Very Satisfied	Satisfied	Average	Unsatisfied
☐	☐	☐	☐

Comments:-

From what you have learned from the awareness session, do you think that using Simulation tools can help SIT Ltd improve their processes?

Yes ☐ No ☐

If the above answer is NO, Please comment on your answer:-

Is Simulation an area which you would interest in and would pursue to learn more about?

Yes ☐ No ☐

Please use overleaf if you wish to add any further comments or suggestions.

11.4 APPENDIX D: Coding for VBA Sequence Creation (Sequence creations according to part formats)

VBA Code

```
Private Sub Sequence_Click()

'Open EXCEL
On Error Resume Next
Set XL = GetObject(, "Excel.Application")
If Err.Numjber <> 0 Then 'Excel wasn't loaded; start it
   Err.Clear
   Set XL = CreateObject("Excel.Application")
   If Err.Number <> 0 Then
      MsgBox "Unable to load Microsoft Excel."
   Exit Sub
   End If
End If
Err.Clear

'Open INPUT workbook

  InputFile = "C:\Documents and Settings\Josep00L\My Documents\Research Material\part
format.xls"
Set XLBook = XL.Workbooks.Open(InputFile)
'XLOrderlnputFile is the file handle for InputFile XLInputFile XL.Workbooks Count
XLInputFile = XL.Workbooks.Count
XL.Visible = False

  '*** Reset TRACE sheet ***
  TraceRow = 3
  Set XLSheet = XL.Worksheets("Sheet 1")
'-------------------------------------
'sequence generation
'Dimension the variable m as a model object
Dim m As Model
'Set m equal to this models object
Set m = ThisDocument.Model

'Dimension the variables below as Module Objects
Dim Seqmod As Module

'The code below creates the Create module from the template
'my code
Let ScheduleRowno = 4

Do While XLSheet.Cells(ScheduleRowno, 1).value <> "END OF PART LIST" ' this checks
whether the end of the file has been reached
```

```
VarLoopCount = 1
 Do While XLSheet.Cells(ScheduleRowno, 1).value = ""
 If XLSheet.Cells(ScheduleRowno, 1).value = "" Then
 ScheduleRowno = ScheduleRowno + 1
 VarLoopCount = VarLoopCount + 1
 If VarLoopCount >= 10 Then
 XL.Quit
 End
 Else
 End If
 Let varcellvalue = XLSheet.Cells(ScheduleRowno, 1).value
 'MsgBox (varcellvalue)
  If XLSheet.Cells(ScheduleRowno, 1).value = "END OF PART LIST" Then ' this checks whether
the end of the file has been reached
      End
   End If
End If
Loop

'The following three lines assign the sequence name

Set Seqmod = m.Modules.Create("AdvancedTransfer", "Sequence", -2000, -72)
Seqmod.Data("Name") = XLSheet.Cells(ScheduleRowno, 1).value
seqname = XLSheet.Cells(ScheduleRowno, 1).value
'-------------

' the first number gives the level that we are at.
' the second number dictates that we are looking at station 2
' if you want to populate all of sequence 3 then this is how.

Dim stnNumber As Integer
Dim EndOfSequence As Boolean
'Let EndOfSequence = False

Let x = 1

Do While XLSheet.Cells(ScheduleRowno, 1).value <> ""
Seqmod.Data("Name") = XLSheet.Cells(ScheduleRowno, 1).value
Let seqname = XLSheet.Cells(ScheduleRowno, 1).value
'If seqname = "" Then
'  EndOfSequence = True
'Else

'The following lines assign the Station name and attributes
' StnName is the machine Name!

Let StnName = "Stn" & XLSheet.Cells(ScheduleRowno, 5).value
Seqmod.Data("Station(" & x & ")") = StnName

Let ProLoad = XLSheet.Cells(ScheduleRowno, 6).value
Seqmod.Data("Att(1," & x & ")") = "ProLoad"
Seqmod.Data("Value(1," & x & ")") = ProLoad
```

```
Let Process = XLSheet.Cells(ScheduleRowno, 7).value
Seqmod.Data("Att(2," & x & ")") = "Process"
Seqmod.Data("Value(2," & x & ")") = Process
x = x + 1
ScheduleRowno = ScheduleRowno + 1

'End If
Loop

Seqmod.UpdateShapes
ScheduleRowno = ScheduleRowno + 2
Loop

 ' declare the value of the variables.
   TraceRow = 3
   UtilRowNo = 1
   ScheduleRowno = 0
UserForm1.hide
XL.Quit
End Sub
```

Part ID	Description	Operation ID
S81_9#10#11#12_SP		10
S81_9#10#11#12_SP	Precision Forged H_AC	70
S81_9#10#11#12_SP	Precision Forged H_AC	80
S81_9#10#11#12_SP	Precision Forged H_AC	120
S81_9#10#11#12_SP	Precision Forged H_AC	120
S81_9#10#11#12_SP	Precision Forged H_AC	130

ProLoad	Process	Load Time mins	Process Time mins	Batch Size		Ass Priority	Inter Arrival Rate
Issue	Storeman	0	5	0	18	1	0
Hexagon	Hexagon	0.5	6		18	1	
Turn Spigot	Lynx210#Act20	0.5	6		18	1	
Glaze . Polish	ManualGlaze2	0	6		18	1	
Glaze . Polish	ManualPolish2	0	6		18	1	
U#T Clean	AVD 500	1	20		18	1	

<u>VBA Fire Block</u>

```
Private Sub VBA_Block_1_Fire()
Dim s As SIMAN
Set s = ThisDocument.Model.SIMAN
Set XLSheet = XLBook.Worksheets("Priority")
'Use the EntityAttribute property of the SIMAN Object to assign a value to the "Process
Time"
'attribute. The SymbolNumber method of the SIMAN Object allows you to reference the
attribute
'by its name rather than its number. The left-hand side of the equation below is making use
'of Arena's Object Model, while the right-hand side of the equation is making use of Excel's
'Object Model. For information on Excel's Object Model you will need to refer to Excel's
'online help and documentation.
'MsgBox (ScheduleRowno)


ScheduleRowno = IIf(ScheduleRowno = 0, 4, ScheduleRowno)
If IsEmpty(XLSheet.Cells(ScheduleRowno, 3)) Then
'last row in schedule
' MsgBox ("Last Time" & BilletIDIndex)

ScheduleRowno = 0
s.EntityAttribute(s.ActiveEntity, s.SymbolNumber("BilletID")) = 0
Else

s.EntityAttribute(s.ActiveEntity, s.SymbolNumber("PartNoInBatch")) =
XLSheet.Cells(ScheduleRowno, 4).value
s.EntityAttribute(s.ActiveEntity, s.SymbolNumber("PartName")) =
XLSheet.Cells(ScheduleRowno, 1).value
s.EntityAttribute(s.ActiveEntity, s.SymbolNumber("DesiredTemp")) =
XLSheet.Cells(ScheduleRowno, 11).value
```

<u>Code to build models</u>

```
Sub create_a_model()
Dim m As Model
Dim s As SIMAN
Set m = ThisDocument.Model
Set s = m.SIMAN

Dim createmod, processmod, disposemod As Module
Dim statmod1, statmod2, routemod As Module
Dim TheRoute As route
'The code below highlights how to create a Create module and populate the
'module with data.

Set createmod = m.Modules.Create("BasicProcess", "Create", 100, 100)
createmod.Data("Name") = "Orders Enter"
```

```
createmod.Data("Interarrival Type") = "Expression"
createmod.Data("Expression") = "Expo(5)"
createmod.Data("First Creation") = "1.0"
createmod.UpdateShapes

'The code below highlights how to create a Station module and populates it
'with the appropriate information.

Set statmod1 = m.Modules.Create("AdvancedTransfer", "Station", 1000, 100)
statmod1.Data("Name") = "Beginning Station"
statmod1.Data("Statn") = "Station1"
statmod1.UpdateShapes

'The code below highlights how to create a Route module and populates it
'with the appropriate information.

Set routemod = m.Modules.Create("AdvancedTransfer", "Route", 2000, 100)
routemod.Data("Name") = "Move to Next Station"
routemod.Data("RouteTime") = "15"
routemod.Data("Units") = "Minutes"
routemod.Data("Station") = "Station2"
routemod.UpdateShapes


'The code below highlights how to create a Station module and populates it
'with the appropriate information.

Set statmod2 = m.Modules.Create("AdvancedTransfer", "Station", 1000, 1000)
statmod2.Data("Name") = "Ending Station"
statmod2.Data("Statn") = "Station2"
statmod2.UpdateShapes


'The code below highlights how to create a Process module and populate the
'module with data.

Set processmod = m.Modules.Create("BasicProcess", "Process", 2000, 1000)
processmod.Data("Name") = "Cashier Counter"
processmod.Data("Action") = "Seize Delay Release"
processmod.Data("Priority") = "High(1)"
processmod.Data("Resource Type") = "Resource"
processmod.Data("Resource Name(1)") = "Operator"
processmod.Data("Quantity(1)") = "1"
processmod.Data("Resource Name(2)") = "Cash_Register"
processmod.Data("Quantity(2)") = "1"
processmod.Data("DelayType") = "Normal"
processmod.Data("Value") = "10"
processmod.Data("StDev") = "2.5"
```

```
processmod.UpdateShapes

'The code below shows how to create a Dispose module and populate the
'module with data.

Set disposemod = m.Modules.Create("BasicProcess", "Dispose", 3000, 1000)
disposemod.Data("Name") = "Finish Order"


'This code shows how to place animated stations and a route in your
'model window.

Dim sta1, sta2 As station
Dim xarray(2) As Long
Dim yarray(2) As Long
Set sta1 = m.Stations.Create(1000, 2000)
sta1.Identifier = "Station1"
Set sta2 = m.Stations.Create(3000, 2000)
sta2.Identifier = "Station2"

'Below we define the intermediate points for the route
'If we did not define them the route path would be by default
'a straight line

xarray(0) = 1500
yarray(0) = 1500
xarray(1) = 2000
yarray(1) = 2000
xarray(2) = 2500
yarray(2) = 1500

Set TheRoute = m.Routes.Create(sta1, sta2, True, True, xarray(), yarray())

End Sub
```

VBA Code to Input Routings

```
Sub run_simulation()

Dim oArenamodel As Arena.model
Dim strmodelname As String

Call sort_routings

   strmodelname = "C:\Documents and Settings\Josep00L\My Documents\Research
Material\smart 001.doe"
```

```
    Arena.models.Open strmodelname

    'If this is set to false the model will close at the end of its run
    Arena.Visible = False

    Set oArenamodel = Arena.ActiveModel

    'set run settings

    'Number of replications the model makes
    'oArenamodel.numberofreplications = 1

    'Length of each replication
    'oArenamodel.replicationlength = 5040

    'No pop ups from arena are displyed if quietmode = true
    oArenamodel.QuietMode = True

    'Runs the Arena model
    oArenamodel.Go

    'Closes the ARena model
    oArenamodel.End

End Sub

Sub sort_routings()
'
' sort_routings Macro
' Macro recorded 07/10/2006 by mnelso
'
    Range("A2:G1500").Select
    Selection.Sort Key1:=Range("A2"), Order1:=xlAscending, Key2:=Range("B2") _
        , Order2:=xlAscending, Key3:=Range("C2"), Order3:=xlAscending, Header:= _
        xlGuess, OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom, _
        DataOption1:=xlSortNormal, DataOption2:=xlSortNormal, DataOption3:= _
        xlSortNormal
    Range("H27").Select
End Sub
```

Model Variables

Machine Shift patterns

Machine	Shift Pattern
Pre_Lapper	3_shift
Okuma	3_shift
Blohm_1	3_shift
Blohm_2	3_shift
Inspection	stand_days

3 shift	Monday 6am - Friday 6pm
Standard days	7:30am-4:00pm, lunch 42mins, 1 Fı
Standard day/night	Days 7:30am-4:00pm, lunch 42min:
	Nights 9:10pm - 7:30am, dinner 60

Overtime

Saturday	every_saturday
Sunday	every_sunday

Shift patterns
3_shift
stand_days
Stand_day_night

Overtime
every_saturday
every_2nd_saturday
every_3rd_saturday
every_4th_saturday
every_sunday
every_2nd_sunday
every_3rd_sunday
every_4th_sunday

11.5 APPENDIX E: Example of Automated model run routine

Engine Range	Comp. Num	Op No	Machine	Setup Time	Op time	Single Piece Flow	Subcontract activity
RM	11271	010	pre_lapper	10	30	n	n
RM	11271	020	okuma	30	150	n	n
RM	11271	030	blohm_1	20	150	y	n
RM	11271	040	Blohm_2	20	150	n	n
RM	11271	999	Inspection	0	15	n	n
RM	11272	010	pre_lapper	10	30	n	n
RM	11272	020	okuma	30	150	n	n
RM	11272	030	blohm_1	20	150	y	n
RM	11272	040	Blohm_2	20	150	n	n
RM	11272	999	Inspection	0	15	n	n
RT	11272	010	pre_lapper	10	30	n	n
RT	11272	020	okuma	30	150	n	n
RT	11272	030	blohm_1	20	150	y	n
RT	11272	040	Blohm_2	20	150	n	n
RT	11272	999	Inspection	0	15	n	n
RT	11273	010	pre_lapper	10	30	n	n
RT	11273	020	okuma	30	150	n	n
RT	11273	030	blohm_1	20	150	y	n
RT	11273	040	Blohm_2	20	150	n	n
RT	11273	999	Inspection	0	15	n	n

Sort Routings

Run Model