The development of a computerised simulation model to guide the South African higher education sector in short and long-term planning of TEL infrastructure

by

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Abstract

This study deals with the development of a computerised simulation model to guide the South African higher education (HE) sector in short and long-term planning of TEL (technology enhanced learning) infrastructure. A critical realist orientation was adopted, using a case study approach focusing on provision of TEL infrastructure at three Natal universities, namely, the Durban University of Technology, the University of KwaZulu-Natal and Mangosuthu University of Technology. A mixed methods approach was used, combining qualitative with quantitative techniques, in order to collect data to establish key model specifications. The qualitative aspect comprised an online survey to obtain user feedback on the proposed computerised simulation. Quantitative methodology involved using functional decomposition design to extract the specifications from the data. The computerised simulation model was developed using a system dynamics approach which could define forecasting in operational terms, and thus offer various scenarios to guide institutional decision-makers in future planning. The systems model thus developed was then configured online using simulation software and tested out with key stakeholders. While computerised simulations currently exist in the area of infrastructural forecasting, the new contribution to the field is thought to be in forecasting the provision of TEL infrastructure.

Preface

Declaration of originality

I, Pregalathan Reddy, declare that this thesis is my own work and all the sources used or quoted have been indicated and acknowledged by means of complete references. The only form in which this work has previously been published is in conference papers

SIGNED: ______________________ DATE: 11 May 2023

Research articles and conference papers

Reddy, P. and Pratt, D. D. 2022. Case study of migration from local in-house data centre at the DUT to Azure Cloud. In: Proceedings of *2022 Conference on Information Communications Technology and Society (ICTAS)*. Durban University of Technology, 9-10 March 2022, 1-9.

Reddy, P. 2019. A computerized simulation model to forecast higher education TEL infrastructure: arriving at the simulation development process. In: Proceedings of *13th International Technology, Education and Development Conference*. Valencia, Spain, 11-13 March 2019.

Reddy, P. 2019. Computerized simulation model for TEL infrastructure. In: Proceedings of *10th International Conference on Intelligent Systems and Communication Networks (IC-ISCN 2019)*. Mumbai, India, 22- 23 February 2019.

Reddy, P. 2012. The development of a language learning object repository (LLOR) for second language teachers in KwaZulu-Natal, South Africa. In: Proceedings of *5th International Conference of Education Research and Innovation*. Madrid, Spain, 19-21 November 2012.

Referencing style used

The referencing style used is that given in the *Referencing guide: Harvard referencing style* (Mitha, Naidoo and Thomas 2017). *EndNote 20.3* referencing software was used to generate the Reference list, using the DUT Harvard *EndNote* style 2017.

Conventions used

The following conventions have been applied in this thesis:

- To maintain anonymity, pseudonyms have been used to replace the names of all university staff and students mentioned in the thesis, except in the case of theses, articles, papers and/or reports published or disseminated for open access.
- While the web addresses of individual websites mentioned in the text as exemplars are given, the websites are not listed in the Reference list.
- Personal communications (telephone conversation, interviews and e-mail) are noted in the in-text reference but are not included in the Reference list.
- Square brackets have been used (where necessary) to indicate approximate page numbers on publications from Internet sites, following Hofstee (2006: 252).

Dedication

This thesis is dedicated to my late brother Peran, and my father Morgan, who both inspired and stimulated me long before I dreamt of this crowning achievement. I will be forever indebted to you for inculcating the joy of reading through visits to the library when the keys to knowledge, awe, excitement, wonderment and more could be accessed only through the analogue of the printed form.

My father, Morgan Reddy

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I would like to express my gratitude and appreciation to the many people who have either directly or indirectly made the completion of this dissertation possible:

Professor Deirdre Pratt, for entertaining the many ideas I suggested and helping me to settle on this one, and then energising and infusing it from conception to this artefactually real instantiation. You are a formidable force, who has given me a renewed thirst for knowledge production, and to whom I am eternally grateful.

Professor Olugbara, who provided expert advice despite being extremely busy and was instrumental in pushing me over the line.

Professor Stewart, who always had my back and supported and encouraged me to “just do it”.

My mother, who supported me in all that I did, giving selflessly as only a mother could.

My wife and children, who motivated me to start this journey and are the reason that I completed it.

My colleagues, who inspired and spurred me on taking on my responsibilities when I needed them to and willing me to get it done.

Ridwan Essop, my friend and greatest supporter, who saw something in me long before I did and demanded more from me than the bare minimum.

To all those who contributed their time and insight by participating in my data collection, without your input this study would have not been possible.

Acronyms

BMP	Business modelling process
EIS	Enterprise information systems
ELF	ELearning framework
FDD	Functional decomposition design
LMS	Learning management system
LTI	Learning technology interoperability
OKI	Open knowledge initiative
SCORM	Scale-able content object relational model
SOA	Service oriented architecture
TEL	Technology enhanced learning
TRIS	Theory of inventive problem solving
UML	Universal mark-up language

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Chapter 1: Background and context

1.1 Introduction

To provide the background and context to this study, Chapter 1 first looks at the higher education context in South Africa, showing how it is a challenge for universities to plan TEL for higher educational use because of the difficulty of anticipating the necessary resources, as well as the costs incurred by consulting professional risk consultants. The problem is complicated by the disparity between different types of university as well as their different socio-economic circumstances, as both the traditional universities and so-called universities of technology (UoTs) are historically disadvantaged institutions (HDIs). The chapter then looks at the concept of technology enhanced learning (TEL), giving a provisional definition which will be developed further in the course of this thesis. Next, a rationale for technology forecasting will be provided, showing how both continuity and future development need to be assessed in the light of the rapidly evolving technological landscape. Anticipating technological development and preparing adequately for transitioning into long term supported systems requires insight which may be a challenge as it may require the services of professional information technology risk consultants, which can be prohibitively expensive.

1.2 The South African higher education context

The context in South African higher education is sufficiently unique in comparison to other countries due to the following reasons. Firstly, there are relatively few institutions catering for a large cohort of eligible students exiting high school each year (26 institutions can currently cater for approximately 208 000 students) while over 750 000 students wrote the matric examinations in 2018 and approximately half of these passed. The mismatch in capacity is roughly 167 000 who will not be placed in the institution of their choice, and who will have to settle for private colleges at a considerably higher registration and tuition fees. Secondly, due to the relatively low number of governmentsubsidized higher education institutions in South Africa, LMS adoption is characterized by insulated market forces, resulting in dominance by one product (Blackboard) effectively resulting in brand lock-in over the past two decades. Lastly, increasing costs of the dominant LMS system since it is pegged to USD pricing which is prone to forex fluctuations and correspondent reliance of these entrenched TEL systems creates a volatile environment for all stakeholders should there be any forced change of LMS system. The proposed system dynamics simulation is intended to assist in decision making around LMS/TEL reviews and to assist in preparing to change to other LMS/TEL systems if the situation demands it, albeit with insight about the requirements and critical issues or red flagging about potential consequences without any actual harm being done.

In order to assist universities to provide for future iterations of TEL, the research problem has been identified as finding a means to address the real-world problem of TEL infrastructure planning. The proposed solution is the development of a computerised simulation model to guide the South African HE sector in short and long-term planning of TEL infrastructure. The computerised simulation model will involve a system dynamics approach (Chen, Yu and Wakeland 2016) to define future forecasting in operational terms, and thus offer various scenarios to guide institutional decision-makers in future planning.

1.3 Technology enhanced learning (TEL)

Currently, higher education institutions (HEIs) rely on various enterprise systems to provide a dependable basis for the university's services, of which TEL (technology enhanced learning) is now considered an indispensable part (Kirkwood and Price 2014: 6). The term TEL is open to a very broad range of interpretations and is not restrictive with respect to either types of technology or pedagogical approaches (Goodyear and Retalis 2010: 8; Kirkwood and Price 2014: 1). TEL is considered to provide enhancements to teaching and learning in respect of both the delivery medium and method (Kirkwood and Price 2014: 26), the precise nature of the enhancements being dependent on context-specific definitions of learning (HEFCE 2009: 2). For the purposes of this study, TEL is defined as tuition occurring in contexts "where technology plays a significant role in making learning more effective, efficient or enjoyable" (Goodyear and Retalis 2010: 8). The real-world problem, or life-world problem (Waghid 2002: 472), which this research attempts to address is the difficulty universities currently experience in anticipating short and long-term requirements for providing TEL infrastructure, as well as maintaining continuity in the development of TEL.

Up until the present time, universities have relied predominantly on the traditional learning management system (LMS), even though the landscape has changed considerably since the days when the technology was by today's standards primitive and, more tellingly, limited in both choice and features. The universities' main reasons for maintaining the traditional LMS are the availability and convenience of such pre-packaged options, as well as the level of control it gives to the university management (Dron 2006: 1; Murphy 2012: 828). However, there are other factors which have led to retaining the traditional LMS, such as continuity, vested interests, narrow skill sets, interlinkages with other corporate systems, inter-operability and brand loyalty (Masoner and Nicolaou 1996: 208). The rapid developments in digital technology, the powerful yet unpredictable influence and affordances of social media, and the prohibitive cost of procuring commercial TEL software applications, including the traditional LMS, make future projections problematic. The architectural makeup of the LMS and virtual learning environment (VLE) has evolved considerably over the past fifteen years, so much so, that pundits have already, since the 2000s, forecast the end of (traditional) LMS/VLEs, which are facing what Adetunji, Bischoff and Willy (2018) term "system obsolescence".

In order to assist universities to provide for future iterations of TEL, the research problem has been identified as finding a means to address the real-world problem of TEL infrastructure planning. The proposed solution is the development of a computerised simulation model to guide the South African HE sector in short and long-term planning of TEL infrastructure. The computerised simulation model will involve a system dynamics approach

(Chen, Yu and Wakeland 2016) to define future forecasting in operational terms, and thus offer various scenarios to guide institutional decision-makers in future planning.

The role of the researcher in this study is significant, as the features and inputs used for the forecasting simulation is the result of the cumulative professional experience and knowledge spanning over two decades in the technology enhanced learning space. The researcher participated in the piloting of WebCT for the National Research Foundation (NRF) in 1999, where he was responsible for converting word processed content into html. From 2000 until 2003 he provided academic support to lecturers in the role of Web-based Learning (WBL) consultant. In that capacity, he ran workshops on content development for online teaching (WebCT) and offered support to academics related to this. He then moved to Industry in the role of Information Officer at a specialist geo-technical library where he revolutionised and modernized systems, which process included setting up a web-searchable image database of the case study photographs, an online Content Management System (CMS) to access technical literature and specifications, and an interactive web-based CD-ROM sales kit for sales representatives to use while consulting with clients. From 2008 until 2018 he managed the Learning Management System (LMS), and has led in the transition from WeBCT to Blackboard (2009) and from Blackboard to Moodle (2018/2019). The combined depth and breadth of expertise includes content development, server management, LMS management, change management, and procedure and policy development. In view of his professional involvement with seeing that TEL infrastructure is provided and working as required, this project has been far more than just an "academic" exercise for the researcher.

1.4 Rationale for TEL forecasting

Within the context of a rapidly evolving world of technology evolution and shorter and shorter periods of brand lock-in, obsolescence stills hold sway, especially in a critical industry such as higher education and choosing the right mix for eLearning provision has become even more vital than ever.

At the inception of eLearning, roughly coinciding with the beginnings of the internet via the world wide web (www) made available to the public in the early 1990s, the stack used to provide eLearning was typified by physical servers comprising a web server (such as IIS or Apache), a database server (such as MS SQL or MySQL) and the application which was typically split across these (some logic and scripts were hosted on the application server and some aspects were part of the database routines). As Lahiri (2017) mentions, “servers were large, flat, physical boxes installed in server rack[s] and connected to the network”. Public facing access was through the internet using the ubiquitous protocol of the www provided by the web server (on a physical machine). Lahiri (2017) goes on to suggest that “serverless architecture is the newest cloud computing paradigm”. However, he cautions against the loosely applied term “serverless” being, sometimes falsely, used to imply the absence of servers. Fast forward to the present, and the technological landscape is characterised by the cloud, virtualisation, instances, Infrastructure as a Service (IaaS), and Software as a Service (SaaS), where compute hours is the lingua franca, and it is not necessary to have on-premises infrastructure to deliver robust eLearning. In spite of the evolution of the core infrastructure required for eLearning provision, the landscape is still prone to brittleness as unplanned change from an existing system can derail services to the (higher education) consumers, namely staff and students. The reality is that mitigation from total collapse of eLearning provision can be the difference between make or break in a competitive market such as Education.

Against this backdrop of evolutionary quantum leaps in available infrastructure is the reality of quickly devolving legacy deployments of LMSs constrained by prohibitive cost differences between self-hosted and managed hosting, that a technology forecasting simulation application can help navigate the murky waters of the nether regions of the unknown towards a workable solution.

1.5 The COVID conundrum

As if the issues mentioned in the previous section were not enough, from 2020-to 2022 universities were faced with a new and more formidable challenge, the COVID-19 pandemic. The "conundrum" facing universities was whether to switch to totally online learning or to attempt to maintain a blended approach in the face of the pandemic. With the enforced COVID-19 lockdown in 2020, universities had no choice, and hurriedly implemented what Czerniewitz *et al.* (2020: 946) termed "Emergency Remote Teaching and Learning (ERTL)". In Kwazulu-Natal, the majority of DUT's students were most badly hit, in terms of their dependency on the University for computers and the Internet as well as for a quiet, physical learning space. It has also been well documented (Oblinger and Oblinger 2005) that Millennials, while "techno-savvy", desire live interaction with faculty and peers, and do not want to be relegated to machine learning and to be seemingly abandoned by teachers (Bhorat 2014: 26). In fact, the opportunity for live (i.e., face-to-face) group interaction has been identified as an integral part of university functioning, not just for social activities, but for effective carrying out of curricular activities (Rodgers and Raider-Roth 2006;Tan 2021; Singh, Singh and Mathees 2022).

The complete lockdown during the pandemic not only deprived students of the opportunity for live classroom interactions, but also caused widespread fear and anxiety amongst staff and students (Czerniewitz *et al.* 2020: 946; Mthethwa and Land 2022: 30). In a "snapshot" survey of solutions used around the globe to deal with the exigencies caused by the pandemic, it was found that hybrid forms were mostly used; these ranged from predominantly live classroom interactions, with strict precautions taken against COVID-19, to predominantly online interactions (Ngcongo-James and Pratt in press). The advice of the South African Education Department that educational institutions should use "multi-modal teaching and learning" (South Africa 2020: 2) was not particularly helpful to universities that were ill-prepared for Internet learning, let alone able to supply a variety of modes. DUT was caught napping in terms of not using sufficient foresight for project management (see Reddy and Pratt 2022).

1.6 Research problem and aims

As mentioned in section 1.2, the real-world or life-world problem (Waghid 2002: 472), which this study attempts to address is the difficulty universities, in particular, disadvantaged South African universities, currently experience in anticipating short and long-term requirements for providing TEL infrastructure, as well as maintaining continuity in the development of TEL.

1.6.1 Research problem

The research problem was identified as finding a feasible solution to address the problem of long-term planning of TEL infrastructure so as to provide continuity as well as development to accommodate the changing needs of HE.

1.6.2 Aim of the research

The aim of the research was to develop a computerised simulation forecasting model which could be used to generate various scenarios for the infrastructural aspects of TEL provision, based on user input.

1.6.3 Research objectives

Three main objectives were identified in order to achieve the aim of the research:

1. Formulating a system dynamics model;
2. Constructing a computerised simulation; and
3. Testing the simulation

1.7 Definitions of key terms

Technology enhanced learning (TEL) is in this study defined as tuition occurring in contexts "where technology plays a significant role in making learning more effective, efficient or enjoyable” (Goodyear and Retalis 2010: 8). It is understood that the technology currently used for the purpose of learning is computer and Internet technology, but by no means a given that it will remain so, and it is beyond the scope of this study to speculate on future technological developments.

Infrastructure refers to "the system of hardware, software, facilities and service components that support the delivery of business systems and IT-enabled processes" (Gartner Information Technology Glossary 2021: [1]). As with TEL, there is no guarantee that the present systems will be used in the future, as the pace of technological change is increasing at an exponential rate, countered only by the rate of ecological disasters hindering progress.

Technology forecasting "predicts the future trajectory of a certain technology based on existing data" (and is the focus of this study) while ***technology foresight*** involves gathering information on the most important emerging technologies on the foresight map and then focusing on developing these (Chen, Wakeland and Yu 2012: 81).

Models are understood in this study as defined by Page:

> Models are formal structures represented in mathematics and diagrams that help us to understand the world. Mastery of models improves [y]our ability to reason, explain, design, communicate, act, predict, and explore (Page 2018: 13).

A ***simulation*** is defined as "an abstract model of a real demographic system, and can be manipulated to yield insight into how that system works, or applied to real world systems to explain or predict" (Burch 2017: 15). However, simulations remain "imaginative structures – created by the human mind" (Burch 2017: 45). A simulation, then, is a hypothetical construct, rather than being based on data, and is useful for producing forecasts or predictions rather than for explaining how or why phenomena occur.

The ***computerised simulation***, developed in this study, on the other hand, is an artefact, designed and programmed by humans for human use.

These terms will be defined more comprehensively in the Literature review.

1.8 Research approach and design

The research approach adopted was critical realist, using a case study approach which focused on the provision of TEL infrastructure at three KwaZulu-Natal universities, namely, the Durban University of Technology, the University of KwaZulu-Natal and Mangosuthu University of Technology. A mixed-methods approach was used, comprising the Hybrid Delphi method, which combines qualitative and quantitative methods. Qualitative techniques (Landeta, Barrutia and Lertxundi 2011) were used to collect data in order to establish key specifications of the proposed model. The quantitative aspect consisted of an online survey (Babbie 2012: 290) in order to obtain user feedback on the computerised simulation. The proposed computerised simulation model was developed using a system dynamics (SD) approach (Sterman 2001; Chen, Yu and Wakeland 2016), which defines future forecasting in operational terms, and thus could offer various scenarios to guide institutional decision-makers in future planning. The systems model was then configured online using simulation software (i.e., InsightMaker), and was tested out with key stakeholders.

1.9 Contribution to new knowledge and value of the research

While computerised simulation models currently existed in the area of infrastructural forecasting at the time of this study, the new contribution to the field is thought to be in forecasting the provision of TEL infrastructure. The value of this type of technology forecasting is thought to be as follows. As mentioned above, the rapidly evolving technological landscape poses obstacles to continuity and future development of TEL, making it a challenge for universities to plan TEL for higher educational use because of the difficulty of anticipating both the necessary and the costs incurred by consulting professional risk consultants. The different types of university in South Africa, as well as their different socio-economic circumstances, and the relative lack of government subsidies make higher education institutions in South Africa vulnerable to dominance by market forces and brand lock-in. The present economic climate in South Africa (bordering on “junk” status) creates a difficult and volatile situation in which most universities cannot afford (Naidu 2019: 6), a forced change of their LMS system. The proposed system dynamics simulation is intended to assist universities in decision making in an affordable and accessible way by allowing them to “pre-plan” changes via the simulation.

1.10 Conclusion

The next two chapters follow the usual thesis structure of Literature review (Chapter 2) and Research design (Chapter 3). The development of the artefact, the computerised forecasting simulation, is presented after this as follows:

Chapter 4: Establishing design specifications

Chapter 5: Configuring the simulation online

Chapter 6: Testing the forecasting simulation

The rationale for this is that, while the actual development was a complex, recursive process with some backtracking, and with some aspects having to be developed simultaneously, there were certain sequential operations, made clearer, it is hoped, by following the objectives described in the research design (above, and see Table 3.1, p. 32). Thereafter, the usual thesis structure of Conclusions and recommendations (Chapter 7) is followed.

Chapter 2: Literature review

2.1 Introduction

As indicated in Chapter 1, forecasting of TEL infrastructure is a necessary process to assist universities with decision-making in terms of the complexity involved in providing for current and future online instructional delivery. This chapter first defines TEL, then look at TEL in South Africa, and shows why provision is complicated. The chapter then looks at the issue of technology forecasting and technology foresight, and the distinction between the two. As is explained, technology forecasting (the approach adopted in this study) has implications for planning provision of TEL in countries like South Africa where many HEIs do not have the means to prepare beyond short to medium-term futures. The chapter then gives an overview of approaches commonly used for technology forecasting, and next, goes on to discuss modelling in more detail and why system dynamics, the modelling method used in this study, was chosen. Next, the research approach used in this study, critical realism, is shown to be a suitable perspective for the philosophy underpinning systems analysis. Such a perspective is consistent with a depth realism where explanation is not about prediction but about the steady unearthing of deeper levels of structures and mechanisms. The critical realist approach has a significant bearing on not only how the research problem is framed, but also what emerges from it and, importantly, explaining why things happen the way they do.

2.2 Technology enhanced learning (TEL)

Technology enhanced learning is concerned mainly with the form that the delivery mode takes, in terms of being mediated by digital technology, in other words, learning is enhanced by this technology. This means that, strictly speaking, “learning” may not have changed much, but teaching has, or to be more precise the “teaching aids” have changed considerably. Having said that, it would be brave to suggest that anything other than the bare essentials of chalk and blackboard are a requisite for teaching (Arnold and Sangrà 2018). The reality is that few educators would stick to just the bare essentials, as the millennial learner has a reasonable expectation to get a more varied learning experience, comprising visual aids (charts, maps, diagrams, and so on) and moving images (not all processes are static), audio-visual (sound with pictures such as videos), and not only in the classroom of yore, but learning spaces accessible in digital form immediately and from wherever the learner is.

Bates (2015: 199), a seminal author in technology enhanced learning, refers to digital technology as "a system that combines computers, telecommunications, software, rules and procedures or protocols". In the same work, technology-enhanced learning is referred to as "technology used as classroom aids; a typical example would be the use of Powerpoint slides and/or clickers" (Bates 2015: 311). However, it is clear that Bates (whose initial teaching focus was on use of media technology) is adjusting this view to focus on the digital technology of computers and the Internet: "We see e-learning as a continuum, from no use of technology at one end, to all delivery by information and communications technology at the other" (Bates 2015: 41). At the time he was writing, he identified the "modes of delivery" as:

- classroom teaching with no technology at all;
- blended learning, which encompasses a wide variety of designs; and
- fully online learning with no classroom or on-campus teaching, which is one form of distance education (Bates 2015: 310-311, abbreviated).

Bates also refers to the "continuum of technology-based learning" (2015: 309, 310) when listing the various delivery modes, echoing the point made earlier (Bates and Sangrà 2011: 41). Later, Arnold and Sangrà (2018: 1) note the options described by Bates as follows, redefining TEL to draw it more fully into the eLearning fold: "Technology-Enhanced Learning (TEL) is to be understood as the use of technology in any teaching and learning situation, on a continuum from face-to-face to fully online learning".

It must be noted that the techno-systems involved on the Internet were not developed simultaneously, but as the result of a long series of technological innovations. As Aunger (2010: 775) comments:

> Through mutual involvement in the economy, technological products from different categories came to be interconnected: objects, structures or networks were embedded in existing configurations of artefacts to make a technological system.

This means that techno-systems "are composed of many different kinds of artefacts". This makes it difficult to anticipate future changes in TEL, as we cannot know the pace or course of technical development as well as contingent aspects which might impact significantly on provision of TEL (e.g., a reliable electricity source as well as affordable data). However, what can be done is to identify the key components of TEL infrastructure, such as standards, interoperability, and APIs to track to against the respective technology roadmap.

As technology has evolved, it has facilitated rapid changes in teaching and learning; yet this does not mean the innovation technology has brought to teaching and learning has been adopted as quickly in the actual classroom. Granted, even the traditionally conservative nature of education has not prevented the almost universal transformation of teaching and learning the world over. However, while technology in general is available, access to this technology depends on funds and existing priorities, and therefore the trend is for the latest technology to be snapped up by those with the finances, and then followed by the late adopters. One important initiative that is intended to redress equitable access to education is, as Orr, Weller and Farrow (2019: 1) report, "the Sustainable Development Goal 4.3, which states: 'By 2030 ensure equal access for all women and men to affordable quality technical, vocational and tertiary education, including university' ".

In suggesting that technology enhanced learning is the use of technology to enhance learning, this definition may be open-ended or specific, depending on other contextual considerations, such as modality (how it is being provided), or how it was previously provided, if this has changed. There may not be a definitive timeline of the evolution of how education has been delivered. However, Li (2018) suggests, in Figure 2.1, that the development stages are from correspondence (i.e., written communication) to distance learning (1960-1985), then distance learning (1985-1995), until reaching online learning (1995-2007), and finally reaching interactive online learning after 2008. Figure 2.1 contains the suggested timeline, which comprises five phases that starts in the 1960s (correspondence) and ends with the "interactive online learning" phase that is operating in present time.

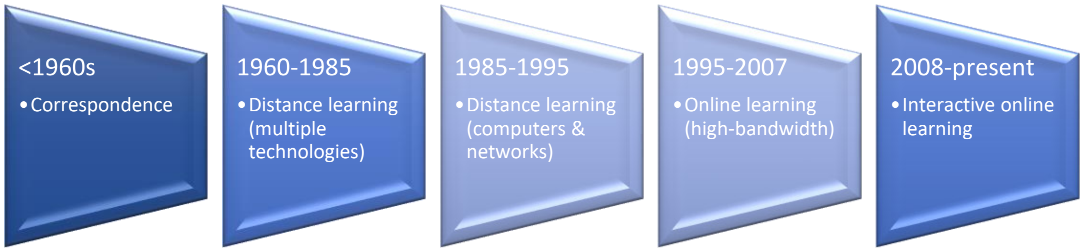


Figure 2.1 The evolution of instructional delivery (Li 2018: 411-413, adapted)

The term TEL is open to a very broad range of interpretations, and is not restrictive with respect to either types of technology or pedagogical approaches (Goodyear and Retalis 2010: 8). TEL is considered to provide enhancements to teaching and learning in respect of both the delivery medium and method (Kirkwood and Price 2014: 26), the precise nature of the enhancements being dependent on context-specific definitions of learning (HEFCE 2009: 2). For the purposes of this study, TEL is defined as tuition occurring in contexts "where technology plays a significant role in making learning more effective, efficient or enjoyable" (Goodyear and Retalis 2010: 8). Currently, computers and the Internet play a major role in this process. However, in the future, technology may evolve into different forms.

2.3 TEL infrastructure

As defined in Chapter 1, infrastructure refers to "the system of hardware, software, facilities and service components that support the delivery of business systems and IT-enabled processes" (Gartner Information Technology Glossary 2021: [1]). In view of the emphasis placed on online learning by its emergency - and probable continued - use caused by the COVID-19 pandemic, the issue of providing a robust TEL infrastructure becomes a key issue in the continued survival of universities. Mhlanga and Moloi (2020) explain that, in response to the national lockdown that was instituted in South Africa (26 March 2020 to 16 April 2020), several learning institutions responded "by moving some of their courses to their online platforms" (Mhlanga and Moloi 2020: 3).

Continuity in changing circumstances, mainly unforeseen, is the main problem (Stoneburner, Goguen and Feringa 2002; National Institute of Standards and Technology 2017). While investment is a workable solution, it is needed immediately, and it is difficult to predict which technology future to target. However, this is a legitimate strategy used at national levels where promising technologies are identified for development: this is termed "technology futures". This suggests that some means of forecasting provision of TEL infrastructure is urgently needed, so that continuity is assured but current resources are not wasted. This section, while outlining related aspects such as the definition of TEL, and types of TEL predicting, takes cognisance of the added challenge of Covid-19 which can be categorised as being high-impact and having immediate impact requiring rapid change (Reddy and Pratt 2022), in sharp contrast to regular change factors such as software obsolescence or financial distress (Agbedo 2012).

2.4 TEL in South Africa

TEL in South Africa differs from its use internationally in terms of dealing with smaller numbers of HE institutions, as well as the nature of the systems in use. Moreover, the international higher education landscape cannot be generalised except regionally or geo-politically, such as in the case that North America will include Canada and the United States of America.

2.4.1 Benchmarking TEL in South Africa

In a benchmark carried out using a web search in 2016, it was established that, within the South African HE context, there were twenty-six institutions, of which twenty-three used an LMS (fourteen used Blackboard, five used Sakai and four used Moodle); three did not use an LMS at all.

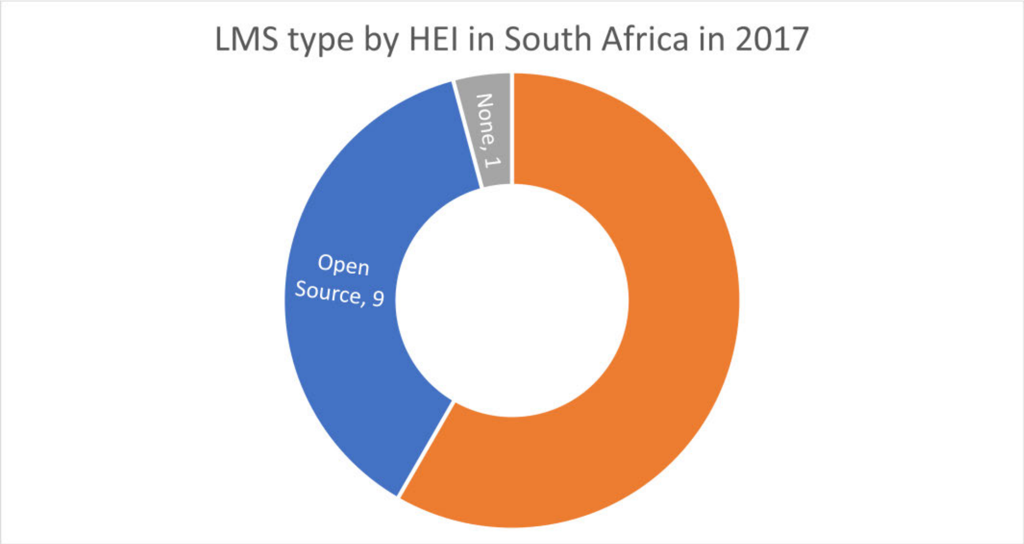


Figure 2.2 LMS distribution by type in HEIs in South Africa

The South African benchmark was followed up with in-person interviews conducted about the existing TEL provisions in eight HE institutions from Europe. It was established that only one was still using the proprietary LMS (Blackboard), one used an in-house system, and the other six used open-source systems. The university which was still using a proprietary system subsequently changed to another proprietary system (Canvas) in August 2017. This partly supports the assertion that the needs for TEL infrastructure provision by institutions have changed, necessitating re-evaluation of currently used TEL related systems which would benefit from the simulation model being developed in this study.

2.4.2 TEL in the COVID-19 context

In South Africa in particular, the mode of delivery for most of the HEIs, such as traditional universities and Universities of Technology, has been largely contact-based with some aspects being offered online. By contrast, pure distance learning higher education institutions (correspondence) have most of the interactions between lecturers and students taking place outside the "brick and mortar" norms that are associated with UoTs, and this (for them) simplified the transition to the physically distanced delivery mode needed because of the COVID-19 contingent factors and restrictions such as lockdowns.

Most of the South African institutions assembled task teams to lead the response to the restrictions implemented by the strict Level 5 lockdown that came into force on 26 March 2020. These teams in some cases did not consult with representatives from the academic support sector and the solutions put forward reflected this, as little consideration or deep understanding of teaching was apparent in the solutions put forward. In one case Microsoft Teams was chosen as the primary medium to deliver eLearning, although it was later shown to lack the key features that a learning management system has, such as a robust assessment tool. This decision about Microsoft Teams was made by a team that were from the IT support section, who had no expertise with eLearning provision, and were probably swayed by the fact that MS Teams was already covered by the existing enterprise licence and the need to demonstrate leadership. This type of decision making in the midst of a crisis can be attributed to the perceived need by senior management to provide a solution quickly, and lack of understanding of where expertise lies in the organisation (the name "Rapid Response Task Team" suggests a hasty need for a solution, see https://www.dut.ac.za/dut-covid-19-response-task-team-statement-22-october-2021/ for a sample of that bulletin).

Czerniewicz (2021) suggests that "there is a consensus that *the digital* is going to be part of teaching and learning from now on, even for universities which pride themselves on being residential". She goes on to suggest that "the opportunities offered and that have been learnt over this period[1] cannot afford to be lost" (Czerniewicz 2021: 3).

2.5 Forecasting of TEL infrastructure

Chen, Wakeland and Yu (2012: 81) distinguish between "technology forecasting which predicts the future trajectory of a certain technology based on existing data" (and the focus of this study) and "technology foresight", which involves gathering information on the most important emerging technologies on the foresight map and then focusing on developing these.

2.5.1 Technology forecasting

Having said that, it would be prudent to keep in mind that the progress of technology foresight initiatives could have a bearing on trajectories that current systems could possibly transition into. In other words, the two methods are not mutually exclusive, although they have different aims; in fact, a technology forecast is unlike to be accurate if it disregards technology foresight commitments.

One approach towards technology forecasting that Xingwang and Yanjie (2012) describe involves "building a bridge between patent map[s] and technology forecasting":

> This involves the development of a technology forecasting system by conducting patent analysis which uses patent maps that analyse the past and present status of a technology and forecasts the future status of it using the results according to technology activity, technology cycle time and technology evolution trend (Xingwang and Yanjie 2012: 4).

It should be acknowledged that, although technology forecasting as a modelling tool is gaining prominence, much of the early work in the fields of "world modelling and integrated assessment modelling (IAM)" (Hughes 2016: 98) forms the backdrop to technology forecasting which is essentially a modelling

[1]The 2020-2021 lockdown during the COVID-19 pandemic.

tool or method. Hughes (2016: 98) suggests that IAM and world modelling were two primary traditions in global forecasting.

It is worthwhile tracing and contextualising technology forecasting, and, as indicated by Hughes (2016: 55), “International Futures (IFs) [which] is a world model or computer simulation of long-term global development”, and a modelling project, “had its roots in the world models of the 1970s”. The key characteristic of IFs that is shared with technology forecasting is that they both examine trends instead of simply extrapolating them, in addition they are both focused on producing forecasts through alternative scenarios and not trends (Hughes 2001: 55,57).

2.5.2 Technology foresight

Popular methods used to conduct technology foresight planning include: patent analysis, data envelopment analysis, analytical hierarchy process, Delphi method, road mapping, and Theory of Inventive Problem Solving (TRIZ). Patent analysis is the method that will be focused on in more detail as it enjoys more prominence in comparison to the other methods mentioned.

Martin (1995: 140), who, together with Irvine, was one of the seminal authors in technology foresight (see Martin and Irvine 1989), explained the meaning of foresight as follows:

> Here, I use the term 'foresight' in the following sense:
>
> > ... the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research[9] and the emerging generic technologies[10] likely to yield the greatest economic and social benefits.
>
> Two aspects of foresight should be stressed. One is that foresight is a ‘process’, not just a set of techniques. It involves consultative procedures to ensure feedback to and from relevant actors. Secondly, the starting point of foresight, as with la prospective in France," is the belief that there are many possible futures. Precisely which of these futures we will arrive at depends in part on the decisions we take now. The aim of foresight is systematically to explore these alternative futures.” [12] “Thus, foresight involves a

> consciously ‘active’ attitude towards the future, recognizing that the choices made today can shape or even create the future. [13, 2]

Martin’s seminal concepts are oft-cited by later commentators, and Miles (2010: 1455) picks up on Martin’s suggestion that foresight involves an “active” stance which can not only shape but even *create* the future, which is a daunting thought.

Chen, Wakeland and Yu (2012) define technology foresight as follows:

> … a process that systematically looks at the long-term future of science, technology, and society with the aim of identifying the areas of strategic research and emerging technologies that will be likely to yield the greatest economic and social benefits (Chen, Wakeland and Yu 2012: 1255).

China used a Delphi study that helped to identify the need to promote research and development (R&D) to realize the implementation of 4G technology by the planned time frame year 2020. This is a recent example of the use of technology foresight in action (Chen, Wakeland and Yu 2012).

South Korea implemented technology futures (TF) exercises that were five-year plans to identify the general-purpose technology to focus on. The results were incorporated into longer-term (5 – 30 years) science, technology and innovation plans (Pietrobelli and Puppato 2016).

2.5.3 Patent analysis

The analysis of patents gives some early indications of technologies that are evolving. In some instances, breakthroughs in a particular technology may be identified in patents being filed. This has game-changing implications, as it may point at related technologies that face obsolescence, or present opportunities to develop bridges between the old and the new. The patent space is highly

---

[2] Martin’s in-text references are to:
Elzinga, A. 1983. Foresight as anticipatory intelligence. Ottawa: Science Council of Canada.
Irvine, J. and Martin, B.R. 1989. Research foresight: creating the future. Zoetermeer, Ketherlands: Ministry of Education and Science.

active, and in 2018 there were 3,3 million patents applications. In addition, 14,3 million trademarks, 2,1 million utility models and 1,3 million industrial designs were filed (World Intellectual Property Organization [WIPO] 2019).

When narrowed down to the two fields of technology that have bearing on this study, namely, computer technology and semiconductors, Table 2.1 gives one an idea of what the magnitude of the task of patent analysis is, simply due to the high number of patents being filed.

Table 2.1 Top ten countries by number of patents for computer technology and semiconductors from 2017-2018 (WIPO Statistics Database 2019)

	Origin	Field of technology	2017	2018
1	United States of America	6 - Computer technology	39,833	38,232
2	China	6 - Computer technology	30,077	33,995
3	Japan	8 - Semiconductors	17,915	15,945
4	Japan	6 - Computer technology	17,663	16,472
5	United States of America	8 - Semiconductors	10,348	9,265
6	Republic of Korea	6 - Computer technology	9,940	10,271
7	China	8 - Semiconductors	8,810	8,407
8	Republic of Korea	8 - Semiconductors	8,159	8,293
9	Germany	6 - Computer technology	2,961	3,203
10	Germany	8 – Semiconductors	2,551	2,501
		Totals	**150,274**	**148,602**

Table 2.1 shows that for the top ten countries there were just over 150,000 and 140,000 patents filed for the fields of computer technology and semiconductors in 2017 and 2018 respectively. The task at hand, namely that of tracking and identifying "outliers" from all the patents being filed, is not by any means insurmountable, as the source of patent information is available online in searchable databases, the patents have keywords assigned from a controlled vocabulary, and various algorithms have been developed that help sift the wheat from the chaff.

2.6 Modelling as a means of forecasting

Page (2018: 13) suggests that "Models are formal structures represented in mathematics and diagrams that help us to understand the world." He suggests that "mastery" of models "improves your ability to reason, explain, design, communicate, act, predict, and explore" (Page 2018: 13). While there may be consensus that the practice of modelling has many benefits, that is as far as any shared understanding goes. Page suggested that models are formal "structures", yet there are informal modelling structures, such as those in Alvin Toffler's *Future Shock*, which may not be reducible to algebraic formulae but still meet the above definition in all other ways. There is a distinction between formal and informal models. Essentially, modelling involves explaining or understanding systems, so that modelling that is informal is not necessarily inferior to formal modelling; the opposite but equally fallacious conclusion is that all computational modelling is superior to non-computational modelling.

Miller and Page (2007: 5) cite Adam Smith's (1776) writings (*The wealth of nations*) as representing one of the earliest coherent descriptions of complexity in social systems. However, the models developed by writers such as Adam Smith 1776), Alvin Toffler (1970) and Milton Friedman (see Kimm and Nelson 1999) were never presented in the ways to which we are now accustomed. Instead, only their results and analysis were presented, while the models used to inform these could be inferred only.

2.6.1 Modelling approaches in general

Modelling has been used in various disciplines to achieve in principle the same objectives, with the choice of model used being dependent on the purpose. What distinguishes modelling that is used in the hard sciences, such as mathematics, versus that used in the softer sciences, such as the social sciences, is acknowledgement that the social system has more complex properties than the hard sciences, which makes model building more challenging.

Two contrasting approaches to modelling are the "many model approach" (Page 2018: 41-55), and the "one model approach" (Cooper, Seiford and Zhu 2000). Franck's "system of functions" (Franck 2002) is an example of a one model approach. However, the intention is not for it to be used as is, but rather to use it to guide the formulation of a more specific model, such as in the Service Delivery Model (Makhubu 2011) and the Systemic Model of Communicative Functions (Pratt 2007: 25). Page, on the other hand, suggests that a multi-model approach could be more beneficial because it focuses on many discrete aspects of the system separately instead of on the entire system that is being explained.

Burch (2017), referring to Meehan (1981: 89-90), who makes a sharp distinction between explanations and forecasts, sums up the differences as follows:

> Unlike a prediction, which enables us to anticipate an outcome and adjust to it, explanation, given its clear causal structure, also provides a basis for intervention in a system and control of the outcome, at least in principle (Burch 2017: 56).

Burch explains one of the key difficulties associated with simulation, which he identifies as the "problem of how to assess the relationship between complex simulation models and empirical data", which he says, "has plagued the practice of computer modeling from the beginning, and has yet to be adequately resolved" (Burch 2017: 56). A simulation, then, is a hypothetical construct, rather than being based on data, and is useful only for producing forecasts or predictions. In spite of this caveat, Burch concludes that "the computer will enable twenty-first century social scientists to match the breadth and depths of their insights with expanded powers of logical inference, leading to a true marriage of theory and empirical research" (2017: 63).

Although modelling may be used in different disciplines, including health, science, business (industrial, corporate and financial) and education, amongst others, Page (2018) provides the following reasons for using models:

> In school, we apply models to explain data. In practice, we can also use models to predict, design, and take actions. We can use models

> to explore ideas and possibilities. And we can use models to communicate ideas and understandings (Page 2018: 27).

As mentioned previously, there are various types of modelling, and some of the types used in social science research (but not exclusively so) include the categorization model, diffusion and SIS (susceptible-infected-susceptible), linear, Schelling, decision theory, Granovetter and Markov processes. The focus of this research is on forecasting, and therefore the focus is on models that are used for forecasting. This list of modelling types, although not exhaustive, includes the most commonly used ones in the field of social science. Having said that, we should mention that modelling is used in disciplines such as mathematics, engineering, health sciences, management sciences, and computational sciences.

2.6.2 System dynamics modelling

Forrester (1995) is credited with being the inventor of system dynamics, according to the article entitled "The beginning of system dynamics" that was published in *The McKinsey Quarterly* 1995 (Forrester 1995: 4). Forrester (1995) recalls the first instance when he simulated how General Electric made hiring and inventory decisions, using a pencil and a page in a notebook as the first pencil and paper inventory control system, which was the beginning of system dynamics. (Forrester 1995: 9). The transition from the analogue method to a digital version that eventually resulted in the DYNAMO compilers was due to Forrester requiring computer simulations for an article he was writing for the *Harvard Business Review* in 1958, for which he assigned the task of coding the equations to his computer programmer (Richard Bennett) who, instead, programmed a compiler that would in turn generate the code. According to Forrester (1995: 9): "This result was the SIMPLE compiler – Simulation of Industrial Management with Lots of Equations."

Sterman (2001: 10) suggests that the system dynamics modelling approach can be used to improve learning in complex systems. Tang and Vijay (2001: 1) trace the origins to Forester's seminal work in 1959 on system dynamics to his book *Industrial dynamics* (Forrester 1961). Forester may have applied system dynamics specifically to analyse corporate decisions, but since 1968, system dynamics had gone beyond industrial problems to tackle problems of larger social systems such as urban planning of cities and countries.

Sterman (2001: 9-10) defines systems thinking as the ability to see the world as a complex system, in which we understand that "you can't do just one thing" and that "everything is connected to everything else". System dynamics has been used widely and across multiple industries and disciplines, such as environmental (climate change, traffic congestion, pollution) transport, urban planning, economics, and supply management. Kanti *et al.* (2018: 4) define systems thinking as "a formalised methodology consisting of methods of problem definition, dynamic hypothesis, modelling and policy analysis to understand and manage complex and dynamic systems". Page describes systems dynamics models as follows:

> These models analyze systems with feedbacks and interdependencies. They are used to model ecologies and economies, supply chains and production processes. They improve our capacity to think through logical chains that include negative and positive feedbacks. A systems dynamics model consists of sources, sinks, stocks, flows, rates, and constants. Sources produce inputs into the system. Sinks absorb outputs. Stocks keep track of levels of variables, and flows capture feedbacks between levels of stocks. Rates and constants apply to the flows, which can be fixed or change over time (Page 2018: 198).

The focus of this research is on forecasting, and, more specifically, forecasting of TEL infrastructure, and, although research about this specifically is sparse, there are copious amounts of research in the area of forecasting that can be drawn on to be applied to the forecasting to TEL Infrastructure.

In explaining what system dynamics modelling is, Yearworth (2020: 15) quotes Peter Senge, who states that it is:

> …a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots…systems thinking is a discipline for seeing the '**structures**' that underlie complex situations, and for

> discerning high and low leverage change (Yearworth 2020 citing Senge, 1990).

Yearworth (2020: 4) goes on to suggest that "structure" is the key word, and that dynamic behaviour is a consequence of system structure and information feedback. This brings in the concept of "explicit representation" as in modelling.

The system dynamics approach is well suited to certain aspects of forecasting as it provides a mechanism (causal loop) which allows for configuration of each parameter, while the actual loop and each parameter is informed by the algorithm that is defined. The output of the forecast may be easy to produce using the simulation model, and this is in the form of a scenario based on the underlying algorithm (that is fixed) and the user input. However, this is only one aspect of the simulation model. The second important aspect is the accompanying narrative, which will be based on analysis and interpretation by the developer.

2.7 Theoretical underpinning

The overall research orientation used in this study is Bhaskar's (1978) critical realism, a post-positivist approach (Guba 1990: 20-23) which is not, however, a paradigm, but a philosophy developed mainly by the British philosopher Roy Bhaskar (1978, 1986, 1989, 1998).

2.7.1 Overview of critical realism

The critical realist philosophy provides a meta-theory clearing the way for more specific disciplinary approaches (Dobson 2012: 66-76) the latter being categorised as "substantive theories" (Mutch 2010: 507). The development of such substantive theories is necessary, as critical realism is a philosophical overview which does not focus on methodological matters (Alvesson and Sköldberg 2009: 43), giving researchers the option of applying a methodology which fits their particular area or discipline, in this case, systems analysis.

Critical realism argues that there is a real world and that objects exist independently of one's perception of them (Jefferies 2011: 4). Key concepts in critical realism are causality, as well as the mechanisms which are thought to be the causes of events, and which Bhaskar describes as the “essence” of things (1978: 88). Another key concept is that of social structure, a type of mechanism comprising the system of relationships which both contextualize and motivate human social behaviour (Porpora 1998: 344). Bhaskar’s main contribution is considered to be his work on ontology, which shows reality as operating at three different dimensions, namely, the domain of real, the domain of actual and the domain of empirical (see Table 2.2). Table 2.2 (from Bhaskar 2008: 47) contains the ontological assumptions of Bhaskar’s critical realism, showing the domains in which mechanisms, events, and experiences are situated. Note that the domain of real should not be viewed as necessarily containing material objects (Fleetwood 2005: 2). According to Kaboub (2001: 1), the critical realist ontology contends that an entity is real if it can cause observable consequences: “In other words, in critical realism something is real if it is causally efficacious (e.g., unemployment, a magnetic field, poverty)”.

Table 2.2 Bhaskar’s three domains (Table 1.1 in Bhaskar 2008: 47)

	Domain of Real	*Domain of Actual*	*Domain of Empirical*
Mechanisms	√		
Events	√	√	
Experiences	√	√	√

The ontology represented in Table 2.2. shows that, while experience is a “real” phenomenon, the residue of such experiences exists only in the domain of empirical as thoughts, beliefs or memories (note that, while the activity of thinking is real, the object of our thoughts may not be). Furthermore, our perceptions of events (i.e., our experiences) are often out of phase with the real structures causing these events (Bhaskar 2008: 2). This means that we are not likely to perceive the deep level causes or mechanisms clearly, but only the surface features of the events they bring about. The key concepts in Bhaskar’s philosophy can be seen to arise from his conceptualizing of reality in a three-fold way, and the distinction he draws between ontology and epistemology (Bhaskar 2010: 1).

2.7.2 Relevance of critical realism to systems analysis

Critical realism is thought to be a suitable orientation for this study as, according to Mingers (2011: 303):

> Critical realism, especially as developed by Roy Bhaskar, embodies at its heart systemic and holistic concepts such as totality, emergence, open systems, stratification, autopoiesis and holistic causality. These concepts have their own long history of development in disciplines such as systems thinking and cybernetics…

The following attributes of critical realism make it a suitable approach for systems analysis. Critical realism:

- defends a strongly realist ontology that there is an existing, causally efficacious, world independent of our knowledge.
- recognizes that our access to this world is in fact limited and always mediated by our perceptual and theoretical lenses
- accepts the existence of different types of objects of knowledge - physical, social, and conceptual - which have different ontological and epistemological characteristics (Mingers, Mutch and Willcocks 2013: 795, abbreviated).

The first attribute means that analysis is not limited to a form of positivism which focuses only on aspects of entities which can be observed and measured, nor forms of constructivism which focus only on what humans know about such entities, but is about a real world which exists independently of what we know about it. The second attribute acknowledges the relative nature of epistemology in that knowledge is always “local and historical”, and that “all viewpoints must be equally valid” (Mingers, Mutch and Wilcocks 2013: 795, i.e., valid as ways of thinking, not in terms of what is thought). The third attribute implies that a mixed methods approach is likely to be necessary in order to analyse different types of entities or phenomena (i.e., those existing in the different domains).

Carlsson advocates critical realism as a philosophical framework for systems design rather than its (often implicit) grounding in positivist or pragmatic approaches (2005: 93-94). This is not a rejection of empirical science but more in the nature of an adjustment. As Sorell (2018: 1269) points out, “critical realism seeks to bridge some long-standing divisions within the social sciences - such as between positivism and interpretivism”. The view that critical realism has much to contribute to systems thinking is shared by Mingers (2011, 2014), Mutch (2002, 2010) and Dobson (2001, 2002, 2012), and, more recently, by De Souza (2022). De Souza has summarised Mingers (2014) with specific references to Bhaskar’s (1978, 1998) seminal works. Elements relevant to systems analysis are shown in Table 2.3

Table 2.3 Critical realist concepts relevant to systems analysis (extract from Table 1 in De Souza 2022: 73).

Systems thinking	**Critical realism** (Bhaskar 1975-2008) *A realist theory of science* and *The possibility of naturalism* (Bhaskar 1998)
Open and closed systems	Open and closed systems
Hierarchy or nesting of systems	Stratified ontology, laminated systems (Bhaskar 1998: 198-199)
Systems	Structures, mechanisms, “things”
Relationships	“Relational conception of society” (Bhaskar 1998: 181)
The observer and the observed	Transitive and intransitive domains
Emergent properties	Power, liabilities, tendences, emergent properties
Structure generates behaviour or process	Mechanisms generate events; “society …an ensemble of structures, practices and conventions which individuals reproduce or transform… (Bhaskar 1998: 39)

As Bhaskar’s writings on critical realism tend to be diffuse and, as an overarching philosophy, are not intended to be directed at any specific field or methodology, summaries showing its relevance to specific research areas (in this case, systems dynamics) are extremely useful in “cutting to the chase”, as it were. However, one needs to relate the commonalities identified by Mingers (2014) and summarised in Table 2.3 by De Souza (2022: 73) to the actual process of systems analysis. To sum up, critical realism views the world as consisting of different domains, as shown in Table 2.2. Positivist research tends to use quantitative methods to investigate linear causal relationships between different variables, operating the domain of actual, that is, using what can actually be observed (Roberts 2014: 3). However, the mechanism which causes the pattern of observed behaviour or events may not be directly observable but can be inferred only by viewing the world as an open system, that is, in Bhaskar's domain of real. As Roberts (2014: 3) points out:

> This is a more qualitative approach to the issue of causality because causal mechanisms are examined in the social world through real open contexts where they interact with one another in often contingent and unpredictable ways.

The complex nature of the interactions often means that the real causes of events or conditions (social and material) are not apparent on the surface (Bhaskar 2008: 2).

Bhaskar's ontology postulates experience as being part of the real domain; experience - as well as the attitudes it develops - is then not just personal, but "socially real" (Fleetwood 2005: 3). The researcher is taking into account not only the laws of electronics when developing the computerised simulation, but also the causal laws (as real as the laws of physics) which shape decision-making. What the artefact does, then, is to direct unpredictable human decision-making into channels which will show the foreseeable outcomes of such decisions but acknowledge that *the actual outcomes are unpredictable* as they are the result of complex sociotechnical factors. More importantly, the artefact will offer users scenarios which show the probable results of their decisions, given the constraints operating at the time, that is, the probable consequences of going down any given path. Critical realism is thought to offer a more balanced version of causality than solely positivist or interpretative approaches, and to provide more than a mere combination of quantitative and qualitative methods. However, critical realists acknowledge that features of the open context they attempt to describe are subject to continual change, and forecasting at best offers probable outcomes only.

2.8 Conclusion

In this chapter, TEL was defined and then contextualised by being set in the South African context. Technology forecasting was defined and distinguished from technology foresight, and the choice of technology forecasting for this research project was supported. However, related but different methods such as technology foresight and International Futures were reviewed, as aspects of these were used to develop the proposed model. Modelling is a broad term, and this chapter defined and assessed different types of modelling before system dynamics was chosen, although applying system dynamics to the practical aspect of the simulation design was predicated on disaggregation of the TEL system by using functional decomposition design.

The theoretical approach was identified as critical realist, which was considered appropriate for a university context in changing times in terms of its acceptance of a real world beyond human knowledge, the realisation that human perception is limited, and the fact that the objects of human knowledge are not only physical but also social and conceptual. All of these factors must be considered in future forecasting, which can be seen to have material, social and conceptual elements. The next chapter will deal in more detail with the research approach and design used to achieve the research objectives given in Chapter 1 (p. 7).

Chapter 3: Research design

3.1 Introduction

The chapter first gives an overview of the research design used in this study, and then goes on to discuss in more detail the various elements of the design. To recap the purpose of this study: it deals with the development of a computerised simulation model to guide the South African higher education (HE) sector in short and long-term planning of TEL (technology enhanced learning) infrastructure. The research design process is outlined using the following sections: orientation, methodology, research instrument and approach, and is then further divided into objectives, methods and research products. The chapter then gives an overview as to how these elements were dealt with in the course of the research.

3.2 Overview of the research design

The research design used in this study is shown in Table 3.1.

Table 3.1 Research design

	RESEARCH DESIGN			
ORIENTATION	Critical realism			
METHODOLOGY	Case study based on TEL infrastructure provision in three universities			
RESEARCH INSTRUMENT	System dynamics modelling			
APPROACH	Mixed methods approach			
Objectives	1. Formulating a system dynamics model		2. Constructing a computerised simulation	3. Testing the simulation
Methods	*Qualitative:* semi-structured interviews	*Quantitative:* functional decomposition design process	*Quantitative:* formulation of equations	*Qualitative:* web-based survey
Research products	Computerised simulation design		Computerised forecasting simulation	

The research orientation used was Bhaskar's critical realism (Bhaskar 1978, 1979; Archer *et al.* 1998), which is concerned with "the explanatory power" of hypotheses (Judd 2003: 55). The methodology comprised a case study of TEL infrastructure provision at three KwaZulu-Natal universities (DUT, University of KwaZulu-Natal and Mangosuthu University of Technology). The research instrument used to develop the proposed computerised forecasting simulation was system dynamics modelling (Sterman 2001), with a mixed methods approach to gather qualitative and quantitative data. The following specific research objectives were formulated: 1. Formulating a system dynamics model; 2. Constructing a computerised simulation; and 3. Testing the simulation. Three stages were involved in achieving these objectives: 1. Establishing design specifications; 2.Configuring the simulation online; and 3. Testing the simulation. Both quantitative and qualitative methods of data collection were used in these stages. Table 3.1 shows the relationship between the various elements of the research design.

3.3 The system dynamics modelling process

The design process of the computerised simulation model is shown in Figure 3.1, which shows a high-level depiction of the simulation design used in this project in terms of data collection, the simulation and the testing.

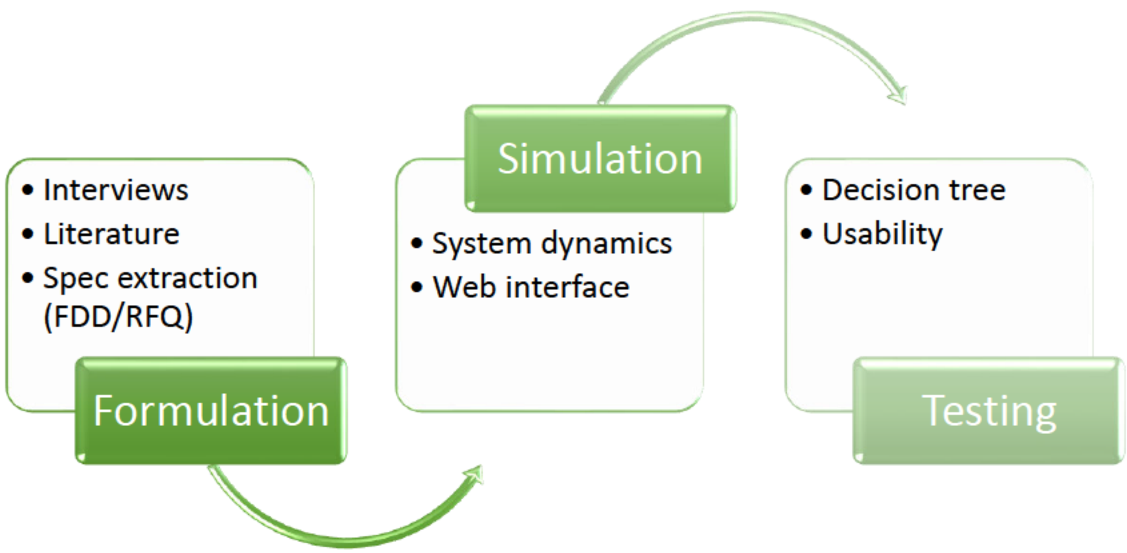


Figure 3.1 The simulation design process

As shown in Figure 3.1, data used to formulate the simulation (by providing specifications) were collected by means of interviews with key decision makers. Evidence was also found in the literature about the viable options available for TEL infrastructure. Functional decomposition design (FDD) was used to extract the specifications from the data. The resulting simulation was then developed as a web application using a systems dynamics approach and tested out in terms of usability and usefulness. The simulation design process is explained in more detail in the following sections.

3.4 Formulating the system dynamics model

Formulating the system dynamics model involved gathering data from key stakeholders, as well as using specifications obtained from the literature. Data were gathered by means of a mixed-methods approach (Creswell 2013) involving in-depth qualitative interviews (Brinkmann and Kvale 2022) with stakeholders. These comprised four university staff members selected from three higher education institutions (HEIs) to obtain a "snapshot" of their present and future plans and their commitments with respect to the provision of TEL infrastructure at their institutions. The selected members were as follows:

- Director: ITSS (1)
- Director: CELT (1)
- Specialist: ELearning and Educational Technology (1)
- Manager – UTEL (1)

Functional decomposition design (FDD, see Valckenaers *et al.* 2003: 383) was used by extracting the request for quotation (RFQ) specifications for procuring TEL systems in order to develop the logic and parameters informing the design of the decision tree.

The use of FDD to inform the decision-making model is a novel application of FDD which is more commonly used in software or electronic engineering. The reason for using it in this study is because TEL environments are comprised of such a multitude of variables that it would not be feasible to isolate and incorporate these into the decision tree design. The FDD application using the RFQ helped to focus on aspects involving, in the experience of the researcher, the decision areas related to TEL infrastructure. This is illustrated in Wang and Kinuthia's depiction of a TEL environment (see Figure 3.2), which, it must be emphasised, deals with "core components" only (Wang and Kinuthia 2004: 2725).

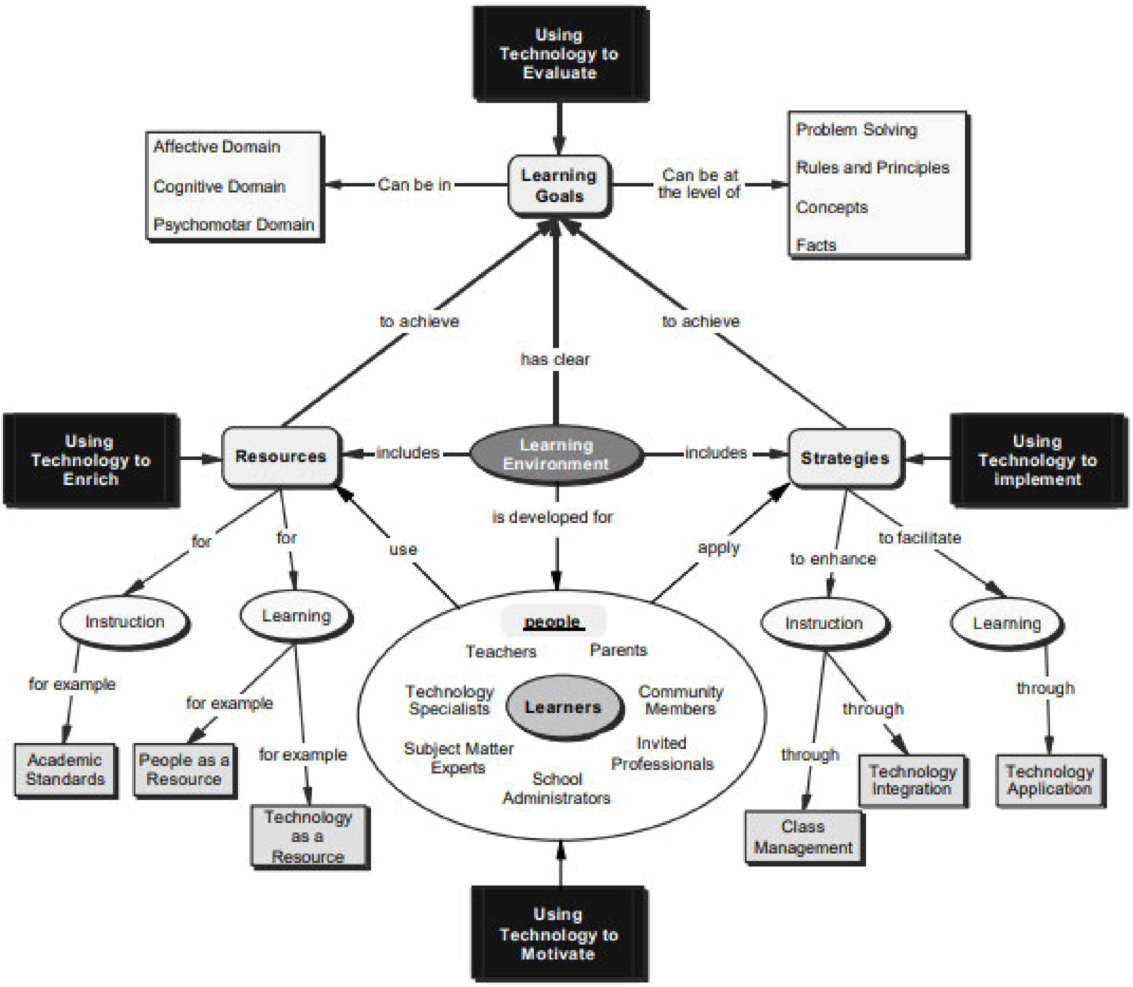


Figure 3.2 Core components of a technology enhanced learning environment (Figure 1 in Wang and Kinuthia 2004: 2725)

As Wang and Kinuthua concede, there will be different opinions about what learning goals might be (2004: 2726), and this present study does not necessarily agree on their depiction of the "core components". However, this study does take cognisance of the fact that the decisions of certain people (i.e., key decision makers) impact on a technology enhanced learning (TEL) environment, that resources (i.e., TEL infrastructure) are a key component, and that the system involved is dynamic, rather than static.

3.5 Constructing the computerised simulation

The simulation was designed so as to produce different outcomes for different inputs, with the result that modification of inputs (variables) adjusts the outcome in real time. This meant that the simulation was dynamic and not static.

3.5.1 Decision tree classification for online use

An interactive decision tree was created as part of the process of developing the computerised simulation for online use. A web application, SilverDecisions, was used to develop the decision tree that was used as the basis for the simulation (Kamiński, Jakubczyk and Szufel 2018, 2022). Structuring the decision problem can help avoid subjectivity in decision making and it makes it easier to focus on the quantitative aspects of decision outcomes (Kamiński, Jakubczyk and Szufel 2022: 10). Kamiński, Jakubczyk and Szufel (2022: 11) go on to explain that decision trees are a way to model the sequential decision problems.

The following description of the functioning of SilverDecisions is provided by Kamiński, Jakubczyk and Szufel (2022: 51-52):

> A decision tree consists of three types of nodes: decision, chance, and terminal. Nodes are connected by arrows that will be called edges; we will say that the arrow points from source to destination. In SilverDecisions, by default, decision nodes are presented as red squares, chance nodes are yellow circles, and terminal nodes are green triangles. In Figure 3.1, we present an example of a decision tree in which we have one decision node called A, one chance node called B, and three-terminal nodes C, D, and E.

They then go to explain the rules governing the ways in which the arrows are drawn (see Figure 3.2). These rules are as follows:

- The root node, as its name suggests, is the base of the tree structure, and cannot have any node prior to it or have any destination leading to it.
- All subsequent nodes are reached by one arrow only.
- Terminal nodes, as their names suggest, are the end destination (i.e., of that path), and, by definition, cannot lead to any further destination/s, but chance nodes have at least one arrow leading from them.
- There is only one path from the root node to any other node in the decision tree.

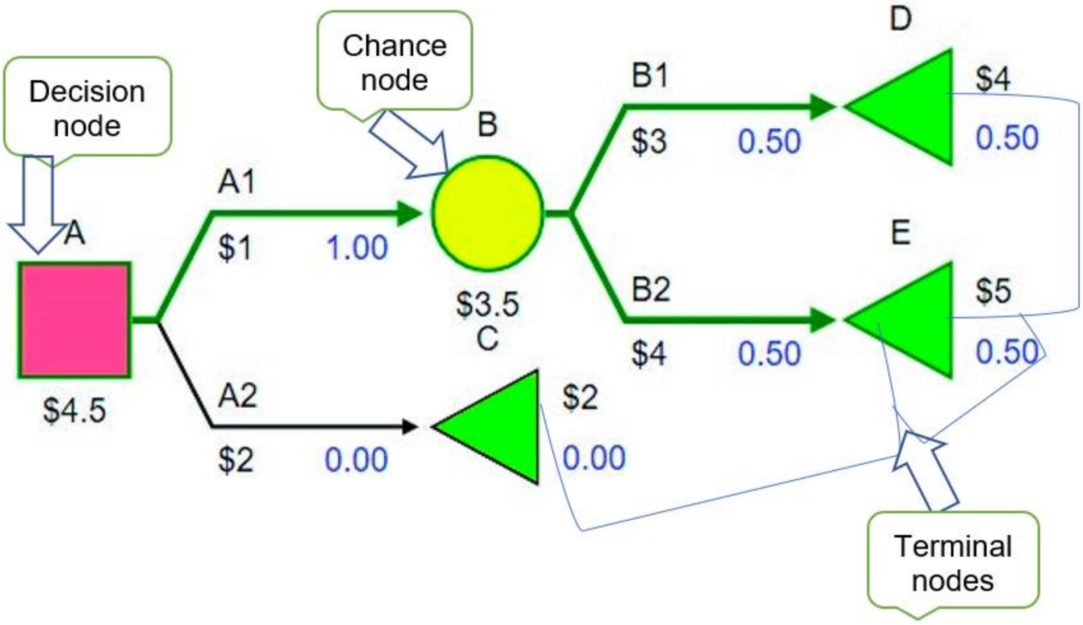


Figure 3.3 Example of a decision tree (from Kamiński, Jakubczyk and Szufel 2022: 51, adapted)

This explanation deals with the functionality and operational aspects of the SIlverDecisions decision trees, but it is also useful and important to know that it is premised on a mathematical foundation which is shown in the formula.

In this study, the scores arising from the synthesis of the qualitative and quantitative data were used as inputs to inform the optimum path taken by the decision tree. The application is interactive and user configurable, in that every value at each of the decision nodes could be changed, and the simulation therefore produces forecasts of pathways based on contextual input.

SilverDecisions is informed by graph theory, which is a well-known machine learning (ML) model, or algorithm (Joshi 2023:1-2). As explained by Kamiński, Jakubczyk and Szufel (2022: 51-52), a decision tree *T* consists of nodes forming set V that are connected by edges forming a set:

$$E \subseteq \binom{v}{2} = \{\{u_i v\}: u, v \in V \; and \; u \neq v\}$$

Each node $v \in V$ in a decision tree is associated with the following functions:

1. *T (v)*: type of a node, which can be decision, chance, or terminal
2. *N (v)*: name of a node

The excerpt below from Kamiński, Jakubczyk and Szufel (2022: 51-52) explains the mathematics underpinning the SilverDecisions application.

> Since each node $v \in V$ has exactly one of the three values assigned to $T(v)$, the set of nodes V is partitioned into three sets: $V_d = \{v \in V : T(v) = decision\}$, $V_c = \{v \in V : T(v) = chance\}$, and $V_t = \{v \in V : T(v) = terminal\}$; in particular, $V = V_d \cup V_c \cup V_t$.
>
> On the other hand, each edge $e \in E$ in a decision tree is associated with the following functions:
>
> 1. $Y(e) \in \mathbf{R}^n$ is a vector of n payoffs associated with this edge;
> 2. $v_1(e)$ is a start node of this edge;
> 3. $v_2(e)$ is an end node of this edge;
> 4. if $v_1(e) \in V_c$, then $p(e) \in [0, 1]$ is the probability of selecting this edge;
> 5. if $v_1(e) \in V_d$, then $d(e) \in \{0, 1\}$ is the decision about selecting this edge;
> 6. $N(e)$: name of an edge.
>
> Since each edge, $e \in E$ is a pair of nodes, one of which is a start node and the other one is an end node, a decision tree is, in fact, a directed tree.

Figure 3.4 Excerpt from Kamiński, Jakubczyk and Szufel (2022: 51-52) explaining the mathematics underpinning SilverDecisions

It would be impossible to attempt to simplify the mathematics behind the functioning of the decision tree system without rendering that explanation into a poor and "wrong" one.

3.5.2 Web design for inputs to the simulation

A web application (InsightMaker) was used to develop the computerised simulation so that users could provide inputs based on the context and requirements of their organisations. The InsightMaker application was chosen to help make decision making not only transparent and interactive, but also accessible to anyone who had access to a web browser. The two key specifications of the InsightMaker web simulation tool were that it was freely available (there was no cost for using it) and that it was powerful enough to develop sophisticated forecasts while having a relatively short learning curve to start using as a developer. There were other simulation software products such as VenSim, and Dynamo, but these were older systems that were desktop based and required a licence. InsightMaker provided the blank canvas, tools and underlying computational model to build a simulation. However, it was still necessary to configure the parameters and design the simulation. In addition, a workflow - or workflows - between the primitives and stocks had to be created.

3.6 Testing the computerised simulation

The components of the simulation were tested with participants in terms of usability and usefulness. The usage feedback survey (ELS-PS, see Appendix D) was used to test out both the usability and usefulness of the computerised simulation to show whether it worked reliably for the stakeholder group involved (i.e., key decision-makers).

3.7 Conclusion

The real-world problem this research set out to address was the challenge universities experience in anticipating short and long-term requirements for providing and maintaining continuity for technology enhanced learning (TEL). The research problem was identified (see Chapter 1, p. 5) as finding a feasible solution to address the problem of long-term planning of TEL infrastructure. The chosen solution for this study was to develop a computerised simulation forecasting model which could be used to generate various scenarios for the infrastructural aspects of TEL provision, based on user input. This chapter provided an overview of how the research problem was tackled in the research design, before discussing the various elements of the design in more detail in subsequent chapters, as these developed in the course of the research, as earlier and ongoing decisions - and their results - impacted sequentially on later processes. The products of the research were identified as the computerised simulation design and the computerised forecasting simulation itself, which is described, as well as its operation, in Chapter 5. In Chapters 4 and 5, more detailed accounts are given of the actual working out of the research design in the development of the decision tree and the resulting computerised simulation. The testing of the resulting computerised forecasting simulation and results are discussed in Chapter 6.

Chapter 4: Establishing design specifications

4.1 Introduction

This chapter starts with the case study approach and the participants involved, explaining why they were used as a data source as well as what the intent of this aspect of the data collection was. The rationale is given for the universities chosen, and the designations of the participants are provided to show in what sense they were key players, although they are referred to by pseudonyms and not their actual names. After looking at the response rate, the chapter shows how coding was assigned to the themes derived from the interviews. The chapter then explains the data synthesis process, which involved combining the qualitative and quantitative data. Next, it is shown how the computerised decision tree design, using SilverDecisions, was used to create decision pathways informed by the data analysis. The chapter concludes by describing how the interview data was merged with the FDD data.

4.2 The case study approach and participants involved

The research design as shown in Chapter 3 in Table 3.1 (Research design) provides the rationale and outlines the sequence used for the data collection part of this research, conducted as part of a case study. As Njihia (2008) explains, unlike empirical statistical surveys or grounded theory, realist research data collection is theory-, rather than data-driven. In principle, any valid data source or analytical technique that enriches the account of events and understanding of potential mechanisms would be admissible (Njihia 2008: 90-91).

The focus of this research was on technology forecasting, specifically for technology enhanced learning or TEL, and the intent of this aspect of data collection was on the following:

- Contextualising the decision-making processes that each of these institutions follow (evaluating fitness for purpose of key decision makers);

- Understanding planning processes;
- Assessing the expertise of decision makers;
- Exploring willingness to commit to technology change;
- Reviewing obstacles to adopting improved technology.

The case study group comprised key TEL decision makers from the Durban University of Technology, Mangosuthu University of Technology and the University of KwaZulu-Natal. These institutions were chosen based on their geographical locations and their homogeneity in aspects of funding, as all three are funded by DHET and therefore can be categorised as publicly funded institutions. In addition, these institutions were all offering face-to-face, contact-based tuition as well as eLearning at the time the research started, and were all using TEL platforms. Effectively this was a purposive choice, and the choice of interviewees was determined by roles and willingness to participate in the research. It must be noted that the predominant source of data was qualitative, and not quantitative, like the data obtained from the functional decomposition design (FDD). The participants selected from the three universities and their designations are shown in Table 4.1. Note that pseudonyms have been used for all participants, who are referred to subsequently by their codes.

Table 4.1 Participants from the three universities

Person	Code	Designation	Institution
Prof Thabani Ndlovu	TN	Director – Centre for Excellence in Learning & Teaching	UNI 1 (UoT)
Dr Philani Mkhize	PM	Chief Information Officer	UNI 1 (UoT)
Mr Chuma Nxumalo	CN	Specialist Education Tech & ELearning (TLDC)	UNI 2 (UoT)
Mr Joseph Collins	JC	Project Manager: UTEL, UKZN	UNI 3 (Trad)

4.3 The interviews

This section looks at the response rate of the participants interviewed, and shows how they and the question categories were coded. The tables following show the rationale for the questions, tabulate the results and provides keys to the themes and weightings.

4.3.1 Response rate

The response of 4/7 for the interviews was 57%. However, this included one person who redirected the invite to another person (a subordinate) and therefore the response rate can be taken as 4/6, which is 66.7%. There were seven persons identified for participation in the research, and as mentioned, one person redirected the role to her subordinate; the other two non-participants did not respond to requests for participation. The responsibility for an ambit or functional division of an organisation may be that of the top-level manager or executive. However, this does not translate to their being personally involved in every decision made. In fact, it is common practice to delegate duties which include decision making to subordinates. This can be contentious, as there is a difference between what staff members perceive as legitimate delegation and dereliction of duties.

4.3.2 Coding

Interviewees were assigned the following codes shown in Table 4.2 and Table 4.3. Each of the questions used in the interviews was assigned a category, which in turn was assigned a short code. Table 4.4 provides the rationale for each of the questions and Table 4.5 tabulates the results of the analysis of the responses from the interviews with their weightings. Table 4.6 then shows the key to the themes and weighting from the interviews.

The coded responses from the interviews with scores and weighting by question within category are shown in Table 2.

Table 4.2 Coded responses from interviews

Question	Code	Person/s	Score	Average	Weight	Total
1	TR	PM	1	3.5	0.1	0.35
		CN	5			
		TN	3			
		JC	5			
2	MS	PM	1	3.5	0.1	0.35
		CN	5			
		TN	3			
		JC	5			
2.1	MS	PM	5	4	0.1	0.4
		CN	5			
		TN	5			
		JC	5			
2.2.1	MS	PM	5	1.25	0.1	0.125
		CN				
		TN				
		JC				
4	MS	PM	3	2.5	0.1	0.25
		CN	1			
		TN	3			
		JC	3			
4.1	TP	PM	5	3.5	0.1	0.35
		CN	1			
		TN	3			
		JC	5			
4.2	TP	PM	5	3.5	0.1	0.35
		CN	1			
		TN	3			
		JC	5			
4.2.1	TP	PM	5	2.5	0.1	0.25
		CN				
		TN	5			
		JC				
4.3	TP	PM	5	3.5	0.1	
		CN	1			
		TN	3			
		JC	5			

Question	Code		Person/s	Score	Average	Weight	Total
5	TP		PM	5	2	0.1	0.2
			CN	1			
			TN	1			
			JC	1			
5.1	TP		PM	5	2	0.1	0.2
			CN	1			
			TN	1			
			JC	1			
5.2	TP		PM	5	2	0.1	0.2
			CN	1			
			TN	1			
			JC	1			
5.3	TP		PM	5	4	0.1	0.4
			CN	5			
			TN	5			
			JC	5			
6	I&I		PM	5	4	0.1	0.4
			CN	5			
			TN	5			
			JC	5			
6.1	I&I		PM	5	3.5	0.1	0.35
			CN	1			
			TN	3			
			JC	5			
6.2	I&I		PM	5	3.5	0.1	0.35
			CN	1			
			TN	3			
			JC	5			
6.2.1	I&I		PM	3	2	0.1	0.2
			CN	3			
			TN	1			
			JC	1			
6.2.3	I&I		PM	5	3.5	0.1	0.35
			CN	1			
			TN	3			
			JC	5			

Question	Code		Person/s	Score	Average	Weight	Total
7	FLCC		PM	5	3.5	0.1	0.35
			CN	1			
			TN	3			
			JC	5			
8.1	HCI		PM	5	4	0.1	0.4
			CN	5			
			TN	5			
			JC	5			
8.2	PF		PM	3	3	0.1	0.3
			CN	3			
			TN	4			
			JC	2			
8.3	I&I		PM	4	4.25	0.1	0.42
			CN	3			
			TN	4			
			JC	4			
8.4	I&I		PM	3	4	0.1	0.4
			CN	3			
			TN	3			
			JC	3			
8.5	I&I		PM	2	2.25	0.1	0.25
			CN	3			
			TN	3			
			JC	1			
8.6	FLCC		PM	4	3	0.1	0.3
			CN	3			
			TN	5			
			JC				
9	I&I		PM	5	3.5	0.1	0.35
			CN	1			
			TN	3			
			JC	5			

Each of the LMSs is scored within the thematic areas, and the weights in Table 4.3 are applied to this. The final weighted score is used in the Silver Decisions program as parameters for the decision tree simulation.

Table 4.3 Indicative weightings of specifications for case study

Thematic area	**Code**	**Weighting**	**Percentage**
Technical requirements	TR	0,1	10%
Integration & interoperability	I&I	0,1	10%
Human Computer Interaction	HCI	0,1	10%
Maintenance & Support	MS	0,1	10%
Technology Planning	TP	0,15	15%
Pedagogical functionality	PF	0,2	20%
Full life-cycle costing	FLCC	0,25	25%
Total		**1**	**100%**

The above sections dealt with the analysis of the interview data conducted with the case study representatives. Next, coding was assigned to the themes (which were derived from the questions), and then combined with the RFQ categories. The combined categories of data were assigned weights which were used as parameters for the prototype. The values in Table 4.4 are used to illustrate the results for this study.

Table 4.4 LMS scoring with weights applied

Code	**Weighting**	**Open Edx**	**Weighted score**	**Canvas**	**Weighted score**	**D2L**	**Weighted score**	**Moodle**	**Weighted score**
I&I	0,1	7	0,12	6	0,12	7	0,14	7	0,11
HCI	0,1	5	0,08	5	0,10	6	0,12	5	0,08
MS	0,1	8	0,13	5	0,10	4	0,08	6	0,10
TP	0,15	4	0,10	6	0,18	5	0,15	5	0,12
PF	0,2	9	0,30	7	0,28	6	0,24	7	0,22
FLCC	0,25	4	0,17	3	0,15	3	0,15	7	0,28
Total	**1**	43	1	36	1	36	1	43	1
Weighted scores calculated by using the scored assigned (from 1-10) against the weighting in each corresponding thematic area.									
Scores range from minimum of 1 to maximum of 10.									

With the weighting completed, the next step was to evaluate the previously identified candidate systems against the criteria of each of the categories of the RFQ. The actual categories and the number of categories would be determined by each organisation using the simulation, and the actual means used to score the categories would be at the discretion of the organisation; the key is to ensure that the sum of the weighting is equal to one. Assigning a percentage might help users to assign weightings which are expressed as a decimal number.

4.4 Data synthesis process

The data synthesis involved combining the two sources of data, namely, qualitative, which emerged from the interviews conducted and the quantitative data that was extracted from the FDD process using the RFQ depicted in Figure 4.1.

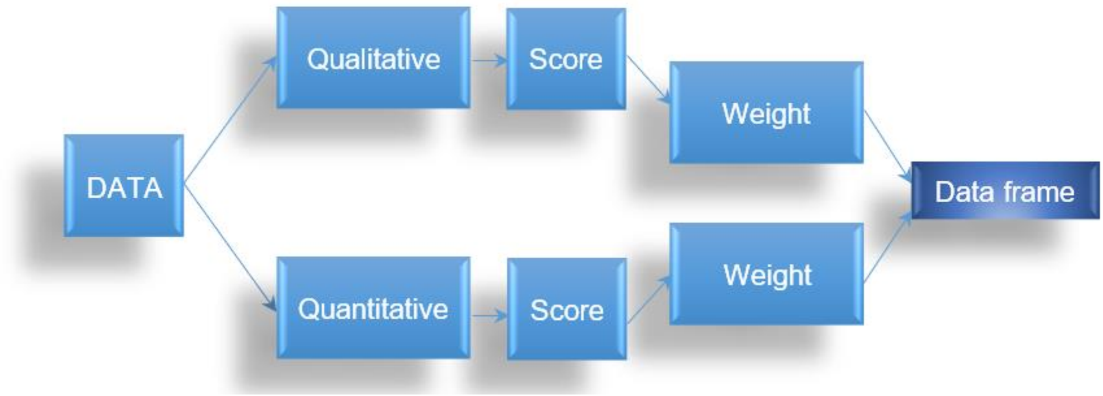


Figure 4.1 Data synthesis process

4.5 Merging the interview data with the FDD data

The thematic areas shown in Table 4.5 were derived from data in a Request for Quotation (RFQ) document. The source of the RFQ data was the University of John Moore Liverpool (UJML) and was based on the Request for Quote (FRQ) document provided by the CIO of Information Services as part of an exploratory study of the European Landscape conducted in 2017. RFQs were used to choose the best service provider as per the detailed specifications and in some cases are better than FDD.

Table 4.5 Question codes and themes from interviews

Question	Thematic area	Code
1. If you were given the task of designing/selecting the architecture for the system/s that will support online learning at your institution what steps would you take?	Technical requirements	TR
2. There is the common perception that Open -Source costs less than proprietary, do you agree with this?	Maintenance and support	MS
2.1 If yes, have you seen any evidence to support this?	Maintenance and support	MS
2.2.1 What evidence can you provide?	Maintenance and support	MS
2.2 If no, are you aware of any evidence to support your answer?	Maintenance and support	MS
2.2.1 What evidence can you offer?	Maintenance and support	MS
2.2.2 If unsure, elaborate.	Maintenance and support	MS
3. What (TEL) system/s do you use at your institution?	Integration and interoperability	II
4. Do you have a technology infrastructure plan?	Technology planning	TIP
4.1 If yes, how do eLearning systems get evaluated and at what frequency?	Technology planning	TP
4.2 If no (you don't have a 'technology infrastructure plan but have another IT type plan), at what frequency are the eLearning systems evaluated?	Technology planning	TP
4.2.1 If not, is this a potential problem for future proofing, planning and strategizing?	Technology planning	TP
4.3 If yes to previous question, how and why? Are there any contingencies in place?	Technology planning	TP
5. Have you heard of a Service Oriented Architecture (SOA):	Technology planning	TP
5.1 In relation to eLearning systems?	Technology planning	
5.2 In any context?	Technology planning	
5.3 If it was shown that this SOA could be an improvement of the current architectural model, would you be interested in learning more about it?	Technology planning	TP
6. Migration from one system to another might be a risky and potentially catastrophic operation, and a deterrent to changing periodically, even if present systems have significant shortcomings.	Integration & interoperability	
6.1 What are your feelings about the previous statement, and do you think that these misgivings are shared by your peers?	Integration & interoperability	I&I
6.2 If you had a tool that could make this process easier, would you be more likely to consider changing systems?	Integration & interoperability	I&I
6.2.1 Do you know of any such tool?	Integration & interoperability	
6.2.2 Please indicate the tools here.	Integration & interoperability	
6.2.3 What would be the most significant factors that should be provided by the aforementioned 'tool'?	Integration & interoperability	I&I

Question	Thematic area	Code
7. Can you give me more information about the costs of your current system including staffing, infrastructure and support (if not part of your regular staffing)?	Full life-cycle costing	FLCC
8.1 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Ease of use by faculty & students.]	Human Computer Interaction	HCI
8.2 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Functionality & available tools.]	Pedagogical functionality	PF
8.3 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Transition, ease & cost of migration.]	Integration & interoperability	I&I
8.4 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Integration with other enterprise-wide tools.]	Integration & interoperability	I&I
8.5 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Extendibility - to the university systems]	Integration & interoperability	I&I
8.6 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Cost.]	Full life-cycle costing	FLCC
9. Student centredness is being increasingly fore fronted, and a criticism of LMSs is that they emphasize the 'management' of learning instead of putting the learners in control of their learning. SOAs makes student-centredness easier as, 'topic maps' allow learners to navigate relevant content based on their individual context. (This is one example). What do you feel about this statement?	Integration & interoperability	I&I
10. Do you have any questions you would like to ask?		
11. Please feel free to contribute any other guidance, advice and comments that you think will aid this research initiative.	Not applicable	N/A
Note: The shaded rows are not rateable.		

Table 4.6 Question choice and purpose

Question	Rationale / purpose
1. If you were given the task of designing/selecting the architecture for the system/s that will support online learning at your institution what steps would you take?	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
2. There is the common perception that open-source costs less than proprietary, do you agree with this?	To ascertain if there are any preconceptions about costs of TEL systems.
2.1 If yes, have you seen any evidence to support this?	To check if this is a justified response.
2.2.1 What evidence can you provide?	To check if this is a justified response.

Question	Rationale / purpose
2.2 If no, are you aware of any evidence to support your answer?	To check if this is a justified response.
2.2.1 What evidence can you offer?	To check if this is a justified response.
2.2.2 If unsure, elaborate.	To check if this is a justified response.
3. What (TEL) system/s do you use at your institution?	Get a list of systems being used, to be used in the forecasting model.
4. Do you have a technology infrastructure plan?	To assess preparedness for technology change.
4.1 If yes, how do eLearning systems get evaluated and at what frequency?	To assess preparedness for technology change.
4.2 If no (you don't have a 'technology infrastructure plan but have another IT type plan), at what frequency are the eLearning systems evaluated?	To assess preparedness for technology change.
4.2.1 If not, is this a potential problem for future proofing, planning and strategizing?	To assess preparedness for technology change.
4.3 If yes to previous question, how and why? Are there any contingencies in place.	To assess preparedness for technology change.
5. Have you heard of a Service Oriented Architecture (SOA):	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
5.1 In relation to eLearning systems?	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
5.2 In any context?	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
5.3 If it was shown that this SOA could be an improvement of the current architectural model, would you be interested in learning more about it?	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
6. Migration from one system to another might be a risky and potentially catastrophic operation, and a deterrent to changing periodically, even if present systems have significant shortcomings.	To assess preparedness for technology change.
6.1 What are your feelings about the previous statement, and do you think that these misgivings are shared by your peers?	To assess preparedness for technology change.
6.2 If you had a tool that could make this process easier, would you be more likely to consider changing systems?	To assess preparedness for technology change.
6.2.1 Do you know of any such tool?	To assess preparedness for technology change.
6.2.2 Please indicate the tools here.	To assess preparedness for technology change.
6.2.3 What would be the most significant factors that should be provided by the aforementioned 'tool'?	To ascertain if there are any preconceptions, commonalities about choosing TEL architecture.
7. Can you give me more information about the costs of your current system including staffing, infrastructure and support (if not part of your regular staffing)?	To determine prioritization for this aspect.

Question	Rationale / purpose
8.1 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Ease of use by faculty & students.]	To determine prioritization for this aspect.
8.2 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Functionality & available tools.]	To determine prioritization for this aspect.
8.3 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Transition, ease & cost of migration.]	To determine prioritization for this aspect.
8.4 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Integration with other enterprise-wide tools.]	To determine prioritization for this aspect.
8.5 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Extendibility - to the university systems]	To determine prioritization for this aspect.
8.6 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Cost.]	To determine prioritization for this aspect.
9. Student centredness is being increasingly fore fronted, and a criticism of LMSs is that they emphasize the 'management' of learning instead of putting the learners in control of their learning. SOAs makes student-centredness easier as, 'topic maps' allow learners to navigate relevant content based on their individual context. (This is one example). What do you feel about this statement?	To determine prioritization for this aspect.
10. Do you have any questions you would like to ask?	
11. Please feel free to contribute any other guidance, advice and comments that you think will aid this research initiative.	
Note: The shaded rows are not ranked, however the responses are discussed in Chapter 6.	

Table 4.7 Interview question codes with weights

Question	Code	Weight
1. If you were given the task of designing/selecting the architecture for the system/s that will support online learning at your institution what steps would you take?	TR	0.1
2. There is the common perception that open-source costs less than proprietary, do you agree with this?	MS	0.1
2.1 If yes, have you seen any evidence to support this?	MS	0.1
2.2.1 What evidence can you provide?	MS	
2.2 If no, are you aware of any evidence to support your answer?		
2.2.1 What evidence can you offer?		
2.2.2 If unsure, elaborate.		
3. What (TEL) system/s do you use at your institution?	I&I	0.1
4. Do you have a technology infrastructure plan?	MS	0.1
4.1 If yes, how do eLearning systems get evaluated and at what frequency?	TP	1.15
4.2 If no (you don't have a 'technology infrastructure plan but have another IT type plan), at what frequency are the eLearning systems evaluated?	TP	1.15

Question	Code	Weight
4.2.1 If not, is this a potential problem for future proofing, planning and strategizing?	TP	1.15
4.3 If yes to previous question, how and why? Are there any contingencies in place.	TP	1.15
5. Have you heard of a Service Oriented Architecture (SOA):	TP	1.15
5.1 In relation to eLearning systems?	TP	1.15
5.2 In any context?	TP	1.15
5.3 If it was shown that this SOA could be an improvement of the current architectural model, would you be interested in learning more about it?	TP	1.15
6. Migration from one system to another might be a risky and potentially catastrophic operation, and a deterrent to changing periodically, even if present systems have significant shortcomings.	I&I	0.1
6.1 What are your feelings about the previous statement, and do you think that these misgivings are shared by your peers?	I&I	0.1
6.2 If you had a tool that could make this process easier, would you be more likely to consider changing systems?	I&I	0.1
6.2.1 Do you know of any such tool?	I&I	0.1
6.2.2 Please indicate the tools here.	I&1	0.1
6.2.3 What would be the most significant factors that should be provided by the aforementioned 'tool'?	I&I	0.1
7. Can you give me more information about the costs of your current system including staffing, infrastructure and support (if not part of your regular staffing)?	FLCC	0.25
8.1 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Ease of use by faculty & students.]	HCI	0.1
8.2 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Functionality & available tools.]	PF	0.2
8.3 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Transition, ease & cost of migration.]	I&I	0.1
8.4 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Integration with other enterprise-wide tools.]	FLCC	0.25
8.5 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Extendibility - to the university systems]	I&I	0.1
8.6 With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least? [Cost.]	FLCC	0.25
9. Student centredness is being increasingly fore fronted, and a criticism of LMSs is that they emphasize the 'management' of learning instead of putting the learners in control of their learning. SOAs makes student-centredness easier as, 'topic maps' allow learners to navigate relevant content based on their individual context. (This is one example). What do you feel about this statement?	I&I	0.1
10. Do you have any questions you would like to ask?		
11. Please feel free to contribute any other guidance, advice and comments that you think will aid this research initiative.		
Note: The shaded rows are not ranked, however the responses are discussed in Chapter 6.		

Table 4.8, Question codes and themes from FDD, is the second part of the mixed-method data collection as indicated in Table 3.1 Research design in Chapter 3, and is part of the quantitative methodology involving the functional decomposition design (FDD) process.

Table 4.8 Key to themes and weighting from interviews

Thematic area	Code	Weighting	Percentage	
Technical requirements	TR	0.1	10%	
Integration & interoperability	I&I	0.1	10%	
Human Computer Interaction	HCI	0.1	10%	
Maintenance & Support	MS	0.1	10%	
Technology Planning	TP	0.15	15%	
Pedagogical functionality	PF	0.2	20%	
Full life-cycle costing	FLCC	0.25	25%	
Total		**1**	**100%**	

Table 4.9 provides the key to the Request for quotation priorities and the weighting that was assigned to these. The priorities are typically found in bid specification processes and perform a useful role in whittling out providers that do not meet the criteria. This helped to assist participants to avoid the selection of unsuitable providers for the next, phase which is more comprehensive.

Table 4.9 Key to RFQ priorities and weighting

Priority	Rating	Weighting	Percentage
Mandatory (M)	4	1	100%
Highly Desirable (HD)	3	0.66	0.66%
Desirable (D)	2	0.33	0.33%
Pass	1	1	100%
Fail	0	0	0.00%

In Table 4.10 the rest of the RFQ themes are assigned weights using percentage values in preparation for use in the data synthesis process.

Table 4.10 RFQ themes and weighting

Category	Feature	Code	Weighting
Technical requirements	System administration [SA]	SATR	20%
Integration and interoperability	System administration [SA]	SAII	20%
Maintenance and support	System administration [SA]	SAMS	20%
Administrator requirements	System administration [SA]	SAAR	20%
Course content	Pedagogical Functionality [PF]	PFCC	60%
Assessment	Pedagogical Functionality [PF]	PFA	60%
Collaboration & communication	Pedagogical Functionality [PF]	PFCC	60%
Course management	Pedagogical Functionality [PF]	PFCM	60%
Personalisation	System administration [SA]	SAP	20%
Mobile requirements	System administration [SA]	SAMR	20%

Obtaining the above specifications made it possible to create the detailed decision path described in the next section.

4.5.1 Decision pathway: Blackboard > LMS X

The SilverDecisions program was used to create a detailed decision path (see Kamiński, Jakubczyk and Szufel 2022: 61-62), starting from the Blackboard LMS, which was used for illustrative purposes, through the nodes licensing > operating system > hosting > and finally the terminal node (see Figure 4.2). The decision path in Figure 4.2 starts with two possible branches (Proprietary or Open Source), which lead to four chance nodes (Proprietary – Windows[1] or Linux [2], Open Source – Windows [3] or Linux [4]). The chance nodes leading from these are either Windows hosting or Linux hosting, and finally terminate with either self-hosted or managed hosting.

In Figure 4.2, from the first branch of the decision tree, there are two possibilities in terms of licencing, which are proprietary and open source. For each of these possible licence types, there are two possible operating systems, namely, Windows and Linux. It must be noted that some Linux distributions are supported commercially, namely, by Red Hat, OpenSuse and Canonical. From these operating systems there are two possible hosting options, namely, self-hosted and managed.

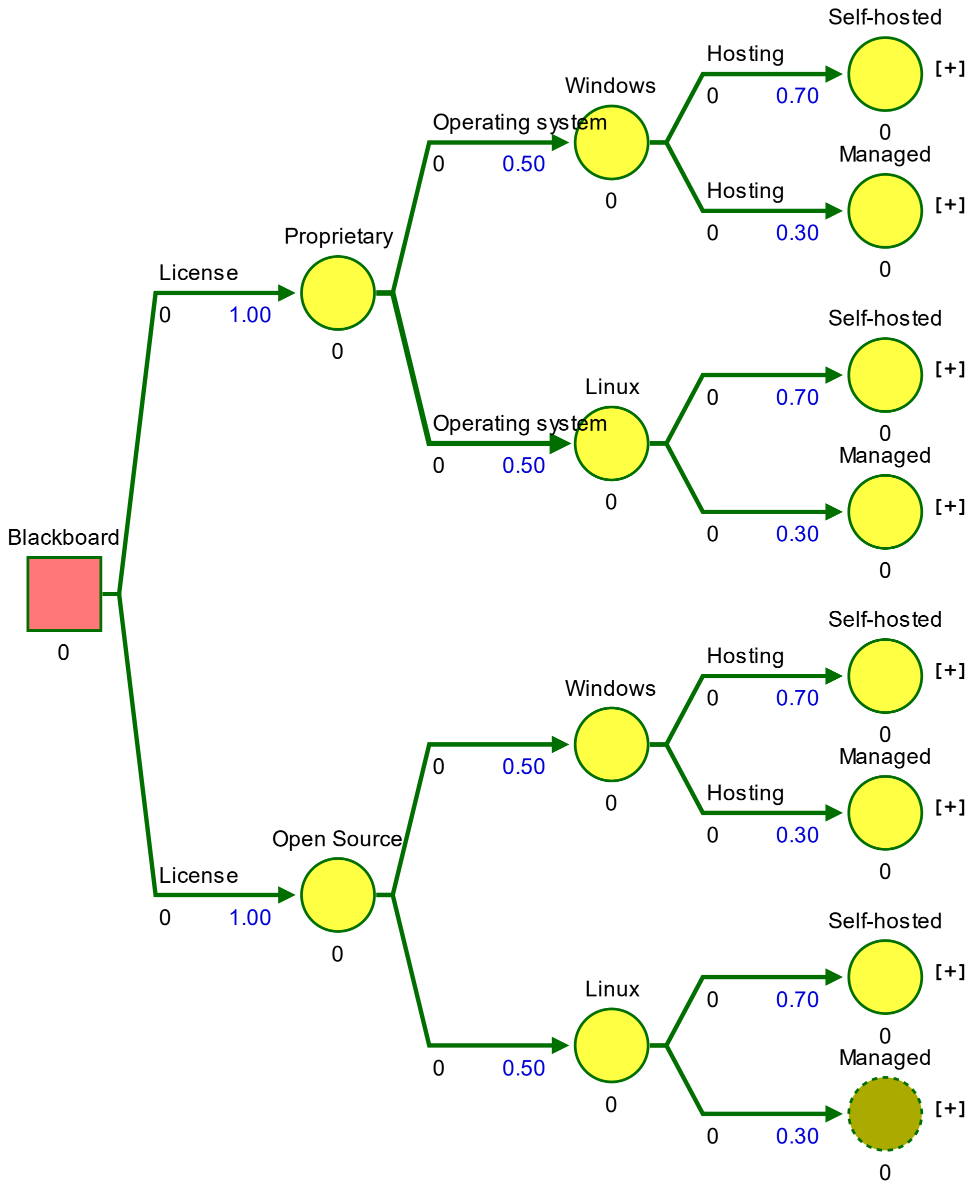


Figure 4.2 High-level decision path from Blackboard to candidate LMS

In Figure 4.3, two chance nodes are expanded, namely Proprietary | Windows | Self-hosted and Open Source | Linux | Self-hosted for illustration. The final LMSs are shown at the terminal node, this may be the same for both the proprietary and open-source paths, if these are available in both licensing types (it is possible that a specific LMS may not be supported in both licencing types).

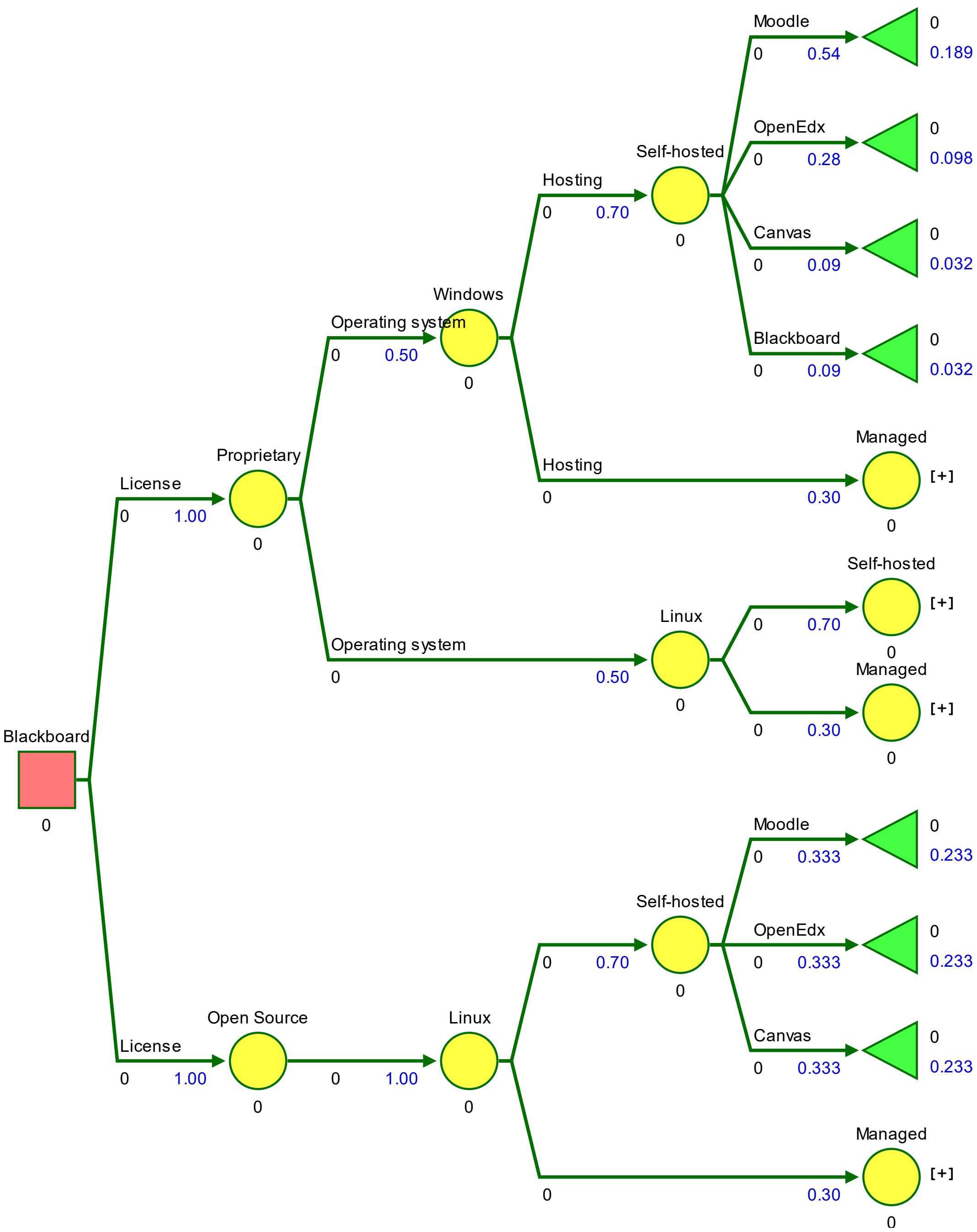


Figure 4.3 Detailed decision path from Blackboard to candidate LMS

4.5.2 Probabilities

So far it was not necessary to assign weights (probability values) to any of the chance nodes, as they all had an equal chance of being selected. This can be seen in Figure 4.4, where the total number of all the probabilities is equal to one. In Figure 4.4, moving from the case of the LMS being self-hosted, there are four options, namely, Moodle (0.25), OpenEdx (0.25), Canvas (0.25) and Blackboard (0.25) and these are therefore divided equally.

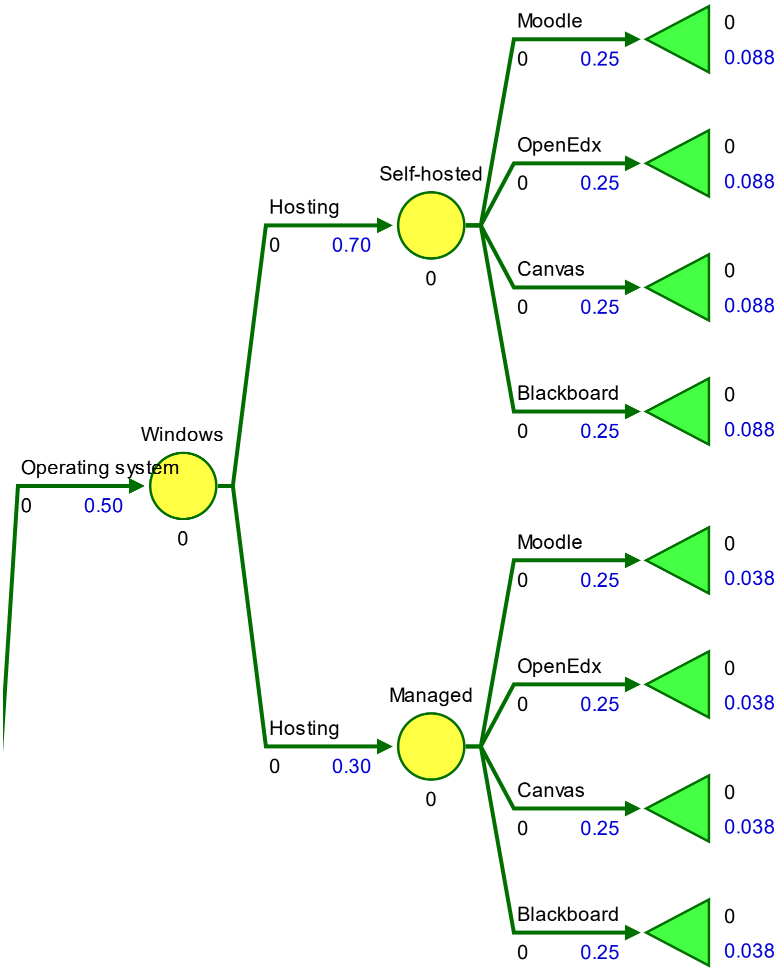


Figure 4.4 Chance node probability value

The hosting options were assigned probabilities, Self-hosted (0.70) and Managed (0.30), which were based on the results of the RFQ process. This meant that hosting could already be narrowed down to self-hosted. However, the LMS had not yet been assessed, and how this was done is shown in Chapter 5.

4.6 Conclusion

The prototype (SilverDecisions decision trees) developed was focused on achieving research objectives 1 and 2, namely:

1. Formulating a system dynamic model.
2. Constructing a computerised simulation.

The first objective aligns with both the prototype design and the simulation design, as the simulation design relied on the prototyping to be completed. The second objective is also in alignment with both the prototype design and the simulation design. The research approach used to develop the inputs for the artefacts (SilverDecisions decision trees and InsightMaker) was a combination of data from interviews and FDD, the resulting data being used as the basis for the parameters used by these artefacts. In Chapter 5, it is shown how the prototype is used as the basis to construct the InsightMaker simulation.

Chapter 5: Configuring the simulation online

5.1 Introduction

This chapter focuses on the transformation of the SilverDecisions decision tree that was presented and discussed in Chapter 4 into a dynamic and interactive InsightMaker simulation. It must be noted that the two processes are sequential, and are therefore co-dependant. In this case, the InsightMaker simulation was derived from the decision tree constructed with SilverDecisions.

5.2 What InsightMaker is and why it was chosen

The InsightMaker tool was chosen to help make decision making both transparent and interactive, and it is also accessible to anyone who has access to a web browser. In short, the two key specifications of the InsightMaker web simulation tool is that it is freely available (there is no cost for using it) and that it is powerful enough to develop sophisticated forecasts while having a relatively short learning curve to start using as a developer. There are other simulation software products such as VenSim, and Dynamo, but these are systems that are desktop-based and require a licence. In addition, there is a steeper learning curve to master these tools in comparison to InsightMaker.

5.3 Deciding what to simulate

Deciding what to simulate and why was the first step, as it might not have been worthwhile to focus on projecting the weighted scores for each category over time. Instead, the scores that were given could be compared using a line graph as shown in Figure 5.1. This depiction is useful in gauging the comparative scores given to each LMS by category. It cannot determine which LMS is a better choice but this can - and should - be evaluated by designers using their own judgement. This judgment would be based on the earlier processes (RFQ) where the needs of one's own organisation would establish specifications and the weightings applied to these categories. These now appear in Figure 5.1: Weighted Scoring of LMSs, and, although the categories together form the basis for comparisons, these cannot be aggregated as they are aspects which are distinct from each other.

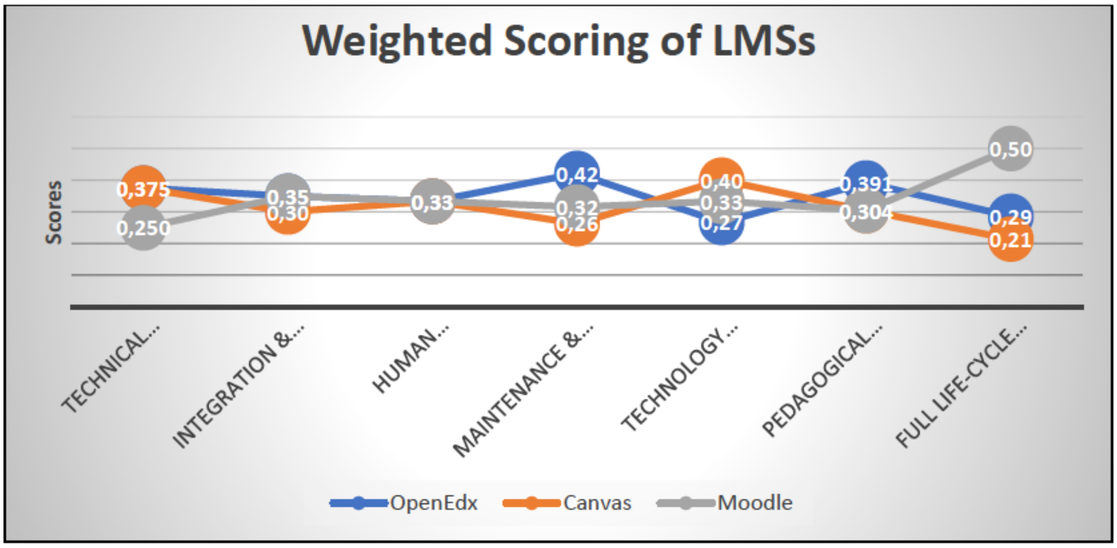


Figure 5.1 Weighted scoring of LMSs

5.4 Adjusting scoring on the fly

The weighted scores entered are not fixed, and with use of the variable slider these can be adjusted with the changes being visible in real time. This would be useful if there had been a material change now evident to one of the categories.

An example of this is shown in Figure 5.2, Full-life cycle costing for LMS choice line graph, where the scores had to be adjusted as required due to changes in budget allocations. In Figure 5.2, scores for each of the candidate LMSs under consideration were assigned as shown in Table 5.1, Full-life cycle for LMS choice scores. The higher the score the greater the preference for that choice. In this case OpenEdx has been assigned the score of 41. OpenEdx is therefore preferred over the other two systems, namely Moodle (31) and Canvas (28).

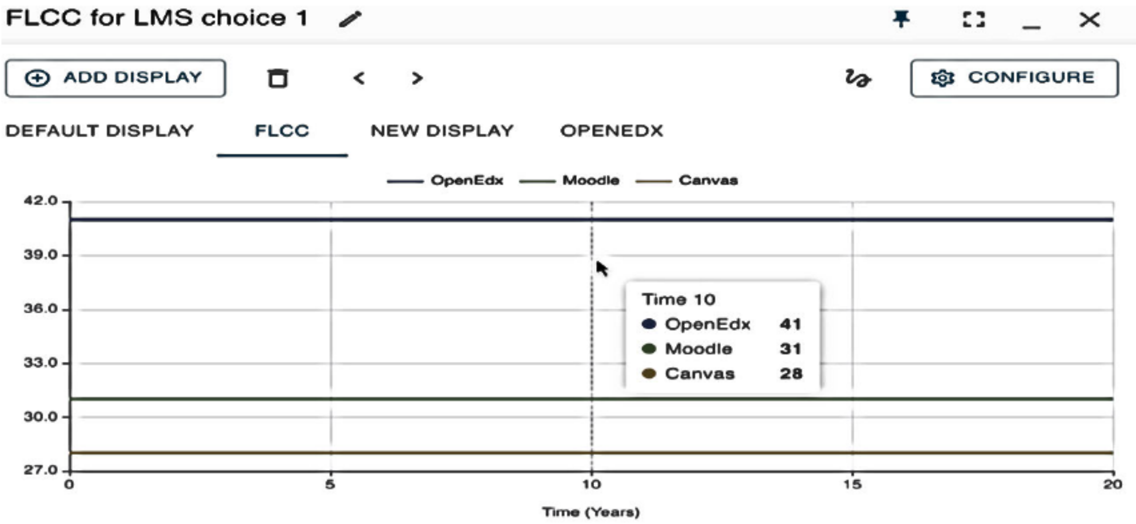


Figure 5.2 Full-life cycle costing for LMS choice line graph

Table 5.1 Full-life cycle for LMS choice scores

LMS	Score
OpenEdx	41
Moodle	31
Canvas	28

As shown above in Figure 5.2, Full-life cycle costing for LMS choice line graph, the scores are shown for eight years, but these are all the same, and that is of limited use. The value of populating with real values would be realized in the future when priorities might have changed. Service providers generally provide the option of fixing costs if the contractual term is for more than one year (three-year fixed cost contracts are common).

In the same example of Full life cycle costing for LMS choice for years 0-2 (Table 5.2), in year zero in the column "Time", we note the results of the evaluation done for the current year, which is the first year. In year "3" the result (of the evaluation) will be recorded and will indicate the choice for the next three years, namely, year four, five and six as shown in Table 5.3, Full-life cycle costing for LMS choice table for years 3-5.

Table 5.2 Full-life cycle costing for LMS choice for years 0-2

DEFAULT DISPLAY FLCC **NEW DISPLAY** OPENEDX

Time	OpenEdx	Moodle	Canvas
0	41	31	28
1	41	31	28
2	41	31	28
3	41	31	28
4	41	31	28
5	41	31	28

Table 5.3 Full-life cycle costing for LMS choice table for years 3-5

Three year [3-5]

ADD DISPLAY

FLCC DEFAULT DISPLAY THREE YEAR [0-2] **THREE YEAR [3-5]**

Time	OpenEdx	Moodle	Canvas
3	26	37	27
4	26	37	27
5	26	37	27

We can now see that the LMS scoring the highest is Moodle, which has changed from the first simulation, and this is a result of changes in costing which is typical in real life scenarios (see Figure 5.3).

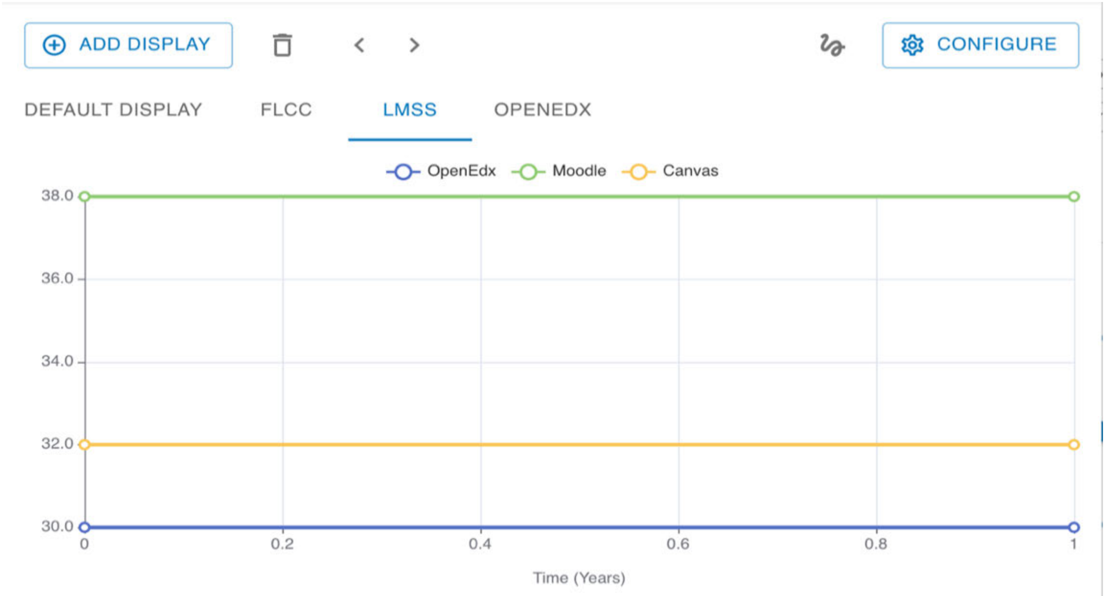


Figure 5.3 Full-life cycle costing for LMS choice table

In Figure 5.4, Conceptual simulation of FLCC scoring, this category is shown to demonstrate simulating how three candidate LMSs are compared in real time, with the option to adjust any of the scores.

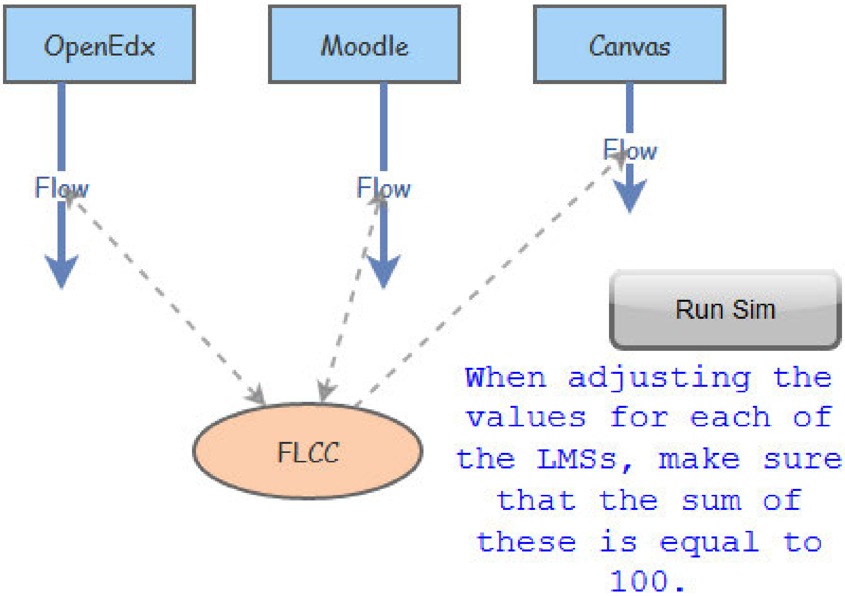


Figure 5.4 Conceptual simulation of FLCC scoring

Each of the LMSs has been given scores which are linked to the stock (FLCC) that has 100 assigned. The sum of scores for the three LMSs cannot be more than what is assigned to FLCC (i.e., 100).

5.5 Weighted scores for all categories

Simulations for the seven categories namely, Pedagogical functionality, Technology planning, Maintenance and support, Human computer interaction, Integration and Technical requirements are shown in this section. The simulations are not available publicly as they are proof of concept that may be revised in future iterations that are not going to be included in this research study. They may, however, be reported on in subsequent research publications.

5.5.1 Technical requirements

In Table 5.4, Technical requirements for LMS choice scores, scores for each of the candidate LMSs under consideration have been assigned.

Table 5.4 Technical requirements for LMS choice scores

LMS	Score
OpenEdx	37.5
Canvas	37.5
Moodle	25.0

The higher the score, the greater the preference for that choice. In this case both OpenEdx and Canvas have been assigned the same score of 37.5. This means that both LMSs have an equal chance of being selected and Moodle (25) has been rated the lowest of the three systems.

5.5.2 Integration and interoperability

In Table 5.5, Integration and interoperability for LMS choice scores, scores for each of the candidate LMSs under consideration have been assigned:

Table 5.5 Integration and interoperability for LMS choice scores

LMS	Score
OpenEdx	35
Canvas	30
Moodle	35

The higher the score the greater the preference for that choice. In this case, both OpenEdx and Moodle have been assigned the same score of 35. This means that both LMSs have an equal chance of being selected and Canvas (30) has been rated the lowest of the three systems.

5.5.3 Human computer interaction

In Table 5.6, Human computer interaction for LMS choice scores, scores for each of the candidate LMSs under consideration have been assigned:

Table 5.6 Human computer interaction for LMS choice scores

LMS	Score
OpenEdx	35
Canvas	30
Moodle	35

The higher the score, the greater the preference for that choice. In this case, both OpenEdx and Moodle have been assigned the same score of 35. This means that both LMSs have an equal chance of being selected, while Canvas (30) has been rated the lowest of the three systems.

5.5.4 Maintenance and support

In Table 5.7, Maintenance and support for LMS choice scores, scores for each of the candidate LMSs under consideration have been assigned:

Table 5.7 Maintenance and Support for LMS choice scores

LMS	Score
OpenEdx	42
Canvas	26
Moodle	32

The higher the score the greater the preference for that choice. In this case, OpenEdx has been assigned the score of 42. OpenEdx is therefore preferred over the other two systems, namely Canvas (26) and Moodle (32).

5.5.5 Technology planning

In Table 5.8, Technology planning for LMS choice scores, scores for each of the candidate LMSs under consideration have been assigned.

Table 5.8 Technology Planning for LMS choice scores

LMS	Score
OpenEdx	27
Canvas	40
Moodle	33

The higher the score, the greater the preference for that choice. In this case, Canvas has been assigned the score of 40. Canvas is therefore preferred over the other two systems, namely OpenEdx (27) and Moodle (33).

5.5.6 Pedagogical functionality

In Table 5.9, Pedagogical functionality for LMS choice, scores for each of the candidate LMSs under consideration have been assigned.

Table 5.9 Pedagogical functionality for LMS choice scores

LMS	Score
OpenEdx	29
Canvas	21
Moodle	50

The higher the score the greater the preference for that choice. In this case Moodle has been assigned the score of 50. Moodle is therefore preferred over the other two systems, namely, OpenEdx (29) and Canvas (21).

5.6 Conclusion

This chapter used some of the specifications used in Chapter 4 with the SilverDecisions decision tree application, to develop the InsightMaker simulation. It then went on to describe the scoring of all the other specifications, and then used the example of Figure 5.4, Conceptual simulation of FLCC scoring, to look at it in more detail. It can be seen from this chapter that specifications of the artefact being developed depended not only on the choices of key role players but also on factors in real life scenarios which are subject to change, such as cost and maintenance and support, and not just the anticipated advantages of technological innovation per se. Previous choices by key players may also impact in terms of continuity. The computerised simulation must then be programmed to take into consideration critical real-life factors which will impact on provision of TEL infrastructure. The next chapter tests out to what extent the computerised forecasting simulation is usable and useful for the selected key players.

Chapter 6: Testing the forecasting simulation

6.1 Introduction

This chapter fulfils objective 3. by testing out the computerized forecasting simulation with participants in terms of: (a) usability, and (b) usefulness. This section evaluates the artefacts in terms of its usability by analysing qualitative data obtained from expert users in both the higher education and business sectors. The testing was conducted with Microsoft Forms, a web-based survey tool which provides an unmoderated remote testing approach. The primary purpose of the usability testing was to identify further key issues that the developer may not have included, to confirm or refute the hypothesis that the artefacts works as intended, and to evaluate the usefulness of these two artefacts. This purpose thus differs in scope from that of development for a client in a business scenario, where the aim is to perfect the interface iteratively, and in that case multiple tests might be needed.

6.2 Unmoderated remote usability testing

The choice of mode to conduct the usability testing was unmoderated remote testing for the following reasons; firstly, the participants are known, and the simulation is web-based, with the only requirement being the ubiquitous web-browser that is easily available to all, and secondly, the absence of a controlled test environment is most likely to yield realistic and objective feedback (Bevan 1995).

6.3 Test group for usability and usefulness evaluation

The user group as shown in Figure 6.1 comprised six expert persons, one (JC) who participated in the case study interviews and five from different organisations, including three from industry, one from a higher education college and one from the financial services industry. According to (Nielsen 1992: 376), just five users are sufficient to identify 85% of problems with an interface. The key attribute that most of the participants have that determines their appropriateness for the usability assessment is that they have strategic decision-making roles. Some other attributes include expertise in interface design (an Associate Professor), and a participant in the case study (Project Manager: Technology Enhanced Learning). The user group is therefore ideally suited for this task. Their responses are presented and discussed in the next section.

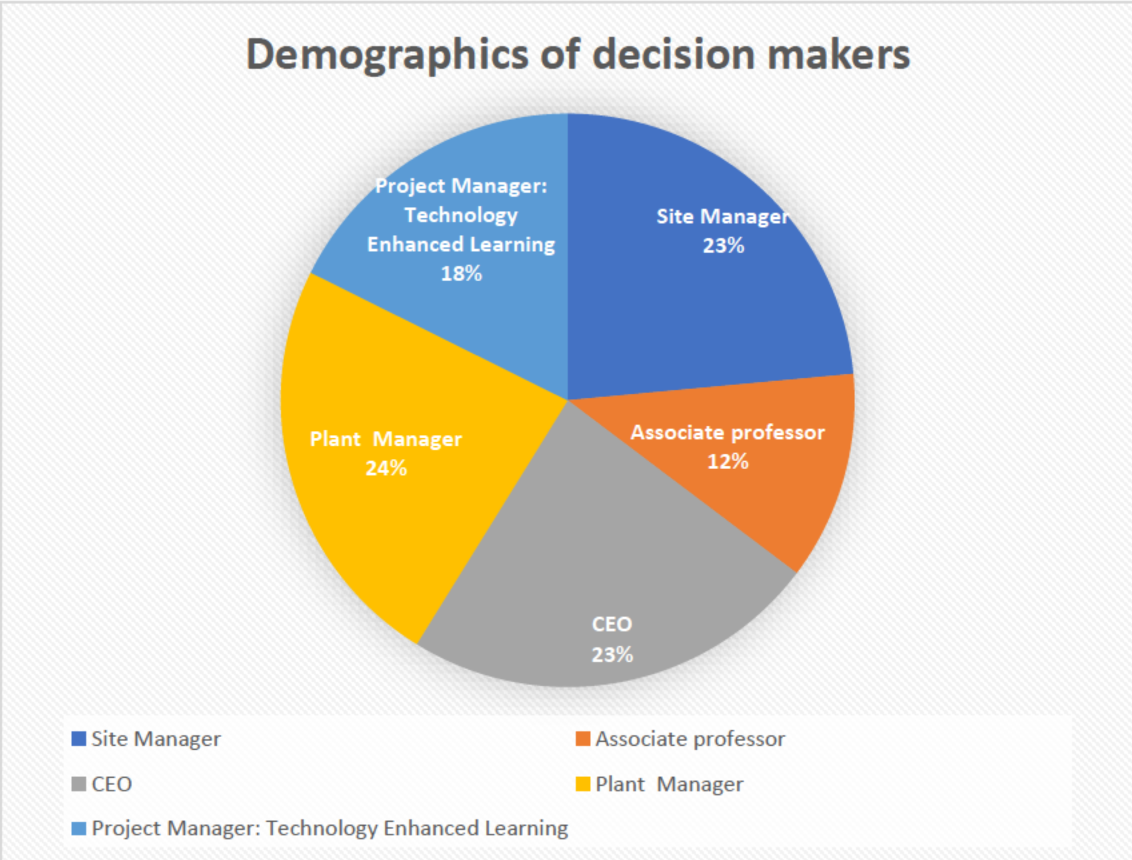
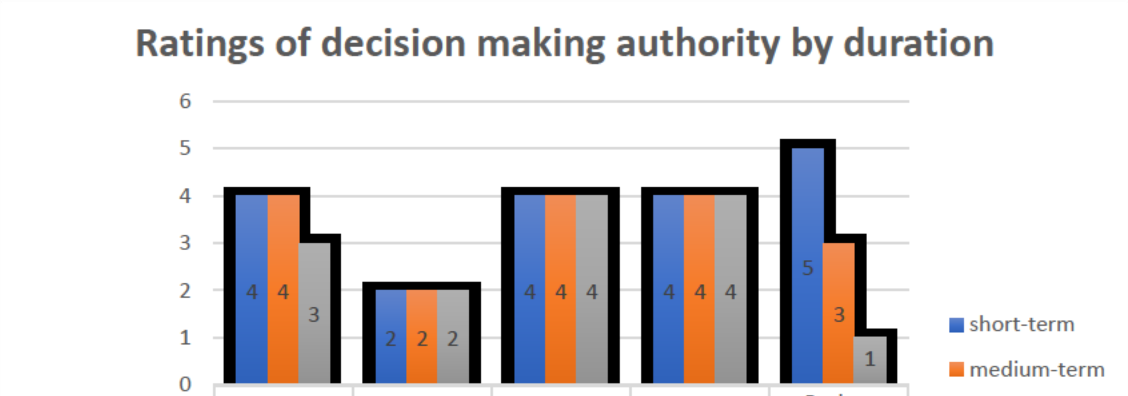


Figure 6.1 Demographics of decision makers

6.4 Ratings of decision making by duration

In Figure 6.2 the participants rated their decision-making authority for three categories, namely, short-term (less than two years), medium-term (two to five years) and long -term (more than five years). The rating scale used was five points with one being least and five being most. The Site Manager rated short-term and medium-term as four and long-term as three, which is consistent with the level afforded that designation in the organisation. The Associate Professor rated all the durations with two, which is consistent with that role in the organisation. The CEO rated all categories as four, which is typical of that role. The Plant Manager also rated all categories as four, which is similar to the Site Manager's ratings. The Project Manager: Technology Enhanced Learning rated short-term as five, medium-term as three and long-term as one, which is indicative of the more complex hierarchy of the higher education institution.



	Site Manager	Associate professor	CEO	Plant Manager	Project Manager: Technology Enhanced Learning
short-term	4	2	4	4	5
medium-term	4	2	4	4	3
long-term	3	2	4	4	1

Figure 6.2 Ratings of decision-making authority by duration

6.5 Correlations between medium and short-term decision making

In Figure 6.3 a strong correlation has been found between the ratings of medium and long-term decision-making authority, which tells us that these duration decision-making periods have more in common with each other than with short-term duration.

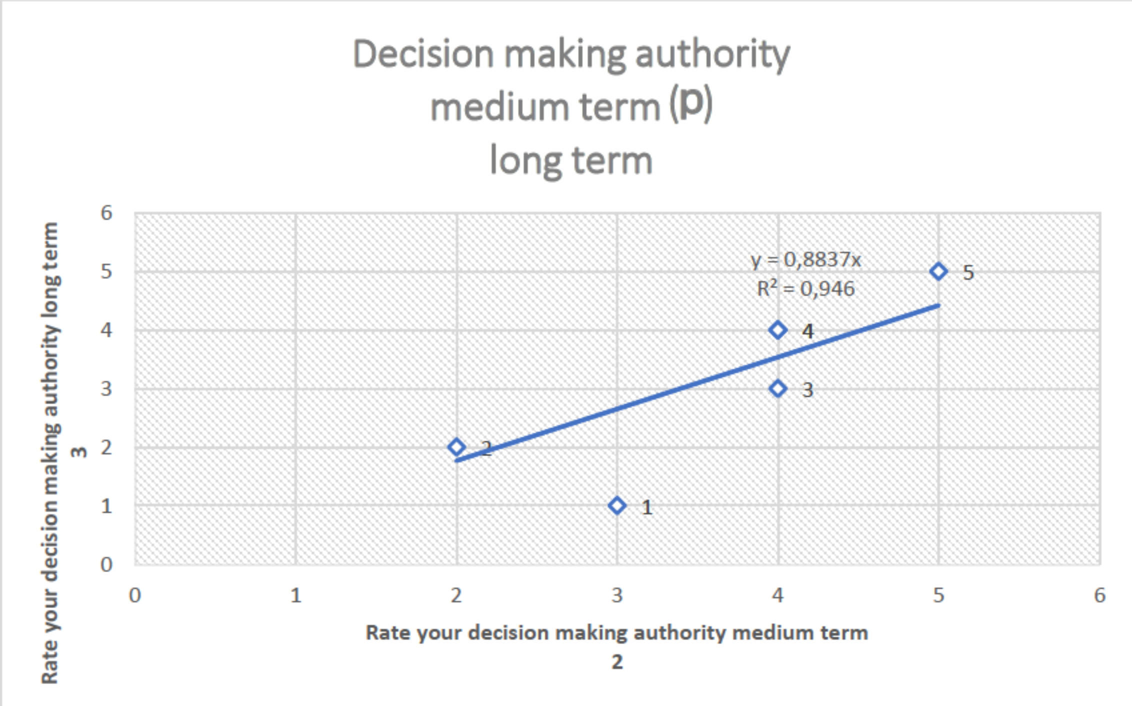


Figure 6.3 Decision making authority medium (p) long-term

6.6 Usability and usefulness of the simulation

The usability and usefulness of the simulation was evaluated by the user group described in section 6.3, and the results of this are discussed for both the SilverDecisions decision tree and InsightMaker. The user group was asked to rate usability by choosing a rating starting from one star being the minimum, to five stars being the maximum.

The questions that evaluated usability were as follows:

- Overall look and feel (how easy or difficult it was to see what was being presented)
- Ease of use (to change values)
- What would you change to improve the decision tree?
- Interactivity (how easy or hard it was it to interact with)

6.6.1 Overall look and feel correlated with Interactivity

There is a strong correlation between the look and feel (presentation) and the interactivity, as shown in Figure 6.4 Overall look and feel (p) Interactivity. This makes sense, as both these features dovetail into each other.

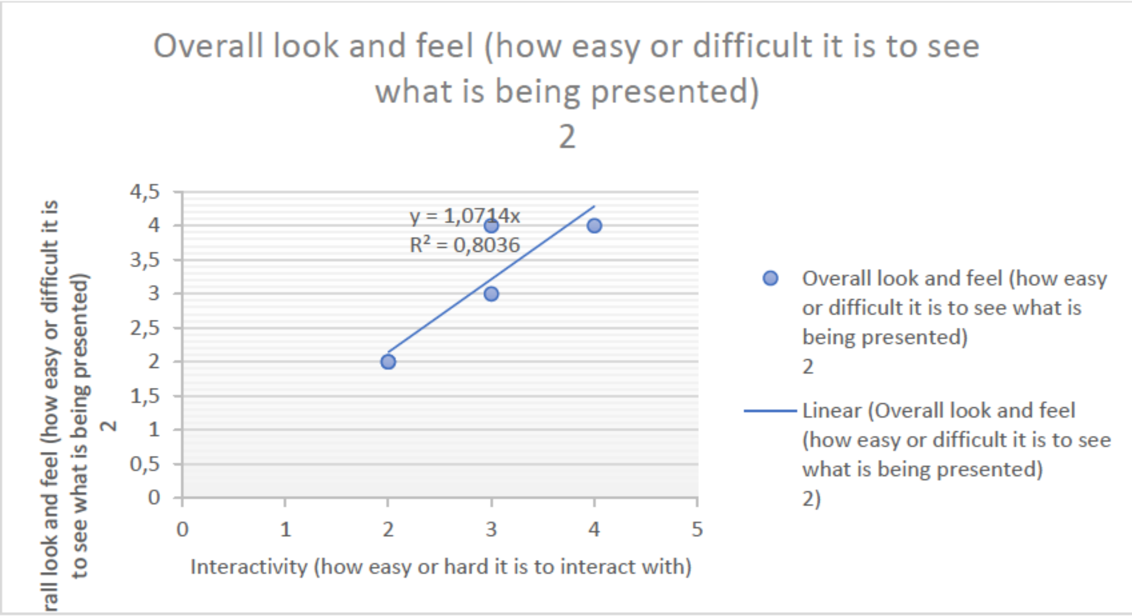


Figure 6.4 Overall look and feel (p) interactivity

6.6.2 Overall look and feel of the decision tree

In Figure 6.5 there were two users who rated the decision tree overall look and feel four, two rated it three and two users rated it two. On average the ratings are three, which indicates that there was neither agreement nor disagreement about the overall look and feel of the SilverDecisions decision tree. This, however, is a positive rating and supports the aim, which was to provide an easy-to-understand decision tree.

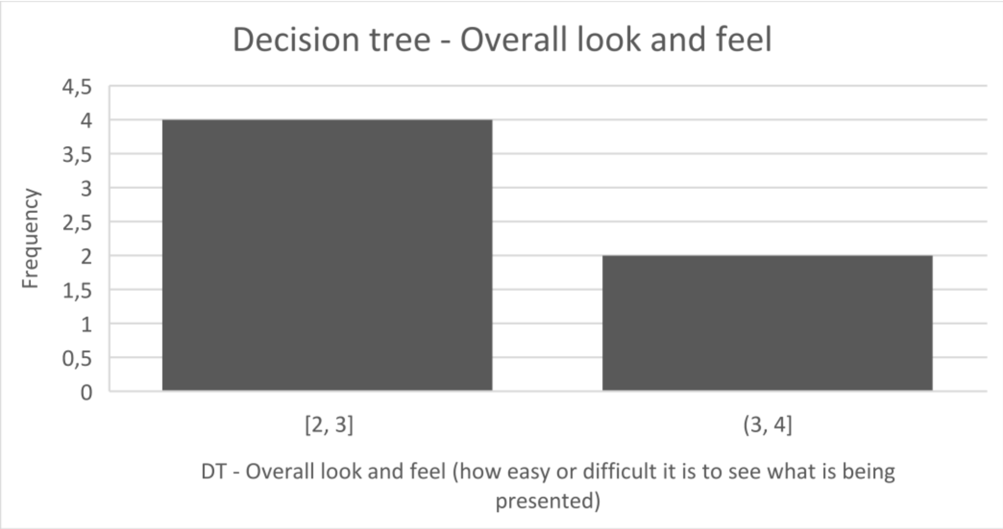


Figure 6.5 Decision tree – overall look and feel

In Figure 6.6 there were four users who rated the decision tree (ease of use to change values) four, and two users rated it two. On average the ratings are 3.3, which indicates that there was agreement that it was easy to change values for the SilverDecisions decision tree. This is also a positive rating, and supports the aim, which was to provide an easy-to-use facility to change values for the decision tree.

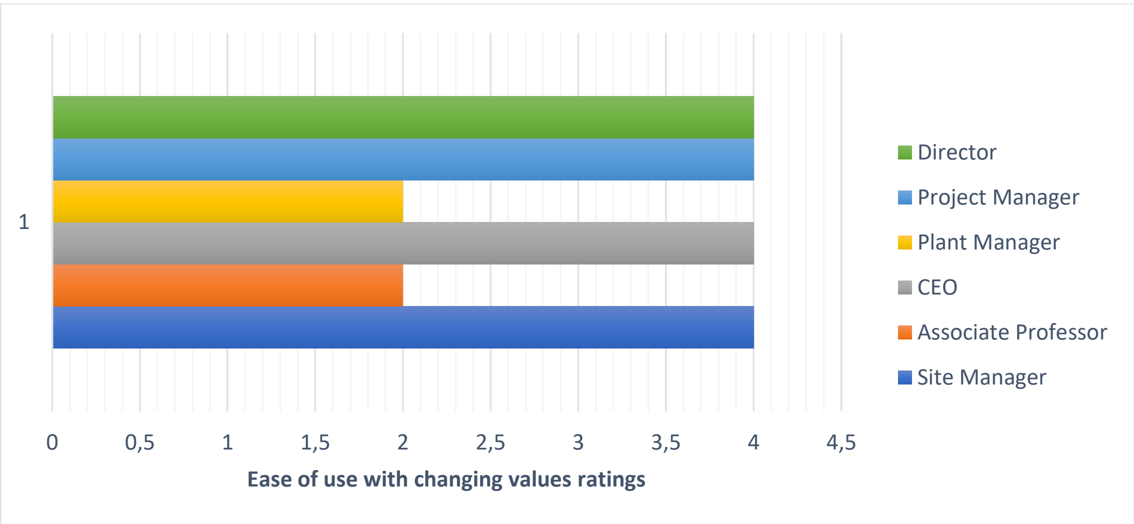


Figure 6.6 Ease of use

In Figure 6.7 there was one participant who rated the interactivity of the decision tree five; another rated it four, two users rated it three and two rated it two. On average the ratings are 3.1 which indicates that there was agreement that the SilverDecisions tree was easy to interact with. This is also a positive rating and supports the aim, which was to provide an easy-to-use decision tree.

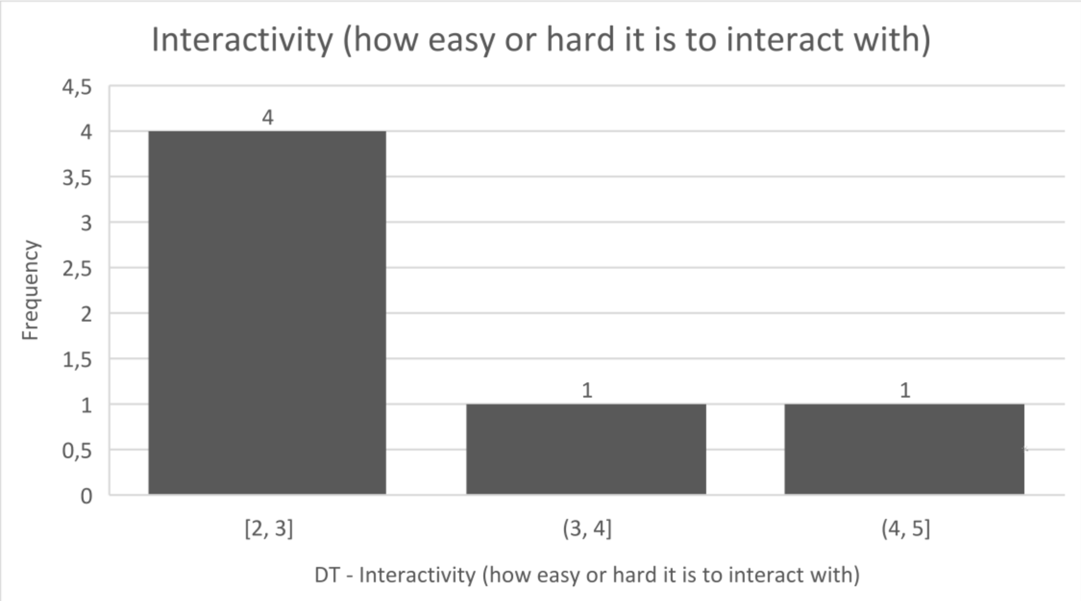


Figure 6.7 Decision Tree – interactivity

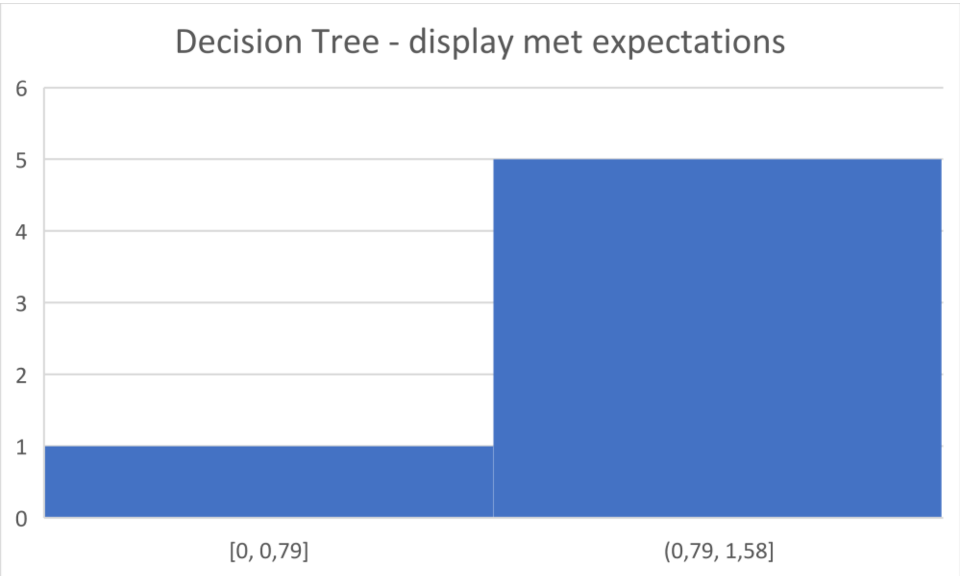


Figure 6.8 Decision Tree – display met expectations

In Figure 6.8 there were five testers agreeing that the display met expectations and one said that it did not. This supports the aim of providing a decision tree that would meet the expectations of the audience.

6.6.3 Interactivity of the InsightMaker simulation

The responses in Figure 6.9, Simulation – interactivity, included two ratings of five, one rating of four, one of three and two rating it with two. Overall, this averages to 3.5 and supports the aim of providing easy interactivity with the InsightMaker simulation.

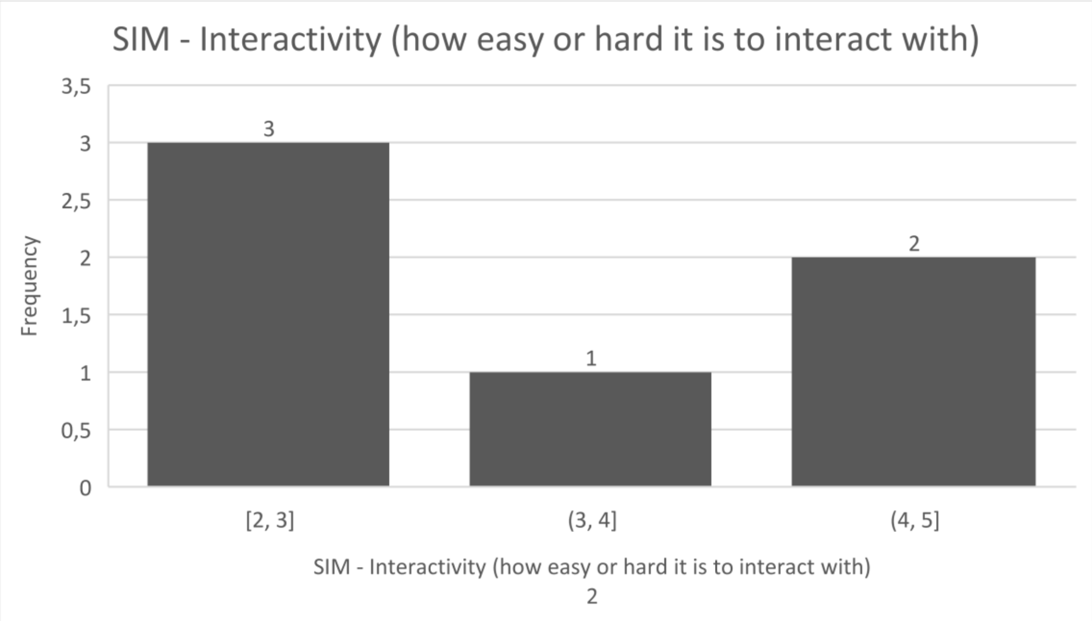


Figure 6.9 Simulation – interactivity

6.6.4 Usefulness of the InsightMaker simulation

As shown In Figure 6.10, the user group was asked to indicate which part of the simulation was most useful and the reason for this. There was one non-response, the others offered the following feedback: Inter-activeness - More accurate simulation, controlling it, values easy to change, being able to do adjustments, interaction, and ease of use.

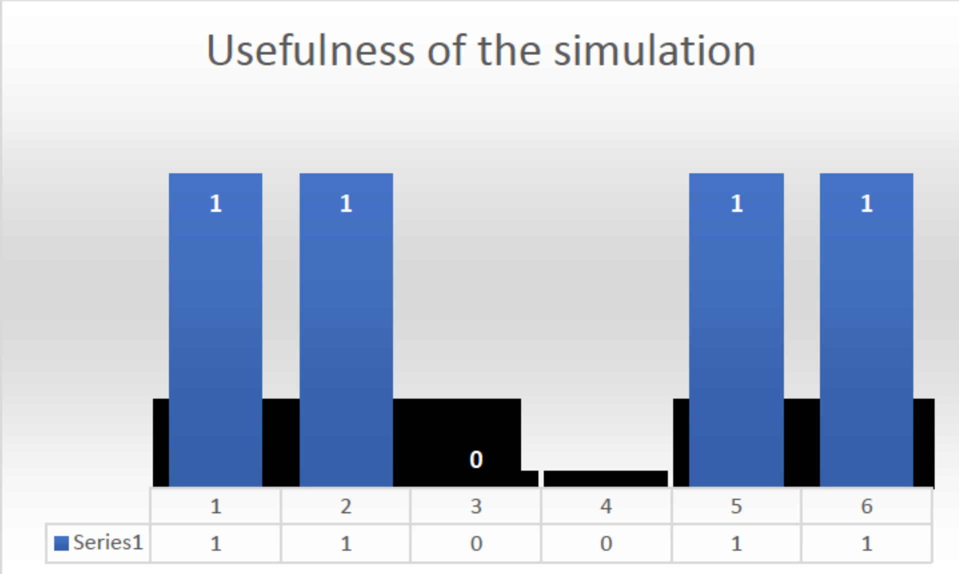


Figure 6.10 Usefulness of the simulation

6.7 Conclusion

The web-based survey conducted in an unmoderated remote mode provided insights into how the simulation artefacts were perceived by the user group. Testing was conducted as planned and aimed to confirm or refute that the components, the SilverDecisions decision tree and InsightMaker simulation, were usable and useful. The survey was mainly quantitative to encourage responses from the user group, although some open-ended questions were also included. In using the unmoderated remote mode of delivery to gather insights from the user group, it was evident that there were some drawbacks to this approach such as the fact that lack of guidance during the exercise could prevent optimal testing of usability. In addition, the user composition was based on generic characteristics underlined by levels of decision-making authority; another ideal characteristic is to be in the specific role of TEL decision maker. Having said that, the overall responses to both usability and usefulness aspects suggest that both the SilverDecisions decision tree and InsightMaker simulation met the brief in terms of overall look and feel, interactivity, ease of use and usefulness. This does not mean that there is no room for improvement, and should there be further development of these artefacts, input from this user group will be used to direct the revision.

Chapter 7: Conclusions and recommendations

7.1 Introduction

As explained at the outset, this study involved developing a computerised simulation model to guide the South African HE sector in short and long-term planning of TEL infrastructure. This chapter will show how fulfilling the specific objectives resulted in addressing issues of technical, systemic and social structure, and will draw conclusions based on the findings in these areas. After reflecting on the research process and its outputs, recommendations will be made as to the further development of the TEL forecasting simulation.

7.2 Artefact design process and result

Artefact design was geared towards achieving objectives 1, 2, and 3, namely:

1. Formulating a system dynamic model.
2. Constructing a computerised simulation.
3. Testing out the simulation

To achieve these objectives, three stages were involved that mirrored the objectives:

Stage 1: Establishing design specifications

Stage 2: Configuring the simulation online

Stage 3: Testing the simulation

The development of working prototypes of the artefacts required the expertise and knowledge of the researcher in the domain of TEL infrastructure and also technical expertise with SilverDecisions decision maker and InsightMaker simulation designer. This meant applying the system dynamics methodology within a critical realist ontology when translating the specifications into the final simulations. The data from the two sources, being the interviews and the RFQ data, were combined, the scores allocated and then weighted, which result was then used to develop and configure the decision tree and the simulation.

7.3 Designing and setting up the decision tree and InsightMaker simulation

The design of the simulation involved arriving at the design specifications, which required translating interview feedback and synthesizing with RFQ requirements. The next phase involved developing a high-level mapping of the decision tree as shown in Figure 4.2 in Chapter 4. Arising from this high-level decision path was the detailed decision path shown in Figure 4.3. The technical aspects of these processes are overt and more comprehensible than the arguably more significant underlying social impetus that they were driven by. The techno-system (Aunger, 2010: 776), when created, would then make manifest, or represent in material form, some of the elements of the social system involved in technology forecasting.

The extent to which the basic specifications of the simulations were carried out in the end-product will be discussed below, based on the usability testing.

7.3.1 Ratings of decision-making duration

The participants of the usability study were asked to indicate which type of decision-making duration they exercised autonomy over (short-term, medium-term, and long-term). Their suitability for the study was confirmed, as three of the participants indicated a high level of decision-making autonomy across all three durations, one of the respondents rated a low level, and the remaining respondent indicated more variation in their autonomy with the highest level being short-term and the shortest for long-term. The composition of the user group was therefore found to be representative of what the usability study needed to test out the artefacts.

7.3.2 Correlations between medium and long-term decision making

An interesting correlation was found between medium and long-term decision-making durations, which suggests that these two durations are closer to each other than short-term is to any of these. A case could be made to consider this when entrusting decision making scope for an organisation's management staff.

7.4 Usability of the artefacts

7.4.1 Overall look and feel correlated with interactivity

The feedback about the overall look and feel and interactivity indicated a positive correlation. This supports the aim of the design which was to provide an interface that supported interactivity. Each of the questions was asked separately, and the answers revealed the strong correlation to both these questions.

7.4.2 Decision Tree – Overall look and feel

Feedback about the overall look and feel supported the aim of providing an easy-to-understand decision tree.

7.4.3 Ease of use

The ease with which the values of the decision tree could be changed by the testers was rated positively. This supports the intention of providing a mechanism that was easy to use and intuitive in design.

7.5 Decision tree and simulation content choice

In using one category of decision making for demonstrating the usability and usefulness of the artefacts, it was considered prudent to settle on only one category instead of pre-emptively focusing on all eight categories. Having said that, it was still necessary to start by developing the detailed decision tree as this was the only way to identify all possible pathways. The category chosen was the full-life cycle costing (FLCC) for an LMS, as this would be the most likely category to affect the overall choice in the case of a tie. The chosen decision tree was then translated for use as an InsightMaker simulation. As, in actual practice there are various possible ways of categorisation, scoring, and weighting, these should be formulated based on the specific context and needs of the organisation.

Artefact testing was geared towards achieving specific research objective 3, namely, testing the simulation. This involved usability testing of the decision-tree and the simulation, in the form of end-user feedback.

7.6 Conclusions drawn on usability of the decision tree and simulations

The following conclusions on usability testing were reached, based on the data obtained in testing. The usability and usefulness of the decision tree and the simulation was tested using unsupervised remote. The results indicate that both the decision tree and the simulation were considered usable, therefore satisfying the objective of testing out the simulation.

7.7 General conclusions

The researcher identified the "real-world" problem (p. 3) as being lack of foresight with respect to technology enhanced learning planning (TEL) around infrastructure. The development of computerised simulations to model the requirements for TEL provision was offered to address the problem. The approach used to develop the artefacts involved interviewing decision makers and synthesising their input with technical specifications to produce the parameters that underpinned the operation of the simulations. The key aspect of this process was use of the system dynamics approach within a critical realist orientation, which informed the design of the model and the artefact (simulation).

The identified products of the research were the computerised simulation design and the computerised forecasting simulation itself. The resulting simulation satisfies the research objectives: 1. Formulating a system dynamics model; 2. Constructing a computerised simulation; and 3. Testing the simulation. While this process appears relatively straightforward at surface level, it was in fact quite complicated in the actual carrying out. For this reason, conclusions will be drawn about the actual process followed so as to make recommendations (in that section) to developers wishing to develop similar forecasting mechanisms.

7.7.1 Sequencing the artefact development

In order to arrive at the systems analysis design and the computerised simulation based on it, there was a logical order in which data needed to be elicited. For instance, data was needed from key decision makers as to the specifications needed to provide the TEL infrastructure needed for their universities. The problem was that most key decision makers tend to have broad strategic plans for TEL, but lack knowledge of detailed technical specifications; these details are usually left to subordinates with the necessary technical expertise in the actual carrying out of the strategic plans. The researcher realised that some of the participants would not be able to answer some of the technical questions. A solution to this problem was to ask open-ended questions, so that respondents would not be made to feel inadequate and could answer questions in their own lay terms.

Next, the data had to be elicited before key design specifications could be established, but the data would then be combined with the RFQ categories, then coded and weighted. By this stage, it was not possible to go back to the key decision makers and clarify responses or ask additional questions. This meant that the personal experience of the developer in working with TEL infrastructure was important in identifying key issues *before* data collection commenced. Moreover, in actual practice, some of the processes were carried out simultaneously rather than sequentially, making it difficult for the developer to assess the emerging data, and adding more stress and time to the process. Introduction of a feedback loop at various stages would have facilitated any adjustment needed rather than risk a re-think after testing, which in this case, thankfully, was not a problem. An advantage future developers would have to deal with such issues would be to have recourse to an emerging body of literature on the development of TEL forecasting.

7.7.2 The artefact development process

Sequencing would also be assisted for future development by establishing how the conceptualising of the computerised forecasting simulation "pans out" in the actual process of artefact development. Figure 7.1 shows how the computerised forecasting simulation was conceptualised by the developer.

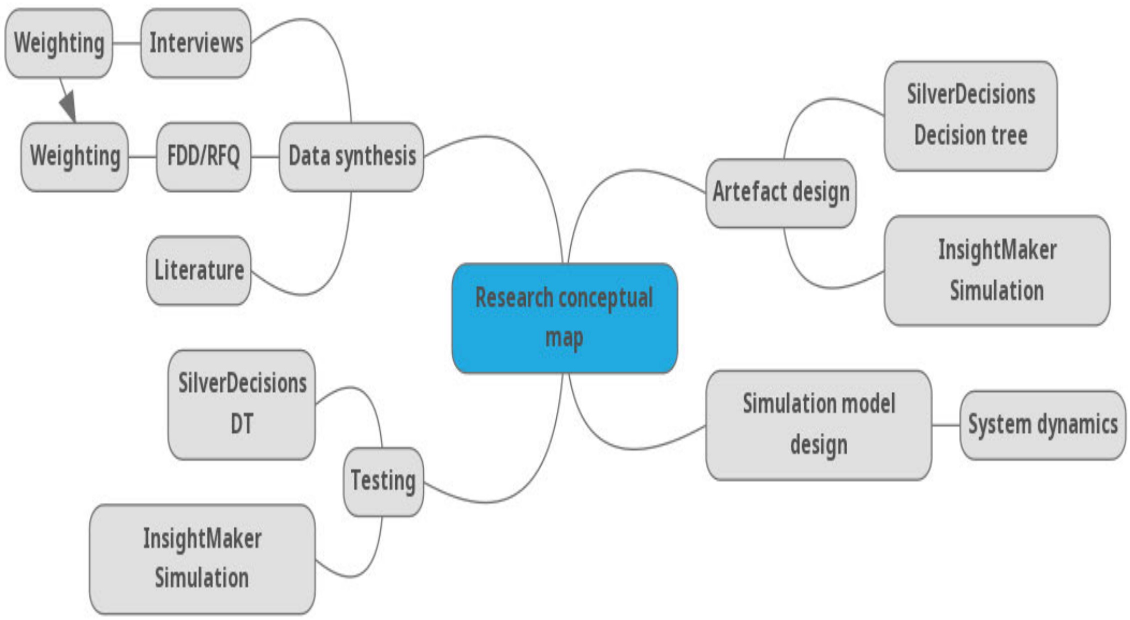


Figure 7.1 Conceptualising the computerised forecasting simulation

However, this "conceptual map" needed to be translated into a workable process to develop the computerised forecasting sim, so as to achieve the research objectives of formulating a system dynamics model of the simulation, constructing a working version of the computerised sim, and testing it out. Figure 7.2 show the stages in the development of the computerised forecasting simulation.

Again, this is more complicated than it looks, as various levels and types of entities are involved, including different artefacts and simulations on the way to the actual end product. For example, both SilverDecisions and InsightMaker are themselves artefacts *and* simulations of a kind.

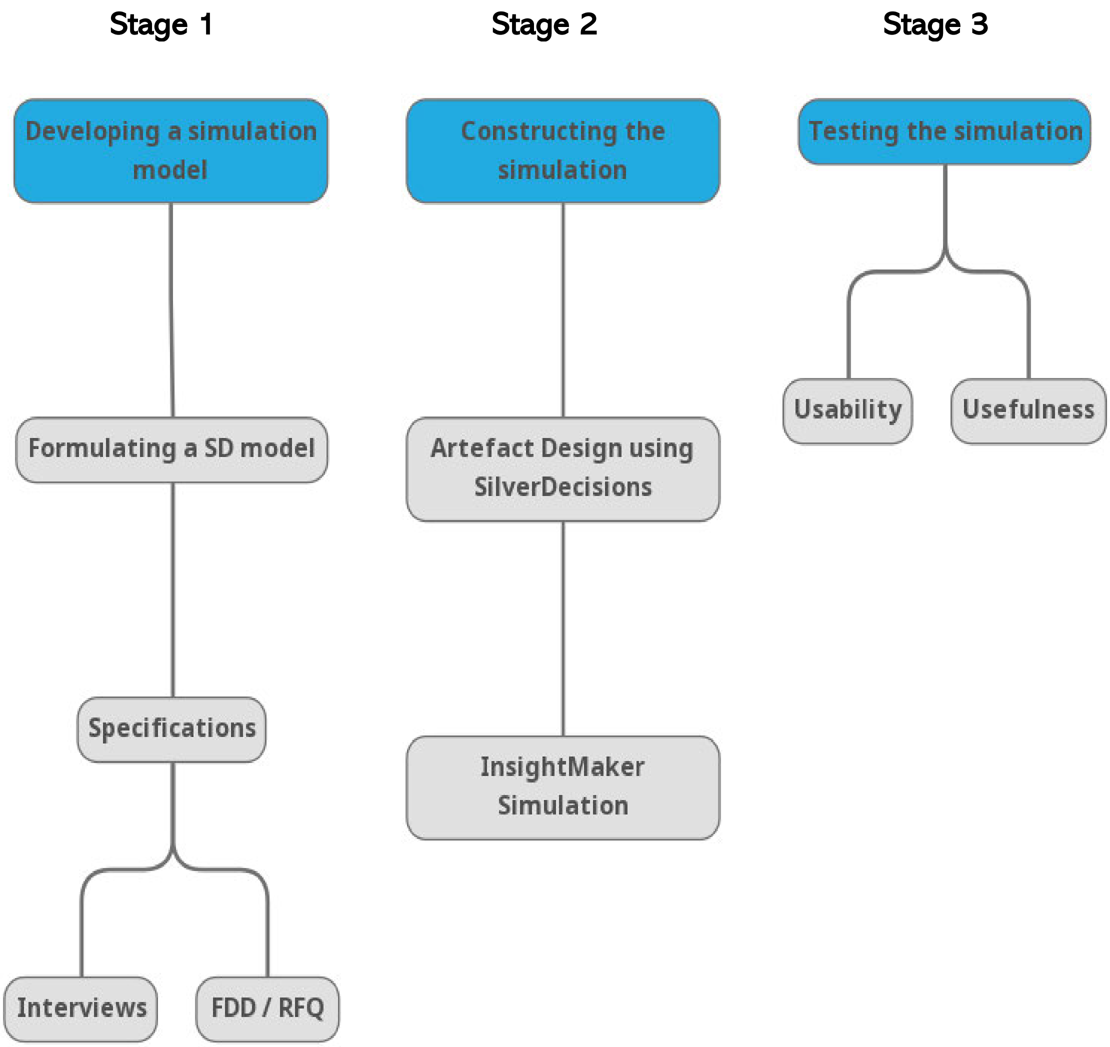


Figure 7.2 Stages in developing the computerised forecasting simulation

Both applications also “substitute” for mechanisms which are more familiar in the context of computer programming, namely, program design and actual programming code. The rationale for using SilverDecisions and InsightMaker was given in previous chapters, and a general conclusion is that both the process and the tools used were successful in doing the job as well as if performed by conventional programming means, and much more quickly.

7.8 Recommendations

Based on the above conclusions, the following recommendations are made.

7.8.1 Development to improve scope and practical use

While the decision tree and the InsightMaker simulation satisfied the objectives of this research project, it is recommended that more development is done to improve the scope and practical use of the provided computerised simulation in order to make it accessible to a wider audience beyond the defined target group of higher education institutions.

7.8.2 Capacitating others to develop their own forecasting simulations

Consideration should be also given to capacitating others with skills and expertise that would enable them to develop their own decision trees and simulations for more specific applications or broader contexts. Focus groups in a workshop setting could be one way to offer training as well as gather further insights into how effective the transference of these skills is. This in turn could be used to produce a journal article, a book chapter, or even a book, consisting of a “how to” manual showing both the theoretical basis and practical application of the process developed here. The manual could show how the concepts informing such applications might be transformed into the process whereby they are developed, as the section above has attempted to do.

7.9 Self-critique

I feel it is appropriate here to add some reflections on this research journey. In adopting a critical realist approach, as discussed in chapter two, it was indicated that entities are real if they can cause observable consequences, and it was also suggested that, while providing a philosophical overview, the choice of methodological aspects is up to the researcher. The justification for adopting the systems dynamic approach was made in Chapter two (2.7.2), which, in short, supports the contention that critical realism is methodologically agnostic. It is one thing to develop a proposal that is convincing and seems feasible at the start, and quite another to look again after completion to assess, critically, if that was indeed the case. It should be made clear that the intent of this initiative went beyond finding a novel application for using the systems dynamic approach within a critical realist ontology. In fact, the final outcome was to develop a useful forecasting simulation that could be used to guide decision making.

Stepping back for a minute, the “real-world” problem that this research addressed was lack of foresight in infrastructural planning for technology enhanced learning (TEL), and from a critical realist perspective we can intuit that the “observable consequence” of not having the means or the faculty to provide this foresight is potentially catastrophic.

When I first started work on developing the proposal, I spent time in Spain with professors whose expertise and insight could have been more beneficial if it were not for the language challenges. Much later, when I already forged ahead with the empirical work, I realised that my main contact and advisor at the University of Rey Juan Carlos had suggested that I was working on a recommendation system. I did investigate developing a recommendation system, but I realised that none of the systems would do what I wanted, which was to allow end users to choose their context and add their input to simulate the result. Recommendation systems follow the artificial intelligence (AI) machine learning (ML) approach (Singh 2020; Joshi 2023), which uses trained or untrained data sets to recommend something based on known criteria about the users' preferences. This could be, for example, recommending a product based on previous purchases, or browsing history, or a related product based on the users’ stated interests.

In one sense, recommendation systems also provide decision-making features, but in a different way, where the user is not in control or aware of the mechanics behind the suggestions made for them. An important distinction between the two systems is that the former uses aggregation as its main source of sentient suggestions, while the latter is much more transparent, and allows decision makers to be become more aware of the factors influencing their decisions.

They can then become active shapers of their TEL environments, including the infrastructural landscape, rather than passive consumers.

7.10 Concluding thoughts

The reason for my burgeoning interest in simulation design and forecasting may have been invoked by experiences with decision making processes encountered in my work as an eLearning systems administrator. The absence of planning for futures may be attributed to deficiencies with the organizational structure which in turn does little to incentivise personnel entrusted with the role of eLearning infrastructure provision. In addition, the “closing of ranks” to avoid acknowledging this glaring omission compounds the folly. When something this important is absent, as in “the right person in the right place”, there are consequences. Decision making becomes stop-gap and reactionary, instead of visionary and data driven, and rapid response may be seen as inspiring, instead of what it really is, which is desperation. The provision of a mechanism as in the TEL simulation artefact is not intended to mask the inherent deficiencies unearthed but can still be added to the war chest of personnel responsible for planning and making decisions that are out of their area of expertise and hopefully, help key players make sounder decisions.

Appendix A: Ethical approval

DUT DURBAN UNIVERSITY OF TECHNOLOGY

FACULTY OF ACCOUNTING & INFORMATICS

Faculty Research Office
Durban University of Technology
27 August 2018

Mr P Reddy
Student Number: **20303056**
Degree: PhD in IT

Email: preggyr@dut.ac.za

Dear Mr Reddy
ETHICAL APPROVAL: LEVEL 2

Your email correspondence in respect of the above refers.
I am pleased to inform you that the Faculty Research Committee (FRC) at its meeting on 24 July 2018, has granted preliminary permission for you to conduct your research "***The development of a computerized simulation model to guide the South African higher education sector in short and long-term planning of TEL infrastructure***".

You are required to present this letter to the central DUT Research office to obtain full permission to conduct the research at DUT. Please also note that each of your questionnaires must be accompanied by a letter of information and a letter of consent for each participant, as per your research proposal.

A summary of your key research findings may be submitted to the FRC on completion of your studies.

Kindest regards.
Yours sincerely

Dr Delene Heukelman
Faculty Research Coordinator (Acting)

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946

10th October 2018

Mr Pregalathan Reddy
c/o Department of Information Technology
Faculty of Accounting and Informatics
Durban University of Technology

Dear Mr Reddy

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers. I am pleased to inform you that the Institutional Research and Innovation Committee (IRIC) has granted full permission for you to conduct your research "The development of a computerized simulation model to guide the South African higher education sector in short and long-term planning of TEL infrastructure" at the Durban University of Technology.

The DUT may impose any other condition it deems appropriate in the circumstances having regard to nature and extent of access to and use of information requested.

We would be grateful if a summary of your key research findings can be submitted to the IRIC on completion of your studies.

Kindest regards.
Yours sincerely

PROF CARIN NAPIER
DIRECTOR (ACTING): RESEARCH AND POSTGRADUATE SUPPORT DIRECORATE

Appendix B: Letters of information and consent

LETTER OF INFORMATION [*FOR INTERVIEWS*]

Dear ___________________

Thank you for agreeing to be a participant in my research study!

The title of the research study is: "The development of a computerised simulation model to guide the South African higher education sector in short and long-term planning of TEL infrastructure". What I am trying to do is to find out the reasons and thinking behind decision making related to the choice of Technology Enhanced Learning (TEL) systems that may include Learning Management Systems (LMSs) such as Blackboard or Moodle.

I, Pregalathan Reddy, am the main researcher in this project, and Professor Dee Pratt is my supervisor. The research involves conducting personal semi-structured interviews.

The research procedure will be as follows. You will be asked to agree to being interviewed at a place, date and time that suits you. The interview will be conducted by me in person, and your responses will be captured in writing. Once the answers have been captured firstly on paper and then transcribed in a Google Form, you will be granted access to check and amend the answers before I start using the responses in my research. You will not spend more than one and a half hours in the research interview.

There are no foreseeable risks or discomforts for you or others participating in the project.

You may in fact benefit by gaining a richer understanding of technologies that are available that support TEL. Based on this project, I hope to produce journal articles and conference papers, in which you may be invited to co-author. I also hope the model developed as part of this research will be useful to you or your institution for decision making related to TEL for future deployment.

There will be no adverse consequences for you should you choose to withdraw, which is entirely up to you.

While you will not receive any monetary or other types of remuneration for taking part in the project, you will not be expected to cover any of the costs of the project.

The information that will be collected from you and other participants, will not be shared. Pseudonyms (false names) will be used in all written documents to protect your identity. Computer files will be password-protected, and the files will be deleted after I have completed the project, written up the results, and published journal articles (approximately two years).

In the event of any problems or queries, the person to contact is my supervisor, Prof Dee Pratt, on 031 373 6003, or myself, on 031 373 6754. You could also contact the Institutional Research Ethics Administrator, on 031 373 2900. Any complaints can be reported to the Deputy Vice-Chancellor, Research, Innovation and Engagement, Professor Sibusiso Moyo, on 031 373 2576 or moyos@dut.ac.za .

Best regards

Pregalathan Reddy

Date: *******

LETTER OF INFORMATION [*FOR USABILITY TESTING*]

Dear ___________________

Thank you for agreeing to be a participant in my research study!

The title of the research study is: "The development of a computerised simulation model to guide the South African higher education sector in short and long-term planning of TEL infrastructure". What I am trying to do is to find out the reasons and thinking behind decision making related to the choice of Technology Enhanced Learning (TEL) systems that may include Learning Management Systems (LMSs) such as Blackboard or Moodle.

I, Pregalathan Reddy, am the main researcher in this project, and Professor Dee Pratt is my supervisor.

The research involves conducting a usability study about two types of simulations related to decision making about TEL systems. The mode used to carry out the evaluation is unmoderated remote usability testing.

The research procedure will be as follows. You will be asked to consent to participating in this usability study. Microsoft Forms will be used to collect your responses to questions related to the simulations that are being evaluated. You will not spend more than ten minutes to answer the questions.

There are no foreseeable risks or discomforts for you or others participating in this project.

You may in fact benefit by gaining a richer understanding of technologies that are available that support TEL. Based on this project, I hope to produce journal articles and conference papers, in which you may be invited to co-author. I also hope the model developed as part of this research will be useful to you or your institution for decision making for future deployment.

There will be no adverse consequences for you should you choose to withdraw, which is entirely up to you.

While you will not receive any monetary or other types of remuneration for taking part in the project, you will not be expected to cover any of the costs of the project.

The information that will be collected from you and other participants, will not be shared. Pseudonyms (false names) will be used in all written documents to protect your identity. Computer files will be password-protected, and the files will be deleted after I have completed the project, written up the results, and published journal articles (approximately two years).

In the event of any problems or queries, the person to contact is my supervisor, Prof Dee Pratt, on 031 373 6003, or myself, on 031 373 6754. You could also contact the Institutional Research Ethics Administrator, on 031 373 2900. Any complaints can be reported to the Deputy Vice-Chancellor, Research, Innovation and Engagement, Professor Sibusiso Moyo, on 031 373 2576 or moyos@dut.ac.za .

Best regards

Pregalathan Reddy

Date: ********

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Pregalathan Reddy, about the nature, conduct, benefits and risks of this research study - Research Ethics Clearance Number: [Pending],
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the project.
- I am aware that the results of the project, including personal details regarding my name and designation will be anonymously processed into a project report.
- In view of the requirements of research, I agree that the data collected during this research study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in this research study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the research study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

____________________	__________	__________	____________________
Full Name of Participant	**Date**	**Time**	**Signature / Right Thumbprint**

I, _____________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above project.

____________________	__________	____________________
Full Name of Researcher	**Date**	**Signature**
____________________	__________	____________________
Full Name of Witness (If applicable)	**Date**	**Signature**
____________________	__________	____________________
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

Appendix C: Interview semi-structured questions

Interview semi-structured questions

Aim/Definitions

The aim of this research is to develop a systemic model guiding the adoption/choice/development of a coherent, reliable and stable infrastructure that supports TEL. Technology Enhanced Learning or TEL is the term used to describe the use of technology to improve or enhance learning.

Introduction

Dear XXX

You have been specifically selected based on your role/designation and decision making with respect to TEL system/s used at your institution. It is understood that this decision is rarely made by a single person or department and I have therefore attempted to include at least two persons or representatives from your institution.

Your contribution will be used to assist the researcher to identify any functions which must be performed to provide Technology Enhanced Learning (TEL). These essential functions (or 'prerequisites') will be used to formulate a model of TEL operation which identifies the commonalities and variations in the provision of TEL.

Interviewee's particulars

Name	Surname	Email	Tel	Designation	Institution & Address

Questions

1. If you were given the task of designing/selecting the architecture for the system/s that will support online learning at your institution what steps would you take?
2. There is the common opinion that Open Source costs less then proprietary, do you agree with this?
    a. If yes, have you seen any evidence to support this?
    b. If no, are you aware of evidence supporting your answer? What is this evidence?
    c. If unsure, elaborate.
3. What (TEL) system/s do you use at your institution?
4. Do you have a technology infrastructure plan?
    a. If yes, how do eLearning systems get evaluated and at what frequency?
    b. If not, at what frequency are the eLearning systems evaluated?
    c. If not, is this a potential problem for future proofing, planning and strategizing? How/why?
5. Have you heard of a Service Oriented Architecture (SOA):
    a. In relation to eLearning systems?
    b. In any context?

c. If it was shown that this SOA could be an improvement of the current architectural model, would you be interested in learning more about it?

6. Migration from one system to another might be a risky and potentially catastrophic operation, and a deterrent to changing periodically, even if present systems have significant shortcomings.
   a. What are your feelings about the above statement, and do you think that these misgivings are shared by your peers?
   b. If you had a tool that could make this process easier, would you be more likely to consider changing systems? Do you know of any such tool, and, if so, what is it?
   c. What would be the most significant factors that should be provided by the aforementioned ‘tool’?
7. Can you give me more information about the costs of your current system including staffing, infrastructure and support (if not part of your regular staffing)?
8. With respect to weighting (as used when evaluating systems) how would you order the following categories/aspects from most important to least?

Categories	**Order**
Ease of use by faculty and students	
Functionality and tools available	
Transition, ease and cost (migration)	
Integration with other enterprise-wide tools	
Extendibility – to the university environment	
Cost	

It is understood that all of these are important and some have equal weighting.

Please use 1 – 6 to rate, 1 being least significant and 6 most.

Adapted from: (Bennett 2011)

9. Do *you* have any questions you would like to ask?
10. Please feel free to contribute any other guidance, advice and comments that you think will aid this research initiative.

Thank you once again for your valuable time and contribution. Please rest assured that all the information provided by you will be kept confidential and that I will send you a transcript of this interview for vetting and correction before using it.

Appendix D: Usability and usefulness questionnaire

ELS-PS

Usability and usefulness of TEL forecasting simulation

The survey will take approximately 6 minutes to complete.[FORMS added 5-10 minutes] The survey will take approximately 5-10 minutes to complete. The aim of the research is to provide a computerized simulation forecasting model which can be used to generate various scenarios for the infrastructural aspects of TEL provision, based on user input. You are being asked to evaluate the simulations that have been developed in terms of usability (how easy or hard it is to use) and usefulness (does it it offer any value).

The two resources provided demonstrate this with one scenario as described here:

1. https://telforecasting.blogspot.com/2022/11/enhanced-learning-forecasting-aim-of.html
The actual decision tree has already been assigned scores and the recommended LMS is shown (it is the tree that is in bold). You can also change values to see how the recommended path changes.

2. https://telforecasting.blogspot.com/2022/11/tel-simulations.html
The InsightMaker simulation demonstrates one category from the decision tree shown in https://telforecasting.blogspot.com/2022/11/enhanced-learning-forecasting-aim-of.html and is indicative of how the other categories can be simulated. While you can also interact with this, it is not intended for that purpose as it is is provided for context and as a proof of concept.

Please click https://github.com/preggyr-dut/silver/blob/44774f37270c7b6abaa25e0e93203fcb96b3d104/docs/LETTER%20OF%20INFORMATION_usabilty.pdf to view the letter of information detailing the research being undertaken.

Please confirm that you were informed about my research and have granted me consent to use the answers provided in the first question.

Consent to participate with my research study

1. I consent to participate in this research study. *

◯ Yes

2. Date

Please input date (M/d/yyyy)

3. Email address

4. Please tell me what your designation is. *

5. Rate your decision making authority.

Short term [less than 2 years]

6. Rate your decision making authority.

Medium term [from 2 to 5 years]

7. Rate your decision making authority.

Long term [more than 5 years]

Usability

How usable is the SilverTree decision tree simulator?

8. Overall look and feel (how easy or difficult it is to see what is being presented)

9. Ease of use (to change values)

10. What would you change to improve the decision tree?

11. Interactivity (how easy or hard it is to interact with?)

12. Which part of the decision tree is most useful and why?

13. What would you change about the current decision tree? *

14. Did the decision tree meet your expectations in terms of what it displayed? *

- ◯ Yes
- ◯ No
- ◯ Unsure

15. Please provide any feedback or suggestions.

InsightMaker Simulation

16. Overall look and feel (how easy or difficult it is to see what is being presented?)

17. Ease of use (to change values)

18. Interactivity (how easy or hard it is to interact with?)

19. Which part of the simulation is most useful and why?

20. What would you change about the current simulation? *

21. Did the simulation meet your expectations in terms of what it displayed? *

- ◯ Yes
- ◯ No
- ◯ Unsure

22. Please provide any feedback or suggestions about the simulation shown.

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