Embedding Simulation Technologies in Business Processes

Ruby Wai Chung, LAU

A thesis submitted in partial fulfilment of the requirements of
Sheffield Hallam University
for the degree of Master of Philosophy

July 2007

Abstract

The need to fully integrate simulation as a daily tool has been subject to much attention over the past few years, however little research has previously contributed to this area. This study examines the development of systematic guidelines to enable companies to strategically implement simulation as a mainstream technology within their businesses.

An extensive review of the literature was conducted in order to investigate the reasons behind the limited use of simulation and to establish the failure and success factors of companies implementing new technology. The importance of knowledge management in developing simulation technology was also investigated. Additionally, a questionnaire survey was conducted to examine the ways in which simulation technology has been used and developed within different companies. Furthermore, a case study was conducted in order to understand and investigate the processes of implementing simulation in a real organisation.

Subsequently, an easy-to-follow framework for enabling companies to embed simulation technologies into their business processes was developed. This framework comprises five key stages, namely: Foundation, Introduction, Infrastructure, Deployment and Embedding. Each stage provides a best practice approach to guide companies in achieving every objective of that stage. Adjustments to the framework were made in the validation and reliability section to reduce any limitations.

In creating a relevant and workable framework, this study has contributed significantly to the research gap established within existing simulation integration studies.

Acknowledgements

This work was conducted at Sheffield Hallam University in the UK, between October 2005 and July 2007. Throughout this period I have received countless support and help from many people, to all of whom I would like to express my sincere gratitude.

First of all, I would like to express special thanks to my project supervisor, Prof Terrence Perera, for his excellent supervision and continuous encouragement to develop this dissertation into its present form.

I would like to express my deepest gratitude to Mr David Hodgson and the people I met during my six-month research period at Caterpillar Peterlee Ltd. Thank you David for being always willing to help, for being so patient with me and for your advice and useful comments on my study.

I wish to also make a special mention to Mr. Edwin Valentine, for his helpful advice and information.

Most of all, my deepest thanks go to my parents and my brother for their unconditional love and support.

Contents

List of Tables and Figures

CHAPTER 1

INTRODUCTION

1.1 Introduction

Increasing competition, accelerating technological change and new modes of competition are forcing manufacturing companies to change their business and manufacturing processes in order to improve product quality, and reduce production costs and lead times. The reality is that business and manufacturing processes rely on complex interactions between random events, human behaviour and changing technical resources, therefore, mathematical methods are no longer robust enough to predict and analyse these processes.

Discrete-event simulation (hereafter referred to as "simulation") is a superior alternative which supports the analysis of dynamic systems through its ability to model random activities and capture the behaviour of both human and technical resources. Additionally, simulation models can be easily modified to follow changes in the real system, which can be used to understand the behaviour of a system, predict system performance, and select the best solution from a range of alternatives.

A wide range of other sectors are increasingly using simulation for analysis of queuing systems, such as hospital patient management systems, call centre systems and vehicular traffic management systems. Simulation applications and its benefits are discussed in more detail in Chapter 2.

1.2 Current status in simulation

To succeed with simulation technical skills alone are not sufficient. Sadowski and Sturrock (2006) discuss several issues which can affect the success of a simulation project. As business situations and problems become more complex, simulation studies can be easily misguided by too ambitious or ill-defined objectives. Additionally, assessing the right level of detail to support a project goal is always a challenge. Therefore, Sadowski and Sturrock suggest keeping simulation models simple; a full understanding of the target system/process can be critical. Furthermore, Sadowski and Sturrock state another important issue with simulation is the "data" – either too little data or too much data can be dangerous. McLean and Leong (2001) consider the challenge of the data format, which can involve high costs incurred by re-entering data or reformatting data between simulation and other manufacturing software applications. Various authors have endeavoured to consider this area and the concept of "standardisation" (Ingemnasson, Ylipaa and Bolmsjo, 2005; McLean *et al.,* 2003; Holst, 2001).

Additionally, several authors have considered the long-term benefits of implementing simulation as a strategic tool (Murphy and Perera, 2002; Holst, 2001). However, a review of the literature indicated that there is little evidence to support simulation as a strategic tool. In fact, simulation is still used on a one-shot basis or as a stand-alone tool, which is typically used to address very specific problems in isolation. In most situations outside consultants are engaged to develop simulation-based solutions, or project teams are disbanded after specific objectives are met, therefore this hinders the strategic use of simulation by industry today.

1.3 Why an operating guideline is important

A survey conducted by Holst (2001) recognises the need to address the problems of simulation used on a one-shot basis and suggests a guideline is essential to help companies adopt simulation and increase their level of simulation integration. Just like most new technologies, successful cases studies on implementing new technologies are always followed by a strategic approach. Several benefits of adopting a strategic approach as a guideline to implement new technologies are identified by Lientz and Bennet (2000). These are:

- more easily understood by management;
- always linked with business goals;
- greater acceptance from staff;
- clarity regarding what to do and what not to do.

1.4 Purpose of the study

If companies wish to reap the full benefit of this versatile and powerful technology, it is vital to embed simulation technologies into their business processes. Once embedded, the use of simulation would no longer be driven by individuals and enthusiasts. Instead, potential deployments would be identified and directed by business processes, enabling companies to utilise simulation as a strategic decision support tool.

However, embedding simulation into business processes should follow a systematic approach. For example, appropriate infrastructure and internal expertise need to be built gradually to embed simulation into the business process. The main aim of this study is to develop a framework to embed simulation into business processes. The proposed framework will enable companies to develop a holistic and well-structured strategy that can assist in the adoption and implementation of simulation as a mainstream technology – in much the same way as they would develop and introduce any new technology.

1.5 Aim and objectives

The aim of this study is to develop a framework to enable companies to embed simulation technologies into their business processes. This aim will be accomplished through the following five objectives:

1.5.1 Conduct a literature survey to review current practices and to identify success factors

An extensive literature survey will be conducted to identify the current practices in industry. This will attempt to identify the key drivers when companies elect to implant simulation, then how simulation solutions are developed and finally will determine the problems and difficulties companies have encountered during implementation. It will also attempt to identify why simulation projects sometimes fail and examine how companies manage the knowledge gained through simulation projects.

1.5.2 Conduct a questionnaire survey and case study with analysis to identify the key reasons behind limited implementation of simulation technology in industry

A questionnaire survey will be designed to identify the reasons behind limited implementation of simulation in industry. To supplement this information, a case study will be carried out at the collaborating company, Caterpillar Peterlee Ltd (a division of Caterpillar UK).

1.5.3 Develop a systematic approach to embed simulation in business processes by synthesizing information collated from the above exercises

Data collected from the above exercises will be used to build a systematic approach towards embedding simulation technologies into business processes. All important stages such as introduction, integration, deployment, embedding and knowledge management will be covered (further stages may be identified during the research program). Each stage will be carefully analysed to develop the best possible strategies. It is expected that this approach can present a best framework to guide companies to embed simulation technologies into business processes.

1.5.4 Conduct validation process to the proposed framework

Validation will be conducted with the aim of collecting comments about the validity and reliability of the proposed framework. This validation exercise will seek comments from academic and industrial parties who have experience in simulation. A validation form will be designed to collect feedback from this team of experts.

1.5.5 Evaluate comments and suggestions from the validation

Comments and suggestions collected from the validation will be evaluated and discussed. Then, necessary modifications will be made to the initial framework in order to finalise a best framework, which can guide companies to embed simulation technologies into business processes with a systematic approach.

1.6 Thesis Structure

This chapter places the research in context and describes the motivation for the study, it is followed by a description of the problem area, a summary of the objectives of the study and the structure of the thesis.

A literature review is conducted in Chapter 2, which aims to examine current practices and problems concerning the use of simulation in various industrial sectors. The second part of Chapter 2 provides documented evidence of the success and failure factors of implementing new technologies into business, identifying the best approaches. In addition, the importance of knowledge management as a success factor in embedding simulation into business processes is discussed in the final part of the chapter.

Chapter 3 first provides an overview of the research processes then identifies and describes the motivation and benefits of the methodology used in this study. Finally, the design issues relating to the quantitative and qualitative research methods are discussed.

The outcome and findings of the collected data from the quantitative and qualitative studies are presented in Chapter 4. A summary of the best approaches to embed simulation into business processes is presented at the end of the chapter, which will contribute to the following chapter where the proposed framework is developed.

Chapter 5 develops a framework to guide companies in the embedding of simulation into business processes. The structure of the proposed framework will be presented and each stage of this framework will be discussed in more detail in each sub-section. Then, this proposed framework will be presented to target populations from both academic and industrial fields in order to collect adjustments on the validity and reliability of the framework.

Finally, Chapter 6 will examine and discuss the results from the validation. Then, necessary changes will be made, finalising a best practice framework, which can help companies to embed simulation technologies into business processes through a systematic approach.

The structure of this thesis is illustrated in Figure 1. The chapters are shown in boxes, where the chapter under review is highlighted. For example in figure 1, "Introduction" is the chapter under discussion.

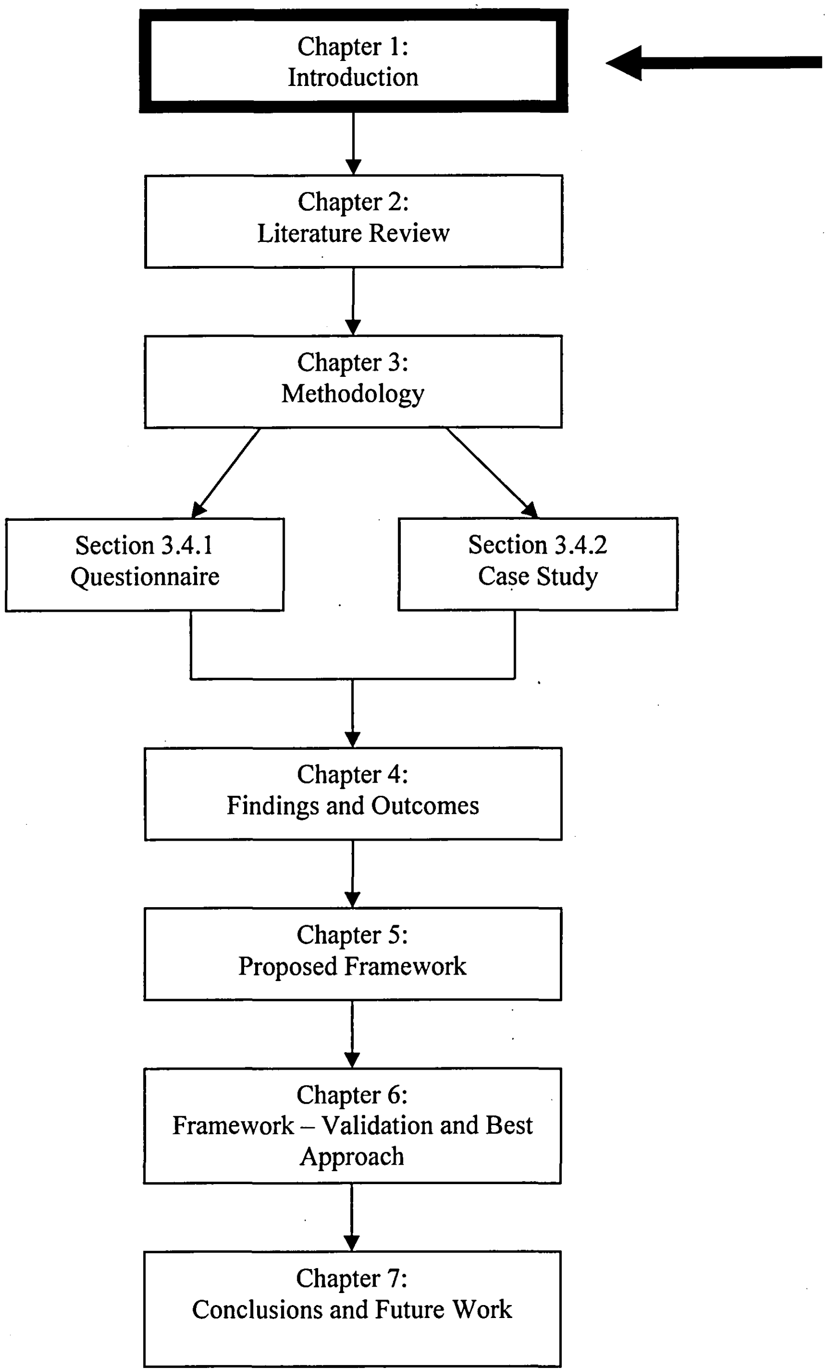
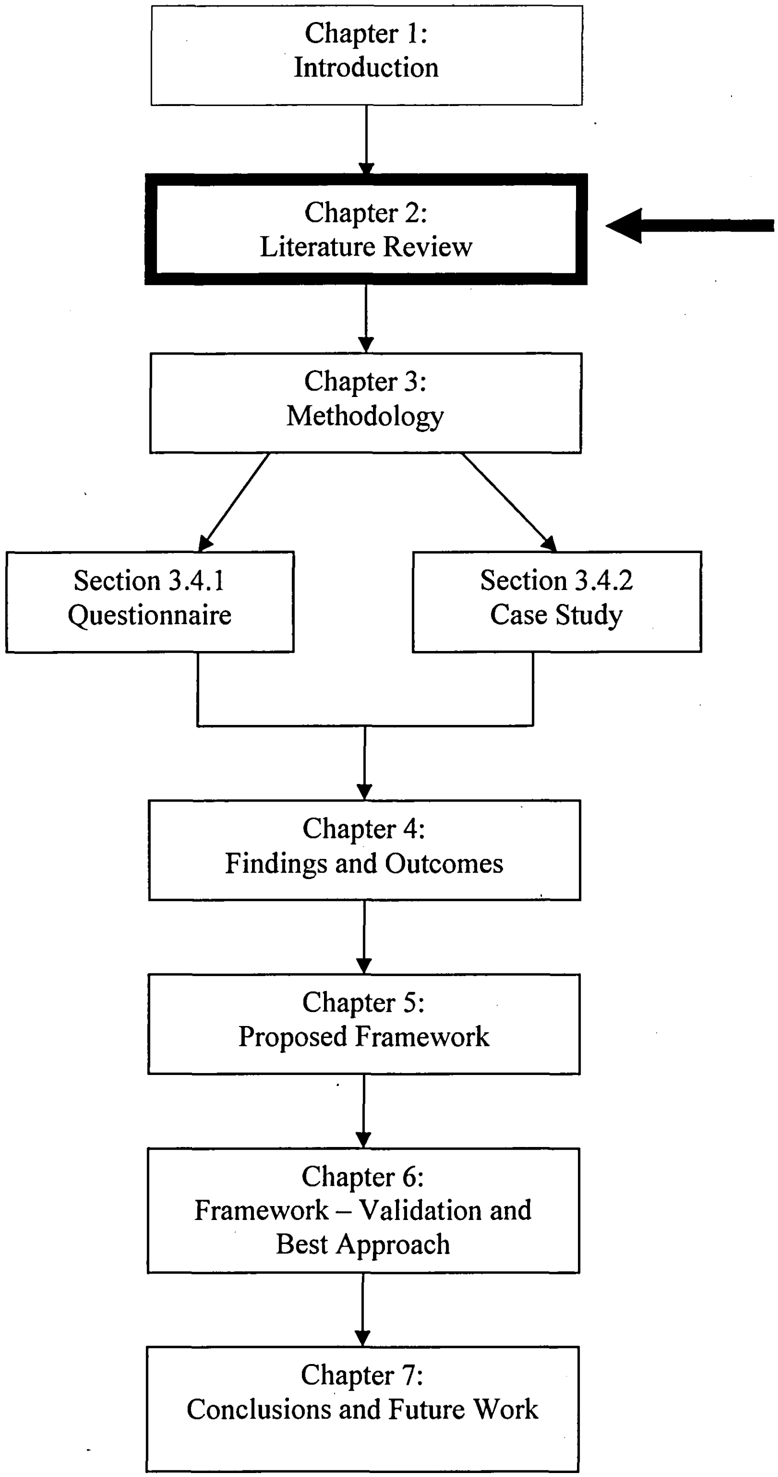


Figure 1.1: Overview of Thesis Structure

CHAPTER 2: LITERATURE REVIEW



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Firstly, this chapter examines the ways in which simulation has been used to address a variety of business problems and issues, which is followed by examples of simulation applications undertaken by different industries. Additionally, this chapter provides an insight into the reasons behind the fact that simulation is increasingly used by industries but only in a piecemeal fashion, which inspired the main focus of this study - companies have to embed simulation into their business processes, in order to reap the full benefit of this technology. A few examples of companies that have attempted to embed simulation into their business processes are also presented.

The second part of this chapter provides case study reviews on the approaches of implementing new technologies - some successful, some not so. Furthermore, this chapter discusses why management of simulation knowledge is important, and highlights the main benefit of applying Knowledge Management (KM) as a process to maintain simulation knowledge in an organisation.

Finally, this chapter reviews relevant research regarding the integration of simulation technologies and highlights the critical directions which need to be considered while developing a framework to help companies embed simulation technology into business processes. Figure 2.1 shows the overview structure of this chapter:

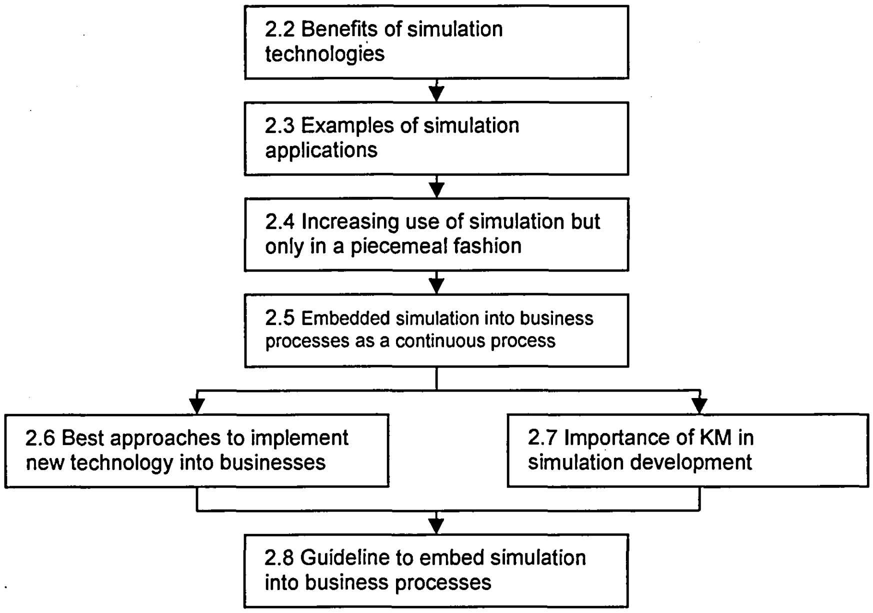


Figure 2.1: Structure of Chapter 2

2.2 Benefits of simulation technologies

Simulation has the ability to capture dynamics, variability, complexity and interconnectivity of business processes, which allows "what-if" analysis to be performed before changing a real system, therefore, it becomes a very useful decision-making tool for industries (Robinson, 2003). Many benefits from the use of simulation are evident from recent literature (Hlupic *et al.* 2005; Holst, 2001). One of the main benefits is the ability to simulate and analyse alternative changes in business processes prior to implementation. Since real changes can be risky and costly for businesses, with simulation models, effects from the changes can be tested in a more cost-effective way (Hlupic *et al.* 2005). According to Holst (2001), the benefit of the use of simulation is remarkable for manufacturing industries, such as significantly improving system knowledge, speeding up production ramp-up time, shortening development lead time, increasing utilisation or productivity, and supporting decision-making throughout an organisation.

2.3 Simulation application areas

To understand how simulation can be used to model a wide range of business processes, it is important to reference example applications. In fact, there are a number of potential areas for simulation application. Kellner *et al.* (1999) categorised them into six main areas (i.e. strategic management; planning; control and operational management; process improvement and technology adoption; understanding; training and learning). Murphy and Perera (2002) investigated manufacturing processes in more detail and defined a set of simulation application areas as follows:

- Product/assembly design;
- Physical prototyping;
- Tooling/equipment design;
- Product manufacturing;
- Product assembly;
- Human operations and tasks;
- Machine/robotic programming;
- Facility planning;
- Facility system planning;
- Training.

Based on the six simulation application areas categorised by Kellner *et al.* (1999), Table 2.1 reviews case studies about successful simulation applications and categorises them based on each of these application areas within three main industries (i.e. manufacturing, service industries and healthcare).

Simulation application areas	Simulation success stories identified by this study		
	Manufacturing	Services Industries	Healthcare
(1) Strategic management	**An Apparel manufacturing company** - used simulation to predict uncertainties on the intermediate product migration from the old national distribution centre to a new regional distribution system. [1]	**Neurology outpatients department (NOD) in a *metropolitan* hospital** - used simulation to analyse existing and future processes in order to decide which would be the best options for future business processes.[7]	**Cooper Hospital University Medical Centre** - Simulation enabled Cooper Health Systems to test new processes and investments in staff before deciding to implement "live". [12]
(2) Planning	**Ford Automotive Corporation (Brazil)** - simulated a new plant for the production of Ford's Endura engine to answer "what-if" questions. i.e. What is the optimal plant layout? What equipment will be needed? Where will we locate the needed resources? [2]	**United Parcel Service of America** – their simulation model enabled planners to schedule resources (work crews, equipment allocation) based on aircraft arrivals and departures, and package volumes. [8]	**Labour and Delivery room at Jackson Memorial Hospital** - simulation developed to plan the scheduling of patients, staffing scheduling, room scheduling and doctor's room assignment. [13]
(3) Control and Operational	**Stamping plant** - used simulation model to evaluate material handling resource utilisation and the throughput relative to press schedules, shift patterns, the number of material handling resources and storage inventory levels. [3]	**British Airways (Heathrow airport)** - a number of simulation models were built to investigate check-in facilities in order to determine desk and staffing requirement.[9]	**Coopers & Lybrand** developed a simulator that could simulate the patient cycle in a surgical ward, called OP-SIM. This can be used to formulate clear goals for patient cycles and the planning of operations. [13]
(4) Process improvement and technology adoption	**Intrax Technology Group, Ltd** used simulation to analyse material flow capacity and to consider many alternatives in order to determine the most effective way to increase throughput, decease inventory, lower overall operating expenses, and reduce cycle time. [4]	**Munich Airport** - used simulation to understand the arrival passenger flows and their way through the terminal in order to improve efficiency. [10]	**Good Hope Hospital** - developed a Care Pathway Simulator (CPS) to identify and quantify the bottlenecks within the existing processes that limited capacity. [14]
(5) Understanding	**Manufacturing** - Simulation has been used to understanding the concepts of Lean Manufacturing, i.e. systematic approach to identifying and eliminating waste. [5]	**Shell Oil company** - Simulated an oil commodities trading floor. This virtual-pipeline made the company acutely aware of a new marketplace, new behaviours and new vocabulary of value management.[11]	**Jackson Memorial Hospital (JMH)** - simulation was used to study the different flows for their labour and delivery rooms to identify the bottleneck for the inefficiency. [15]
(6) Training and learning	**Supply Chain Management learning** – study proved discrete event simulation enhances the traditional hands-on learning in supply chain management which can cover more materials and in less time[6]	**Line operational simulations (LOS)** - are commonly used for training and evaluating pilot crews under realistic conditions. [12]	**Emergency department, Hospital Kuala Lumpur** - simulation was used to perform classroom training of medical responders for airport disaster with Lumpur International airport [16]

Table 2.1: Simulation success stories summarised into six main application areas

Key to references for Table 2.1:

[1] http://www.arenasimulation.com/pdf/APRMFR-AP001A-EN-P.pdf (2001) |

[2] http://www.arenasimulation.com/pdf/fiesta.pdf | [3] Williams *et al.* (2006)
[4] http://www.arenasimulation.com/pdf/INTRAX-AP001A-EN-P.pdf (2001) |
[5] Schroer (2004) | [6] Adams *et al.* (2005)
[7] Hlupic and de Vreede (2005) |
[8] http://www.arenasimulation.com/pdf/UPSERV-AP001A-EN-P.pdf (2001) |
[9] Robinson and Stanger (1998) | [10] Fornasier (Munich airport International), (2006)|
[11] Schrage (2000) pp.184-185| [12] http://www.g-forceinternational.com/pdfs/mis.pdf
[13] http://www.arenasimulation.com/pdf/OPSIM_eng.PDF
[14] Br J Healthcare Comput Info Manage (2005)
[15] Peters *et al.* (2001)
[16] Idrose *et al.* (2007)

2.4 Increased use of simulation but only in a piecemeal fashion

Simulation has been widely used by different industries, for example manufacturing, healthcare and services industries (Table 2.1). During the last three decades, the manufacturing system has become more complex which has caused a dramatic increase in the use of simulation to design and optimise these systems (Baldwin *et al.*, 2005). Additionally, with customer satisfaction now a main concern in service industries such as banks, hospital, and call centres (Chandra and Conner, 2006), the use of simulation models for efficient staff scheduling, minimising customer waiting time, improving quality, and dealing effectively with constant change are obviously increasing within these industries.

Despite the obvious increase in the use of simulation, many companies have used simulation only in exceptional situations - few have managed to fully integrate simulation into their business processes (Robinson and Stanger, 1998; Holst, 2001; Jagstam and Klingstam, 2002; Greasley, 2004). Below some statements which support this view:

"*Many organisations have seen the use of simulation evolve, often in something of a **piecemeal fashion**.....*" Robinson and Stanger, (1998)

"......DES (referring to simulation) is used on a ***one-shot basis*** *only, troubleshooting specific problems such as bottlenecks, usually in late stages of the manufacturing system lifecycle, or as a* ***stand-alone tool****, both of which reflects a* ***low level of integration****."* Holst, (2001)

"Few companies have managed to make simulation a ***corporate norm*** *to achieve the ongoing, long-term benefits with using the technique...."* Jagstam and Klingstam, (2002)

Holst (2001) explained the reasons for this limited use of simulation.

- First of all, there is still a low level of simulation knowledge and capability in industry, which results in poor commitment to simulation projects.
- Secondly, companies seem to focus on costs rather than benefits (i.e. simulation is still viewed as a high-investment tool) often depending highly on external consultants rather than providing internal training for staff to perform this task.
- Finally, ad-hoc projects often result in poor documentation, without a good reference, the knowledge and model concept is hard to follow and redevelop. Thus, with limited knowledge, organisations often have difficulties in using simulation technologies to cope with these problems within their own limits.

Hlupic (2005) also states that there is no doubt that simulation is a powerful tool for scenario testing which can be useful in testing alternative changes before implementation. However in practice, implementation details of new management concepts are sometimes not fully specified during the early phase. Therefore, the idea of the use of simulation may be abandoned as these details are not ready for performing simulation analysis.

Four main reasons for the limited use of simulation are summarised:

- Low level of simulation knowledge and capability;
- Highly dependent on external consultants, thus the cost of the simulation project becomes expensive;
- Poor documentation in ad-hoc projects which is difficult to follow and redevelop within the company's own limits.
- No standardised format to store data which causes difficulty when developing simulation models.

It seems that this limited use of simulation is not so much related to the technology itself, but that companies are not well-prepared and lack knowledge of simulation, rendering them incapable of using this technology in a structured way and with a holistic view with regard to business processes.

Therefore, this problem leads to the following critical aim of this thesis:

To develop a framework for embedding simulation technologies into business processes.

The following few sections will contribute towards the stated aim of this work through examining the literature.

2.5 Embedding simulation into business processes

The importance of simulation integration has been noted in literature for several years (Holst, 2000; McLean and Leong, 2001; Vernadat, 1996). According to Holst (2001), the meaning of "Simulation Integration" is to integrate simulation from functional, structural, hierarchical, and procedural aspects into the manufacturing system development process. This study is concerned with *Embedding simulation technologies into business processes,* where the definition "embedding simulation" means simulation will not be only an "add on" technology to the current system, rather, it will be routinely used in the everyday work environment. Since the concept of "embedding simulation" is absent in the literature, a detailed literature review is provided which focuses on the area of simulation integration in the following sub-sections.

2.5.1 Simulation integration

Vernadat [1996, p.11] states:

"...it must be stressed that integration is a never-ending process. First, because it is a goal. Second, because the enterprise is in a permanent process of change."

Vernadat suggests there is a close interrelationship between "Integration" and "Change in business process" within an organisation - changes will never stop within companies, therefore, integration becomes a continuous process within an organisation. There is no doubt that simulation is a powerful tool to handle alternative changes. Therefore, this is essential for companies integrating simulation as a continuous process within organisations.

McLean and Leong (2001) share the same view on integrated simulation; that a continuous process is beneficial. They state that *"... major long-term benefits could result from the 'widespread and pervasive' implementation of manufacturing simulation technology...."* Here they refer to the worldwide implementation of office automation software, i.e. word processors and spreadsheets which are fitted in the characterisation of "widespread and pervasive". However, simulation technology is still not fitted.

Therefore, in order to implement simulation as a "widespread and pervasive" tool, McLean and Leong suggest companies have to develop simulation models of their own operational processes and utilise these tools routinely. Additionally, companies have to regularly include different levels of staff in simulation projects, in order to expand simulation awareness within companies.

2.5.2 The changing role of simulation

The majority of companies are still using simulation on a one-shot basis only, or do not use simulation at all. It is not easy to find companies which continuously use simulation technologies in their business processes.

Some well-known companies have attempted to integrate simulation into their business processes. For example, the big three US based companies (General Motors Corporation, Ford Motor Company and Chrysler Corporation) require all new and modified manufacturing system designs to be verified by simulation analysis before they can be approved for final equipment purchases (Ülgen, 2004). From the Boeing Company, the 777's chief engineer for digital preassembly, Henry Shomber states "*Boeing's goal, is to virtually pre-build the entire airplane in CATIA in order to resolve all design conflicts* *before actual physical assembly*" (Schrage, 2000). These examples indicate that the role of simulation is no longer seen as an ad-hoc decision-making tool, companies are attempting to use simulation on a more regular basis.

In fact, every company can have the ability to use simulation as a long-running strategy. The important factor is to learn the best approach for embedding this technology into their business processes. However, research that takes a holistic and systematic view on how this can happen is scarce, or most researchers only focus on the application side of the use of simulation. Thus, in order to examine a good approach for embedding simulation technologies into business processes, the next section will first look at the important issues when companies integrate new technologies (e.g. Enterprise Resource Planning (ERP) system, e-commerce) for references.

2.6 Integrating new technologies into business processes

2.6.1 How companies have integrated new technologies into business processes

Today, increasing competition and tougher customer demands have led companies to reduce time-to-market, and deal with shorter product life cycles and unpredictable changes in volume. As a result, companies have to integrate new technologies into their workplace in order to deal with these situations. Jessup and Valacich (2006) studied a few companies who have experience in integrating new technologies into their business processes. Some efforts were successful, but some were not! The section below shows a successful case where a company implemented an ERP system.

Successful case: ERP implementation at MANCO

MANCO is a company which produces and sells air purification equipment to commercial customers. Because of increasing customer demands, the CEO realised that there was a need to introduce a new system to remain successful. The first question was asked; *what were the objectives for introducing a new system*? Based on the objectives, the company decided to go for Enterprise Resource Planning (ERP), a package which can support relational databases and allow everyone to access data from different departments. However, before implementing this new system, the CEO found that some critical organisational changes were required which accounted for the lack of coordination and the territorial attitudes between and within each of the company's departments. Without *commitment of departments*, the new system would not be successfully implemented. Therefore, the CEO attempted to make the change from the top to bottom level, which included dismissal of the three vice presidents who were harbouring the territorial attitudes and changing the culture of the company by building the principles of quality into the employee psyche etc. Eventually, after these *initial organisational changes*, the company implemented the ERP package successfully in six stages, which included *pilot implementation and training*.

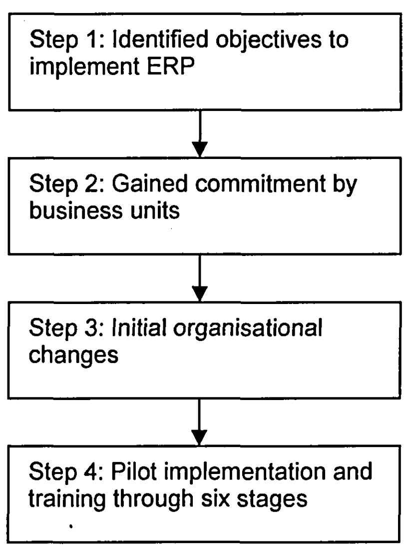


Figure 2.2 Main steps to implement ERP in MANCO (Jessup and Valacich, 2006)

By referring to MANCO's implementation approach, four main steps are identified in Figure 2.2. The key success factor in this case was to define the main objective for introducing the ERP system as a goal, then spread out and educate the organisation to fit with this new system. Lientz and Rea (2000) also support this view, they state "*it does not make sense to implement a new technology or system and leave everything else the same*", therefore, initial organisational change is critical in an implementation process.

However, different companies have different organisational issues, problems and employees. The implementation plan used by MANCO may not apply to another company. Lientz and Rea (2000) have a more holistic view on implementing new technology and use e-commerce implementation as an example.

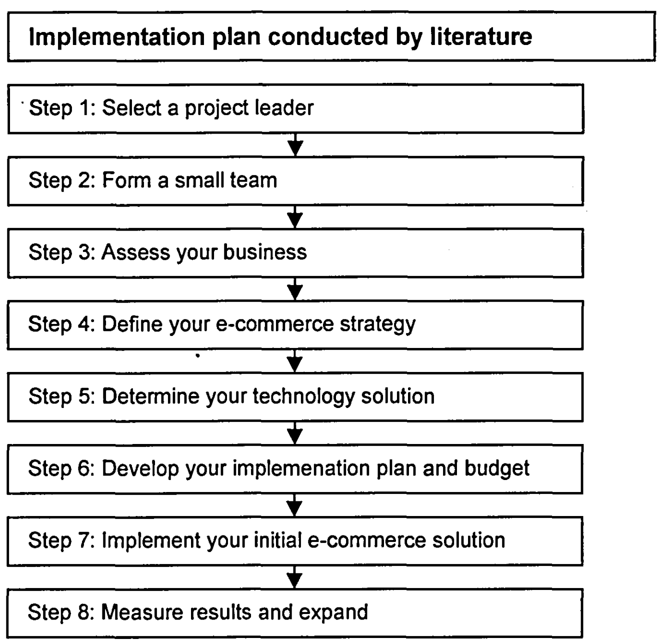


Figure 2.3 Steps in implementing E-commerce (Lientz and Rea, 2000)

Lientz and Rea (2000) state that implementing e-commerce requires a long term strategy. They suggest an eight step plan for implementing e-commerce (Figure 2.3). Details of the plan are discussed below:

- **Select a project leader and form a small team**

Lientz and Rea suggest that a good start is always important for implementing new technology. They suggest that it is important to have a project leader to guide the whole implementation process – someone who has fair knowledge of simulation technologies and has experience of the business areas. Additionally, a team of members who can support and provide opinions on long-term use of e-commerce is also essential – which can include people from the IT department, marketing, other departments who may be involved or external consultants.

- **Assess your business and define your e-commerce strategy**

Lientz and Rea suggest an organisation has to understand its current goal and position on the related market then identify what competitors are offering and what leaders in similar industries are doing. Thus, a competitive e-commerce strategy can be identified with a right direction, scope and target.

- **Determine your technology solution**

Software, hardware and internet connections are important infrastructures for an e-commerce business. Therefore, Lientz and Rea suggest reviewing and setting-up this infrastructure at an early stage - before deploying an e-commerce system.

- **Develop your implementation plan and budget**

Lientz and Rea suggest an implementation plan is essential to guide the deployment which includes different aspects - roll-out schedule, integrate e-commerce to the business processes with necessary changes, installation and setup of the e-commerce software. They also suggest the creation of a budget plan where the required or future expenses need to be carefully planned in the deployment stage. Jessup and Valacich,

(2006) also support this view, they state that many companies reported that their implementation could be more costly and time consuming than originally envisioned due to lack of planning.

- **Implement your initial e-commerce solution**

Lientz and Rea explain there are few key issues to be considered during the initial roll-out, for example testing the capability of the infrastructure (i.e. load and stress testing, monitor server response time and security), testing the web interface, modifying the current business processes to run with e-commerce and promoting the website.

- **Measure results and expand**

The last step on Lientz and Rea's implementation plan is to measure results and expand. This is important to understand and measure the current status after the initial roll-out. Businesses with e-commerce in particular, need to spend time to determine how successful the website was in attracting, retaining, and growing the customer base before further expansion so that e-commerce can be embedded into the entire business process with more confidence.

The above implementation steps of ERP system and e-commerce are valuable references for planning the questionnaire structure of this study which will be discussed in more detail in Chapter 3.

2.6.2 Main failure for integrating new technologies into business

Apart from the above successful plans regarding integrating new technologies, it is also useful to look at the failure modes which have been experienced by other companies. Figure 2.4 summarises several authors' studies on this issue (Lientz and Rea 2000, Holst 2001, Andrews and Johnson 2002, Jessup and Valacich 2006) and the fishbone diagram is used to describe the key failures of integrating new technologies.

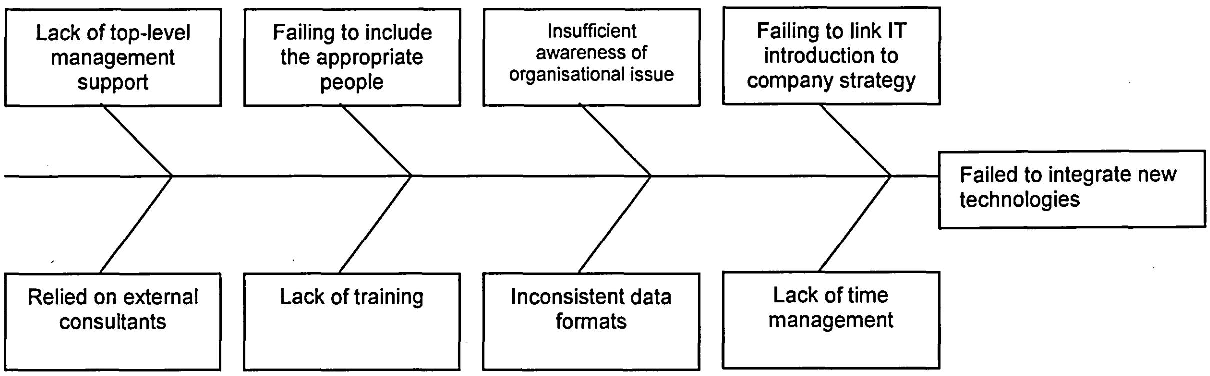


Figure 2.4. Key failures of integrating new technologies (source: Lientz and Rea 2000, Holst 2001, Andrews and Johson 2002, Jessup and Valacich 2006)

1) Lack of top-level management support

It is critical that top-level executives understand the importance of the new technologies or systems so that necessary resources can be supported. Otherwise, they will never view the technologies as a priority within the organisation (Lientz and Rea 2000, Jessup and Valacich 2006).

2) Heavily reliant on external consultants

Companies usually do not want to invest in employing specialists on-site; most of them heavily rely on external consultants. This causes a problem when applications go live and the consultants are no longer there; users are often unable to deal with the system by themselves (Andrews and Johnson 2002, Jessup and Valacich 2006).

3) Lack of training

Performance problems often arise after a new technology or system goes live, as users do not have enough training on the new technology. Therefore, the new technology is not able to perform effectively (Lientz and Rea 2000, Holst 2001, Jessup and Valacich 2006).

4) Failing to include the appropriate people

The end user is usually only involved in the last step of implementation; they have no say in the whole process. Management may lose valuable opinion from this group of users. This may also cause a problem in that users may refuse to use the new technology, in extreme cases, this may cause conflicts and inefficiencies within the organisation (Lientz and Rea 2000, Andrews and Johnson 2002, Jessup and Valacich 2006).

5) Inconsistent data formats

Integrated new technology can be difficult if the required data is spread in various application systems and in inconsistent data formats (Holst 2001).

6) Lack of time management

Implementing new technology can often make a negative effect on the organisation (rather than the intended positive effect), if the "time" is not managed well during the implementation process. As a consequence, delay in implementation can cause a loss of confidence, direction and goal (Holst 2001, Andrews and Johnson 2002).

7) Insufficient awareness of organisational issues

Business processes, individuals and departments all interact with each other within an organisation. If they are unaware of the impact when implementing new technology, it may affect the whole performance of an organisation (Lientz and Rea 2000).

8) Failing to link IT introduction to the company strategy

Implementing new technology without linking it to the company strategy can cause a problem as well. Company strategy is a goal; however, new technology cannot perform with good benefits if it does not relate to the main goal (Jessup and Valacich 2006).

2.7 Knowledge management in embedding new knowledge

When implementing Knowledge Management (KM) into new technology implementation processes, it plays an important role in collecting new information, new experience and new knowledge and then maintaining and sharing them within the organisation. Liebowitz and Megbolugbe (2003) state:

"Once the critical knowledge is identified and captured, it is typically shared with others. Those individuals then apply this knowledge and internalise it to their situation, which in turn creates new knowledge. This 'new' knowledge is then captured, shared, applied, and the cycle continues."

Holst (2001) states that one large Swedish manufacturer faced the problem; simulation was introduced and began to be used by internal staff, however, once those staff left, the company then stopped using simulation without any replacement. In addition, since simulation is still used as ad hoc projects, good documentation is usually absent and any simulation model is hard to follow and reuse. Knowledge of simulation then disappears and awareness of simulation decreases to nothing.

Caterpillar Inc. claimed that one of the main purposes of implementing KM was to capture the expertise of experienced workers before they left the organisation (Ardichvili *et al.* 2003). This reduces the risk of knowledge loss from an organisation and keeps this "cycle" continuous. This is especially important for capturing and maintaining knowledge from new technologies used.

2.7.1 How to implement KM to help embed new knowledge into business processes

Malhotra (2005) establishes from his studies that KM can include building databases, measuring intellectual capital, establishing corporate libraries, building intranets, sharing best practices, installing groupware, leading training programs, leading cultural change and fostering collaboration by creating virtual organisations. However, it is essential that the organisation picks the right KM tools and educates their employees in order to be able to commit to it.

Greasley (2004) reports a company in which several stand alone simulation applications were deployed but the company failed to utilise knowledge gained through these projects to develop a strategic approach to implement simulation based solutions. Therefore, if KM can implement and successfully embed, there is no doubt that it can help the development of simulation technologies. In Chapter 5, this thesis will examine the benefits and look at how KM can be included as one of the steps in the framework to embed simulation technologies into business processes.

2.8 Framework to guide embedding simulation technologies into business processes

In conclusion to the above sections, it is evident that the evolution of simulation technologies should be changed from a one-off project fashion into a long-running strategy approach. In order to gain the full benefits of simulation technology as mentioned in section 2.2, the literature has shown that it is important to embed it into business processes as a continuous strategy.

In addition, by referring to other new technologies implemented into organisations as a long-running strategy, literature evidence was provided to support the argument that a holistic plan is necessary to guide the implementation processes. Apart from this, organisations have to understand and address knowledge management issues which relate to the long-term use of simulation within an organisation.

When combining all the above critical issues from the literature, they contribute to the objective of this study which is:

To develop a framework to embed simulation technologies into business processes.

2.8.1 Direction of the framework

Holst (2001), who has proposed a strategy for integrating simulation into the manufacturing system development process, believes an integration plan should emphasise two important points: (1) the view on integration as a continuous process and (2) the need for a structured approach. According to Holst (2001), this framework for guiding the integration has to be carefully planned and needs to be used as a continuous strategy.

This leads into a discussion on the direction of the framework. Holst (2001) examines this point based on theoretical findings and industrial experience, then suggests three directions:

(1) Generic as opposed to particular: the concept of simulation integration should be applicable across a wide range of manufacturing enterprises;

(2) Holistic as opposed to reductionistic: simulation integration should consider integration from all aspects, just as the manufacturing system and product realisation process should be seen from all its perspectives and over its entire life cycle;

(3) Structured as opposed to ad hoc, unplanned and evolutionary courses of action: ways of implementing simulation integration should provide stepwise, easy to understand, easy to use, well-documented guidelines that are easily adaptable to a specific organisation.

Jagstam and Klingstam (2000) differentiated contributory factors for embedding simulation technologies into the business processes. They found that the main challenges in the continuous use of simulation are technological, operational and organisational issues. They suggest the guidelines should overcome these three main challenges as a goal. Table 2.2 summarises the issues of the challenges in these three main aspects.

Technological challenges	• lack of simulation data ready within company • difficult to decide whether simulation is the right tool for solving the task among management level
Operational challenges	• lack of connection to the business development processes • not easy to use
Organisational challenges	• large efforts to spread simulation within the company via education or training

Table 2.2 Summary of three main challenges towards the integration use of simulation

On the other hand, there are several studies suggesting best practices for the continuous use of simulation technologies (Murphy and Perera, 2001; Williams, 2002; Holst, 2001). Murphy and Perera (2001) examine current best practices of US companies in the use of simulation applications. They then explain these best practices as entailing four stages: Introducing simulation, establishing simulation, practising simulation and developing simulation. In a study conducted by Morgan and Liker (2006) about the success of the Toyota product development system, they built a framework with "people", "process" and "technology" as three main elements which need to be interrelated and interdependent, and work with organisational issues to achieve success. This interprets the important relationship between people, process, technology and organisation.

In addition to the four stages of best practices identified by Murphy and Perera (2001); in Table 2.3, this study will include "people dimension", "technological dimension" and "organisational dimension" as a theoretical framework to gain a better understanding on the issues related to embedding simulation into business processes.

"Best Practices" of simulation used in US		Dimensions
Introducing simulation	• Build confidence and support of management	*"Organisational"*
	• Build a team of experts and engineers	*"People"*
	• Comprehensive software selection • Communication with software vendor	*"Technological"*
Establishing Simulation	• Promote simulation enterprise-wide • Separate budget for simulation activities within projects • Integration of simulation as part of the business process	*"Organisational"*
Practising Simulation	• Develop a model interface to separate the use of model data • Link model data with other system/database • User library of generic model constructs/templates • Reuse models, coding and logic • Use programming language (VB, C++)	*"Technological"*
	• Educate all simulation users to perform experimentation procedures	*"People"*
Developing Simulation	• Provide simulation training in model building and project management • Develop simulation introduction pack for new team members • Share knowledge and expertise amongst team members	*"People"*
	• Set standards in the use of simulation by implementing project procedures	*"Technological"*

Table 2.3 Incorporation of People, Technological, and Organisational dimension with the "best practices" of the used of simulation (Source: Murphy and Perera, 2001)

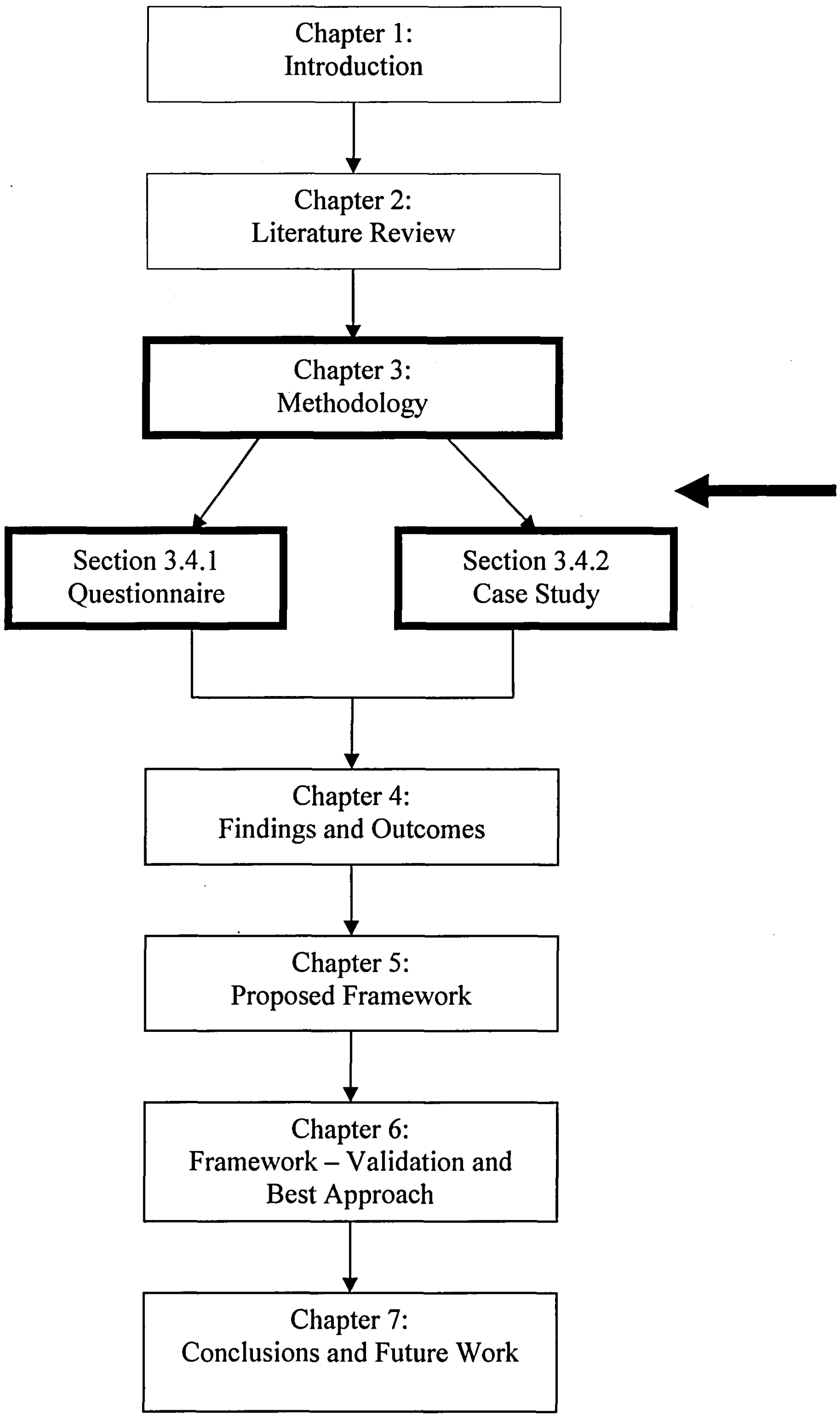
2.9 Summary

The main aim of this chapter was to review the available literature to identify the current practices of the use of simulation for only ad hoc and stand-alone projects, and to identify a need for developing a framework to overcome this situation and to embed simulation technologies into business processes as a continuous strategy. This chapter first gave an overview of the benefits on simulation, and then, through case studies, outlined successful simulation applications from manufacturing, service industries and healthcare and thereby proved the capabilities and benefits of simulation through a realistic picture. This was followed by a critical review of literature on the piecemeal fashion of simulation technologies, which concluded that it is necessary to seek to embed simulation into business processes as a continuous strategy.

By referring to the success stories of implementing other new technologies, key stages of the implementation plans were identified, which will contribute to the design of the survey's questionnaire in Chapter 3. In addition, both failure and success factors of integrating new technologies were reviewed. The literature review also considered the importance of the role of knowledge management in embedding new technology within an organisation.

This chapter emphasised the need to develop a framework to embed simulation technologies into business processes with a strategic focus and plan. This framework has to be "generic", "holistic" and "structured", and consider factors in "people", "technological" and "organisational" dimensions.

CHAPTER 3: METHODOLOGY



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter defines the methodology used in this study. Based on the research objective which was identified in Chapter 2, this chapter seeks to develop and employ the "right" research methodology so that the data collected will be "right" for contributing to the research objective. The structure of the rest of the chapter is as follows:

Section 3.2 - Research Process

This section describes the approach to the study and the aim and objectives of every stage within the approach.

Section 3.3 - Research Methodology

This section defines the methodology used in the study and the motivation for the use of a mixed methods approach.

Section 3.4 - Research Design

After identifying the reasons to use questionnaire survey and case study as the methodology in the study, this section highlights the important issues regarding the questionnaire design and the case study.

3.2 Research Process

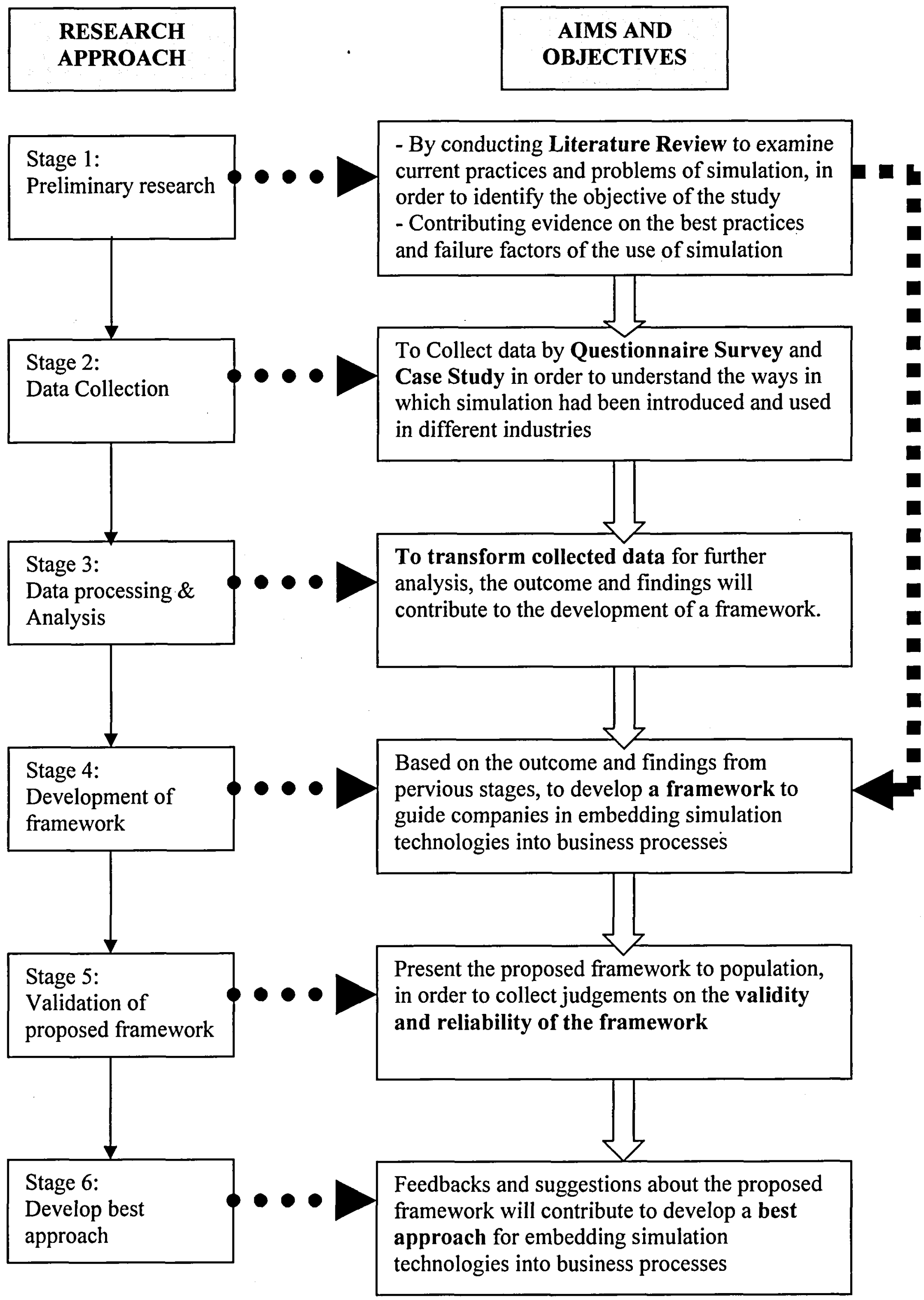


Figure 3.1 Overview of research process

3.3 Research Methodology

Most studies are restricted to either quantitative or qualitative research method. However this situation has changed with the emergence of the mixed methods research. Mixed methods research is formally defined by Johnson and Onwuegbuzie (2004) as "the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study". According to Johnson and Turner (2003), "the fundamental principle of mixed research should collect multiple data using different strategies, approaches, and methods in such a way that the resulting mixture or combination is likely to result in complementary strengths and non-overlapping weaknesses." This study also intends to collect data by mixed methods research, which includes both quantitative and qualitative studies.

The reason for using mixed methods research in this study is to take a holistic and systematic view to collect, identify and analyse the issues related to develop a framework to guide companies in embedding simulation technologies into business processes. One of the advantages of questionnaire surveys as a quantitative method is, as Bartlett, Joe and Chadwick (2001) states, "their ability to use smaller groups of people to make inference about larger groups that would be prohibitively expensive to study." Therefore, questionnaire survey is identified to be the best way to collect the majority of experiences and practices related to the introduction, development and deployment of simulation. However, Yin (2003) comments that if "such questions deal with operational links needing to be traced over time, rather than mere frequencies or incidence", then qualitative methods have to be performed. Therefore, an additional case study is carried out in order to examine and review how simulation activities are happening in a real company - decisions of why simulation was taken, how simulation was implemented and with what result.

3.4 Research design

Yin (2003, p.20) described research design with three explanations. The one that best illustrates this particular section describes research design as a "blueprint of research, dealing with at least four problems: What questions to study, what data are relevant, what data to collect, and how to analyse the results." This study uses mixed research approaches via questionnaire survey and case study to collect appropriate data to support the objective of this study. The following sections focus on the issues of questionnaire design and the background of the case study.

3.4.1 Quantitative - Questionnaire Survey

The main objective of the questionnaire survey is to understand the ways in which simulation technologies has been used and introduced in different companies.

The questionnaire was designed with two formats – word document format and web format. It is considered that the target respondents are mainly from management level with technical backgrounds (i.e. this group of people tend to be extremely busy with their jobs and questionnaires would not be entirely welcome). In order to minimise survey non-response, an online questionnaire was created as another option for respondents. The reasons to use online questionnaire as another choice are: it is comparatively easier and quicker to complete without opening and saving an attachment, and there is no need to notify the opposite party when finished.

One hundred questionnaires were sent out to UK, Netherlands and Hong Kong companies. The overall response rate was 30% after a follow-up to the non-respondents from the first round. A sample of this questionnaire is attached in this thesis as Appendix A.

3.4.1.1 Layout and Sections

According to Yin (2003), the layout of a good questionnaire should be clear, and easy to navigate. This questionnaire organises along 6 sections, with each of them having a brief explanation of its purpose:

(Section 1) - Your business

(Section 2) - Introduction and exploration of potential use

(Section 3) - Pilot project/ first experience

(Section 4) – Infrastructure and communication

(Section 5) – Deployment and standardisation

(Section 6) - Plans to use simulation in the future

The first section aims to understand the background of the respondent's company and to gauge the population of the use of simulation in general.

From Section 2 to Section 5, only companies with current or past simulation experience need to answer. Section 2 aims to examine how aware companies are of simulation technologies and with what results. According to Jessup and Valacich (2006), it is important to experience on a new technology by pilot project before implementing to an organisation. Therefore, Section 3 designed to gather related information about companies with pilot project experience.

Section 4 and 5 deal with the issues related to development and deployment of simulation. Apart from identifying the preferences of companies to use either internal expertise or external consultants to build simulation models, these sections examine the issues of knowledge management, in order to understand the ways companies had reused simulation knowledge, models or data.

The last section aims to understand the future plan of companies in the use of simulation. Those companies with no simulation experience are expected to answer this section for statistical purposes.

3.4.1.2 Issues considered in questionnaire design

According to Yin (2003), "closed questions" can avoid unsatisfied answers so that respondents have to choose only from a list of given options. Therefore, apart from "Yes or No" questions, "closed questions" are designed in the questionnaire in order to collect more reliable answers.

However, the given options may not describe the whole picture - respondents may have experiences other than the given options. Therefore, additionally, an option "Other, please specify..." is applied for most of the questions in the questionnaire.

3.4.1.3 Pretest of questionnaire

According to Yin (2003) and Creswell (2003), it is important to do a pretest for a completed questionnaire before distributing to respondents. For this reason the final questionnaire was sent to four types of professional people for validation: Professor, Ph.D. student, researcher and black-belt manager - all with a certain level of simulation knowledge. Below the key points collected from the validation:

- Structure of the questionnaire
- Grammar/ vocabulary
- Comments on the choice of given answers

Based on their comments, changes were made in the final version. However, it should be noted that these responses were only for pretest use - no results were carried over to the actual analysis of this questionnaire.

3.4.1.4 Statistical analysis

A study conducted by the United States General Accounting Office (GAO) regarding the methods for analysing quantitative analysis states that "Statistical analysis is the manipulation, summarisation, and interpretation of quantitative data."

Using quantitative analysis usually includes answers in the form of Descriptive Statistics (Creswell 2003). Descriptive statistics can be divided into three main forms according to the GAO study (1992):

1) Determining the central tendency in the distribution of a variable;
2) Determining the spread of a distribution;
3) Determining the association among variables.

The results gathered from the questionnaire survey were analysed based on these three forms of descriptive statistics. Specific measures are outlined below:

- Central Tendency: Means, Median, and Mode
- The distribution: Histogram, pie chart
- Association among variables: tables a percentage of the total population

Details of the survey outcome and findings that complemented with statistical measures are discussed in Chapter 4.

In addition, Inferential Statistics were employed throughout the analysis to try to infer from the sample data what the population might be like. Thus, inferential statistics were used to make inferences from the collected data, extrapolating to more general conditions. Descriptive statistics were used simply to describe what is going on in the collected data.

3.4.2 Qualitative - case study

The case study that followed was conducted to look into:

- Defining current practices and understanding of simulation within the case study company
- Identifying problems and requirements to implement simulation technologies within the case study company

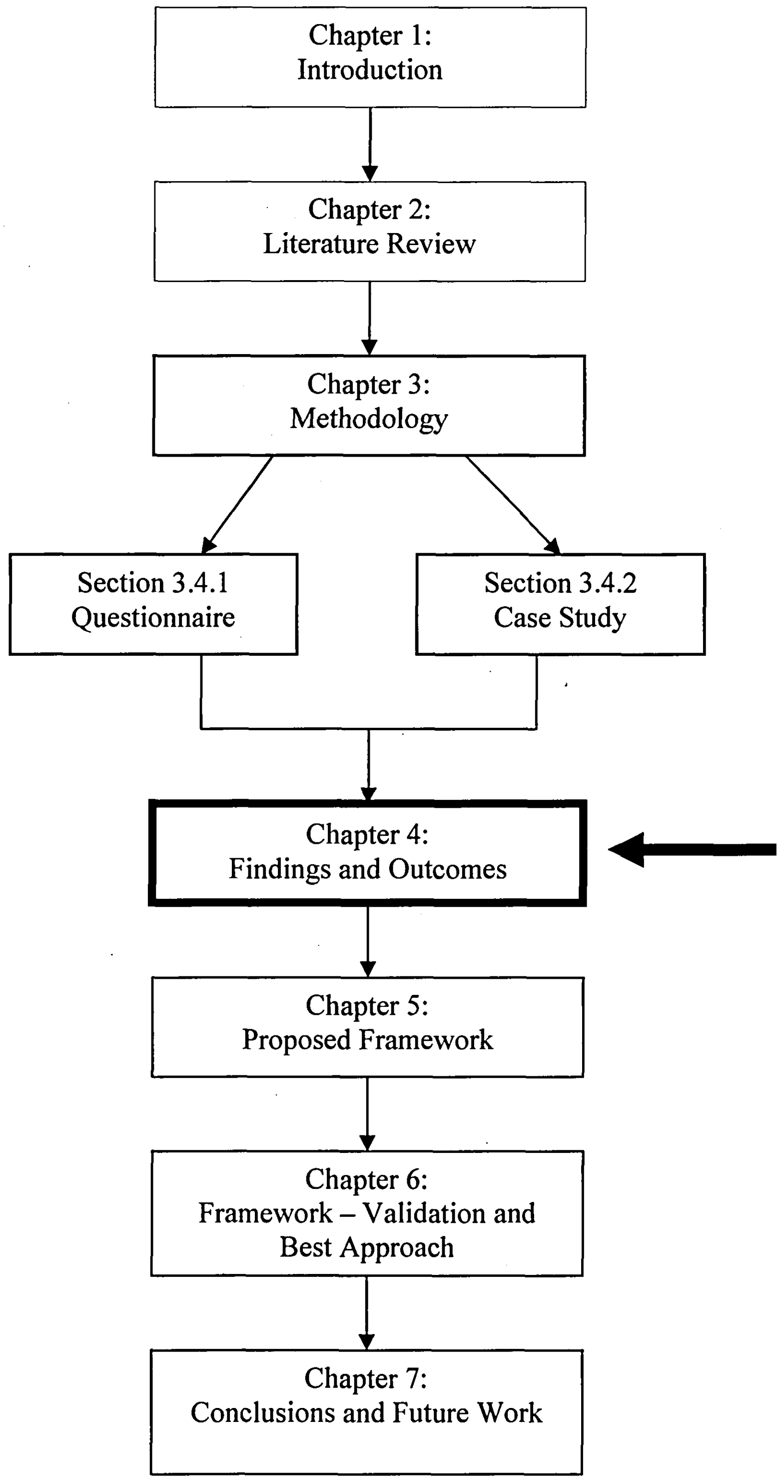
From October 2005 to April 2006, the author worked with Caterpillar Peterlee Ltd (hereafter referred to as "CAT") - a division of Caterpillar UK, the sole manufacturer of Articulated Trucks as a research fellow to support CAT to embed simulation technologies into their business processes. The main objectives of the research were:

- To conduct a questionnaire survey, in order to examine the ways in which simulation technologies had been affecting CAT's employees and CAT's change management.

- To work with CAT's management identifying opportunities to use simulation, building simulation models and supporting model experiments.

The results and analysis for the case study will be discussed in Chapter 4 in more detail.

CHAPTER 4: Findings and Outcomes



CHAPTER 4

FINDINGS AND OUTCOMES

4.1 Introduction

The first part of this chapter presents findings and outcomes of the questionnaire survey, which complemented with statistics measures and inferential statistics. This part of the analysis is started with a classification of the responding companies, which is based on their nature, size and experience in simulation. After that, the following sub-sections present the findings and outcomes in five main issues:

- Introduction of simulation
- Pilot project/ First experience
- Infrastructure and communication
- Deployment and standardisation
- Plans to further use on simulation

The second part of this chapter discusses and examines the author's research work in CAT. Firstly, this part identifies the objectives of the research work, which is followed by a discussion on the work that has achieved: 1) questionnaire survey and 2) introduced simulation technologies into CAT. Additionally, positive points and difficulties which were learnt and experienced are highlighted at the end of this section.

Finally, Table 4.4 summarises and compares the best practices and the key issues in embedding simulation technologies into business processes, which had been discussed in the literature review (Chapter 2), qualitative and quantitative studies of this chapter.

Quantitative Study

Note: The sample of the questionnaire can be found in Appendix A.

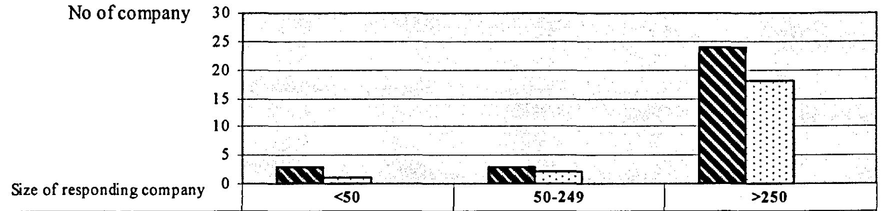
4.1.1 Section 1 – Classification of the responding companies

Nature of Industry	No of companies
Aerospace	1
Automotive	3
Biotech	-
Chemical	1
Steel	1
Shipbuilding	-
Electronics	1
Pharmaceuticals	-
Food & Beverages	4
General Manufacturing	4
Business Services	-
Consultant Service	3
Health Sector	-
Hospitality & Leisure	-
Transportation	2
IT & telecoms	1
Education	-
Other	9
Total	**30**

Table 4.1 Total number of responses based on each industrial nature

Responses to the questionnaire were sought by direct and indirectly invitations. Emails were sent to those companies who worked on simulation project with the university, asking recipients to contribute as well as to distribute the questionnaires to their other contacts, these companies includes companies from the UK, the Netherlands and Hong Kong. 30 responses to the questionnaire were received. Table 4.1 shows the total number of responses based on each industrial nature.

The responding companies vary in size from less than 50 employees to more than 250 employees, the majority (> 80%) of the responding companies were large companies with more than 250 employees. Figure 4.1 shows the number of responding companies in relation to their size and their experience in simulation.



Size of responding company	<50	50-249	>250
responding company	3	3	24
with simulation experience	1	2	18
with simulation experience in %	33%	66%	75%

Figure 4.1 Number of responding companies classified by their size and experience in simulation

From this outcome it seems that the percentage of the responding company with simulation experience is proportional to the company size, i.e. the larger the size of a company, the higher the percentage of companies with simulation experience.

4.1.2 Survey results

Section 2 to section 5 of the questionnaire is designed to ask questions for the companies with simulation experience - either with present or past experience. Therefore, those responding companies with no simulation experience are not calculated in the following statistic analysis (i.e. 21 out of the 30 responding companies with simulation experience).

4.1.2.1 Section 2 - Introduction and exploration of potential use

Section 2 of the questionnaire examines the ways in which simulation has been introduced into companies.

Decide to use simulation by internal decision

In Figure 4.2, the result shows that more than half of the responding companies (63%) had chosen: simulation was identified as an appropriate tool for problem solving. Only 3 % of the responding companies had chosen: simulation was encountered at an external event. This figure shows that the decision to introduce simulation technologies into the responding companies was mainly influenced by internal suggestion.

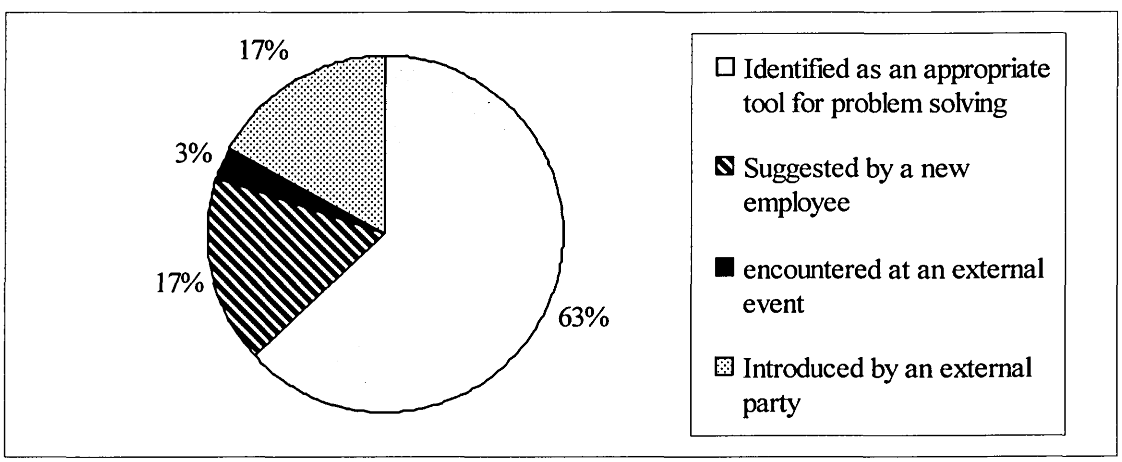


Figure 4.2 Percentage on the ways simulation introduced to the responding companies

Build internal simulation team

On the other hand, by the findings illustrated in Figures 4.3, and Figure 4.4, it is found that the majority of the responding companies introduced simulation via forming an internal team, which the team either has one or more members with previous simulation experience (44%) or the members were sent to external events for simulation training (39%).

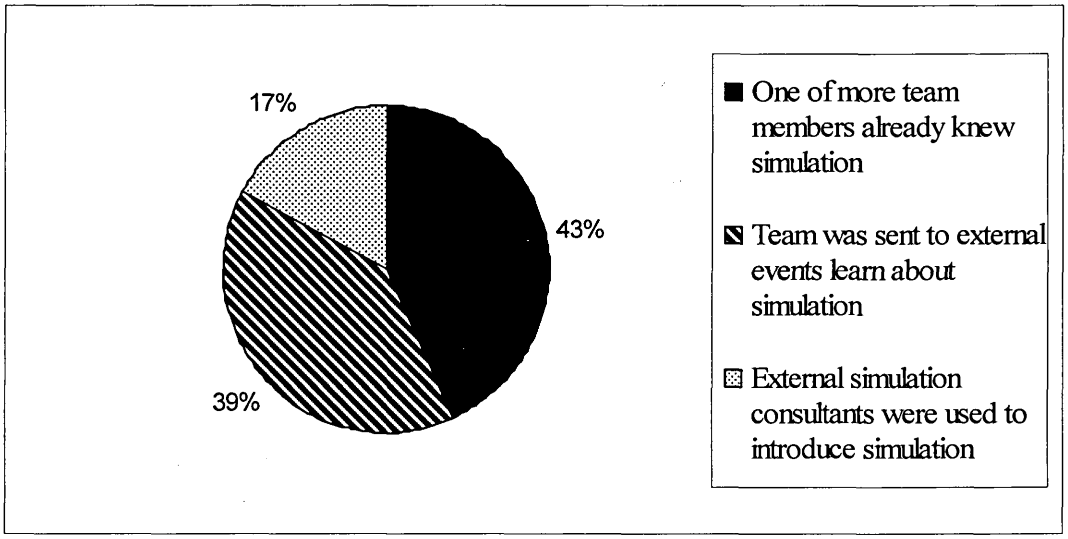


Figure 4.3 Percentage on how simulation team developed simulation knowledge

Involve external consultants

Although the result shows that the responding companies were not heavily reliant on external consultants for introducing simulation, by referring to the data show in Figure 4.4, over 70% of the responding companies still require a certain level of support from external consultants. Question 2.4 examines the main reasons behind this finding. It is found that these companies need the support of external consultants mainly because: 1) they can provide supportive case studies; 2) they can provide estimation on the cost issues; 3) they can advise the simulation team the ways to promote and identify potential applications.

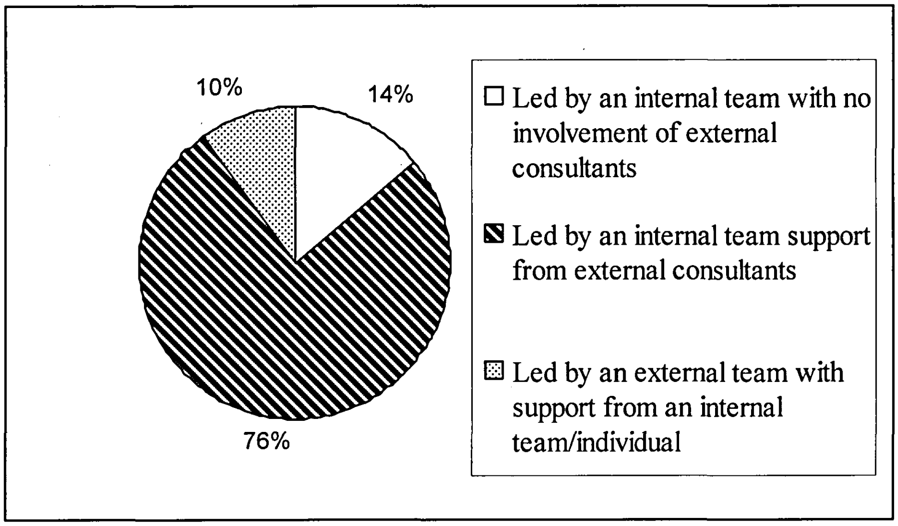


Figure 4.4 Percentage of the choice of responding companies to use either internal team or external consultants for introducing simulation

<u>Key objectives of the introduction stage</u>

Question 2.5 asked about the key objectives of the introduction and exploration stage. Figure 4.5 summarises the responding answers into 7 key objectives, where the point of the arrow represents the most common objective while the base of the arrow represents the least common objective.

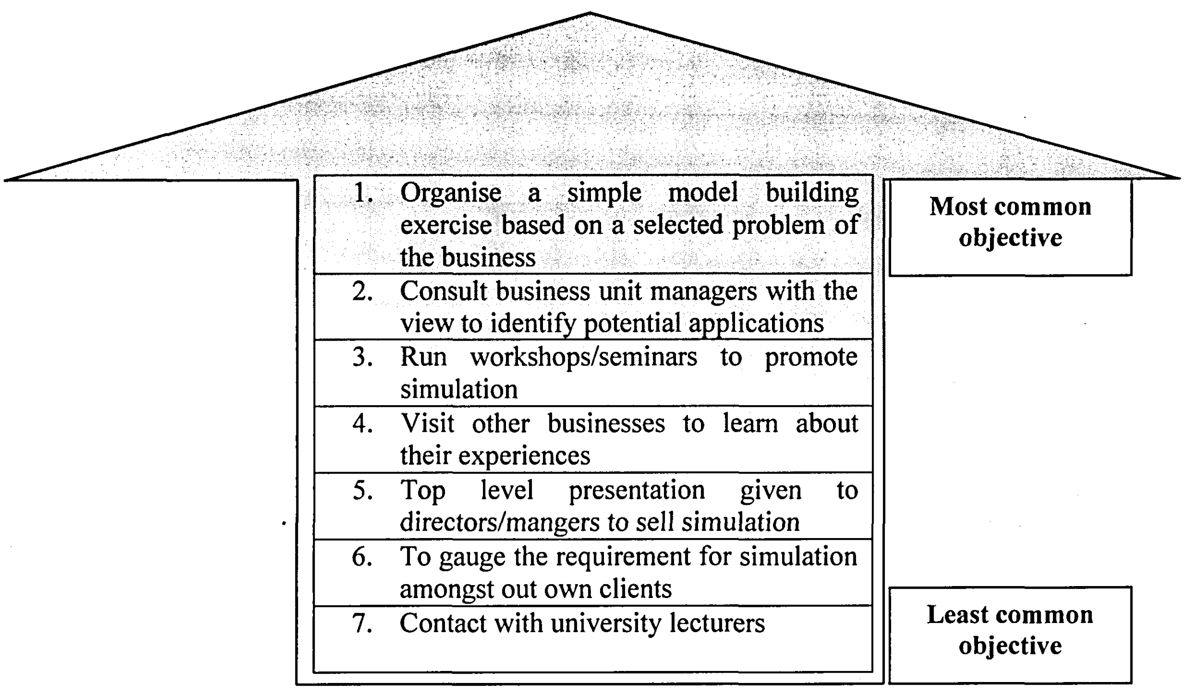


Figure 4.5 Rank of Importance of the identified objectives in the introduction and exploration stage

Outcome on this stage

The above questions focus on two things: 1) the ways in which simulation had been introduced, 2) the key objectives of this stage. Additionally, in Question 2.6, it asked about the main outcome of this stage. Overall, more than half of the responding companies (57%) would happy to proceed and introduce simulation, but only in a limited area of business, 33% of the responding companies would agree to proceed and introduce simulation across the business, and then, 10% of them would just agree to proceed after a successful pilot project (Figure 4.6).

Furthermore, as there is no response in rejecting the continuous use of simulation after the introduction and exploration stage, it is fair to assume that this stage is necessary and important for the embedding process.

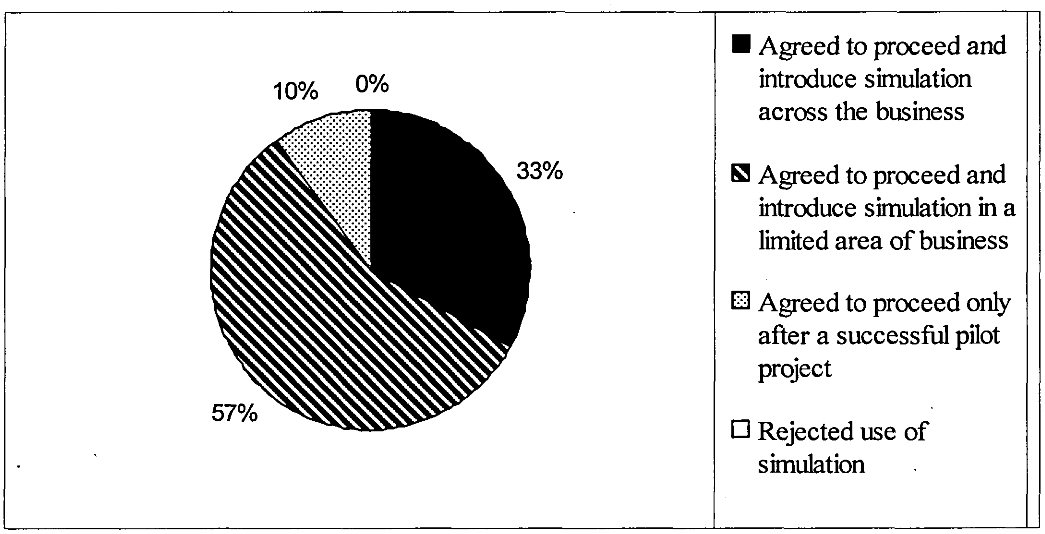


Figure 4.6 Percentage on the actions to continue the use of simulation after the introduction stage

4.1.2.2 Section 3 - Pilot project/first experience

This section of the questionnaire examines the issues regarding the use of pilot project or the first simulation project.

Scope of simulation models in pilot project/first experience

Question 3.1 asked about the scope of the simulation models in pilot project or the first project. Figure 4.7 shows that a higher number (12 responses) of the responding companies used simulation models for determining or analysing a process bottleneck. On the other hand, there is a high number of responses (11 responses) that show they used simulation models: 1) to optimise an existing resource or process; 2) to design or to analysis factory layouts, equipment decisions and operating policies.

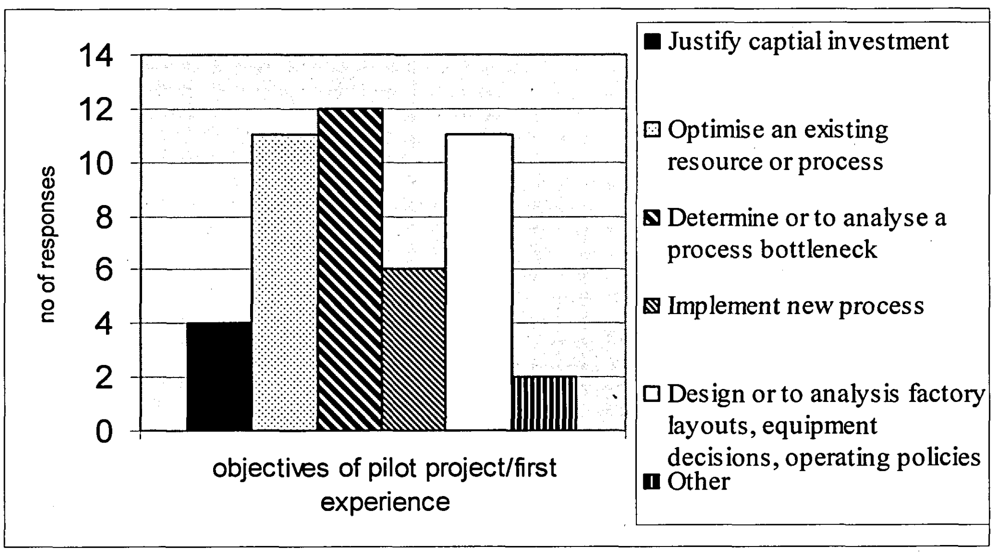


Figure 4.7 scope of pilot project/first experience

Simulation Packages

Figure 4.8 shows simulation packages that were used by the responding companies in the pilot project or the first project. The result shows that higher percentage (42%) of the responding companies used ARENA simulation package. Additionally, Question 3.3 was asking about the reasons for choosing the specific simulation package, the result is summarised into two main reasons: 1) the package was recommended by external consultants; 2) the package was recommended by current team member, mainly because of their experiences in a specific package.

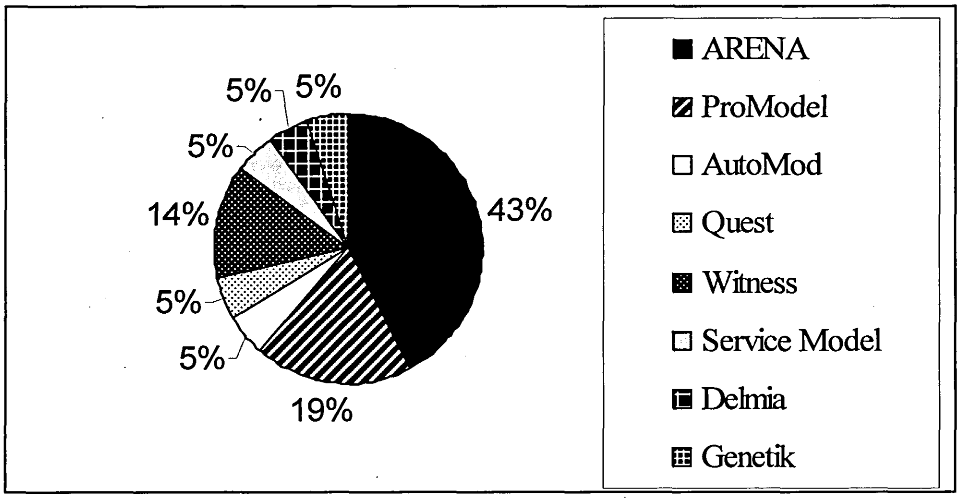


Figure 4.8 Software package used by responding companies in pilot project/first experience

Challenges during the first simulation project

Question 3.4 asked about who developed the first simulation model. The result is summarised in Table 4.2, in which nearly 50% of their first models were developed by external consultants and nearly 50% of them were developed by internal team members. Additionally, Question 3.5 was asking the companies to rank from five challenges, which may be encountered during the first simulation project. Table 4.2 illustrates the result of calculating the average of the collected rankings (i.e. 1 - 5) for each challenge, and then, presents them into two groups: (1) External - companies who used external consultants to build the first model; (2) Internal - companies who used internal team members to build the first model.

	Average of ranks (averages: 1-5)		
Model Builder	**External consultants**	**Internal team**	**average from both**
Deciding the level of detail	3.6	2.4	3
Data collection/Software issues	3.1	3.5	3.3
Model building	3.3	3.1	3.2
Analysis and interpretation	3.6	**3.8**	**3.7**
Communication between model builders and problem owners	**3.8**	2.9	3.4
The number in **Bold** is the major challenge among the column of analysis			

Table 4.2 Average of ranks of the challenges during the first simulation project by responding companies

In Table 4.2, the figures show that "*communication between model builders and problem owners*" was the major challenge during simulation projects, which identified by the external group. On the other hand, the internal group identified "*analysis and interpretation*" was the major challenge during simulation projects.

Further analysis considers the average number of the rankings between the external and the internal groups (Last column in Table 4.2). The final figure shows that "*analysis and interpretation*" was the major challenge during simulation projects. Therefore, it is believed that this type of training and support is important and necessary for both groups of the companies.

Outcome on this stage

Question 3.6 asked about the satisfaction on the outcome of the pilot project or first simulation experience. Figure 4.9 shows that 86% of the responding companies were satisfied with the outcome and decided to proceed with further applications. Therefore, it is assume that this stage (i.e. pilot project or first simulation experience) is critical and important in embedding simulation technologies into the business processes.

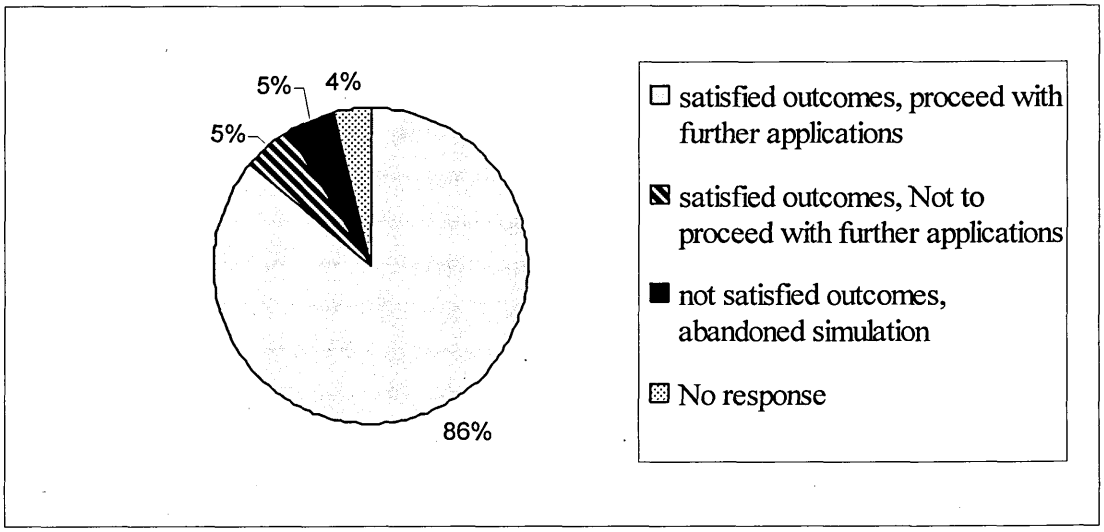


Figure 4.9 Percentage of the satisfaction and related actions after pilot project/first experience

4.1.2.3 Section 4 - Infrastructure and communication

Section 4 of the questionnaire examines the issues on simulation infrastructure and the ways in which companies communicating simulation within organisations.

Simulation awareness

Question 4.1 examines the mechanisms which had been used in order to spread out the concept of simulation within their companies. Figure 4.10 shows the total number of responses based on the three choices. It is found that the majority of the responding companies targeted on meetings with section leaders (13 responses). There are 8 responses for both: 1) organising simulation workshops and 2) via internal publications.

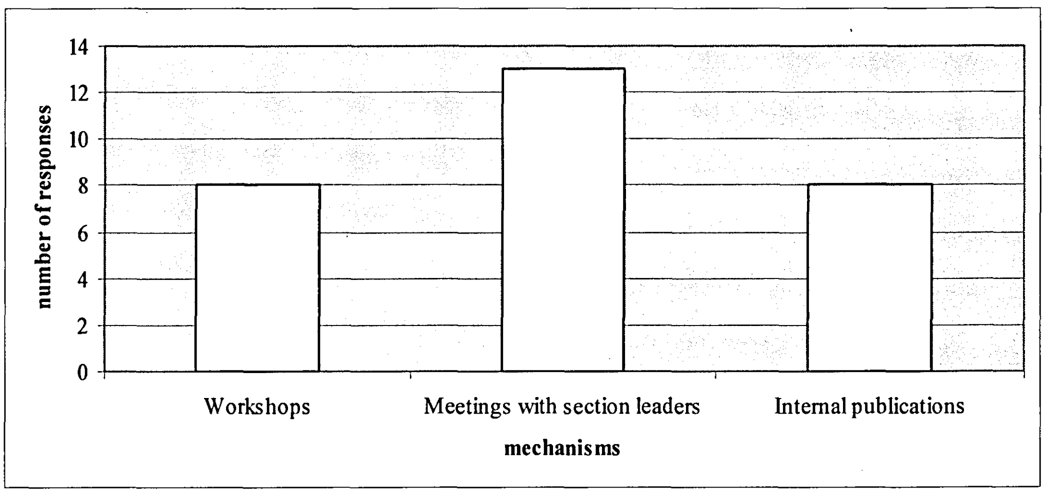


Figure 4.10 Mechanisms to spread out simulation

Acceptance from business units

Figure 4.11 shows that there are slightly higher responses on the choice of "a *number of proposals with no/little encouragement*". Therefore, it is fair to assume that simulation is generally accepted by the business units.

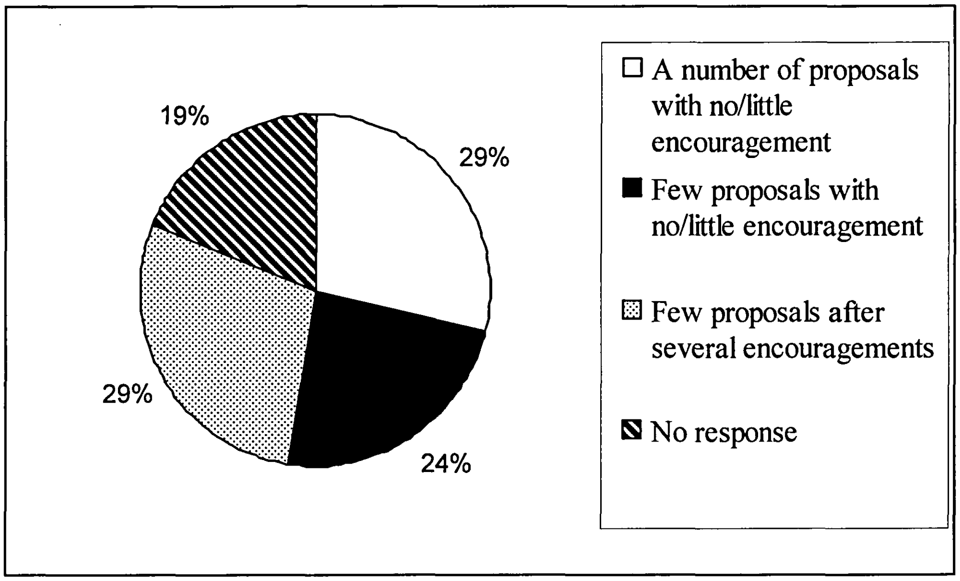


Figure 4.11 Acceptance from business units about simulation

Simulation team

In this section companies were further asked whether an internal team or an external consultant was used to build a simulation model during this stage. By referring to Figure 4.4, it is found that the majority of the responding companies were still keeping the control on the introduction of simulation. From Figure 4.12, there is higher percentage of the responding companies (53%) assigned an internal team for model building, only 33% of them were relied on external consultants (Figure 4.12). This result further approved the important role of an internal simulation team.

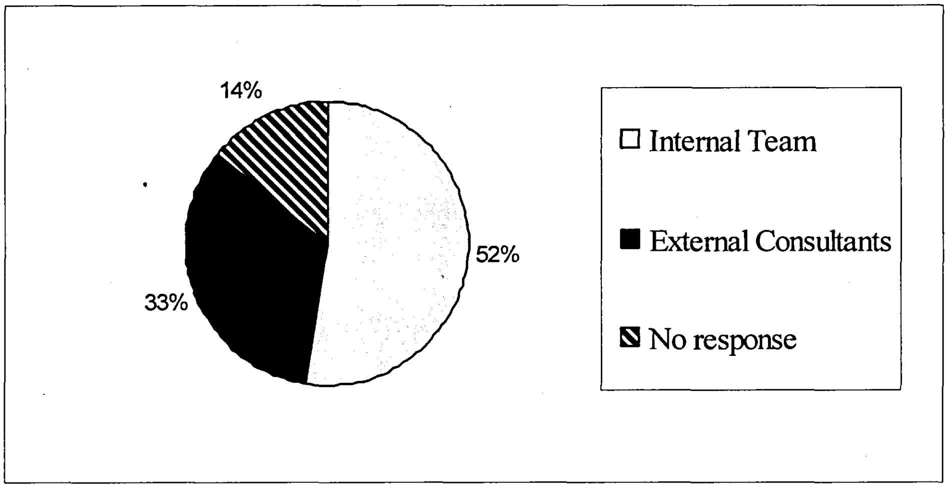


Figure 4.12 Percentage on the use of internal team and external consultants on model building process

Since a higher percentage of the responding companies have an internal simulation team, the following questions asked about the issues related to the team. The results show that the most common simulation team size is 2-5 members. Furthermore, Question 4.3.3 asked how simulation projects were conducted. The result shows that 50% of the responding companies reported that "*problems are brought to the simulation team*" and 36% of the responses reported that "*simulation team attempts to identify appropriate problems for modelling*" (Figure 4.13).

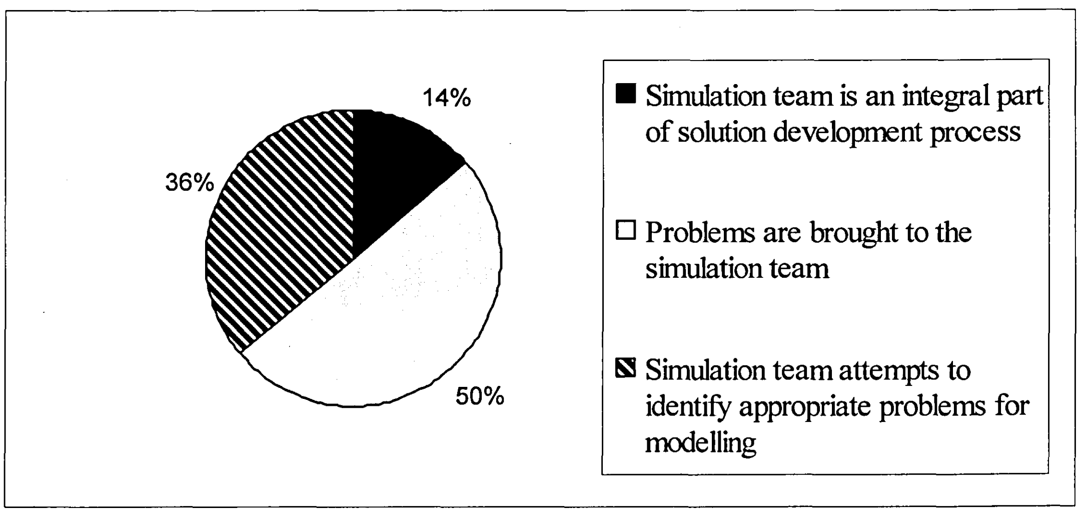


Figure 4.13 Percentage of the interactions between the team and problem owners

Communication

Additionally, Question 4.5 asked about the ways in which completed simulation models had been deployed to problem owners. Overall, about half of the responding companies (48%) reported their simulation team or consultants would manage the entire project and produce simulation models and solutions to the problem owners (Figure 4.14). In fact, there are still a fair amount of responses that report the solutions are developed by problem owners, instead of the simulation team or consultants. It is fair to believe that this situation can be affected by two reasons: 1) the simulation knowledge of problem owners, 2) the level of involvement of simulation team and consultants in decision processes.

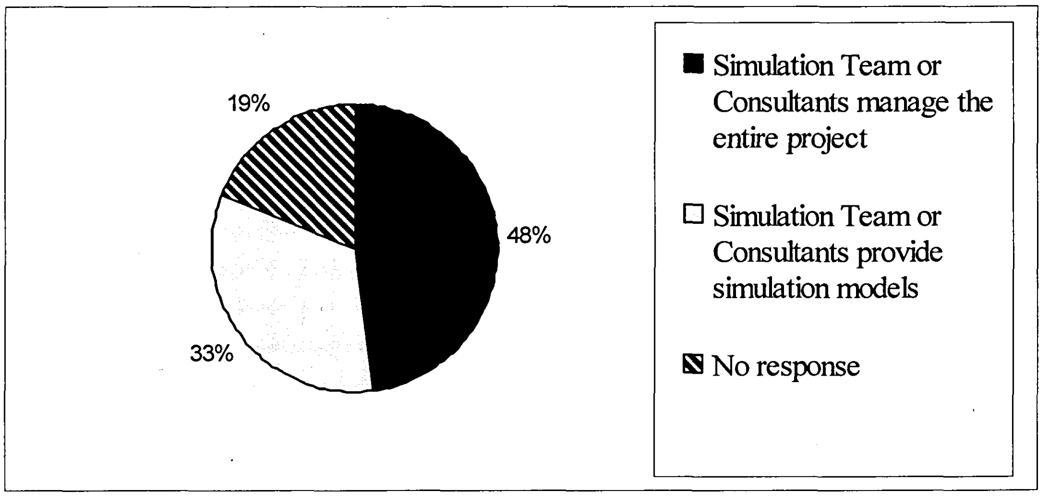


Figure 4.14 Figure to show the way of communication between model builders and problem owners

Simulation training

Question 4.4 asked about trainings that had been provided to the core simulation team. Figure 4.15 shows that the majority of the responding companies were focusing on simulation software training (68%), 14% of them were focusing on simulation project management. There are another 14% of them that were focusing on programming language training, for example Visual Basic Application (VBA).

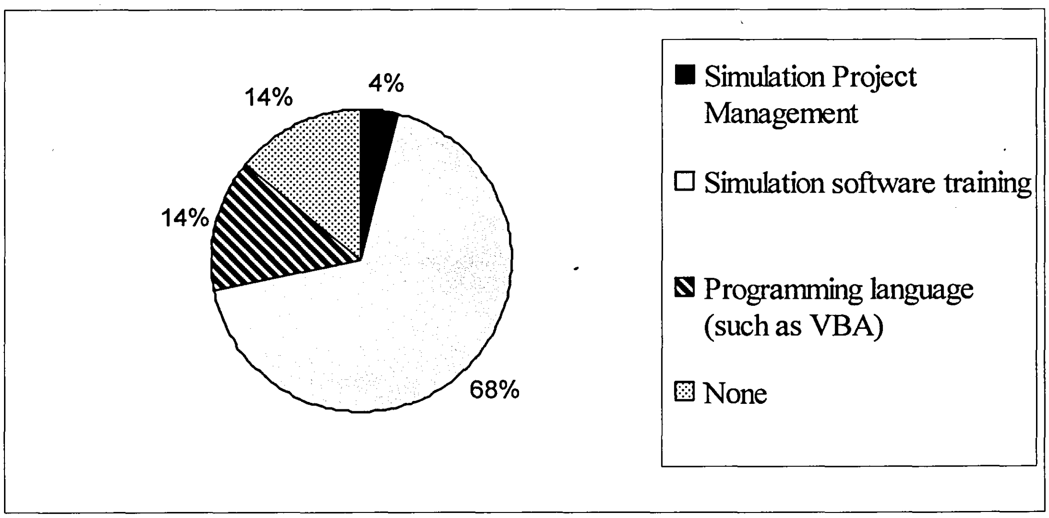


Figure 4.15 Percentage of training has been provided to the core simulation team

4.1.2.4 Section 5 - Deployment and Standardisation

This section examines the ways in which simulation had been deployed after introduction to a company.

Scope and number of projects done

Question 5.1 asked about the type of business problems that had been solved with simulation projects. The most common business problems that had been solved by their simulation models are listed below:

- Justify capital investment,
- Optimise an existing resource or process,
- Determine or analyse a process bottleneck,
- Implement a new process and design or analyse factory layouts,
- Equipment decisions, operating policies.

Question 5.2 asked about the average number of simulation models that had been completed within the past 12 months. The result shows that more than half of the responding companies (61%) had completed 1 to 5 simulation projects within the past 12 months, and approximately 30% of the responding companies had completed more than 5 simulation projects (Figure 4.16).

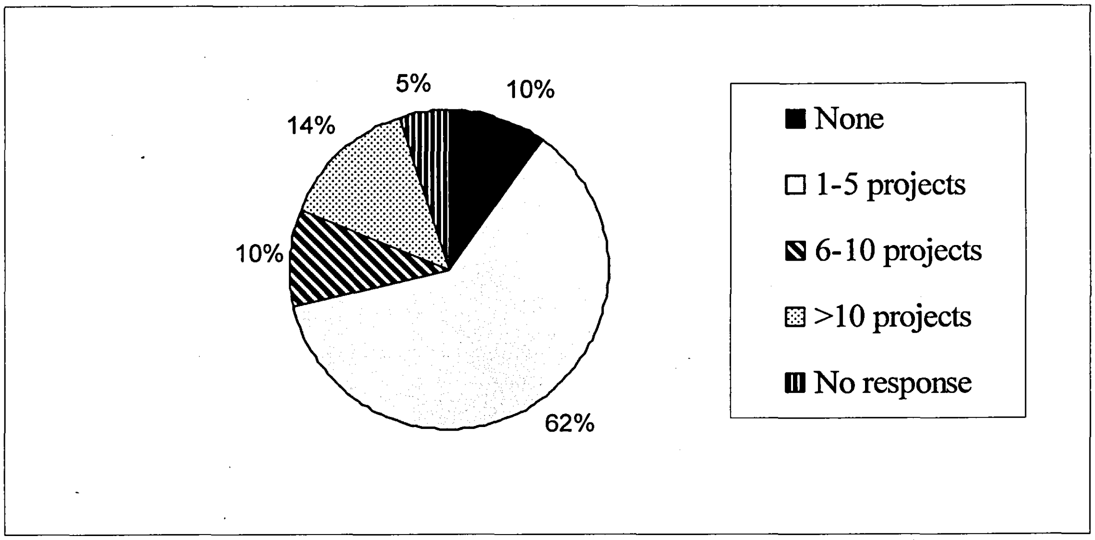


Figure 4.16 Number of simulation projects which had completed within the last 12 months

Simulation data input and output

Question 5.3 and 5.4 asked about the most common mechanism which had been used to present simulation results, and inputting data to models. Figure 4.17 shows that a higher number of responses had chosen "Excel Spreadsheets" as an input interface for data input. Furthermore, Figure 4.18 also shows that higher number of responses had chosen "Customised Excel Spreadsheets" as an output report for presenting simulation results.

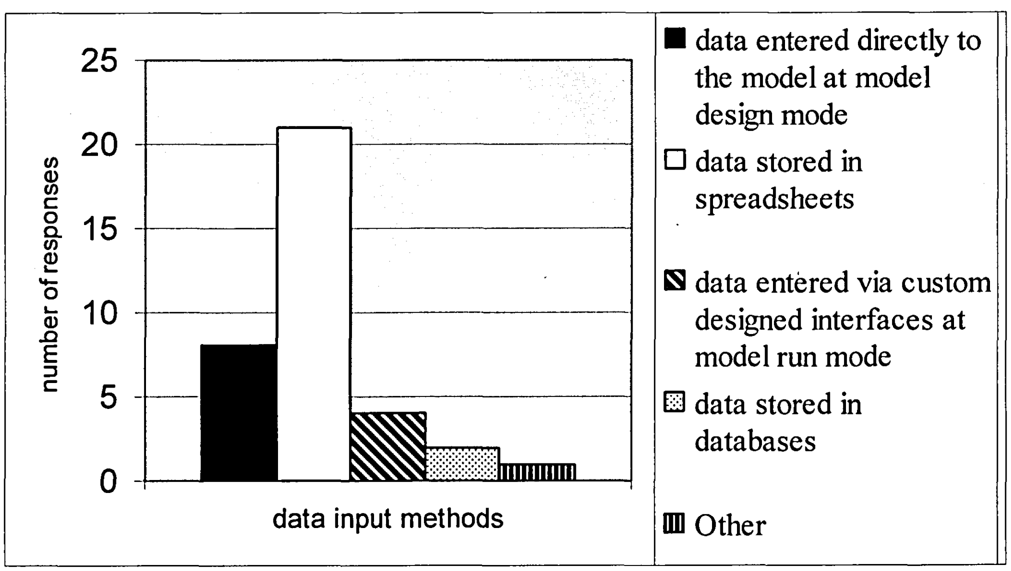


Figure 4.17 data input methods on simulation model

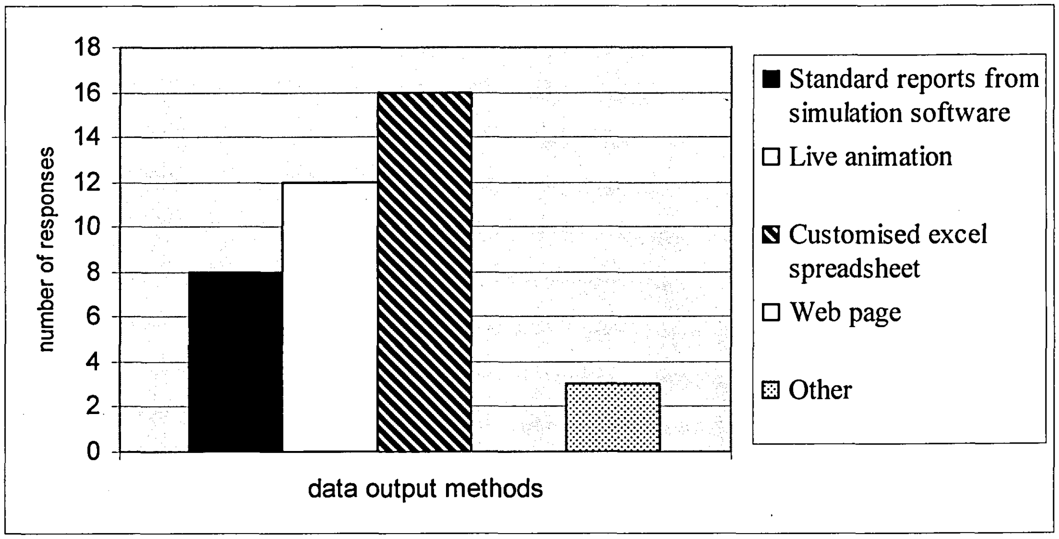


Figure 4.18 data output methods on simulation model

Standardisation

A standardised model development process was identified as an important success factor to expand the use of simulation, for example by reusing simulation model building blocks (so-called "Template" or "Objects" which depends on the software package) is one of a solution (McLean *et al., 2003*).

Figure 4.19 shows that more than half of the responding companies (57%) had chosen "YES" – they had developed customised simulation templates or objects. Therefore, it is believed that standardised model development process by creating customised simulation templates or objects is commonly accepted by companies.

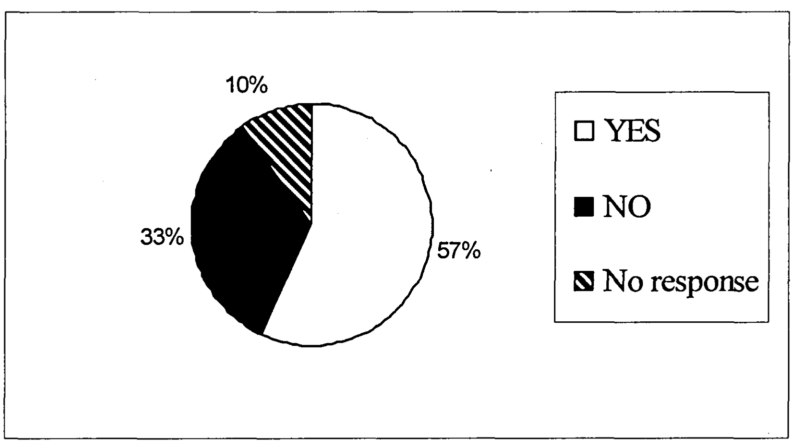


Figure 4.19 Companies which had developed customised simulation model templates/objects

In order to standardise model development process, another solution is to re-utilise existing models. Question 5.6 was asking if the company had re-utilised simulation models, and in which ways the models had been re-utilised. Figure 4.20 shows that approximately 3 in 4 of the responding companies had re-utilised existing models, and only 16% of the responding companies did not re-utilise existing models. Additionally, the result shows that a higher percentage of the responding companies had reused the model coding, the model component or even the full model.

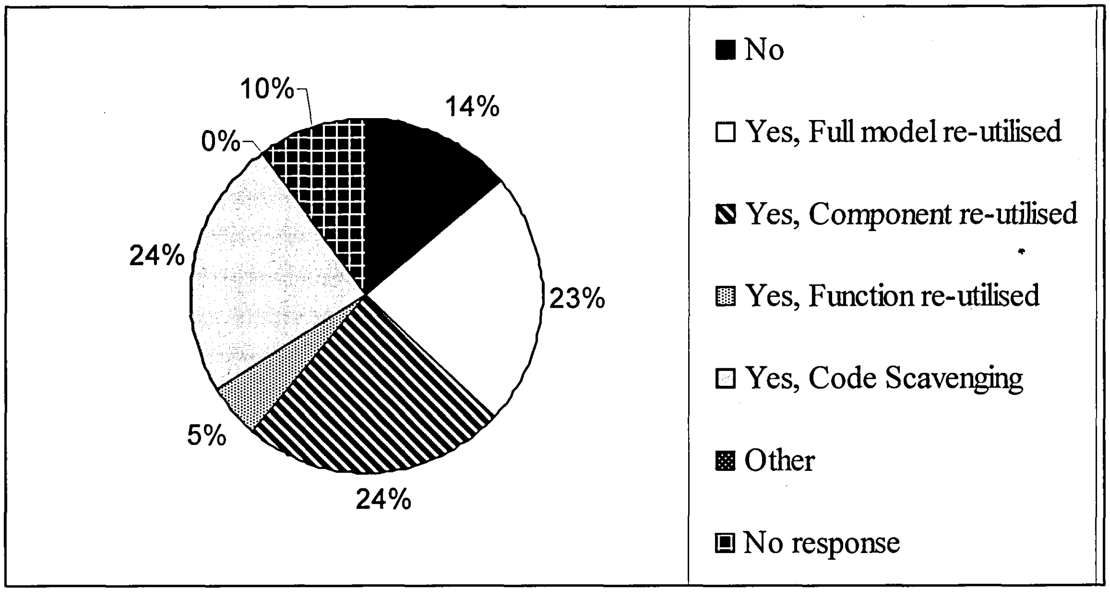


Figure 4.20 The percentage of the responding companies re-utilise existing model

Knowledge management

By referring to Figure 4.20 above, the majority of the responding companies had experience in reusing existing simulation models. However, it is believed that without sufficient and clear project specification or documentation of an existing model or if the model developer is no longer working with the company, it may be difficult for another (new) team member to reuse the existing model. Therefore, the idea of knowledge management is identified as an important element in a simulation deployment stage.

Question 5.7 asked if the responding companies had documented any information of a simulation project. It is found that only one of the responding companies do not keep documentation of simulation projects, while other responding companies had chosen some of the common project information that they had normally kept record of. Figure 4.21 summarises the common project information that the responding companies normally documented. The point of the arrow represents the most common information that had been documented and the base of the arrow represents the least common information that had been documented.

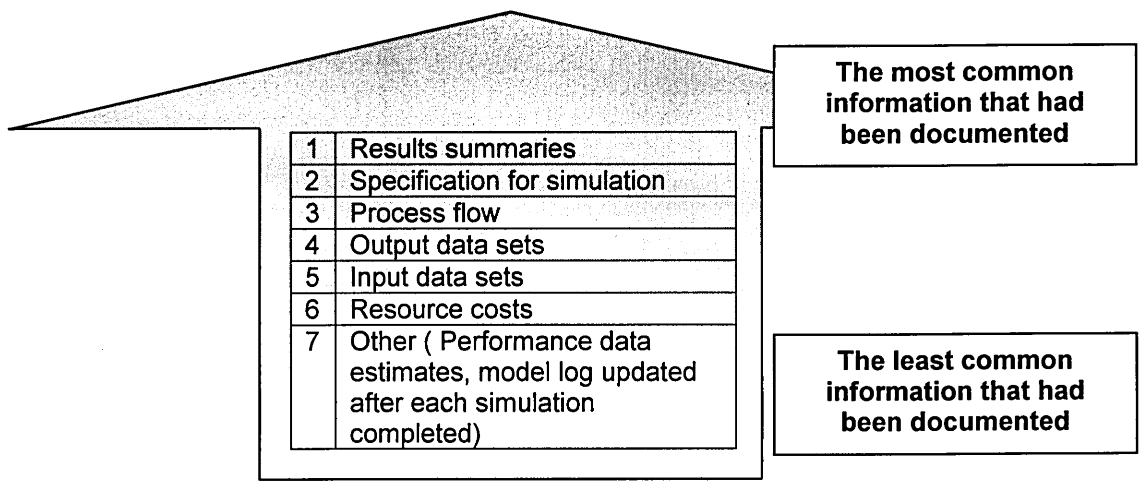


Figure 4.21 Ranking of simulation project information that usually documented

4.1.2.5 Section 6 - Plans to use simulation in the future

Section 6 of the questionnaire examines the ways in which the responding companies will expand the use of simulation in the near future. Responding companies include those with no simulation experience was required to answer questions from this section.

Firstly, Figure 4.22 shows an extreme situation between those responding companies that with simulation experience and those without the experience – a higher number of the responses from those companies with simulation experience plans to expand the use of simulation strategically, however a higher number of the responses from those companies without simulation experience will not consider to use simulation at all.

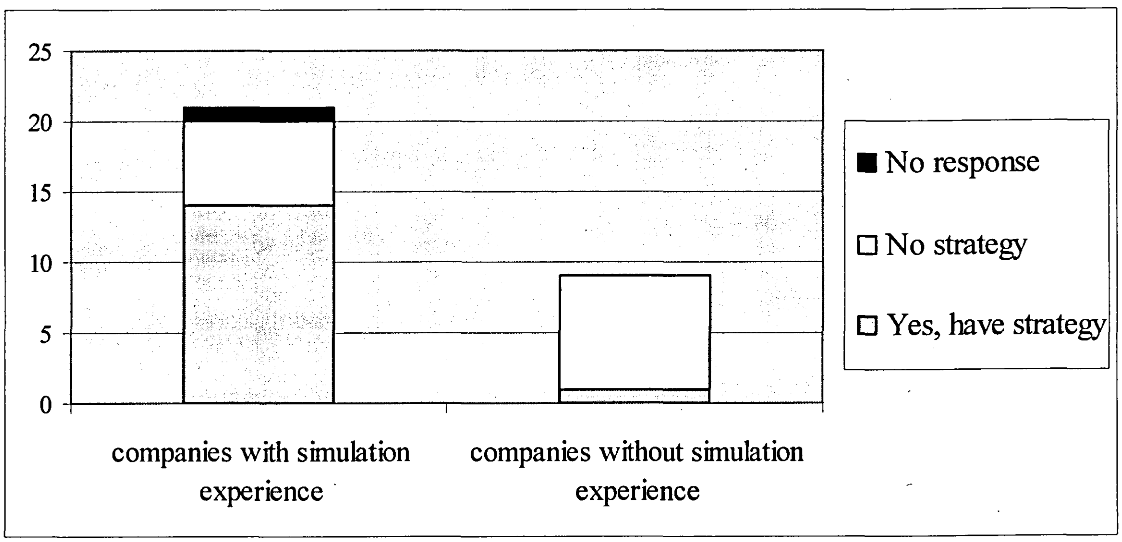


Figure 4.22 Statistic on responding companies to have strategy to further develop the use of simulation

Question 6.2 was further asking those companies the approaches in which they are going to expand the use of simulation. Although not many of these companies had replied to this question, the finding is summarised into several key points:

- expand simulation team and increase simulation knowledge
- spread out simulation to all level of staff
- integrate with other strategic processes (e.g. Six sigma)

4.2 Qualitative study

4.2.1 Case study introduction

From October 2005 to April 2006, the author worked CAT, the sole manufacturer of Articulated Trucks, as a research fellow to support CAT to embed simulation technologies into their business processes. Mr David Hodgson, one of the Six Sigma Black Belt members from CAT was the project coordinator of the study. The main objectives of the study were:

- To conduct a questionnaire survey, in order to examine the ways in which simulation technologies had been affecting CAT's employees and CAT's change management.

- To work with CAT's management identifying opportunities to use simulation, building simulation models and supporting model experiments.

This section is divided into two parts, the first part presents the result of the questionnaire survey and summarises the key issues from the result. The second part of this section summarises several key stages that had been experienced during the introduction of simulation technologies into CAT's system. Additionally, the key issues that had been learned and the key difficulties are discussed in the following sub-sections.

4.2.2 Questionnaire survey in CAT

The questionnaire survey examines CAT's employees' knowledge and their past experience with simulation technologies. Additionally, it establishes an understanding of their expectation on simulation technologies.

Questionnaires were distributed to the employees in management level from different operational developments. 10 responses were received. Table 4.3 shows the classification of the respondents.

Departments	**No. of the respondents**
Technical Resources	6
Operations	1
6 Sigma	2
Manufacturing engineering	1
TOTAL	10

Table 4.3 Classification of the respondents

4.2.2.1 Survey results and analysis

Note: The sample of the questionnaire can be found in Appendix B.

Understanding of the term "simulation"

The result shows that CAT's employees generally have fair knowledge about the term "simulation". The answers are summarised into three types which are shown in Figure 4.23: 1) nature of simulation, 2) benefits of simulation, and 3) both.

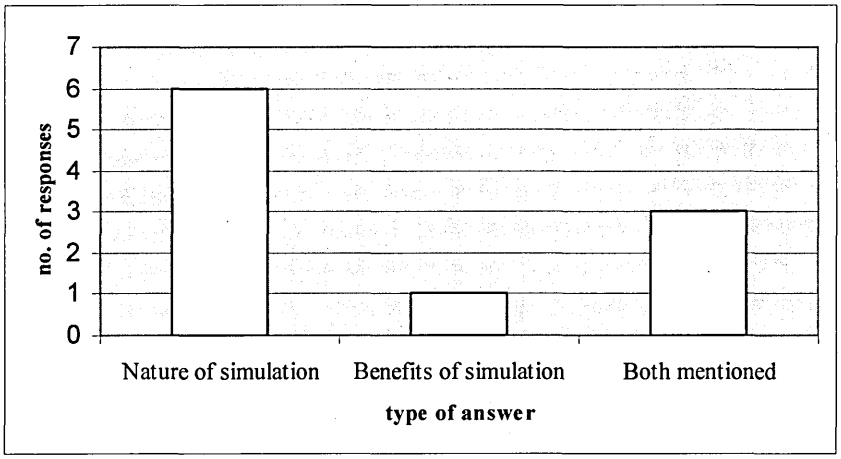


Figure 4.23 understanding of the term "simulation"

Previous experience in simulation technologies

The survey found that 80% of the respondents are aware that simulation activities are happening/were happening in CAT. However, few of them understand detail about the projects.

Additionally, the respondents had been asked whether they had any previous experience in simulation technologies, before working with CAT. In Figure 4.24, it shows that a higher percentage of the respondents (70%) had previous experience in using simulation technologies. It was found that most of them used simulation technologies in university and one of them encountered it from his previous company.

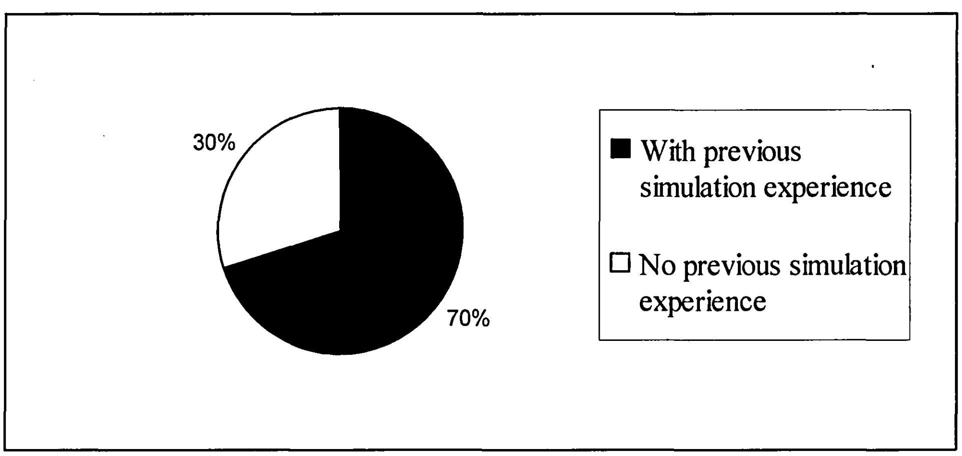


Figure 4.24 Percentage of respondents with previous experience in simulation

Future opportunities

The respondents had been asked if they can foresee any potential simulation applications within their area of work. The result found that 90% of the respondents have future plans on the use of simulation or can foresee potential areas to apply simulation, these opportunities are summarised as follows:

- to analyse implementation issues for combining three production lines into one
- to optimise layout of work cells
- to review buffer sizes, shift patterns and manning
- to improve workflow in assembly line or other manufacturing processes
- work with lean projects and six sigma

Additionally, respondents had been asked if they want to learn more about simulation. The result found that 60% of the respondents said "YES" and 40% of them said "NO". Figure 4.25 summarises the main issues which the respondents want to learn.

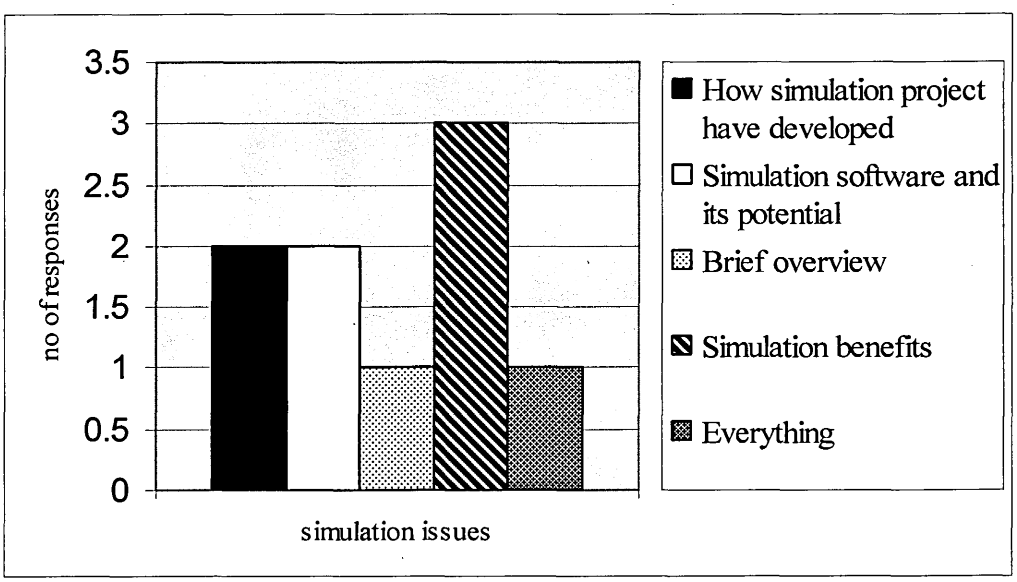


Figure 4.25 Issues of simulation that respondents want to learn/know more

4.2.2.2 Summary of the survey outcomes

Regarding the findings which are discussed in the above section, it is fair to assume that CAT has potential areas to expand the use of simulation for the following reasons:

- support from senior management level
- high awareness of the nature and benefits of simulation
- enough potential simulation application areas

However, it is realised that there are a few main limitations which may affect simulation to be embedded into CAT's business processes. These limitations are:

- lack of strategy to introduce simulation project
- lack of simulation support within CAT (resources, knowledge)
- No standard software, procedure to perform simulation project

4.2.3 Work conducted in CAT

This section presents the approach in which simulation technologies had been introduced to CAT during the research period. This approach includes six stages:

Stage 1 - Introduction

Simulation is not a new concept to CAT's people – the result of the questionnaire found that 90% of the respondents have ideas to use simulation technologies in their areas of work. However, it is realised that few of them are willing to spend time putting these ideas into action, either because they were too busy with their own duties or they did not have enough simulation knowledge to get involved in the project.

During the early stage of the introduction, Mr David Hodgson (the project coordinator) was the person to introduce simulation technologies to the business units and to discuss potential simulation projects with the problem owners. The author is the only simulation model builder at this stage.

Stage 2 - Pilot project

The scope of the first simulation model was to assess the performance of different process times between the welding area and the fabrication area at the rear chassis production line. This production line includes a robot which operates in the welding area and an operator who works in the fabrication area (Figure 4.26). The simulation software package (Arena) was chosen to model this pilot project because of the following reasons:

- Previous experience of the author and the champion
- Expertise support from Sheffield Hallam University
- Flexibility for a broad range of manufacturing applications
- Interface to programming language e.g. Visual Basic Application (VBA)

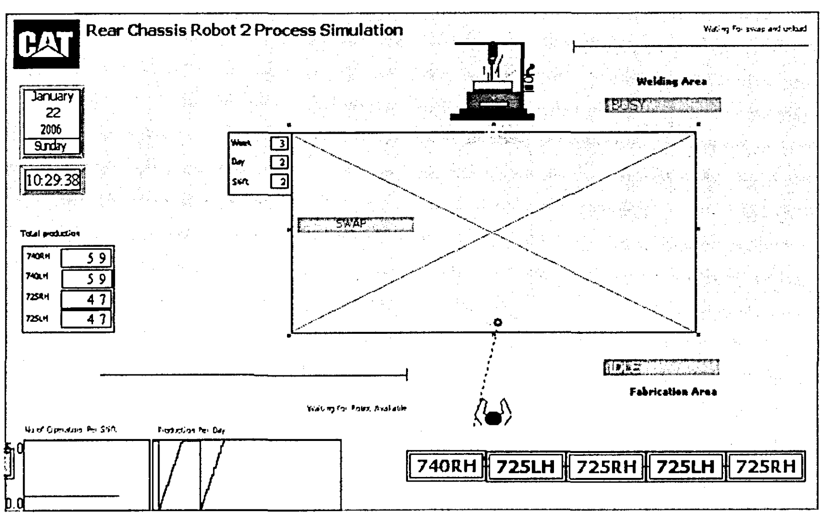


Figure 4.26 Rear Chassis Robot process simulation model

The feedback of this pilot project was positive – the problem owner was happy about the simulation results which can help them to identify a real picture of different scenarios; the simulation team confirmed Arena as a main simulation software package; the management team agreed to support further deployment of the use of simulation in CAT. After the pilot project, the simulation project coordinator started to spread out the benefits of using simulation to other senior managers at company meetings. The project coordinator has become the champion of the simulation team.

Stage 3 - Communication between problem owners, champion and model builder

At this stage, the management team has already had a greater understanding of the potential of simulation technologies. The communication between the champion and the business units is then changed – the champion no longer needed to introduce simulation technologies to business units, instead project requests were raised by several senior managers and project leaders.

Since there were no standard request form or procedure for problem owners to send out project requests to the simulation team, E-mail or informal meetings were the main communication ways between the team and the problem owner.

Stage 4 - Software and Hardware

After a few simulation proposals had been confirmed with business units, the author supported technical staff to install the simulation software Arena (i.e. the simulation tool which had been used in the pilot project) on the users' computers, in order to let users run and perform experiments after training.

Stage 5 - Model building and experiments

The following sub-sections discuss the simulation models which the author had completed during the research.

Model 1: Final finish to QA process

The scope of this model was to identify the system bottlenecks and to assess the impact of alternative operator allocation strategies.

The author considered that most of the problem owners had little knowledge on how to use simulation software. Therefore the model was programmed in VBA to input model data from an Excel spreadsheet (Figure 4.27), so that a user can input or change the model data directly from the Excel spreadsheet without having to configure model data within the software. The author also found that the training time of model experimentation could be eliminated with the use of Excel spreadsheet.

Figure 4.28 shows the animation of the simulation model. The author found that a clear animation of the simulation model can increase the understanding of the problem owner in the overall model.

The output results are also sent to the Excel spreadsheet that was used for inputting model data (Figure 4.29). The problem owner reported that with the Excel spreadsheet they can analyse simulation results data with graphs and create management reports.

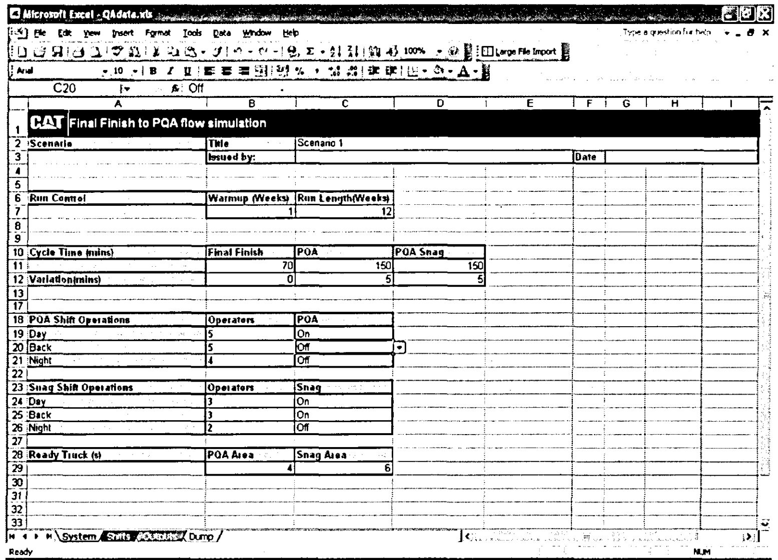


Figure 4.27 Customised Excel spreadsheet for model data input

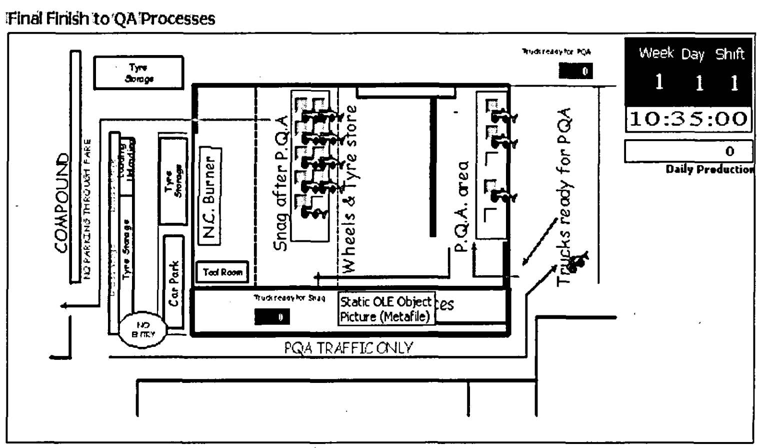


Figure 4.28 Animation of the simulation model

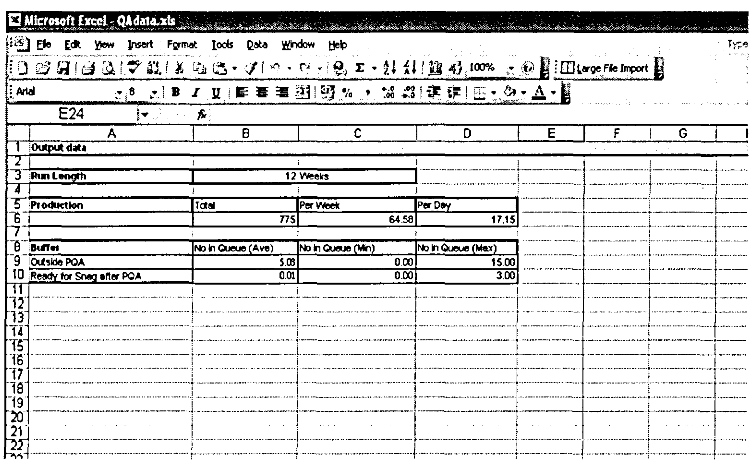


Figure 4.29 Customised Excel spreadsheet for simulation experiment data

Model 2: Tank production line

The scope of this model was to determine maximum buffer sizes and to assess the impact of different shift patterns.

After the previous simulation project the customised Excel spreadsheet has become a standard model data interface to CAT's simulation project. One of the aims of this model was to assess the impact of different shift patterns; therefore data of the shift patterns was critical for this model. The problem owner had been trained by the simulation team to decide on suitable data to use in the simulation model. Figure 4.30 shows the shift patterns provided by the problem owner in the Excel spreadsheet format. The animation of the simulation model is shown in Figure 4.31.

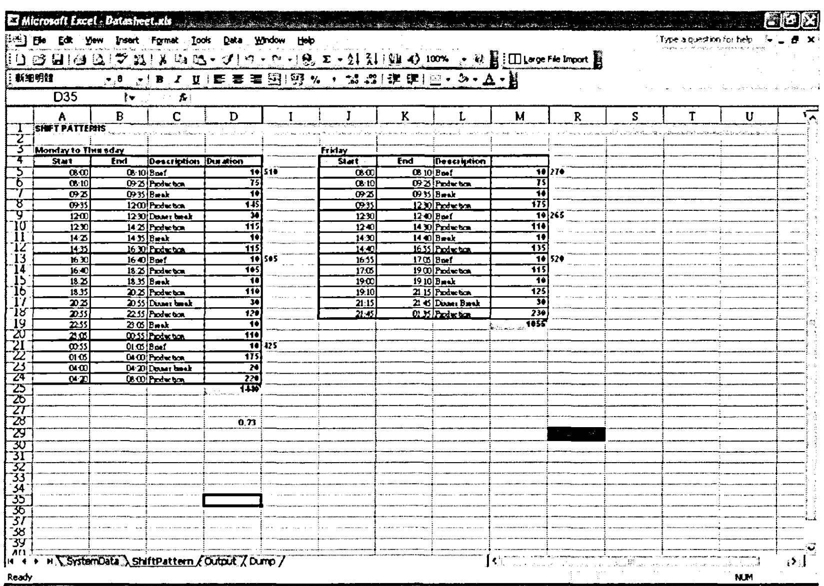


Figure 4.30 Customised Excel spreadsheet for model data input including shift patterns

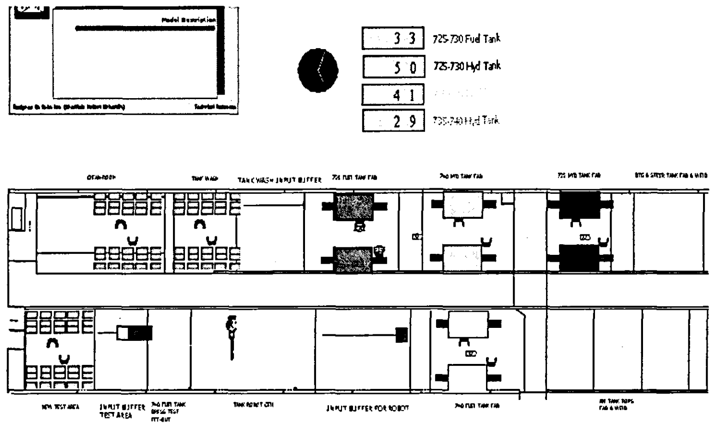


Figure 4.31 Animation of the Tank Production Line simulation

The problem owner was satisfied with the results of the simulation model. The simulation team also provided experimentation training to the problem owner's team so that they have the ability to perform their own experiments in the future.

Model 3: Generation III - new assembly line

The scope of this model was to simulate the new concept of "Generation III" – a new assembly line, and to assess the performance by applying different layout configurations. Customised Excel spreadsheet was used for inputting model data and showing output data. The animation of this model is shown in Figure 4.32.

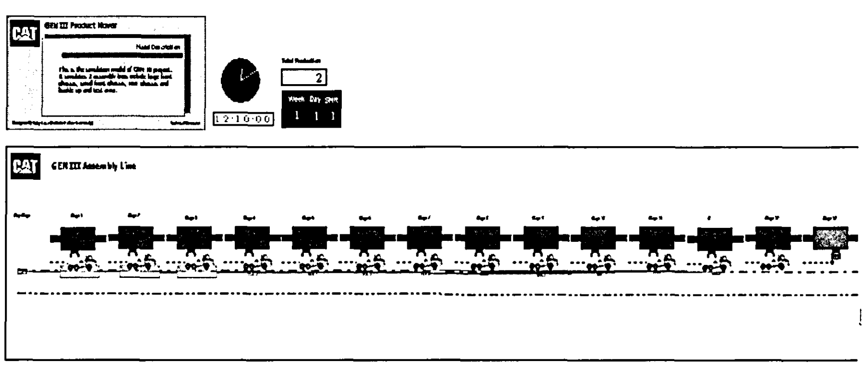


Figure 4.32 Animation of the generation III- new assembly line

Since the development process of the simulation model ran behind schedule - the new assembly line had been implemented before the simulation model was finished. The problem owner found the model less useful as the decision of the layout had already been made at that time. Therefore the model was not useful anymore for the problem owner, unless the same assembly line would need to be examined in the future.

Although one simulation model failed to achieve its objective during the research, all of these projects provided a valuable experience to the simulation team and the problem owners. A few issues are highlighted:

- Excel interface enabled end-users to manipulate simulation models effectively and efficiently. This made experimentation much easier;
- Animation is a powerful tool but careful planning is required to ensure simple and easy-to-understand displays;
- Training is required not only in model building but also in collecting model data, deciding levels of detail, and performing experimentations.

Stage 6 - Strategy to spread out simulation in CAT

Despite the obvious benefits of simulation technologies, CAT management did not realise the full potential of these technologies. This situation changed after the author and the champion completed a number of successful simulation models with the problem owners. The benefits of simulation models were then spread around the company, and requests received by the simulation team increased.

In order to provide a clear picture on how simulation technologies can affect the success of CAT's business processes, the author prepared an article to describe the simulation projects that had been completed during the research period. A few comments from the champion Mr David Hodgson were also included in the article.

One of the feedbacks from this article was:

"A simple EXCEL user-interface made the use of simulation easy. Instead of building simulation models for each and every configuration, a single model intelligently captured all possible configurations." (CPS update, 2006)

The article had been published in the CAT newsletter and the idea of simulation technologies were then spread around the entire organisation.

The expansion of simulation technologies in CAT did not stop after the author left. The simulation team has a new member from Sunderland University, who is a placement student working as a simulation model developer. Additionally, the champion has arranged certain simulation trainings for the new member in order to increase the simulation knowledge of the team.

4.2.4 Learning outcomes

The main aim of the work conducted in CAT was to introduce simulation technologies. The author found that there were a few positive aspects which were learned and contributed:

Below are the positive points:

- Worked with a responsible and knowledgeable champion
- Selected the right simulation tools
- Performed a pilot project
- Gained support from management level
- Standardised the user-interface for all simulation models in the form of a customised Excel spreadsheet
- Used a newsletter to spread the awareness of simulation across the organisation after successful projects
- Provided certain simulation training to the potential staff

However several difficulties have been faced and identified during the research:

- No standard procedure for receiving simulation proposals, which caused difficulties to schedule the project time, and some of them had to be postponed
- Lack of simulation support from the current staff
- Software license issues
- The senior manager had limited knowledge on analysing simulation experiments
- Ac-hoc project style which had no concern for documentation
- Job priorities for simulation projects were low compared to other business projects

4.3 Summary of best practices

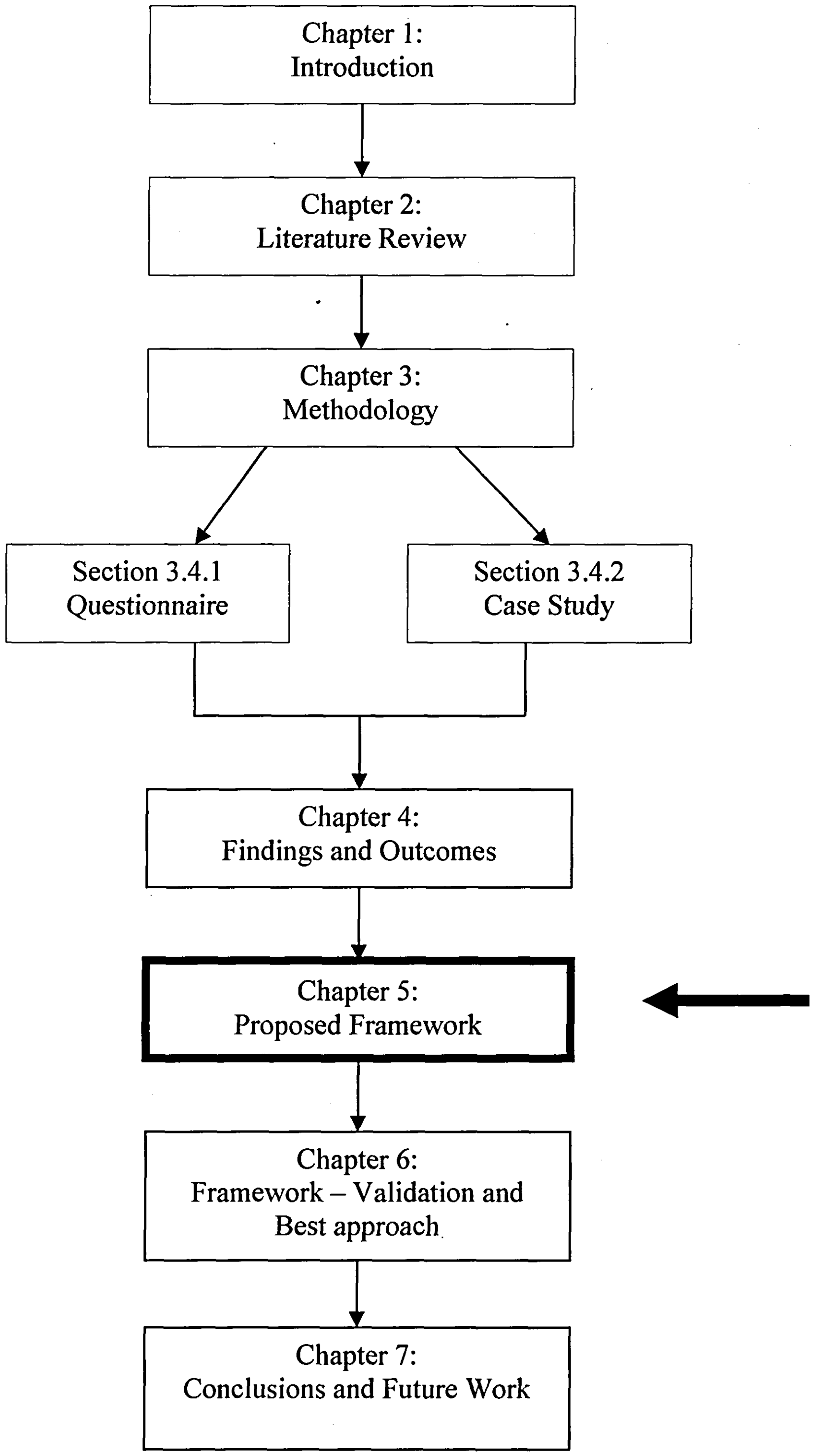
Five main areas were considered in the questionnaire survey (i.e. introduction of simulation, pilot project/First experience, infrastructure and communication, deployment and standardisation and plans to further use on simulation). According to the analysis these five main areas are critical in embedding simulation in business processes. The author defines five key stages: **Foundation, Introduction, Infrastructure, Deployment, and Embedding** to represent these five critical areas.

Table 4.4 summarises and compares a list of best practices for embedding simulation technologies in business processes, where the best practices were identified from the literature review, and the qualitative and quantitative studies. The best practices are grouped according to the five key stages. The table of best practices will contribute to the development of the framework for embedding simulation technologies in business processes, in the next chapter.

Key Stages	Best practices which have been identified	Identified in Literature review	Identified in Qualitative Study	Identified in Quantitative Study
Foundation	Support from senior management	√	√	√
	Build a simulation team of leader, experts and engineers	√	√	√
	Software selection	√	√	√
	Communicate with software vendor	√		
Introduction	Spread out the benefits and nature of simulation	√		√
	Pilot project from particular business area	√	√	√
	Involve future users	√		
	Support by external consultants		√	
	Run workshops		√	
	Commitment by business units	√	√	
Infrastructure	Software/Hardware implement			√
	Separate budget for simulation projects	√		
Deployment	Time management	√		√
	Provide simulation trainings for users	√	√	√
	Deploy simulation as part of the business strategy	√		
	Document simulation projects	√	√	√
Embedding	Spread out the awareness of simulation all over the organisation after some successful projects	√	√	√
	Standardise model data input and output interface	√	√	√
	Reuse models, coding and logic	√	√	√
	Use library of generic model objects/templates	√	√	
	Provide simulation training in model building and project management	√	√	√
	Set standards in the use of simulation by implementing project procedures	√		√
	Share knowledge among the simulation teams	√		

Table 4.4 Best practices of embedding simulation technologies into business processes which identified from literature review, qualitative and quantitative studies

CHAPTER 5: PROPOSED FRAMEWORK



CHAPTER 5
PROPOSED FRAMEWORK

5.1 Introduction

Following the analysis of the outcomes and findings of the quantitative and qualitative studies (Chapter 4), this chapter seeks to develop a framework to enable companies to embed simulation technologies into business processes. This chapter is divided into two parts:

- Firstly, a summary and discussion of the key concepts of the proposed framework which were identified from the literature review, questionnaire survey and case study.
- The second part of this chapter provides an overview of the proposed framework (Figure 5.2).

The proposed framework consists of five progressive stages outlined in Table 4.4 of Chapter 4, i.e. Foundation, Introduction, Infrastructure, Deployment, and Embedding. Each stage of the proposed framework has its input and output elements. Input elements represent best practices; these were identified in the literature survey and through quantitative and qualitative studies. The best practices of each stage are divided into three different dimensions namely, "people dimension", "technological dimension" and "organisational dimension", and under each dimension, there are guidelines to enable each company to achieve each best practice. Output elements represent the main objectives and outcomes which are interrelated with each of the next stages. The general overview of the proposed framework is presented in Figure 5.2. Contents of the proposed framework are described below in greater detail.

5.2 Key concepts

Based on the literature survey and review, several key concepts were summarised in developing a framework to embed simulation technologies into business processes. Figure 5.1 shows these key concepts and indicates that different authors have different levels of emphasis (i.e. Not mentioned, Low emphasis, Medium emphasis, and High emphasis) in each concept.

Key Concepts	**Key Authors**				
	[1]	**[2]**	**[3]**	**[4]**	**[5]**
(5.2.1) Easy to follow	Ⓗ	Ⓛ	Ⓛ	∅	∅
(5.2.2) Generic and holistic	Ⓗ	Ⓗ	Ⓜ	∅	Ⓗ
(5.2.3) Overcome main challenges	Ⓜ	Ⓗ	∅	Ⓗ	∅
(5.2.4) Include best practices	Ⓜ	Ⓛ	Ⓗ	Ⓗ	∅
KEYS : ∅ Not mentioned, Ⓛ Low emphasis, Ⓜ Medium emphasis, Ⓗ High emphasis					
[1] Holst (2000), [2] Jagstam and Klingstam (2002), [3] Murphy and Perera (2001), [4] McLean and Leong (2001) [5] Morgan and Liker (2006)					

Figure 5.1 Comparative assessment of emphasis on the key concepts' contribution to framework development

5.2.1 Easy to follow

Holst (2000) suggested that guidelines for integrating simulation technologies into business processes should follow a structural approach, which is easy to follow and well-documented. This concept is applied to the proposed framework for embedding simulation technologies into business processes. The proposed framework is clearly partitioned into five main stages i.e. Foundation, Introduction, Infrastructure, Deployment and Embedding. In addition, in order to provide stepwise, easy to understand guidelines to organisations, the proposed framework also consists of input elements and output elements. Input elements are the main best practices which focus upon embedding simulation technologies into business processes, whereas the output elements are the main objectives to be achieved at each stage. These elements ensure that the proposed framework reflects a structural approach, whilst being easy to adopt by organisations.

5.2.2 Generic and holistic

Another key aspect of the proposed framework is the requirement to be generic, meaning that it should be applicable across a wide range of enterprises (Holst, 2000). Since this proposed framework is not developed solely to fix a specific type of organisation, it can be flexibly applied to a wide range of industrial sectors attempting to embed simulation technologies into their business processes.

Holst (2000) also suggested that the framework should consider integration from all aspects. This concurred with Morgan and Liker (2006) in their study concerning the success of Toyota's product development system, which was built on a framework with "People", "Process" and "Technology" aspects, as these three main elements are always interrelated and interdependent with organisational issues to achieve success. Because of this concept, the framework proposed in this work also incorporates "People", "Technological" and "Organisational" dimensions within the input elements in order to develop a clear and holistic view of the best practices related to embedding simulation technologies into business processes.

5.2.3 Overcome main challenges

In addition, Jiagstam and Klingstam (2002) also identified some technological and operational challenges in the use of simulation which need to be overcome by a structural approach through simulation methodology. The proposed framework focuses on the challenges and failure factors in the use of simulation which were identified through the literature review and then presents suitable best practices in order to overcome them at each stage.

5.2.4 Include best practices

Murphy and Perera (2001) identified a list of best practices to guide the implementation of simulation from their studies on how simulation has successfully been used in U.S. companies. They suggested UK companies should follow these best practices in order to encourage the use of simulation more openly. McLean and Leong (2001) also agreed that some best practices, (e.g. standardising building blocks and data interfaces in model developing process) can reduce project costs and time which finally increase the accessibility to the use of simulation.

This author applied this key concept to the proposed framework, as best practices are carefully considered to be the main input elements in each stage of the framework. Also, in order to develop a clear and holistic view, these best practices have been grouped into three dimensions i.e. "People", "Technological" and "Organisational" dimensions; these were already mentioned in 5.2.2.

5.3 Overview of the proposed framework

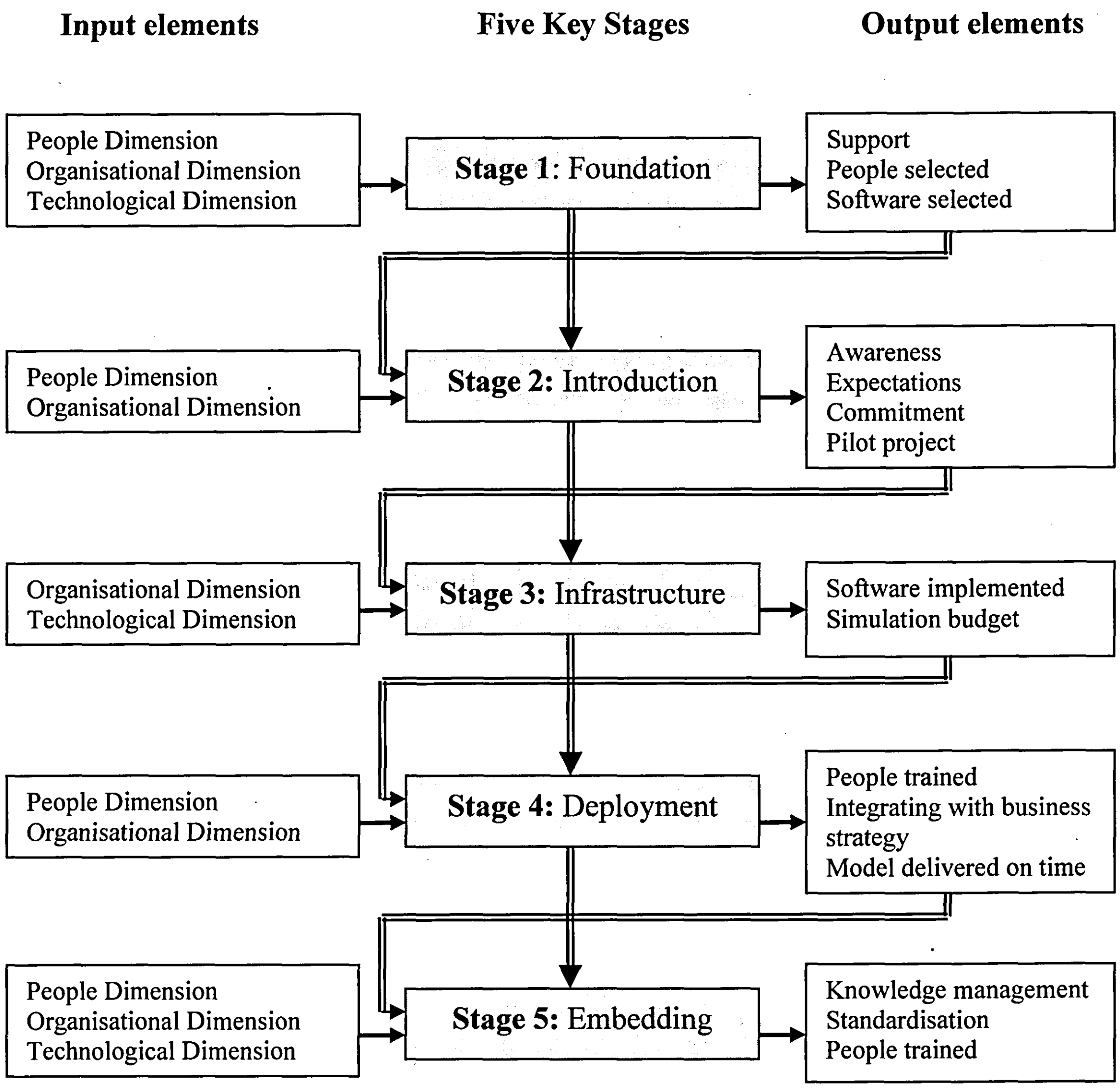


Figure 5.2 Overview of the proposed framework

5.4 Stage 1 - Foundation

This stage aims to provide the foundation for the next stage - Introduction, which aims to introduce simulation technologies from three dimensions i.e. "People", "Organisational" and "Technological". It is believed that as the size of the organisation increases, so too does the importance of the foundation.

5.4.1 Input elements

People Dimension:

- Build a simulation team with 2 to 5 members, including a champion who is to be responsible for integrating and developing simulation projects. This champion should have a fair knowledge of simulation technologies and have experience concerning their impact upon business processes. Additionally, the team should contain a simulation engineer, or specialist, who is able to provide support and actually lead the building of simulation models on a long-term basis.

Organisational Dimension:

- Gain support from senior management by informal presentation, proposal, workshop or demo. Several issues should be considered:

  1 - Benefits and capabilities of the use of simulation

  2 - What other firms or competitors are successfully doing in the area of simulation

  3 - List of possible external consultants, software vendors or internal employees that could be supported on this project.

Technological Dimension:

- Review available simulation software packages considering the following main issues:

  1- Price (i.e. expected budget for hardware and software)

  2- Previous experience of the simulation team

  3- Vendor training and support

  4- Application area

  5- Capabilities of future integration.

Some of these issues can be resolved via software vendors who normally have more experience and information. Therefore, good communication should be maintained between the simulation team and the software vendors at this stage.

The research data of this study suggests that *ARENA, ProModel, Witness*, and *AutoMod* are the most popular simulation software packages adopted by organisations over recent years (by referring to Figure 4.8).

"Best Practices" in the foundation stage
People Dimension Murphy and Perera (2001) state that an effective introduction of simulation into a company needs the correct support in place – a team of experts and engineers who are able to conduct both modelling and management roles.
Organisational Dimension Murphy and Perera (2001) also state that in order to secure the funding for initial investment on the introduction of simulation, it is important to build confidence and support of management in the use of simulation.
Technological Dimension Lientz and Rea (2001) suggest it is critical to select a software package based on capabilities and what is available for your hardware system. The wrong decision in selecting the correct software package could have a negative impact on the performance.

Table 5.1 Best practices in foundation stage

5.4.2 Output elements:

People selected

Forming a simulation team can ensure the company's internal control of simulation projects. One of the advantages is to allow the simulation experience is retained within the company. This also provides confidence for future users as to the internal support of simulation.

Support

Support from senior management is often regarded as the key critical success factor for any new innovation within an organisation. It is usually necessary to gain senior management support from resources to help introduce and develop the future use of simulation. Additionally, this can assist senior management in understanding the direction, scope, target and organisational issues related to simulation during this stage which is essential towards the overall development of simulation within the organisation.

Software selected

Once a suitable simulation software package has been identified, the simulation team can focus on collecting more information about the vendor and the product from their website, for example, issues on subsidiary or additional products that are related to the software package which could extend the capability of the basic package. The information could support the future assessment of this identified software package after the first project or pilot project.

5.5 Stage 2 - Introduction

After the establishment of the foundation to introduce simulation within the company, this stage aims to introduce simulation into the company from two dimensions: "People" and "Organisational".

5.5.1 Input elements

People Dimension:

- Support by external consultants (e.g. software vendors or academic agencies) providing case studies, estimated cost of using simulation and advice for the team as to how to promote and identify potential applications.
- Involve future users in simulation meetings and obtain opinions from this group of users.

Organisational Dimension:

- Communicate the benefits and nature of simulation throughout the entire organisation by company intranet, newsletter or email.
- Run workshops by external consultants to present successful simulation applications to potential users and business units.
- Meeting with business units to discuss potential simulation application areas.
- Start a pilot project in a limited application area.

"Best Practices" in the introduction stage
People Dimension Carson (2003) states, "people who know and understand the actual system is a key resource for project success", it is important to involve their opinions at any future model developments. Murphy and Perera (2001) agree with Carson's view and emphasize the need to establish an effective medium of communication with the software vendor in this introduction stage.
Organisational Dimension Murphy and Perera (2001) state that the success factor for introducing simulation within a company is to spread the benefits of simulation to the entire company – from management to general staff level. Carson (2003) suggests that pilot demonstration is a good practice for introducing new systems/technology before real implementation. First, pilot demonstration can establish credibility for new technology, second it can help to collect feedback for future development.

Table 5.2 Best practices in introduction stage

5.5.2 Output elements

Expectation

External consultants (e.g. software vendor or academic agencies) usually possess a greater level of experience in the use of simulation. It is important to communicate with them, setting expectations together with likely changes, as well as any negative expectations.

Additionally, the involvement of future users in the early stage of the introduction was identified in the literature to be a good practice to help limit resistance to change and ensure valuable opinions can be obtained from future users.

Awareness

In this stage, it is important that the capabilities and general benefits of simulation are spread out to the entire organisation; not only to the potential users and the senior management, but to all levels of staff within the company - it is important that all employees are aware of ongoing simulation activities.

In addition, arranging workshops with software vendors or academic agencies to present successful simulation applications to potential users and business units would increase confidence and support from them.

Commitment

During the introduction of simulation, communication between the simulation team and business units is an important success factor. This can be achieved by meeting with business units to explore the potential simulation application areas, therefore commitment on the use of simulation can be established which is essential for future deployment.

Pilot project

The pilot project plays an important role in capability testing of the identified simulation software, i.e. identifying the weaknesses and main challenges when the team undertake the simulation project, verifying new working procedures, and identifying necessary future trainings. Usually pilot projects focus on a small area of the business in order to minimise the time, risk and costs at this early stage.

5.6 Stage 3- Infrastructure

Once new working procedures and the selected simulation software have been verified through the pilot project, it is time to cascade to a larger audience. However, the infrastructure has to be ready for deployment from the two dimensions below, i.e. "Technological" and "Organisational" dimensions.

5.6.1 Input elements

Technological Dimension:

- Implement selected simulation software package into users' PCs. Since some of the critical capabilities of the software package may not yet be included, it is important to fully test and confirm before the deployment stage.

Organisational Dimension:

- Provide a separate budget for simulation projects. The budget plan should, at the very least, include the following costs:

  1 - Cost of hardware

  2 - Cost of software

  3 - Cost of training

  4 - Cost of documentation

  5 - Cost of personnel, both internal and external.

"Best Practices" in the infrastructure stage
Technological Dimension This is the author's experience from the study at Caterpillar Peterlee Ltd. Selected software package have to be installed into end-user's PCs at an early stage, in order to eliminate any technological problems which may occur during the deployment stage.
Organisational Dimension Murphy and Perera (2001) emphasize that procuring the financial support for the simulation team is critical when establishing simulation within a company, also a separate budget has to be planned for simulation activities.

Table 5.3 Best practices in infrastructure stage

5.6.2 Output elements

Software implemented

Licensing problems with simulation software packages were identified as significant issues prior to the project launch. It is reported, by the case study, that the finished model could not be executed from users' PCs because the license of the software was not capable of executing the developed model. This ultimately delayed the project schedule. Therefore, it is essential to consider the implementation of simulation software in the users' PC, with the right licenses and capabilities, before deployment.

Simulation Budget

An estimation of total costs involved should be prepared and separated for simulation projects at this stage which would reduce unexpected costs and risks during deployment. Indeed, after the deployment, regular updating of this plan should be performed.

5.7 Stage 4 - Deployment

After the essential infrastructure has been established and prepared, this stage seeks to deploy simulation in the company strategically from two dimensions: "People" and "Organisational" dimensions.

5.7.1 Input elements

People dimension:

- Provide simulation training to users involved in the upcoming simulation projects. Such training should cover aspects such as execution and experimentation with the selected simulation software package. This is because research conducted by this study indicated that training in analysis and interpretation of simulation models is mostly required during the early implementation stage. Such training can be provided by the software vendor or alternatively by the internal simulation team.

Organisational dimension:

- Time management. A project master timing plan should be developed and agreed with the problem owner. The simulation team must ensure the model can deliver the project on time for the problem owner.
- Successful simulation projects should be well documented. Such information may include results summaries, specification for simulation, process flows, output data sets, input data sets, resource costs or other minor issues, for example, performance data estimates or a model log updated after each simulation is completed. In addition, it is necessary to provide a good standardised system of documentation, for example a common server for storing the documentation.

- Deploy simulation projects as part of the business strategy. A successful business strategy is a key goal of an organisation. It is important to link simulation projects to the business strategy, with a focus on the benefits and capabilities of simulation in helping decision-making and answering "what-if" questions.

"Best Practices" in the deployment stage
People Dimension Murphy and Perera (2001) identify the importance of ensuring that end-users have the ability to conduct experimentation and correctly study results obtained from the simulation model. This practice is identified as a success factor for encouraging the regular use of simulation within an organisation.
Organisational Dimension Carson (2003) suggests it is good practice to develop time estimates and project timelines for the simulation project. It can ensure the management/ end-users understand the time schedule and decide whether to proceed with the project, or possibly to expand or limit its scope. Additionally, Murphy and Perera (2001) emphasise the need to integrate simulation as part of a business process to ensure simulation can be established within a company as an important decision-making tool.

Table 5.4 Best practices in deployment stage

5.7.2 Output elements

People trained

Lack of simulation knowledge has been identified as one of the main constraints to fully integrating simulation within an organisation. The survey supporting this study identified that the main challenge for first simulation projects was the analysis and interpretation of the simulation model, therefore it is important to provide training in this area, and other basic simulation training for the users involved in simulation projects. This can increase the confidence and motivation of these users in their ability to use the simulation models and carry out experimentation.

Model delivered on time

Poor time management has also been identified as one of the main constraints, which can negatively affect confidence, directions and goals. Therefore, simulation teams should regularly review and revise the schedule of every simulation project with the problem owner, thus ensuring that simulation projects can be deployed in the most efficient and valuable way.

Integrating with business strategy

Simulation is an important technique that can be used to analyse and develop decisions, and answer "what-if" questions to support the business strategy. Below are some examples in which simulation is often used in strategic decision-making:

- Justification of capital investment
- Optimisation of an existing resource or process
- Determination or analysis of a process bottleneck
- Implementation of a new process and design, or to analyse factory layouts
- Equipment decisions and operating policies.

However, it is important to deploy simulation with a link to current business strategies otherwise simulation would be abandoned by the organisation after completing a few projects.

5.8 Stage 5 – Embedding

In order to further embed this technology into business processes, once simulation has been deployed within an organisation, the company should consider the best approach to achieve the goal strategically from "people", "organisational" and "technological" dimensions. Otherwise, projects can become ad hoc and unplanned in style.

5.8.1 Input elements

People dimension:

- Cascade an awareness of simulation throughout the organisation after the completion of some successful projects, e.g. via newsletter, company intranet or email.
- Include simulation training to potential users and senior managers in model building and experimentation, also in project management.
- Provide opportunities for the simulation team or potential users to attend simulation related conferences, e.g. Winter Simulation Conference.
- Share knowledge among the simulation teams, for example, develop a *SharePoint* on the intranet, regular meetings and emails.

Organisational dimension:

- Set standards in the use of simulation by implementing project procedures. The project procedures should include:

  1 - Standard request form for new simulation projects

  2 - Meetings with problem owners to discuss potential projects

  3- Defining the scope of the project

  4- Defining expectation from the project

5- Defining the deadline of the project

6- Agreement between the simulation team and the problem owner

7- Data collection

8- Model building

9- Arrange user training if necessary

10- Documentation.

Technological dimension:

- Develop a standardised model data input and output interface, which separates the data from the actual model, e.g. with a customised Excel Spreadsheet, or link to company databases.
- Re-use an existing simulation model by programming code, component or full model re-utilisation.
- Use library of generic model objects - so-called *Templates* in the ARENA world. This can be achieved by the creation of re-usable simulation model building blocks in order to simplify the model development process.

"Best Practices" in the embedding stage
People Dimension Liebowitz and Megbolugbe (2003) state that an effective knowledge management system is a success factor for maintaining critical knowledge within an organisation – new knowledge has to be captured, shared and applied to new situations and then it is important to keep this cycle continuing within an organisation. Murphy and Perera (2001) specify that actively sharing knowledge between simulation users can finally enlarge the simulation knowledge base of an organisation.
Organisational Dimension Murphy and Perera (2001) state that it is a good practice to set a standard project procedure in order to manage new simulation projects. This can ensure the team and end-users both understand the expectations and specifications of a project, which can eventually keep end-users satisfied and also encourage the regular use of simulation.
Technological Dimension Murphy and Perera (2001) specify that one good practice to encourage the regular use of simulation within an organisation is to utilise pre-defined methods and techniques in modelling.

Table 5.5 Best practices in embedding stage

5.8.2 Output elements

Knowledge management

As mentioned in Stage 4, a lack of simulation knowledge within a company has been identified as one of the main constraints in embedding simulation technologies into business processes. Thus, knowledge management is identified as a critical success factor at this stage by cascading the new information, lessons learned from successful simulation projects, and also by sharing knowledge among the simulation team. Once critical knowledge on simulation is identified and captured from the previous stages, it is important to share it with others. Subsequently, this simulation knowledge can be applied for new situations by other team members, which may in turn create new knowledge and create perennial sharing within the organisation.

Additionally, as this study mentioned earlier, both project plan and documentation are necessary for every simulation project. With this documentation, it is easier for other team members or model developers to follow-up or modify existing simulation models.

People trained

Simulation training in model building and project management is considered to be another good approach for helping embed simulation into business processes. Model building and experimentation training can increase the ability of individuals to widely use simulation in their business areas and encourage them to conduct experimentation. Simulation project management, on the other hand, targets the senior management level which aims to enhance their confidence on simulation projects and to better understand the model application of decision-making. Therefore, it can ensure that simulation is deployed in the right direction, with the correct scope and target.

Standardisation

The literature review noted that standardising the model development process is a key success factor in broadening the use of simulation (McLean and Pegden, 2003). Success can be achieved by applying a customised model data input/output interface or directly linking the model with an existing database - both of which can eliminate data input errors. Additionally, a standardised data format can be re-used by other simulation models, which can share the same model data and increase model flexibility.

On the other hand, by using generic model objects or customised templates, the model development process can be simplified. Here, pre-built objects or templates can be re-used on different models with similar scopes. This can reduce the production costs and lead-times of simulation model development.

By standardising simulation project procedures, several major long-term benefits towards the strategic approach in the use of simulation technologies within the organisation may become apparent, these may include:

- A planned simulation culture, as opposed to an ad-hoc, unplanned scenario
- Reduced overlapping of activities or procedures
- Shorter project lead times with better time management
- Better correspondence between planned and real outcomes of strategic and operational objectives
- Better informed decisions with clear and open procedures.

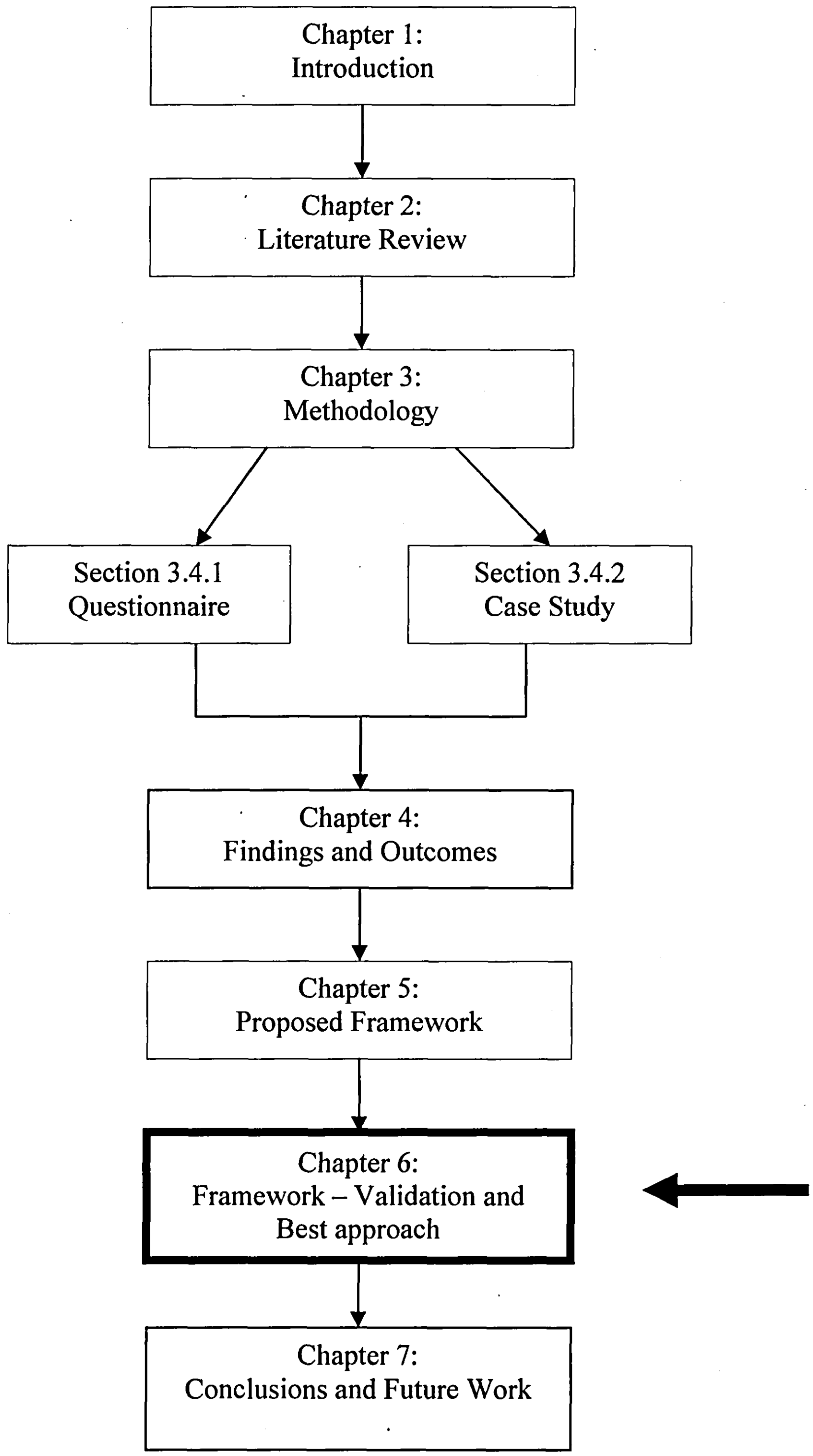
All these standardised procedures will aid the simulation team in the regular use of simulation. Additionally, this enables the simulation team to keep problem owners satisfied with high efficiency and accuracy, which helps to make simulation more acceptable and accessible as a standard tool.

5.9 Summary

This chapter developed a framework aimed towards enabling companies to embed simulation technologies into business processes. The key concepts identified and adopted for this proposed framework were briefly introduced. Five main stages of the proposed framework i.e. Foundation, Introduction, Infrastructure, Deployment and Embedding were presented and explained. Additionally, the input and output elements of each stage were described and discussed. The overview of this proposed framework is shown in Figure 5.2.

Following this, the proposed framework will be cross-referenced with a validation form, which is designed to collect feedback and judgements about the validity and reliability of the proposed framework. This validation process targeted the population from academic and industrial parties who have simulation experiences. A sample of this validation form can be found in Appendix C. Discussion on the validation results will be presented and discussed in the next chapter.

CHAPTER 6: Framework - validation and best approach



CHAPTER 6

FRAMEWORK - VALIDATION AND BEST APPROACH

6.1 Introduction

The purpose of this chapter is to provide an assessment of the proposed framework described in Chapter 5, by collecting feedback and judgements of validity and reliability of the proposed framework. Five respondents participated in the validation; two were from academic backgrounds and three were from industrial backgrounds. All respondents were professionals, and each had over five years of simulation experience.

Additionally, this chapter reviews the collected feedback and judgments from the validation process, highlights the strengths and limitations of the proposed framework, and then modifies the necessary changes in order to develop a best practice framework, which can help companies to embed simulation technologies into business processes through a systematic approach.

6.2 Analysis and results

Note: Detailed results regarding the validation process can be found in Appendix D.

Overall, positive feedback was received from both academic and industrial parties regarding the proposed framework. The proposed framework developed in Chapter 5 provides a holistic and a systematic approach to help companies in embedding simulation technologies into business processes. Indeed there are several strengths and limitations to the proposed framework, which can be summarised from the results of the validation.

Strengths:

1. The proposed framework is easy to follow. It is acknowledged that the concept of the five key stages (i.e. Foundation, Introduction, Infrastructure, Deployment and Embedding) is appealing to users. Implementing new technology is a fairly complicated process which requires a systematic and structured approach so that there is a clear guideline to simplify the process of implementation for users.
2. The proposed framework is generic. Although only five respondents participated in the validation process, they all had a different background and were from different industries. It is thereby believed that the proposed framework supports different kinds of industrial sectors, rather than satisfying purely one type of business.
3. The proposed framework is holistic. "People", "Technological" and "Organisational" issues are typically the main elements of an organisation. The proposed framework uses these three main elements to classify best practices in the input element. This may reduce confusion and increase realisation – allowing companies to focus on each element in order to carry out best practices.

Limitations:

(Note: With reference to Appendix D, any issue with an average ranking lower than 4 is considered to be a limitation of the framework or non-critical.)

1. The proposed framework is built upon the literature reviews and the findings from quantitative and qualitative studies. However, it is acknowledged that the proposed framework appears to be lacking in linkage to these previous studies. Therefore, respondents identified that the proposed framework could not fully achieve two of the key concepts i.e. overcome main challenges and include best practices (Appendix D: Figure D1).

2. Selecting a particular simulation software package in the foundation stage has been identified as less critical. One of the respondents from the industry indicated that all major commercial simulation software packages nowadays are capable of solving 99% of business problems. Additionally, software prices are fairly standard among the most popular software packages. Therefore, it is acknowledged that selecting the particular simulation software package in the foundation stage is not a critical factor to be considered as one of the best practices.

3. Additionally, communication with the simulation software vendor, in order to set expectations of a particular package right from the beginning, has been identified as less critical.

4. A separate budget for simulation projects in the infrastructure stage has also been identified as less critical. One of the respondents explained that simulation technologies should be a tool to help companies save resources and expenses. It is important to consider monitoring savings made with simulation projects rather than setting a clear budget for them.

5. The concept of standardisation in the embedding stage – re-use of model logic, and the set standard project procedure for simulation projects, were both challenged by the respondents. These respondents acknowledged that it would be unusual to have the same requirements for different projects. Indeed different projects require different levels of detail, thus the ability to re-use model logic is uncommon. Additionally, it is recognised that setting standard project

procedures for a simulation project is not critical to be considered one of the best practices.

6.3 Modification to the proposed framework

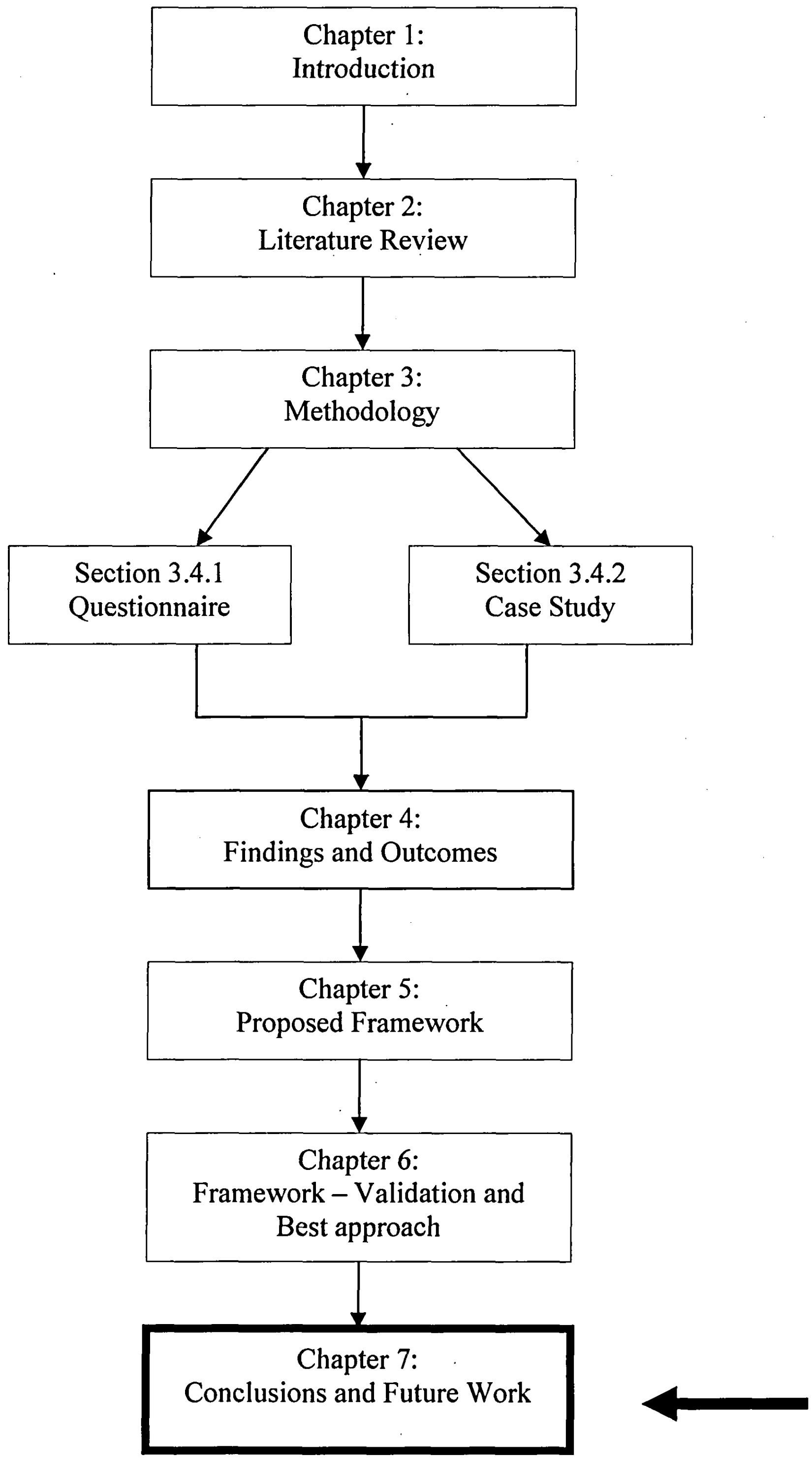
From the above analysis, it is considered that the proposed framework is not sufficient to include the best practices. The author considers this limitation to be an important issue which has to be addressed by this study so that immediate modification is made during the validation process.

The modification was made mainly in Chapter 5 of this study; the tables below were added to the input elements under each key stage.

- Table 5.1 – Best practices of introduction stage
- Table 5.2 – Best practices of foundation stage
- Table 5.3 – Best practices of infrastructure stage
- Table 5.4 – Best practices of deployment stage
- Table 5.5 – Best practices of embedding stage

The purpose of including these additional tables is to highlight the best practices that are considered leading edge in the literature for enabling companies to embed simulation technologies into business processes. This ensures that framework users have a better understanding of each best practice before applying to their companies.

CHAPTER 7: Conclusions and Future Work



CHAPTER 7

CONCLUSIONS AND FUTURE WORK

7.1 Conclusions

This dissertation is concerned with enabling companies to utilise simulation technologies as a strategic decision support tool. Factors that hinder their ability to use simulation in a strategic manner were investigated in the literature review, which provided supportive evidence to the problem outlined in the introduction. Additionally, the questionnaire survey and case study were performed in this research in order to examine the ways in which simulation has been introduced and used in different organisations.

A framework that included a best practices approach for embedding simulation technologies into business processes was developed and presented in Chapter 5, and validated in Chapter 6 of this work. It provides a guideline to enable companies to embed simulation technologies into their business processes which thereby addresses the main aim of this work.

7.2 Contribution to knowledge

A review of the relevant literature indicated that several researchers found there to be a requirement for a structured way of implementing simulation technologies into companies, in order to fully integrate simulation as a daily tool in their businesses (Holst, 2001 and Jagstam & Klingstam, 2002). However, there has been limited research specifically focused on developing a systematic approach to address this research gap.

This study has made a contribution to reduce the research gap in the existing simulation integration studies, with a clear five-stage framework, namely; Foundation, Introduction, Infrastructure, Deployment and Embedding to guide companies in fully integrating simulation into their business processes.

Murphy and Perera (2001) identified that the vital success factor in implementing simulation into a company environment is to include best practices. This study has made an effort to investigate and include the best practices for each stage of the framework, which provides a clear and easy way for users to understand and apply to their particular business. Consequently, this framework should assist companies to establish a strong foundation for implementing simulation as a mainstream technology within their businesses.

7.3 Recommendations for future work

The present work offered a five-stage framework for guiding companies in embedding simulation technologies into business processes. Although validation of the framework and the best practices was conducted in Chapter 6 of this work, it was acknowledged that a weighted ranking analysis only is not enough to test the capability factors of the proposed framework. Accordingly, some recommendations for further work are discussed below.

7.3.1 Validating the framework in a case study format

The author suggests that further work could be expanded upon to validate the framework in a case study format. Yin (2003) defines the scope of a case study as follows: "A case study is an empirical inquiry that: investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." Therefore, it would be an added benefit to further assess and validate the capability factors of the proposed framework by applying it to real organisations. Respondents who participated in the questionnaire survey could be chosen to investigate in depth how efficient and practical the proposed framework could be in guiding them to embed simulation technologies within their business processes.

7.3.2 Further review on the proposed framework

The framework contributed by this work, which provides a best practices approach to guide companies to embed simulation within their businesses, is considered to be new research knowledge in the existing simulation integration studies. The author suggests that future researchers could use the proposed framework as a fundamental structure, review more recent data regarding the good practices and challenges experienced by other studies, and then review the current framework with necessary modifications.

REFERENCES

(ARTICLES /JOURNALS/PROCEEDINGS)

Aust, S. (2000). Ensuring a successful simulation modelling project. *QCI International*

Ahmed, P.K. (1998). Culture and climate for innovation. *European Journal of Innovation Management*, Vol. 1, No. 1, pp. 30-43.

Adams, J., Flatto, J. and Gardner, L. (2005). Combining hands-on, spreadsheet and discrete event simulation to teach supply chain management. In: *Proceeding of the 2005 Winter Simulation Conference* ,ed. M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, pp. 2329- 2337. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Ali, S.A., Seifoddini, H. and Sun, H. (2005). Intelligent Modeling and Simulation of Flexible Assembly Systems. In: *Proceedings of the 2005 Winter Simulation Conference*, ed. M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, pp. 1350-1358. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Ardichvili, A., Page, V. and Wentling, T. (2003). Motivation and barriers to participation in virtual knowledge-sharing communities of practice. *Journal of knowledge management*, Vol. 7, No. 1, pp. 67-77.

Barth, T. and Algee, J. (1996). Proving and Improving Your Process with Simulation. In: *International Industrial Engineering Conference Proceedings,* Institute of Industrial Engineers, pp. 522-525.

Baldwin, L.P., Eldabi, T. and Paul, R.J. (2005). Business process design: flexible modelling with multiple levels of detail. *Business Process Management Journal*, Vol. 11, No. 1, pp. 22-36.

Ballard, S.M. and Kuhl, M.E. (2006). The use of simulation to determine maximum capacity in the surgical suite operating room. In: *Proceedings of the 2006 Winter Simulation Conference*, ed. L.F. Perrone, F.P. Wieland, J.Liu, B.G. Lawson, D.M. Nicol, and R.M. Fujimoto, pp. 433-438. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

CPS update. (2006). Caterpillar Production System newsletter, Caterpillar Peterlee Ltd, 11th to 24th September 2006

Bartholomew, D. (2000). Simulation Strategies. *Industry Week*, Vol. 249, Issue 12, pp. 79.

Bartlett, J.E., Kotrlik, J.W. and Higgins, C.C. (2001). Organisational research: Determining Appropriate Sample Size in Survey Research. *Information Technology, Learning, and Performance Journal*, Vol. 19, No. 1, 2001

Cumming, S.B. (1998). Innovation overview and future challenges. *European Journal of Innovation Management*, Vol. 1, No. 1, pp. 21-29.

Carson, J.S. (2003). Introduction to modeling and simulation. In: *Proceedings of the 2003 Winter Simulation Conference*, ed. S.Chick, P.J. Sanchez, D.Ferrin, and D.J. Morrice, pp. 9-16 Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Hengst, M. Den, Hlupic, V. and Currie, W. (2004). The increasing need for integrating simulation and collaboration to support change management programs. Sprage, R.H. (Ed.): *Proceedings of the Thirty-Seventh Annual Hawaii International Conference on System Sciences*, IEEE Computer Socity, Los Alamitos, CA.

Garnett, J. (1999). The last word on simulation. *IIE solutions*, pp. 45-47.

Groumpos, P.P. and Merkuryev, Y. (2002). A Methodology of Discrete-Event Simulation of Manufacturing Systems: An Overview. Laboratory for Automation & Robotics, University of Patras & Department of Modelling and Simulation, Riga Technical University.

Gaba, D.M. (2004). The future vision of simulation in health care. Qual Saf Health Care

Greasley, A. (2004). The case for the organizational use of simulation. *Journal of Manufacturing Technology Management,* Vol. 15, No. 7, pp. 560-566.

GAO. (1992). Quantitative Data Analysis: An Introduction. Report to Program Evaluation and Methodology Division (PEMD), United States General Accounting Office.

Hlupic, V. and de Vreede, G.J. (2005). Business process modelling using discrete-event simulation: current opportunities and future challenges. *Internal Journal of Simulation & Process Modelling,* Vol. 1, Nos. 1/2, pp. 72-81.

Hlupic, V., de Vreede, G.J. and Orsoni, A. (2005). Modelling and simulation techniques for business process analysis and re-engineering. *I.J. of Simulation,* Vol. 7 Nos. 4-5.

Harrel, C.R. and Hicks, D.A. (1998). Simulation software component architecture for simulation-based enterprise applications. In: *Proceeding of the 1998 Winter Simulation Conference,* ed. D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, pp. 1717-1728. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Hargadon, A. (2005). Technology brokering and innovation: linking strategy, practice, and people. *Strategy & Leadership*, Vol. 33, No. 1, pp. 32-36.

Hunt, K.L., et al. (1997). Simulation success stories: Business Process Reengineering. In: *Proceedings of the 1997 Winter Simulation Conference,* ed. S.Andradottir, K.J. Healy, D.H. Withers, and B.L. Nelson, pp. 1275-1279. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Idrose, A.M., et al. (2007). The use of classroom training and simulation in the training of medical responders for airport disaster. *Emergency Medicine Journal*, Vol. 24 pp. 7-11.

Irani, Z., et al. (2000). Re-engineering manufacturing processes through simulation modelling. *Logistic Information Management,* Vol. 13, No. 1, pp. 7-13.

Ingemnasson, A., Ylipaa, A. and Bolmsjo, G.S. (2005). Reducing bottlenecks in a manufacturing system with automatic data collection and discrete-event simulation. *Journal of Manufacturing Technology Management*, Vol. 16, No. 6, pp. 615-628

Jadhav, P.D. and Smith, J.S. (2005) Analyzing printed circuit board assembly lines using a PCB Assembly Template. In: *Proceedings of the 2005 Winter Simulation Conference,* ed. M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, pp. 1335-1342. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Jagstam, M. and Klingstam, P. (2002). A handbook for integrating discrete event simulation as an aid in conceptual design of manufacturing systems. In: *Proceedings of the 2002 Winter Simulation Conference,* ed. E.Yucesan, C.-H. Chen, J.L. Snowdon, and J.M. Charnes, pp. 1940-1944. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Johnson, R.B. and Onwuegbuzie, A.J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, Vol. 33 Iss. 7, pp. 14, 13 pgs

Johnson, R.B. and Turner, L.A. (2003). Data collection strategies in mixed methods research. Tashakkori, A. and Teddie, C. (eds.) (2003). Handbook of mixed methods in social and behavioral research, pp. 297-319, Thousand Oaks. CA: Sage

Kellner, M.I., Madachy, R.J. and Raffo, D.M. (1999). Software Process Simulation Modelling: Why? What? How? *Journal of Systems and Software,* Vol. 46, Nos. 2/3

Love, P.E.D. and Gunasekaran, A. (1997). Process re-engineering: a review of enablers. *International Journal of Production Economics*, Vol. 50 No. 2/3, pp. 183-97

Waddell, G. (1982). Simulation: Balancing the Pros and Cons. *Training and Development Journal*

Law, A.M. and McComas, M.G. (1998). Simulation of manufacturing systems. In: *Proceedings of the 1998Winter Simulation Conference,* ed. D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, pp. 631-643. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Liebowitz, J. and Megbolugbe, I. (2003). A set of frameworks to aid the project manager in conceptualizing and implementing knowledge management initiatives. *International Journal of Project Management,* Vol. 21, Iss. 3, pp. 189-198

Miller, S. and Pegden, D. (2000). Introduction to manufacturing simulation. In: *Proceedings of the 2000 Winter Simulation Conference,* ed. J.A. Joines, R.R. Barton, K.Kang, and P.A. Fishwick, pp. 85-92. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Musselman, K.J. (1994). Guidelines for simulation project success. In: *Proceedings of the 1994 Winter Simulation Conference,* ed. J.D. Tew, S. Manivannan, D.A. Sadowski, and A.F. Seila, pp. 88-95. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

McLean, C., et al. (2003). The future of the simulation industry. In: *Proceedings of the 2003 Winter Simulation Conference,* ed. S. Chick, P.J. Sanchez, D.Ferrin, and D.J. Morrice, pp. 2033-2043. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

McLean, C., et al. (2003). Simulation Standards: Current status, Needs, and Future directions. In: *Proceedings of the 2003 Winter Simulation Conference,* ed. S. Chick, P.J. Sanchez, D.Ferrin, and D.J. Morrice, pp. 2019-2026. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Murphy, S.P. and Perera, T.D. (2002). Successes and failures in UK/US development of simulation. *Simulation Practice and Theory,* Vol. 9, pp. 333-348

Murphy, S.P. and Perera, T.D. (2002). *The definition of simulation and its role within an aerospace company. Simulation Practice and Theory,* Vol. 9, pp. 273-291.

Murphy, S.P. and Perera, T.D. (2001). Key enablers in the development of simulation. In: *Proceedings of the 2001 Winter Simulation Conference*, ed. B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, pp. 1429-1437. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

McLean, C. and Leong, S. (2001). The expanding role of simulation in future manufacturing. In: *Proceedings of the 2001 Winter Simulation Conference*, ed. B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, pp. 1478-1486. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

O'Kane, J.O. (2003). Simulation as an enabler for organization excellence. *Measuring business excellence*, Vol. 7, No. 4, pp. 12-19.

Peterman, M. (2000). Process simulation is a key in a lean manufacturing company hungering for big results. *Simulation Nation*

Peters, B.A., et al. (2001). A Simulation study of the labour and delivery rooms at JMH. In: *Proceedings of the 2001Winter Simulation Conference*, ed. B.A. Peters, J.S. Smith, D.J. Medeiros, and M.W. Rohrer, pp. 1392-1400. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Robinson, S. and Stanger, M. (1998). Developing a simulation strategy for British Airways OR. In: *Proceedings of the 1998 Winter Simulation Conference,* ed. D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. MAnivannan, pp. 1183-1190. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Robinson, S. (2005). Distributed Simulation and Simulation Practice. *Simulation*, Vol. 81, Iss. 1, pp. 5-13

Strait, C. (2006). Integrating new technology into organisational business processes, BI Report Printed from DMReview.com

Schroer, B.J. (2004). Simulation as a Tool in understanding the concepts of lean manufacturing. *Simulation*, Vol. 80, Issue 3, pp. 171-175.

Seppanen, M.S. (2005). Operator Paced Assembly Line Simulation. In: *Proceedings of the 2005 Winter Simulation Conference,* ed, M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, pp. 1343-1349. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Sadowski, D.A. and Sturrock, D.T. (2006). Tips for the successful practice of simulation. In: *Proceedings of the 2006 Winter Simulation Conference,* ed. L.F. Perrone, F.P. Wieland, J.Liu, B.G. Lawson, D.M. Nicol, and R.M. Fujimoto, pp. 60-66. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Takakuwa, S. and Okada, T. (2005). Simulation Analysis of inbound call center of a city-gas company. In: *Proceedings of the 2005 Winter Simulation Conference,* ed, M.E. Kuhl, N.M. Steiger, F.B. Armstrong, and J.A. Joines, pp. 2026-2033. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

Williams, E.J. (2002). Making Simulation a Corporate Norm. Analytical Software & Operations Research, Ford Motor Company

Williams, E.J., et al. (2006) Material handling resource utilization simulation study for stamping plant. In: *Proceedings of the 2006 Winter Simulation Conference,* ed. L.F. Perrone, F.P. Wieland, J.Liu, B.G. Lawson, D.M. Nicol, and R.M. Fujimoto, pp. 1940-1945. Piscataway, New Jersey: Institute of Electrical and Electronic Engineers.

(ONLINE)

TMR Show Reports. (1998). AUTOFACT97: Virtual Manufacturing Has Become a Reality. *The manufacturing report*. Available online via <www.lionhrtpub.com/tmr/showreviews98/122697autofact.html>

Br J Healthcare Comput Info Manage. (2005). Designing improved healthcare processes using discrete even simulation. Vol. 22, No. 5. Available online via <www.bjhc.co.uk/issues/V22-5/V22-5dodds.htm>

Fornasier, S. (2006). Reorganizing the Passenger Flows in Terminal 2 with support of ARENA. Munich airport International, Simulations-and Automations-Technologies AG. Available online via <www.cadmen.com/sec_page/news/2006/arena_ugm_2006/SAT_ARENA%20MUC%20Success%20Story.pdf>

"Ford Brazil uses simulation to design engine plant from the group up." Available online via <www.arenasimulation.com/pdf/fiesta.pdf>

Holst, L. (2001). Integrating Discrete-Event Simulation into the Manufacturing System *Development Process*. .Available online via <www.robotics.lth.se/publications/2001/holst_lic/PDF/lars_holst_lic.pdf>

Introduction to Discrete Event Simulation. (2004). Available online via <www.dmem.strath.ac.uk/~pball/simulation/simulate.html>

Intrax Technology Group Employs Simulation to Locate Major Bottlenecks for adhesives manufacturer. (2001). Available online via <www.arenasimulation.com/pdf/INTRAX-AP001A-EN-P.pdf>

Krauth, J. (1999). Introducing information technology in small and medium sized enterprises. Bremen Institue of Industrial Technology and Applied Work Science at the University of Bremen. Available online via <www.ici.ro/ici/revista/sic1999_1/art07.html>

Manufacturing - discrete event simulation. (2004). TWI Ltd. Available online via <www.twi.co.uk/j32k/protected/band_3/ksngs002.html>

"OP-SIM - patient cycle and operation ward simulator". Available online via <www.arenasimulation.com/pdf/OPSIM_eng.PDF>

Simulation facilitates apparel manufacturer's transition from national to regional distribution. (2004). Available online via <www.arenasimulation.com/pdf/APRMFR-AP001A-EN-P.pdf>

Rockwell fast tracks patient flow. (2003). *Institute of Industrial Engineers.* Available online via <www.arenasimulation.com/pdf/RockwellPDFAdvertorial.pdf>

Ülgen, O.M. Productivity Simulation in the Automotive Industry. *PMC Publication.* Available online via <www.pmcorp.com/pub_simulation.shtm#Manufacturing>

United Parcel Service reduces aircraft turnaround time from Hours to Minutes. (2001). Available online via <www.arenasimulation.com/pdf/UPSERV-AP001A-EN-P.pdf>

BIBLIOGRAPHY

Andrews, David H. and Johnson, Kenneth R. (2002). *Revolutionising IT- The art of using information technology effective.* John Wiley & sons Inc

Creswell, J.W. (2003). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* 2nd Edition, Sage Publication

Ettlie, Johne E. (2000). *Managing Innovation-new technology, new products, and new services in a Global Economy.* 2nd edition, Elsevier Butterworth-Heinemann

Gundling, E. (2000). *The 3M way to innovation - balancing people and profit.* Kodansha International

Holst, L. (2002). *Integrating Discrete-Event Simulation into the Manufacturing System Development Process: A Methodological Framework.* Lund, Sweden, Division of Robotics, Department of Mechanical Engineering, Lund University

Have, Steve T, et al. (2003). *Key management models - The managements tools and practices that will improve your business.* FT Prentice Hall

Jessup, L. and Valacich, J. (2006). *Information Systems Today.* 2nd Edition, Pearson Prentice Hall

Kelton, W.D., Sadowski, R.P. and Sadowski, D.A. (2002). *Simulation with Arena.* Second Edition, McGraw Hill

Lientz, B.P. and Rea, K.P. (2000). *On Time Technology Implementation - How to achieve implementation success with limited time and resources.* Academic press

Morgan, J.M. and Liker, J.K. (2006). *The Toyota product development system.* Productivity Press

Rhodes, E. and Wield, D. (1985). *Implementing new technology- Choice, decision and change in manufacturing.* Blackwell

Robinson, S. (2003). *Simulation: The Practice of model Development and Use.* John Wiley & Sons, Chichester, UK

Schrage, M. (2000). *Serious play: how the world's best companies simulation to innovate.* Harvard Business School Press

Vernadat, F.B. (1996). *Enterprise Modeling and Integration: Principles and Applications.* Chapman & Hall, Lone

Walters, D. (2000).*Operations Strategy*, Palgrave macmillan

White, T. (2004). *What business really wants from IT?* Elsevier Butterworth-Heinemann

Yin, R.K. (2003). *Case Study Research: Design and Methods.* Sage Publications Inc, 3rd Edition

Appendix A

Questionnaire Survey Sample

Embedding Simulation Technologies in Business Processes
By Ruby Lau

Dear All,

I am a researcher within the Systems Modelling and Integration Research Group, Sheffield Hallam University, UK and aiming to develop a strategy to embed simulation technologies in business processes.

As a part of this research work, I am conducting this survey to understand **practice relating to the introduction, development and deployment of discrete-event simulation tools** (such as ARENA, ProModel, Witness, Simul8) **within businesses**.

This questionnaire will take no more than 10-15 minutes of your time and I would be very grateful if you could assist me by completing it. All information will be kept confidential and will only be reported in aggregate and summary form. If you have any queries, please feel free to contact me or my Director of Studies, Professor Terrence Perera. All participants in the survey will receive a brief report outlining the key findings.

Thank you for your participation. I'm looking forward to receiving your completed questionnaire.

Regards,

Miss Ruby Lau - (+44) 114 225 3395
ruby.w.lau@student.shu.ac.uk
Systems Modelling and Integration Research Group
Systems Engineering & Technology
Sheaf Building, Sheffield Hallam University
Sheffield, S1 1WB, UK.

Professor Terrence Perera
t.d.perera@shu.ac.uk

===

If your company has never used simulation, please answer Section 1 and Section 6 for the purpose of data analysis.

1. YOUR BUSINESS

This section aims to capture the nature and the scale of your business and also whether your business has ever used simulation technologies as outlined in the introduction.

Q-1.1 Please indicate the primary nature of your business

a) Manufacturing

( ) Aerospace	( ) Automotive	( ) Biotech	( ) Chemical
( ) Steel	( ) Shipbuilding	( ) Electronics	( ) Pharmaceuticals
( ) Food & Beverages	( ) General Manufacturing		

b) Service

( ) Business services	( ) Consultant Service	( ) Health Sector	( ) Hospitality & leisure
( ) Transportation	( ) IT & telecoms	( ) Education	

c) Other, please specify below

Q-1.2 What is the size of your company?

( ) <50 employees	( ) 50 - 249 employees	( ) >250 employees

Q-1.3 How many years has simulation been used in your company?

( ) None, Go to section 6	( ) < 1 year	( ) 1 year to 5 years	( ) > 5 years

2. INTRODUCTION & EXPLORATION OF POTENTIAL USE

Introducing a new technology is always challenging. This section attempts to identify steps taken to introduce and promote the potential use of simulation within your business.

Q-2.1 Which statement below best describes the introduction of simulation to your business?

( ) Simulation was identified as an appropriate tool for problem solving
( ) Simulation was suggested by a new employee
( ) Simulation was encountered at an external event (tradeshow, conference etc)
( ) Simulation was introduced by an external party (Simulation software vendor, simulation consultant/ academic etc)
( ) Other, please specify: ...

Q-2.2 Who was tasked with introducing and exploring the potential use of simulation within your business?

( ) Led by an internal team/individual with no involvement of external consultants
( ) Led by an internal team/individual with support from external consultants
( ) Led by an external team/individual with support from an internal team/individual

Q-2.3 How has the internal team developed an understanding of simulation technologies? (the term 'team' in this question represents either individual or team)

( ) One or more team members already knew simulation
( ) Team was sent to external events (e.g. Conferences, training) learn about simulation
( ) External simulation consultants were used to introduce simulation

Q-2.4 If external consultants were engaged, how did they contribute at this stage? Tick all that apply

( ) Provided case studies
( ) Advised the team on how to promote and identify potential applications
( ) Provided information to estimate the cost of using simulation (Training, Software, hardware)
( ) Other, please specify: ...

Q-2.5 What were the key objectives of this Introduction & Exploration Stage? Tick all that apply

( ) Run workshops/seminars to promote simulation
( ) Consult business unit managers with the view to identify potential applications
( ) Organise a simple model building exercise based on a selected problem of the business
( ) Visit other businesses (or other external events, such as conferences) to learn about their experiences
( ) Other, please specify: ...

Q-2.6 What was the main outcome of this stage?

( ) agreed to proceed and introduce simulation across the business
( ) agreed to proceed and introduce simulation in a limited area of business ***Please state which area of business?*** ......
( ) agreed to proceed only after a successful pilot project
( ) rejected use of simulation

Q-2.7 If simulation was rejected, what were the main reasons? Tick all that apply

( ) Couldn't establish simulation as the right solution strategy
( ) Couldn't justify the cost associated with the implementation
( ) Return on investment was not clear
( ) Other, please specify: ...

3. PILOT PROJECT / FIRST EXPERIENCE

Assuming that your business has decided to proceed with simulation, this section aims to capture your experiences in the first simulation project

Q-3.1 What was the scope of the first simulation project? Tick all that apply

( ) Justify capital investment
( ) Optimise an existing resource or process
( ) Determine or to analyse a process bottleneck
( ) Implement a new process
( ) Design or to analysis factory layouts, equipment decisions, operating policies
( ) Other, please specify: ...

Q-3.2 Which simulation software package was used in the first simulation project?

Q-3.3 Why was the above simulation software package chosen?

Q-3.4 Who built the first simulation model?

( ) Internal - experienced simulation model builder	( ) Internal - novice with some simulation training
( ) External - e.g. external simulation consultant or academic	( ) Other, please specify: ...

Q-3.5 Were there any major challenges during the first simulation project? Rank them in order from one to five [1 = Lowest Priority, 5 = Highest Priority]

( ) Deciding the level of detail	( ) Data collection/ Software issues
( ) Model building	( ) Analysis and interpretation
( ) Communication between model builders and problem owners	

Q-3.6 What was the outcome of the pilot/first project?

( ) Satisfied with the outcome, decided to proceed with further applications

( ) Satisfied with the outcome, decided NOT to proceed with further applications

( ) Not satisfied with the outcome, abandoned the use of simulation

Why was the pilot/first project not satisfying? Tick all that apply

( ) Simulation objectives were not clearly defined
( ) Trying to build too many details into the model
( ) Making conclusions from a single simulation run rather than from multiple runs
( ) Making conclusions from animation rather than from statistical report
( ) Simulation results developed too late to allow decisions to be made
( ) Other, please specify:

4. INTRASTRUCTURE & COMMUNICATION

Having decided to proceed with simulation, this section aims to understand how your business developed simulation further.

Q-4.1 What mechanisms were used to make others aware of simulation? Tick all that apply

( ) Workshops	( ) Meetings with section leaders
( ) Internal publications	( ) Other, please specify: ...

Q-4.2 What was the initial response of business units in terms of potential applications for simulation?

( ) A number of proposals with no/little encouragement	( ) Few proposals with no/little encouragement
( ) Few proposals after several encouragements	( ) None

Q-4.3 What option was used to build simulation models?

( ) Internal Team (proceed to Q-4.3.1 to Q-4.3.3)	( ) External Consultants (proceed to Q-4.3.4)

Q-4.3.1 Did you continue to use the software that had been used for the first project?

( ) Yes	( ) No. Please explain the reasons:

Q-4.3.2 How many permanent simulation practitioners are in the team?

( ) 1 member	( ) 2 – 5 members	( ) 6 – 10 members	( ) > 10 members

Q-4.3.3 Please choose from below, which statement best describes the interactions between the team and problem owners?

( ) Simulation team is an integral part of solution development process
( ) Problems are brought to the simulation team
( ) Simulation team attempts to identify appropriate problems for modelling

Q-4.3.4 Why were external consultants used?

( ) Lack of internal expertise	( ) No resources to engage in simulation
( ) Other, please specify:	

Q-4.4 What kind of training has been provided to the core simulation team? Tick all that apply

( ) Simulation Project Management
( ) Simulation software training
( ) Programming language (such as VBA) training for interface building
( ) None

Q-4.5 How is simulation being deployed?

( ) Simulation Team or Consultants manage the entire project and produce simulation models and recommendations/solutions
( ) Simulation Team or Consultants provide simulation models , solutions are developed by problem owners

5. DEPLOYMENT & STANDARDISATION

Once simulation had been introduced, this section aims to capture the simulation practices in your business.

Q-5.1 What type of problem have been resolved using simulations? Tick all that apply

( ) Justify capital investment
( ) Optimise an existing resource or process
( ) Determine or to analyse a process bottleneck
( ) Implement a new process
( ) Design or to analysis factory layouts, equipment decisions, operating policies
( ) Other, please specify:

Q-5.2 How many simulation models on average have been developed within your business in the past 12 months?

( ) None	( ) 1 - 5 projects	( ) 6 - 10 projects	( ) > 10 projects

Q-5.3 What mechanisms are commonly used to present simulation results? Tick all that apply

( ) Standard reports from simulation software	( ) Live animation
( ) Customised Excel spreadsheet	( ) Web page
( ) Other, please specify: ...	

Q-5.4 What mechanisms are used to input data to models? Tick all that apply

( ) Data entered directly to the model at the model design mode	( ) Data stored in spreadsheets and linked to model
( ) Data entered via custom designed interfaces at model run mode	( ) Data stored in databases and linked to model
( ) Other, please specify: ...	

Q-5.5 Do you build customised simulation templates/objects to accelerate the model development process?

( ) YES	( ) NO

Q-5.6 During the last 2 years, have models been re-utilised (either partially or fully)?

( ) No	( ) Yes, Full Model re-utilised	( ) Yes, Component re-utilised
( ) Yes, Function re-utilised	( ) Yes, Code Scavenging	( ) Other, please specify below

Q-5.7 What information has been usually documented after a successful simulation project? Tick all that apply

( ) Specification for simulation	( ) Input data sets	( ) Output data sets
( ) Results summaries	( ) Process flow	( ) Resource costs
( ) None	( ) Other, please specify below:	

6. PLANS TO USE SIMULATION IN THE FUTURE

Simulation is a popular decision support tool in industry. Please let us know if your business has any future plan on using simulation.

Q-6.1 Does your company have a strategy to further develop the use of simulation?

( ) YES	( ) NO
If possible, briefly describe your approach:	

Q-6.2 If you are interested in obtaining a copy of the results summary for this work, or to further your understanding of simulation, please complete the form below:

NAME	
TITLE	
COMPANY NAME	
COMPANY ADDRESS	
COMPANY TELEPHONE	
EMAIL ADDRESS	

THANK YOU!!

Please email your responses to ruby.w.lau@student.shu.ac.uk, or post to:

Miss Ruby Lau
Systems Modelling and Integration Research Group
Systems Engineering & Technology
Sheaf Building, Sheffield Hallam University Sheffield, S1 1WB, UK.

Mobile: (+44) 789 6346471
Office: (+44) 114 2253395

Appendix B

Caterpillar - Questionnaire Survey Sample

Dear Colleague

We have instituted a research project, in collaboration with the *Systems Modelling and Integration Research Group*, Sheffield Hallam University, to develop a strategy to embed simulation technologies in business processes. The first step of this project is to understand *what you know about simulation* and *how you would like to see simulation being used within your own area*. Please help the researcher Ms Ruby Lau by filling-in and returning this questionnaire.

Thanks in advance for your cooperation.

David Hodgson
Six Sigma Black Belt

Department

Job title

Name (Optional)

1. What does the term 'simulation' mean to you?

2. Are you aware of any past or present simulation applications within Caterpillar (Peterlee) Ltd? If YES, please describe them briefly.

   YES ( )   NO ( )

3. Do you have any previous experience (outside Caterpillar) with simulation?
   If YES, please briefly describe your experiences otherwise go to Q5.

   YES ( ) NO ( )

4. How successful was (were) the project(s)? Did you encounter any problems?

5. With your current understanding of simulation technologies, can you foresee any potential applications within your area of work?
   If YES, please describe briefly

   YES ( ) NO ( )

6. Would you like to learn more about simulation?
   If YES, what do you like to know?

   YES ( ) NO ( )

7. Any comments about this project and/or questionnaire?

Appendix C

Validation form Sample

Dear All,

This validation form designed to collect feedbacks and judgements regarding the reliability and validity of the proposed framework.

By referencing to the attached section (P.4 - P.9 of this document), kindly apply the proposed framework to your business or with your own experience on embedding simulation technologies in business processes. Then answer the following questions with appropriate ranks or explanations.

Thank you for your valuable feedbacks!

Thanks and Best Regards,
Ruby Lau

---

1. Please **CIRCLE** or **BOLD** your responses to the following question regarding the proposed framework.

Key concepts *(refer to Chapter 5 - Section 5.2 for more details)*	**How the proposed framework achieved the following key concepts?** **1 (not achieved) to 5 (highly achieved)**
1. Easy to follow	1 2 3 4 5
2. Generic and holistic	1 2 3 4 5
3. Overcome main challenges	1 2 3 4 5
4. Include best practices	1 2 3 4 5

2. Please fill your ranking to the ( ) following stage, dimension, best practice or objective regarding the proposed framework.

1 = Non-essential, 5 = Critical

Key Stages	Dimensions	Input elements - Best practices	Output elements - Objectives
Foundation ( )	*People* ( )	• Build a simulation team of leader, experts and engineers ( )	• People selected ( ) • Support ( ) • Software selected ( )
	Organisational ( )	• Support from senior management ( )	
	Technological ( )	• Software selection ( ) • Communicate with software vendor ( )	
Introduction ( )	*People* ( )	• Support by external consultants ( ) • Involve future users ( )	• Expectation ( ) • Awareness ( ) • Commitment ( ) • Pilot project ( )
	Organisational ( )	• Spread out the benefits and nature of simulation ( ) • Run workshops ( ) • Commitment by business units ( ) • Pilot project from particular business area ( )	
Infrastructure ()	*Technological* ( )	• Software/Hardware implement ( )	• Software implemented ( ) • Simulation budget ( )
	Organisational ( )	• Separate budget for simulation projects ( )	
Deployment ( )	*People*( )	• Provide simulation training for users ( )	• People trained ( ) • Model delivered on time ( ) • Integrating with business strategy ( )
	Organisational ( )	• Time management ( ) • Document simulation projects ( ) • Integrate simulation as part of the business process and strategy ( )	
Embedding ( )	*People* ( )	• Spread out the awareness of simulation all over the organisation after some successful projects ( ) • Provide simulation training in model building and project management ( ) • Share knowledge among the simulation teams ( )	• Knowledge management( ) • People trained ( ) • Standardisation ( )
	Organisational ( )	• Set standards in the use of simulation by implementing project procedures ( )	
	Technological ( )	• Standardise model data input and out interface ( ) • Reuse models, coding and logic ( ) • Use library of generic model objects/templates ( )	

3. Please explain your reason for any stage, dimension, best practice or objective rated **2 or less.**

Stage/Dimension/Best practice/Objective	**Explanation**

Introduction

This study has investigated factors that have impacted on the integration and the use of simulation technologies within companies. As a result of recognising the need to have a systematic approach to guide companies to use simulation as a strategic tool that can be used on a regular basis.

This section presents the highlight of the proposed framework conducted by this study which to guide companies to embed simulation technologies into business processes in each stage. The overview of this proposed framework is shown in Figure 1C.

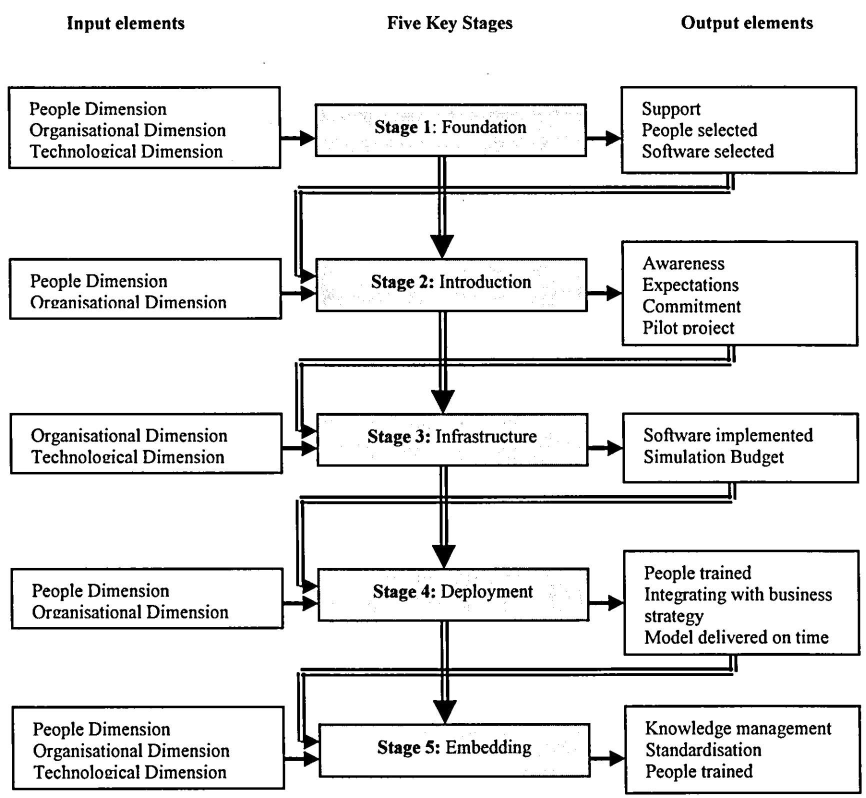


Figure 1C: Overview of the proposed framework

Key Concepts of the proposed framework

Based on the literature review conducted by this study, four key concepts were identified from different authors towards the development of framework to embed simulation technologies into business processes, which are:

(1) Easy to follow
- A guideline for integrating simulation technologies into business processes has to follow a structural approach
- Easy to follow and well-documented
- Thus, the proposed framework is clearly partitioned into five main stages
- Also, input elements and output elements are included for easy adoption

(2) Generic and holistic
- Generic - the framework should be applicable across a wide range of enterprises
- Holistic - the framework should consider integration from all aspects from an organisation point of view
- Thus, the proposed framework has incorporated "People", "Technological" and "Organisational" dimensions on the analysis of the input elements

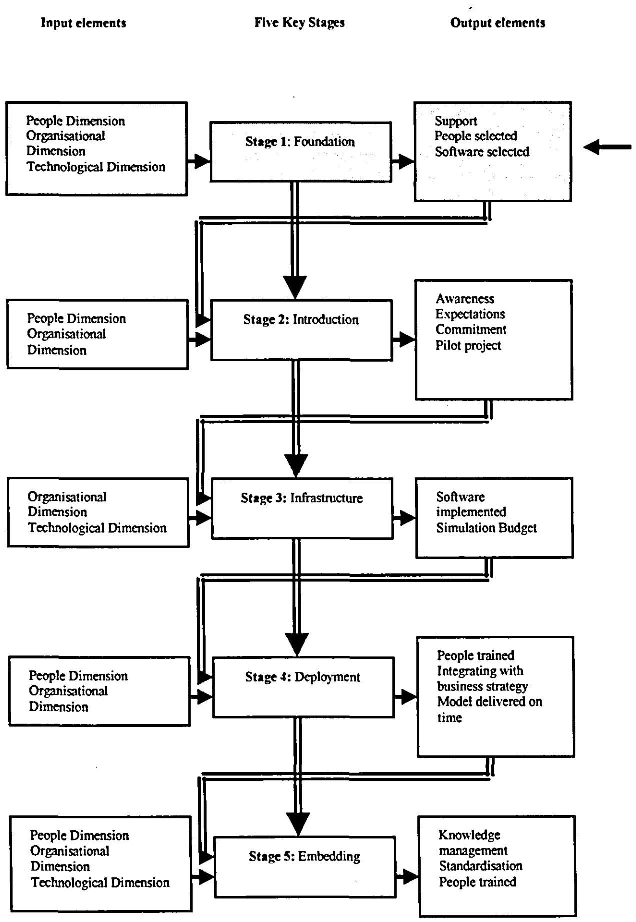
(3) Overcome main challenges
- Overcome technological and operational challenges in the use of simulation
- Thus, this study has examined challenges and failure factors from literature and has identified best practices to overcome them

(4) Include best practices
- Include best practices that identified from successful case studies
- Thus, list of best practices had become the main element which included in the proposed framework

Proposed framework

Stage 1: FOUNDATION

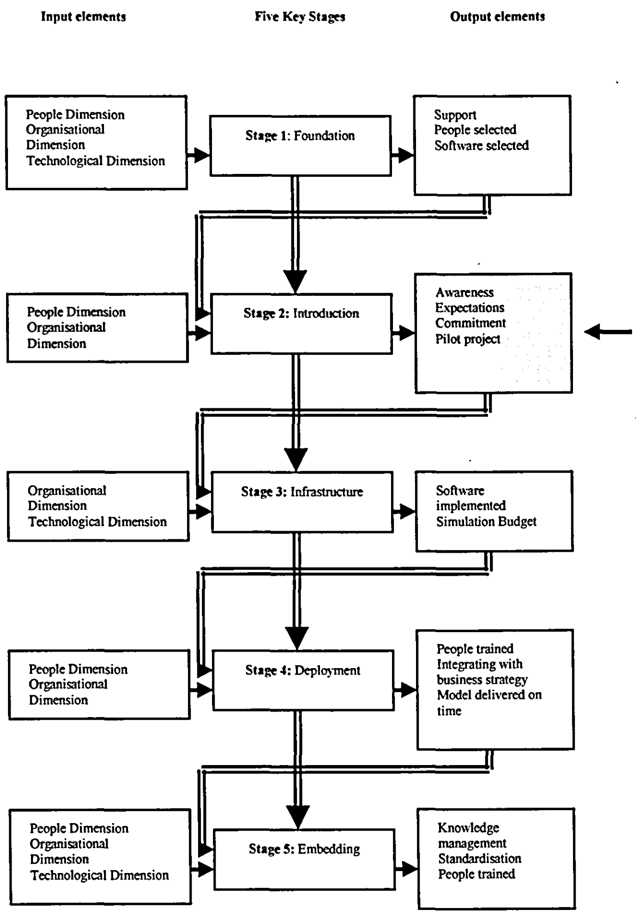
This stage becomes the foundation for the next stage - Introduction, which aims to build up a foundation to introduce simulation technologies from three dimensions i.e. "People", "Organisational" and "Technological". It is believed that the larger the company, the more important of this foundation.



Input elements	Output elements
<u>People Dimension:</u> • Build a simulation team with 2 to 5 members • Include a champion who responsible for integrating and developing simulation projects, this champion should have a fair knowledge of simulation technologies and have experiences on their business processes. • Also, the team should have simulation engineer who can support and provide the actual building of simulation model on a long-term basis.	<u>People Selected:</u> • Forming a simulation team can ensure the company's internal control of simulation projects. • Allow simulation experience to be retained within the company. • Provides confidence for future user on the internal support of simulation.
<u>Organisational Dimension:</u> • Gain support from senior management by informal presentation, proposal, workshop or demo, several issues included: 1 - Benefits and capabilities of the use of simulation. 2 - What other firms or competitors are successfully doing on simulation 3 - List of possible external consultants, software vendors or internal employee can be supported on this project.	<u>Support:</u> • It is necessary to gain support from senior management to help introduce and develop the future use of simulation. • To ensure senior management understands the direction, scope, target and organisational issues related to simulation during this stage which is essential towards the overall development of simulation within the organisation.
<u>Technological Dimension:</u> • Review available simulation software packages based on the following main issues: 1- Price (i.e. expected budget on hardware and software) 2- Previous experience of the simulation team 3- Vendor training and support 4- Application area 5- Capabilities on future integration.	<u>Software Selected:</u> • To select a suitable simulation software package appropriate to the application area of the company and fulfill other basic requirements such as price of the software and support provided from vendor. • Selected software will be used and assessed during the first project or pilot project on the introduction stage.

Stage 2: INTRODUCTION

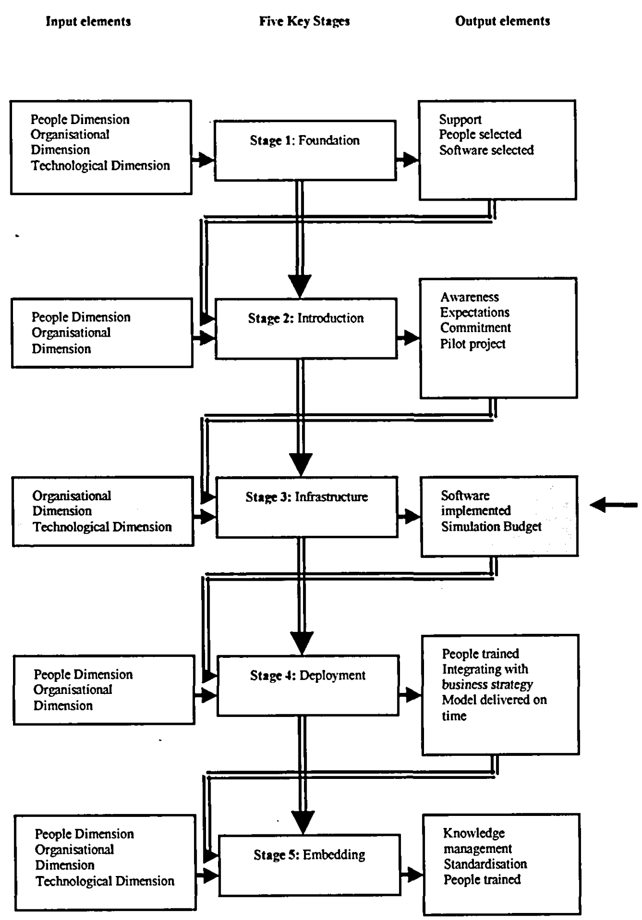
After establishing the foundation for introducing simulation within the company, this stage aims to introduce simulation into the company from two dimensions which are "People" and "Organisational" dimensions.



Input elements	Output elements
<u>People Dimension:</u> • Support by external consultants (e.g. software vendors or academic) on providing case studies, providing estimated cost of using simulation, also advice the team on how to promote and identify potential applications. • Involve future users in simulation meetings and obtain opinions from this group of users.	<u>Expectation:</u> • Communicate with external consultants, setting expectation together with expected changes, and any negative expectation. • Involve future users in the early stage of the introduction was identified in literature to be a good practice to reduce the problem of resistance to change and make sure valuable opinions can obtain from future users.
<u>Organisational Dimension:</u> • Spread out the benefits and nature of simulation over the entire organisation by company intranet, newsletter or email. • Run workshops by external consultants to present successful simulation applications to potential users and business units. • Meeting with business units to discuss potential simulation application area. • Start pilot project on small business area.	<u>Awareness:</u> • It is important to spread out the capabilities and general benefits of simulation to the entire organisation in this stage. • To ensure all level of staff within the company have to be aware simulation is being embedded. • Increase the confidence and support from future users. <u>Commitment:</u> • Meeting with business units to explore the potential simulation application areas, therefore commitment on the use of simulation can be established which is essential for future deployment. <u>Pilot Project:</u> • Pilot project plays an important role to test out the capability of the identified simulation software, identify the weakness and main challenge when the team doing simulation project, verify new working procedures, and identify necessary future trainings.

Stage 3: INFRASTRUCTURE

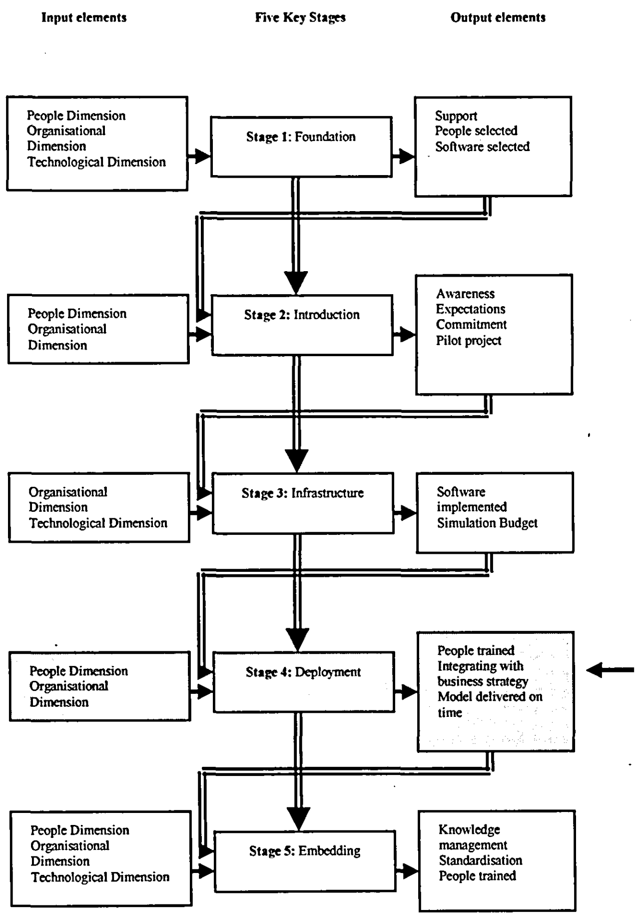
Once new working procedures and the selected simulation software have been verified through pilot project, it is time to roll it out to a larger audience. However, infrastructure has to be ready from below two dimensions i.e. "Technological" and "Organisational" dimensions.



Input elements	Output elements
<u>Organisational Dimension:</u> • Separate budget for simulation projects. The budget plan should at least include the following costs: 1)Cost of hardware 2)Cost of software 3)Cost of training 4)Cost of documentation 5)Cost of personnel for internal and external	<u>Simulation Budget:</u> • An estimation of costs involved should be prepared and separated for simulation projects in this stage which would reduce unexpected costs and risks during deployment. • After the deployment, frequency of updating this plan as well as modification of this plan should be addressed.
<u>Technological Dimension:</u> • Implement selected simulation software package into users' PC. Since some of the critical capabilities of the software package may not yet include, this is important to fully test out and confirm before deployment stage.	<u>Software implemented:</u> • This is essential to implement the simulation software in the users' PC with the right license and capabilities before deployment.

Stage 4: DEPLOYMENT

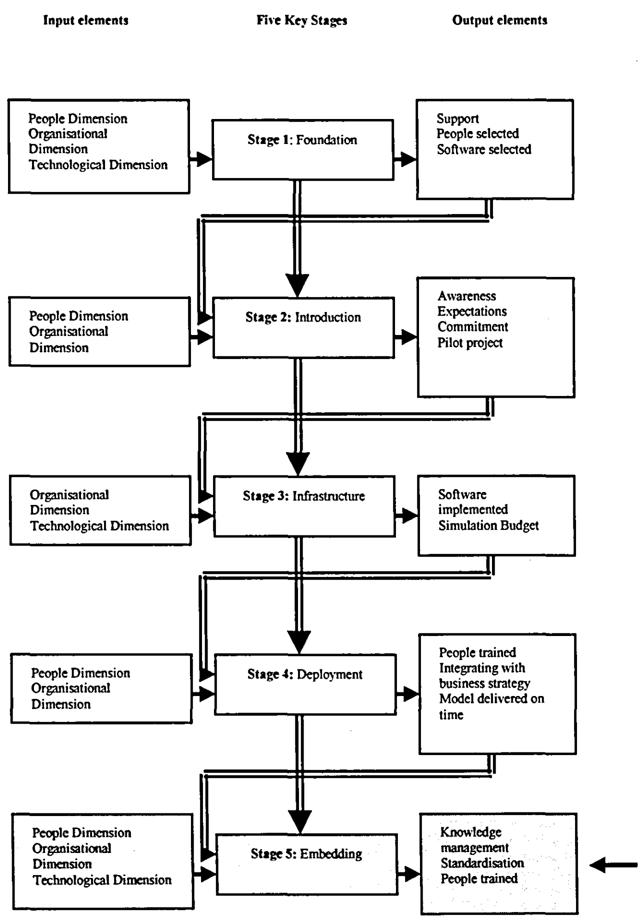
After the essential infrastructure has been established and prepared, this stage is to deploy simulation in the company strategically from two dimensions: "People" and "Organisational" dimensions.



Input elements	Output elements
People Dimension: • Provide simulation trainings to users who are going to involve in the coming simulation projects on how to execute and carry out experiment with the selected simulation software package. • Provide trainings on analysis and interpretation on simulation models which can provide by software vendor or by internal simulation team.	People Trained: • If people trained with necessary simulation skills and knowledge, this can increase the confidence and motivation of these users on the use of simulation model and their abilities to carry out experimentation.
Organisational Dimension: • Project schedule has to be planned and agreed with problem owner • Simulation team has to ensure the model can be delivered on time to problem owner. • Documented successful simulation projects • Develop a good documentation system (e.g. common server) for storing the documentations. • Deploy simulation projects as part of the business strategy	Model delivered on time: • Lack of time management had also been identified as one of the constraint which can cause lost of confidence, directions and goals. Therefore, simulation team should work to a schedule in every simulation project with agreed expectation from problem owner Integrating with business strategy: • It is important to deploy simulation with a link to the current business strategies otherwise this technology would be left out after completing a few projects.

Stage 5: EMBEDDING

Once simulation has been deployed in a company, in order to embed this technology into business processes as opposite to ad hoc, unplanned project style, company should consider the best approach to achieve the goal strategically from "people", "organisational" and "technological" dimensions.



<table>
<tr><th>Input elements</th><th>Output elements</th></tr>
<tr><td><u>People Dimension:</u>
• Spread out the awareness of simulation within the company after some successful projects
• Include simulation trainings to potential users and senior managers in model building and experimentation, also in project management
• Provide opportunities for the simulation team or potential users to attend simulation related conference, e.g. Winter Simulation Conference
• Share knowledge among the simulation teams, for example develop SharePoint on the intranet, regular meeting and email.</td><td><u>Knowledge management:</u>
• Spreading out the new information, lessons learned from successful simulation projects, and also sharing knowledge among the simulation team
• Maintain the cycle of knowledge gained within organisation (i.e. identify and capture critical knowledge on simulation and share with others, then this knowledge can apply for new situations by others which may in turn create new knowledge and keep sharing)
• By documentation, knowledge gained from simulation projects can share and maintain within an organisation</td></tr>
<tr><td><u>Organisational Dimension:</u>
• Set standards on the use of simulation by implementing project procedures</td><td rowspan="2"><u>People trained:</u>
• People trained on project management can support company to embed simulation into business processes, also enhance their confidence on simulation project and to better understand the model application on applying to decision making
• People trained on model building and experimentation training can increase the ability of individuals to widely use simulation in their business areas and encourage them to conduct experimentation

<u>Standardisation:</u>
• Broadening the use of simulation
• Eliminate the data input error, standardise the data format, also this can reuse by other simulation models which can share the same model data and increase model flexibility
• Simplify the model development process with pre-built objects or templates can reuse on different models with similar scopes
• Standardisation can reduce production cost and time on simulation model development.</td></tr>
<tr><td><u>Technological Dimension:</u>
• Develop standardise model data input and output interface which separate the data from the actual model
• Re-used existing simulation model by code scavenging, component re-utilised or full model re-utilised.
• Use library of generic model objects/ templates.This can achieve by the creation of re-usable simulation model building blocks in order to simplify the model development process.</td></tr>
</table>

Appendix D

Validation Results

Appendix D:
RESULTS AND ANALYSIS - VALIDATION FOR THE PROPOSED FRAMEWORK

Figure D1: Analysis of key concepts of the proposed framework

Key Concepts	Response 1	Response 2	Response 3	Response 4	Response 5	Average Rank
Easy to follow	5	5	4	5	4	**4.6**
Generic and holistic	4	5	4	4	3	**4**
Overcome main challenges	4	4	3	3	3	**3.4**
Include best practices	3	4	3	4	3	**3.4**

Note: 1 (not achieved) to 5 (highly achieved)

Figure D2: Analysis of the proposed framework – First Level

Note: 1 (non-essential) to 5 (critical)

First Level: KEY STAGES	Response 1	Response 2	Response 3	Response 4	Response 5	Average Rank
Foundation	3	5	5	5	5	**4.6**
Introduction	5	5	4	5	5	**4.8**
Infrastructure	3	5	4	5	5	**4.4**
Deployment	5	5	4	5	5	**4.8**
Embedding	3	5	5	5	5	**4.6**

Figure D3: Analysis of the proposed framework – Second Level: Input elements – best practices

Key Stages	Second Level: INPUT ELEMENTS - BEST PRACTICES	Response 1	Response 2	Response 3	Response 4	Response 5	Average Rank
Key Stage 1:	Build a simulation team of leader, experts and engineers	1	4	5	5	5	**4**
	Support from senior management	5	5	5	5	5	**5**
	Software selection	2	4	5	5	3	**3.8**
	Communicate with software vendor	3	3	3	5	3	**3.4**
Key Stage 2:	Support by external consultants	4	4	4	4	2	**3.6**

	Involve future users	2	4	5	5	5	**4.2**
	Spread out the benefits and nature of simulation	5	5	4	5	4	**4.6**
	Run workshops	4	4	3	5	5	**4.2**
	Commitment by business units	4	4	4	5	5	**4.4**
	Pilot project from particular business area	5	5	5	5	5	**5**
Key Stage 3:	Software/Hardware implement	2	5	4	5	4	**4**
	Separate budget for simulation projects	2	4	2	5	2	**3**
Key Stage 4:	Provide simulation training for users	5	5	5	5	5	**5**
	Time management	3	4	4	5	5	**4.2**
	Document simulation projects	4	4	3	5	4	**4**
	Integrate simulation as part of the business process and strategy	3	5	4	5	4	**4.2**
Key Stage 5:	Spread out the awareness of simulation all over the organisation after some successful projects	4	4	4	4	4	**4**
	Provide simulation training in model building and project management	2	5	5	4	4	**4**
	Share knowledge among the simulation teams	4	4	5	5	4	**4.4**
	Set standards in the use of simulation by implementing project procedures	3	4	3	4	3	**3.4**
	Standardise model data input and out interface	4	5	4	5	5	**4.6**
	Reuse models, coding and logic	1	5	2	5	3	**3.2**
	Use library of generic model objects/templates	2	5	3	5	5	**4**

Figure D4: Analysis of the proposed framework – Third Level: Output elements objectives

Key Stages:	**Third Level: OUTPUT ELEMENTS - OBJECTIVES**	Response1	Response2	Response3	Response4	Response5	**Average Rank**
Key Stage 1:	People selected	3	4	4	5	4	**4**
	Support	3	5	4	5	3	**4**
	Software selected	1	4	4	5	3	**3.4**
Key Stage 2:	Expectation	3	4	5	4	3	**3.8**
	Awareness	4	4	4	4	4	**4**
	Commitment	4	5	3	5	4	**4.2**
	Pilot project	5	5	4	5	5	**4.8**

Key Stage 3:	Software implemented	1	5	4	5	3	**3.6**
	Simulation budget	2	4	4	4	3	**3.4**
Key Stage 4:	People trained	5	5	4	5	4	**4.6**
	Model delivered on time	4	4	4	4	4	**4**
	Integrating with business strategy	3	5	5	5	5	**4.6**
Key Stage 5:	Knowledge management	4	4	5	5	5	**4.6**
	People trained	3	4	4	5	4	**4**
	Standardisation	3	5	3	4	4	**3.8**

Table D1: Additional comments from respondents:

Stage/Dimension/Best practice/Objective	Explanation/Comments
Software selected	"All major commercial simulation environments are suited for 99% of the problems. Which exactly doesn't matter?"
Involve future user	"Too early, first make a success of the pilot project."
Software implemented	"All major commercial simulation environments are suited for 99% of the problems. Which exactly doesn't matter?"
Provide simulation training	"Organizational, get experts for training, regular retraining and fine-tuning."
Separate simulation budget	"If there is a clear budget then it can easily be shown that simulation is an expense? We should really be monitoring savings made."
Reuse model logic	"Different projects require different level of detail hence the ability to re-use logic diminishes."
General	"I fully agree with your process and framework - I think it represents possibly the only way to fully embed the technology. In view of this, I found it difficult not to score all the items with a "5."
General	"Time management is important"