Identification and Prioritisation of Requirements of a Clinical Decision Support System for Gait-related Diseases in Resource-limited Settings

by

RADFORD BURGER

Student number: 195026365

Dissertation submitted in partial fulfilment of the requirements for the degree
Master: Information and Communication Technology

in the Faculty of Informatics and Design

at the Cape Peninsula University of Technology

Supervisor: Prof Justine Olawande Daramola

Cape Town District Six

Date submitted: …23/10/2024..

DECLARATION

I, Radford Burger, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed ……  **Date:**…23/10/2024……

ABSTRACT

Gait-related disorders, such as multiple sclerosis (MS), Parkinson's disease (PD), cerebral palsy (CP), arthritis, symptoms of stroke, and injury, can drastically impact a person's quality of life. Unfortunately, patients and medical practitioners in resource-limited settings often have limited access to costly specialised treatment and medical equipment required to effectively treat these conditions. Clinical decision support systems (CDSS) can overcome some of these challenges by providing healthcare workers with access to decision-making tools that facilitate diagnosis and treatment.

The implementation and adoption of CDSS in resource-limited settings (RLS) have not been fully realised despite all its potential benefits. Failure to perform proper requirements analysis has been identified as a contributing factor. This study addresses some of these challenges through systematic reviews to identify and prioritise the requirements necessary for a CDSS tailored to the specific needs of RLS.

The objectives formulated to achieve this are (1) Identify the requirements for a CDSS for gait-related diseases in RLS; (2) perform a comparative analysis of requirements prioritisation (RP) techniques for CDSS for gait-related diseases in RLS; (3) apply a selected RP process for CDSS for gait-related diseases in RLS; (4) evaluate the quality attributes of the prioritised requirements for CDSS for gait-related diseases in RLS.

Design science research methodology (DSR) was chosen as a research strategy to guide the execution of the study. The first phase involved analysis of existing literature and document reviews to identify requirements for the development of CDSS that focus on gait-related diseases in RLS.

Literature analysis was used in phase 2 to select a preliminary set of RP techniques that suit the scope of requirements for CDSS for gait-related diseases in RLS.

The third phase determined the criteria for a comparative analysis of the set of selected prioritisation techniques to help with selecting the best-suited one to the identified requirements. To ensure practical relevance and feasibility, researchers, practitioners, and academics in the fields of gait analysis, physiology, biomechanics, physiotherapy or neuro-

mechanics were approached to review the requirements and apply the selected prioritisation technique.

In phase four, software development experts evaluated the quality and accuracy of the prioritised requirements, based on criteria derived from the Wiegers' Quality Model and Pohl's Quality Model.

In the final phase, the findings from the evaluation phase were analysed to derive conclusions and provide actionable insights. Individual requirements received average ratings of between 4 (good) and 5 (excellent). The average rating for the requirements set was 5 (excellent) on all the specified quality attributes.

This study successfully identified and prioritised the requirements for a CDSS tailored to gait-related diseases in RLS. User-centric, technical, and context-specific needs were effectively captured through a comprehensive literature review and engagement with experts. The MoSCoW prioritisation technique proved to be a practical and efficient method for requirement prioritisation in low-resource environments. The findings of this study can be a valuable guide for software developers and healthcare managers on aspects that require the most emphasis during the development of a CDSS in RLS.

Keywords: clinical decision support system, gait-related diseases**,** resource-limited settings, requirements, prioritisation.

ACKNOWLEDGEMENTS

I thank my parents for their unwavering support and continued encouragement to achieve my goals. I am very grateful to my colleagues and friends for offering invaluable insights and encouragement. I express special thanks to my supervisor, Professor Justine Olawande Daramola, for being a bottomless source of knowledge, inspiration, motivation and guidance.

DEDICATION

This study is dedicated to Michael, Nicole and Faith – if you set your mind to it, you can achieve it.

PUBLICATION FROM THESIS

Publications

Requirements Elicitation and Prioritisation for a Clinical Decision Support System for Gait-related Diseases in Resource-limited Settings, International Congress on Information and Communication Technology, London, United Kingdom (In Press)

Table of Contents

DECLARATION iii
ABSTRACT iv
ACKNOWLEDGEMENTS vi
DEDICATION vii
PUBLICATION FROM THESIS viii
LIST OF FIGURES xi
LIST OF TABLES xii
GLOSSARY xiii
CHAPTER 1: INTRODUCTION 1
1.1 Introduction 1
1.2 Background 2
1.3 Research Problem 4
1.4 Aim, Objectives and Research Questions 5
1.4.1 Aim 5
1.4.2 Objectives 5
1.4.3 Research Questions 5
1.5 Delineation of the Study 6
1.6 Significance of the Study 6
1.7 Structure of the Thesis 6
CHAPTER 2: LITERATURE REVIEW 8
2.1 Gait Analysis 8
2.1.1 Gait Analysis Methods and Equipment 9
2.1.2 Gait-related Diseases 12
2.2 Resource-limited Settings (RLS) 14
2.3 Clinical Decision Support Systems (CDSS) 15
2.4 Requirements Engineering (RE) 18
2.4.1 Requirements Elicitation 20
2.4.2 Requirements Prioritisation (RP) 22
2.5 Related Work 24
2.6 Summary 30
CHAPTER 3: RESEARCH METHODOLOGY 31
3.1 Research Philosophy 31
3.2 Research Approach 31
3.3 Research Methodology 31
3.4 Research Strategy 32

3.4.1 Design Science Research 32
3.5 Research Design 33
3.6 Ethical Considerations 35
3.7 Summary 36
CHAPTER 4: REQUIREMENTS IDENTIFICATION AND PRIORITISATION 37
4.1 Requirements Identification: Awareness of the Problem (Phase 1) 37
4.1.1 Identified Requirements 41
4.2 Requirements Prioritisation (RP) 45
4.2.1 Selection of Prioritisation Technique: Suggestion (Phase 2) 45
4.2.2 MoSCoW Prioritisation Technique 48
4.3 Prioritisation Process: Development (Phase 3): 49
4.4 Results of Requirements Prioritisation Process 54
4.5 Summary 61
CHAPTER 5: EVALUATION OF QUALITY OF REQUIREMENTS 62
5.1 Evaluation of Quality of Requirements: Phase 4 62
5.2 Results of Quality Evaluation 66
5.3 Summary 67
CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 68
6.1 Research Summary 68
6.2 Contributions of the Study 70
6.2.1 Theoretical Contribution 70
6.2.2 Practical Contribution 70
6.3 Limitations of the Study 71
6.4 Recommendations 71
6.5 Future Research 71
REFERENCES 73
APPENDICES 78
Appendix A: Ethics Approval Certificate 78
Appendix B: Individual Consent Letter 79

LIST OF FIGURES

Figure 2.1: Normal gait cycle ……..……. 8

Figure 2.2: Wearable technology for gait assessment …….…… 11

Figure 2.3: Key interactions in knowledge-based CDSS ……. 15

Figure 2.4: Key interactions in non-knowledge-based CDSS ……. 17

Figure 3.1: Overview of selected research design ……. 34

LIST OF TABLES

Table 2.1: Direct costs of stroke in SA for 2014 - 2018 ……. 12

Table 2.2: Type of requirements ……. 20

Table 2.3: Summary of related studies ……..... 27

Table 3.1: Research Design process mapping……..…….. 34

Table 4.1: Aspects and scope of identified requirements ……. 40

Table 4.2: Functional CDSS requirements adapted from selected papers …….. 41

Table 4.3: Non-functional CDSS requirements adapted from selected papers ……... 44

Table 4.4: Summary of the suitability of prioritisation techniques based on key criteria… 47

Table 4.5: MoSCoW prioritisation categories……. 48

Table 4.6: Overview of fields of experience of experts…… 49

Table 4.7: Sample of MoSCoW prioritisation responses for functional requirements……. 50

Table 4.8: Sample of MoSCoW prioritisation responses for non-functional requirements.. 53

Table 4.9: Prioritisation responses for functional requirements based on MoSCoW…… 54

Table 4.10: Prioritisation responses for non-functional requirements based on MoSCoW 57

Table 4.11: Prioritised functional requirements ……. 58

Table 4.12: Prioritised non-functional requirements ……... 60

Table 5.1: Quality attributes for evaluating individual requirement statements……. 62

Table 5.2: Quality attributes for evaluating the set of requirements statements……..... 63

Table 5.3: Profiles of software development experts…….....……..... 63

Table 5.4: Requirements quality evaluation document for individual requirements…… 64

Table 5.5: Requirements quality evaluation document for the set of requirements …… 65

Table 5.6: Results of evaluation of individual requirements……..... 66

Table 5.7: Results of evaluation of set of requirements……... 67

GLOSSARY

Acronym/Abbreviation	Definition/Explanation
AHP	Analytic hierarchy process
AI	Artificial intelligence
BST	Binary search tree
CDSS	Clinical decision support system
CP	Cerebral palsy
DSR	Design science research
GA	Gait analysis
ICT	Information and communications technology
IGA	Instrumented gait analysis
JAD	Joint application development
ML	Machine learning
MS	Multiple sclerosis
NDD	Neurodegenerative diseases
PD	Parkinson’s disease
POPIA	Protection of Personal Information Act
RE	Requirements engineering
RLS	Resource-limited setting
RP	Requirements prioritisation
TB	Tuberculosis

CHAPTER 1: INTRODUCTION

1.1 Introduction

Healthcare practitioners are typically expected to manage and analyze a variety of data from different sources to be able to establish accurate patient diagnoses and symptoms as well as make effective treatment decisions. However, Mekonnen et al. (2018) contend that clinicians continue to make diagnostic and treatment decision errors as a result of fatigue and stressful working conditions. Fanta and Pretorius (2018) also added that in resource-limited settings (RLS), the situation is exacerbated with the problems of poor ICT infrastructure, less skilled medical staff, and limited access to basic services.

According to Mekonnen et al. (2018), research on computerised health care systems showed that the use of information technology has been an effective preventive intervention in reducing medical errors and consequently improving patient safety. Shawahna (2019) added that the potential benefits of clinical decision support system (CDSS) utilization are improved healthcare systems, improved accuracy and efficiency of the treatment decision-making process of medical professionals, and reduced healthcare expenses. Laka et al. (2020) were of the opinion that through the utilization of information technology in designing, developing, and deploying devices and health software systems, clinical decision-making by doctors could best be supported. This would lead to correct diagnosis and treatment of patients.

Dekker et al. (2020) explain that supporting CDSS implementation is particularly relevant in the context of the new global public health challenge of non-communicable neurological illnesses. Some of these illnesses often present gait-related symptoms. Originally, this phenomenon had been reported in high-income countries but has more recently also occurred in rural Africa (Maredza and Chola, 2016). Diseases such as cerebral palsy (CP), Parkinson's disease (PD), and stroke are becoming common among Africans. Maredza and Chola (2016) have stated that the high percentage of healthcare system resources allocated to such diseases poses an enormous economic load on poor countries. Fanta and Pretorius (2018), however, have argued that CDSS implementation in resource-limited settings (RLS) is not frequently encountered. This is because the acquisition or development of CDSS is too expensive and there are maintenance charges, economic, social, legal, and technical issues associated with RLS.

This study seeks to explore and understand requirements for the development of CDSS for use in RLS based on determinants of their adoption in such settings. The study's main objective is to enhance the accuracy and effectiveness of diagnosing and treating gait-related diseases by clinicians using CDSS. With this support, CDSS could minimise the potential of human error and maximise patient outcomes, particularly in RLS, where healthcare resources, competency, and infrastructure can be scarce. Deriel et al. (2018) found that additional reporting and research on CDSS development strategies in RLS can enhance the effective implementation of these systems in such situations. Their work indicates that technology in contemporary medicine could revolutionise medical treatment and improve global healthcare.

1.2 Background

According to a 2014 Disability Status Report, a disability that limits or prohibits walking is thought to afflict approximately 10 million persons in the United States alone (Wagner et al., 2019). Simple motor skills like walking and climbing stairs are essential to most people's everyday lives. Impaired motor functions can have severe health and socioeconomic consequences if they are not managed. Gait rehabilitation is, therefore, a health priority for healthcare systems. Marýn et al. (2019) defined gait analysis (GA) as the instrumented measurement of human locomotion patterns and the interpretation of such patterns. Various gait parameters are measured to determine deviations from ‘normal’ human gait, and the causes of these deviations. Gait analysis is a useful technique for diagnosing and assessing certain diseases and neuromusculoskeletal disorders, and for planning ongoing care.

GA has shown benefits in treating patients who have suffered strokes (Marýn et al., 2019), CP patients (Carcreff et al., 2020) and those afflicted with PD (Di Biase et al., 2020). Marýn et al. (2019) claim that a significant degree of success has been achieved in improving the diagnosis and treatment of certain gait-related medical conditions by integrating GA in clinical decision support systems. Common GA tools and methods include the use of ground reaction force measurement systems, video cameras and highly sophisticated motion capture systems. However, according to Wagner et al. (2019), the widespread use of these sophisticated systems is limited due to the extensive infrastructural and financial costs, and the requirement of specialised technicians.

Fanta and Pretorius (2018) contend that in RLS several factors make clinical GA and implementation of CDSS less viable treatment options for patients and medical practitioners. Some of the challenges prevalent in these environments were identified as being high technology costs, poor ICT infrastructure, and lack of computer and medical skills of staff at

clinics. Laka et al. (2020) and Porat et al. (2017) agree that the complex integration of environmental, organisational, and human factors is a barrier to the adoption and effective use of CDSS in RLS. Marcolino et al. (2021) added that system usability was identified as a contributing factor, partly due to technologically disadvantaged health care workers.

A study by Raza et al. (2017), investigating CDSS for PD, achieved a strong measure of success by developing a CDSS that used wearable sensors to monitor symptoms of movement disorders associated with PD sufferers. It was suggested that the incorporation of GA would result in more accurate output from such CDSS. Chia et al. (2020) reported that a decision support system for detecting musculoskeletal impairments in CP patients based on GA showed promising results. The model upon which this CDSS was developed resulted in a particularly beneficial system for less experienced clinicians.

Greenes et al. (2018) reported that despite all the reported benefits of CDSS, accounts of the adoption and implementation rates of these systems have fallen short of their potential. Khairat et al. (2018) discovered that among the identified reasons for their sparse adoption are inadequate attention to clinical care processes that were meant to be supported by the CDSS, minimal consideration for human factor concerns, and user acceptance. Inadequate implementation of requirements analysis is a cause explained by Kabukye et al. (2020) as being responsible for CDSS implementation failure.

Zakane et al. (2017) asserted that careful requirements analysis during the development process can overcome the challenges in implementing a CDSS in RLS. The authors identified proper requirements elicitation and prioritisation processes as an essential initial step to obtain a system that could meet the stakeholders' expectations. As a part of the first phase of requirements engineering (RE), requirements elicitation entails gathering inputs from various stakeholders to determine what information and functionality must be represented in a software system so that users may benefit from it (Pacheco et al., 2018). Appropriate requirements discovery is a guide toward developing the desired product. The revealed raw needs are often conflicting and contradictory and must be analysed and negotiated with stakeholders. Requirements prioritisation (RP) is a technique for determining which requirements are required for a system to be effectively operational based on the criteria and constraints such as time, budget, and levels of user skills (Berander et al., 2006). CDSS designed for developed countries where there are sufficient resources, extremely high rates of health and medical technology, highly developed computer hardware and software technology, and relatively high rates of highly skilled physicians cannot be practically used in RLS (Jawhari et al., 2016).

1.3 Research Problem

Despite research evidence demonstrating the efficacy and value of CDSS, adoption and implementation rates in RLS were low, according to Fanta and Pretorius (2018). The authors reported that computer illiteracy among clinicians and limited and unreliable infrastructure were reasons for the low adoption and use of the systems. Healthcare professionals who used CDSS reported that it negatively affected their workflow and contributed to their administrative workload. Technical problems encountered when using the system required significant time and effort to resolve. Horwood et al. (2023) and Fanta and Pretorius (2018) agree that these factors discourage the use of the system, thereby leading to a lack of healthcare provision services. According to Fanta and Pretorius (2018), many CDSS interventions have been implemented in African settings with positive and effective results. This suggests that such eHealth systems have the potential to support healthcare systems in under-resourced communities challenged by a lack of adequately trained staff, lack of access to modern technology, and financial constraints. Technology can bridge the gap between the resource limitations and the burden of disease encountered in RLS.

CDSS that are designed without understanding the unique and local working conditions of its end-users negatively affect the buy-in from these stakeholders, resulting in the failure of these systems.

1.4 Aim, Objectives and Research Questions

1.4.1 Aim

This study aims to identify and determine the quality of prioritised requirements for a CDSS for gait-related diseases in RLS.

1.4.2 Objectives

The following objectives contributed to the achievement of the aim of this study:

1. Identify the requirements for a CDSS for gait-related diseases in RLS.
2. Determine the requirements prioritisation techniques that are suitable for CDSS for gait-related diseases in RLS.
3. Apply a selected RP process for CDSS for gait-related diseases in RLS.
4. Evaluate the quality attributes of the prioritised requirements for CDSS for gait-related diseases in RLS.

1.4.3 Research Questions

The main research question for this study is:

> What is the quality of identified and prioritised requirements for a CDSS for gait-related diseases in RLS?

To thoroughly investigate the main research question, four research sub-questions (RSQs) were formulated.

1. What are the requirements of a CDSS for gait-related diseases in RLS?
2. Which requirements prioritisation techniques are more suitable for a CDSS for gait-related diseases in RLS?
3. How can a requirements prioritisation process be applied for a CDSS for gait-related diseases in RLS?
4. What are the quality attributes of the prioritised requirements for a CDSS for gait-related diseases in RLS?

1.5 Delineation of the Study

The requirements data elicited for this study apply to a standalone software application, which was developed using an open-source platform. This type of CDSS requires minimal hardware and memory resources. Due to the difficulty in gaining access to medical experts practising in rural environments in other countries, the participants who were requested to prioritise the requirements are all academics based in South Africa.

1.6 Significance of the Study

Research suggests that CDSS for gait-related diseases in RLS could provide many benefits for medical practitioners and patients. However, the implementation and usage rates of such systems have failed to meet expectations. The findings of this study could be of benefit to all stakeholders. It could greatly assist software developers in developing systems that medical practitioners and healthcare workers would want to use. Increased utilisation of CDSS could result in improved medical diagnoses and treatment, combined with reduced costs, which benefit practitioners as well as patients.

1.7 Structure of the Thesis

The thesis is structured into six chapters, each dealing with a distinct aspect of the study.

Chapter 1 provides an introduction and background to the area of research. The problem statement is formulated with objectives, research questions, outcomes, and significance.

Chapter 2 provides a review of the literature in areas related to the domain and scope of the problem statement. The study attempts to address the gap revealed in literature. Previous studies conducted in similar research areas are compared, evaluated and assessed in terms of the implementation and use of clinical decision support systems in low-resource countries.

Chapter 3 outlines the research methodology employed in the study. The research approach is described. An overview of the data collection methods and data analysis techniques is provided.

Chapter 4 describes all the research activities conducted within the framework of the selected research strategy. The methods used for data collection are explained and the respondents are identified. Collected data is evaluated and interpreted.

Chapter 5 describes how the collected prioritised data was evaluated by software development experts, using criteria from established quality models. The results of the evaluation are presented ordinally.

Chapter 6 provides a summary of the research activities undertaken to achieve the study's objectives. The contributions and limitations of the study, as well as recommendations and future research directions, are discussed.

CHAPTER 2: LITERATURE REVIEW

This chapter presents a theoretical background on the selected area of study and a review of related work. An overview of gait analysis (GA) and the role of clinical decision support systems (CDSS) and its implementation in resource-limited settings to improve healthcare related to the treatment of neuromusculoskeletal diseases, and other disorders associated with irregular gait are presented. This is followed by a review of requirements engineering (RE) and its importance in the software development lifecycle.

2.1 Gait Analysis

Esquenazi and Talaty (2011) described walking as an essential motor function that allows humans to participate in daily living activities. It allows a range of daily activities and sports and helps to carry out many other social activities. If left unattended, deviations from normal walking patterns caused by neuromuscular diseases or injury can create significant short and long-term health problems, and in severe cases impact a person's independence. Walking is necessary for many occupations. Any disruption to these essential motor functions can hold severe socio-economic implications. Wagner et al. (2019) advised that gait rehabilitation is therefore a serious issue for clinicians.

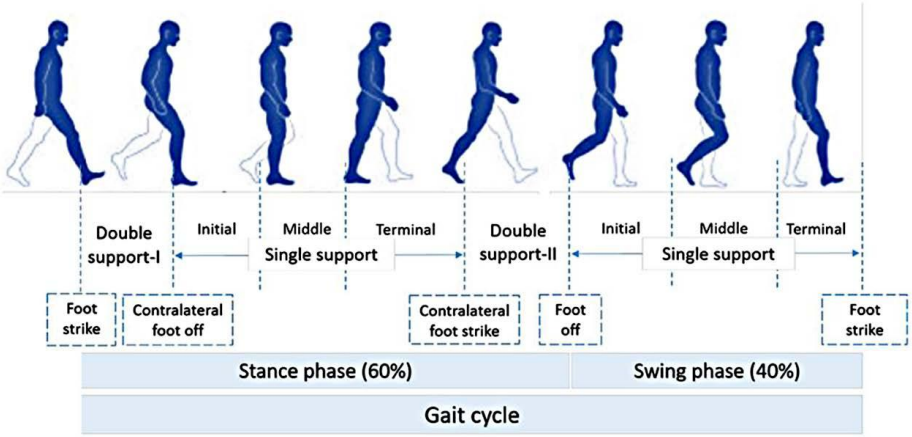

Figure 2.1: Normal gait cycle (Hulleck et al., 2022a)

Köktaş and Duin (2010) expressed that gait analysis (GA) involved the observation and measurement of characteristics of human locomotion or gait. Figure 2.1 shows the different phases in a normal gate cycle. GA plays a significant role in clinical assessment and rehabilitation, providing valuable information about human gait patterns. Clinicians can differentiate gait abnormalities through naked-eye observation, based on data collected using sensors placed on patients' bodies, computer-connected cameras, and custom software and visualization techniques. Wagner et al. (2019) assumed that the information and knowledge gathered through clinical analysis of the data gathered could assist practitioners in decision-making during rehabilitation, postoperative evaluation of motor function, and early detection of neuromusculoskeletal diseases and other disorders of abnormal gait.

2.1.1 Gait Analysis Methods and Equipment

This section explores traditional gait analysis methods and advanced technologies. Gait-related diseases, such as Parkinson’s disease and cerebral palsy, are discussed, and how gait analysis (GA) is used to diagnose and manage such diseases.

2.1.1.1 Traditional methods

As described by Hulleck et al. (2022), a simple form of GA has patients walking back and forth along a 10-metre walkway several times while being video-recorded using standard digital video cameras. A clinician would then watch and analyse the captured video data and assess the patient's gait based on a set of gait parameters or scales. Specific gait-related markers such as gait asymmetry, speed, stride length and cadence, knee joint position at midstance, initial foot contact, etc. are given a rating score. Hulleck et al. (2022) state that in a study, several rating scales have been developed for observational assessment of some gait-related diseases, such as the Unified Parkinson's Disease Rating Scale, Multiple Sclerosis Severity Scale (MSSS), and Alzheimer's Disease Assessment Scale. Observational GA is prevalent in certain settings because it is cheap and straightforward. However, the study does point out that scales for evaluation may not be adequate to measure the severity of disease. The variability and complexity of gait might be inadequately understood and thus may result in suboptimal management.

2.1.1.2 Instrumented gait analysis

Hulleck et al. (2022) describe instrumented gait analysis (IGA) as using instruments to capture and analyse human walking patterns. The authors asserted that such systems would provide an improved estimate of gait patterns and features, resulting in improved patient outcomes. IGA systems usually include walkways and treadmills with implanted sensors, marker-based motion capture systems, and force plates. Medical practitioners have used 3D imaging techniques to complement and enhance current motion capture techniques. Wagner et al. (2019) discussed a knowledge-assisted visual analytics technique called KAVAGait, designed explicitly for clinical GA use. It integrates domain expertise with high-level visualisation techniques, enabling clinicians to work on complex gait data more effectively, improving diagnostic accuracy and treatment planning. However, Qiu et al. (2019) noted that these systems have not gained traction in low-resource settings due to the high cost of specialised equipment, and the requirement of highly skilled clinicians to operate them. Gait assessment using IGA is a very time-consuming process, which usually needs to be applied in a hospital or a laboratory environment.

2.1.1.3 Wearable devices and sensors

According to Hulleck et al. (2022), the rapid advances in modern medical technology and the power of mobile computing has made it possible for continuous monitoring and sharing of data through the development of cost-effective wearable computing devices. This involves a computing processor, and sensors embedded in small wearable devices such as watches or eyewear, or devices attached to the human body in other ways, as shown in Figure 2.2.

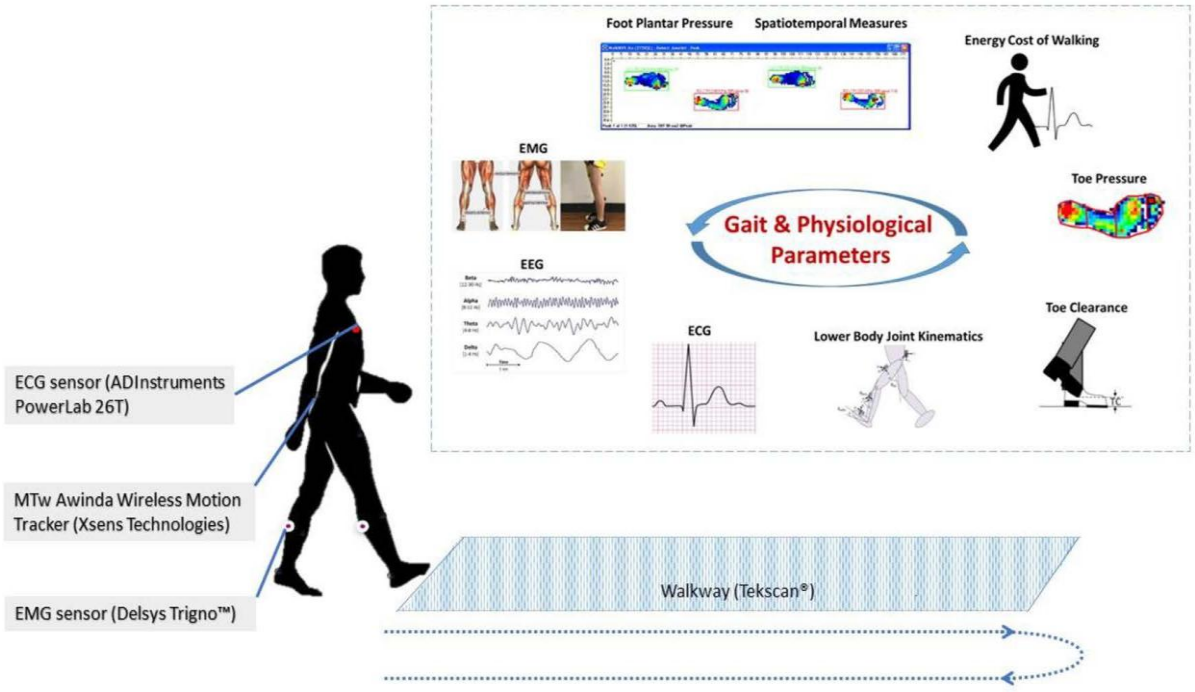

Figure 2.2: Wearable technology for gait assessment (Hulleck et al., 2022)

Seo et al. (2020) and Hulleck et al. (2022) reported on the potential of using smart insoles as a tool for GA. This type of technology expands the scope of GA by capturing human body movement during natural everyday activities, which holds great potential for use in gait-related medical applications (Kang et al., 2018). The information collected from these devices provides immediate feedback and improves understanding of deviations from typical gait patterns (Hulleck et al., 2022). Wearable sensors have proven to be a cost-effective, portable, and practical tool in GA technology, from which data can be extracted remotely (Qiu et al., 2019). Integrating these wearable devices into health monitoring platforms has the potential for improved GA, especially when using this technology in RLS.

2.1.1.4 Advanced methods

CDSS that incorporate advanced GA methods make decisions based on machine learning (ML) prediction models and statistical pattern recognition to identify gait-related disorders (Chia et al., 2020). Machine learning (ML), support vector machine, and artificial neural networks are AI techniques that are becoming a core component of gait assessment (Hulleck et al., 2022). These algorithms learn patterns and relationships in data, which enables them to provide more accurate prediction of clinical outcomes and gait-pathology diagnosis. These

advanced GA methods provide benefits that include computational analysis and interpretation, prediction analysis, and advanced data analytics.

2.1.2 Gait-related Diseases

Neurodegenerative diseases (NDD) damage and destroy parts of the brain (Cicirelli et al., 2022). Symptoms could include progressive cognitive dysfunction and motor disorders. Examples of cognitive dysfunction symptoms include confusion and memory loss. Some examples of motor neuron disorder symptoms are shaking and tremors, balance issues, and slowed or irregular gait. The authors found that there has been a notable increase in NDD cases in the last few decades. Prajapati et al. (2021) noted that abnormal health conditions connected with gait abnormalities are frequently associated with NDD such as multiple sclerosis (MS), Parkinson's disease (PD), brain tumors, certain types of dementia, cerebral palsy (CP), or because of a stroke. van Aswegen et al. (2019) added that some of the clinical symptoms of tuberculosis (TB) affect the patients' gait.

Maredza and Chola (2016) reported that stroke is one of the leading causes of death as well as disability in South Africa (SA). It is also a disease with high economic costs, particularly in rural settings. It is therefore critical that solutions are developed to reduce the economic burden posed by this disease and its treatment in RLS. Table 2.1 shows the direct costs associated with stroke treatment in South Africa for the period 2014 to 2018, as reported by Matizirofa and Chikobvu (2021). The cost values are shown in South African Rands.

Table 2.1: Direct costs of stroke in SA for 2014 - 2018 (Adapted from Matizirofa & Chikobvu, 2021)

Cost items	Estimated cost	%	Average cost
Medication	2,346,747,100	32	65,680.02
Physiotherapy	2,348,398,831	32	65,726.25
Speech therapy	1,175,724,668	16	32,905.81
Outpatient	1,206,290,175	16	33,761.27
Inpatient	2,594,616,496	35	72,617.31
Total direct	7,347,348,497,641		205,282.67

Timotijevic et al. (2020) have reported that PD is a very common NDD globally, with a high prevalence in older adults. The economic impact of treatment of the disease is substantial. Timotijevic et al. (2020) go on to say that PD is also difficult to diagnose and manage due to its fluctuating range of possible symptoms. Symptoms range from motor dysfunction (tremor, gait, balance, and speech disorders), and non-motor dysfunction (dementia, depression,

cognitive disorders). According to Di Biase et al. (2020), the early stages of PD are usually treated effectively with drugs. During more advanced stages, symptoms related to gait irregularity are observed. Gait factors such as reduced smoothness of locomotion, low speed, reduced step length, increased cadence, freezing of gait, and reduced balance control are detected. Di Biase et al. (2020) also claim that the application of GA can assist in diagnosis and symptom monitoring.
Dekker et al. (2020) observed that PD is becoming an increasingly important health concern on the African continent. Neurological services are scarce and cultural perceptions and lack of knowledge lead to stigmatisation, which hinders diagnosis and appropriate treatment.

van Aswegen et al. (2019) and Moyaert et al. (2018) reported that TB is a leading cause of death globally, but particularly so in Africa. Depending on the variation of the disease, symptoms include persistent lower back pain, fatigue, fever, weight loss, and gait and balance abnormalities. Symptoms experienced that affect gait include pain, numbness, burning or aching in the feet or legs. It was noted by Mafukidze et al. (2016) that symptoms of some variations of TB can be treated with drugs while others require physical therapy to focus on muscle strength and conservation of range of motion.

Chia et al. (2020) described CP as a group of conditions that cause physical disability in children due to a brain lesion that occurs shortly before or after birth. This causes neuro-musculoskeletal abnormalities that become progressively worse as the child ages. These abnormalities affect the individual's ability to walk. Clinical gait analysis is used to determine the impairments that affect the individual's ability to walk. Identifying these problems is a difficult process as it involves multiple complex components. Lofterød et al. (2007) reported that a single study using GA demonstrated some success in providing information that changed preoperative surgical planning. The study's outcome shows that information from GA should be seriously considered seriously by surgeons to assist in making recommendations for treatment in children with CP.

Conventional observational GA, through clinical scales, has been utilised effectively when assessing gait diseases (Hulleck et al., 2022). Specific clinical observational gait assessment scales have been developed for most gait-related diseases. For example, the Unified Parkinson's Disease Rating Scale for observational assessment of PD patients, the Multiple Sclerosis Severity Scale for MS sufferers, and the Fugl-Meyer Assessment Scale and Stroke Impact Scale for evaluating patients diagnosed with stroke. Scales, or parameters, which evaluate falls, balance, gait speed and cadence would be typical for observational assessment of PD patients and those who have suffered a stroke.

2.2 Resource-limited Settings (RLS)

In the context of health care, Fritz et al. (2015) defined RLS as places that are challenged by the scarcity of resources such as money, properly trained staff and technical infrastructure. Fanta and Pretorius (2018) described RLS as environments characterised by challenges such as poor Information and Communications Technology (ICT) infrastructure, and limited access to essential services. The high cost of medical devices used in healthcare services is one of the reasons for the unavailability of basic health resources. These challenges present difficulties in delivering healthcare services effectively, leading to healthcare disparities among inhabitants of developing countries.

Moyaert et al. (2018) reported a high incidence of TB among Africans, with the highest estimated cases in SA. TB is a condition that causes physical as well as functional impairment of patients. Stroke is one of the most common causes of death and disability in SA (Maredza and Chola, 2016). The study concluded that urgent actions need to be taken to mitigate the high economic costs of this disease and its treatment in RLS.

The ratio of the number of physicians to the population in Africa is low compared to Europe and the USA (Schluger et al., 2018). According to Fritz et al. (2015), there is less than one doctor for every 1000 persons in African countries. First-world countries have a ratio of approximately 2-to-5 doctors for every 1000 persons. The provision of high-tech eHealth services to complement the limited number of medical doctors in RLS is one of the ways of addressing this disparity. Information technology (IT) healthcare in RLS involves making patients' data available to healthcare providers accurately and timeously. Horwood et al. (2023) concluded that the lack of trained medical personnel and IT personnel in RLS impedes the effective use of IT healthcare systems.

Fanta and Pretorius (2018) determined that an integrated approach to the development of healthcare technology is required to address the issues in RLS. Some of the issues that need to be addressed are inadequate infrastructure, low-level healthcare workers, unstable power supply, poor quality internet connectivity, and the burdens of some diseases. Horwood et al. (2023) concurred that by adapting these technologies to local contexts, healthcare systems can be implemented as sustainable solutions with unbiased access and improved health outcomes despite resource constraints.

2.3 Clinical Decision Support Systems (CDSS)

Fanta and Pretorius (2018) also described eHealth as using ICT in the health industry. Dramburg et al. (2020) described a CDSS as a computerised healthcare system which assists healthcare personnel in integrating and analysing the growing quantity of available information to provide efficient clinical decision-making and an improved quality of care. CDSS integrates patient data and clinical expertise to generate patient-centered assessments or treatment recommendations. Reis et al. (2017) explained that it can be in the form of guidelines, algorithms, and databases used to facilitate clinical decision-making across healthcare fields. This enriched clinical decision-making can maximise the appropriateness and accuracy of the treatment.

CDSS are typically classified as knowledge-based or non-knowledge-based systems (Sutton et al., 2020). Rules (IF-THEN rules) are constructed in knowledge-based systems. The system retrieves information to test the rules and then forms an output or action. Rules can be constructed with evidence from literature, practice experience, or patient-led research. Figure 2.3 shows the architecture and process of a knowledge-based CDSS, as Sutton et al. (2020) described. It shows how an evidence-based CDSS pulls data from different sources of information and feeds them through an inference engine to provide actionable knowledge to healthcare practitioners through the user interface.

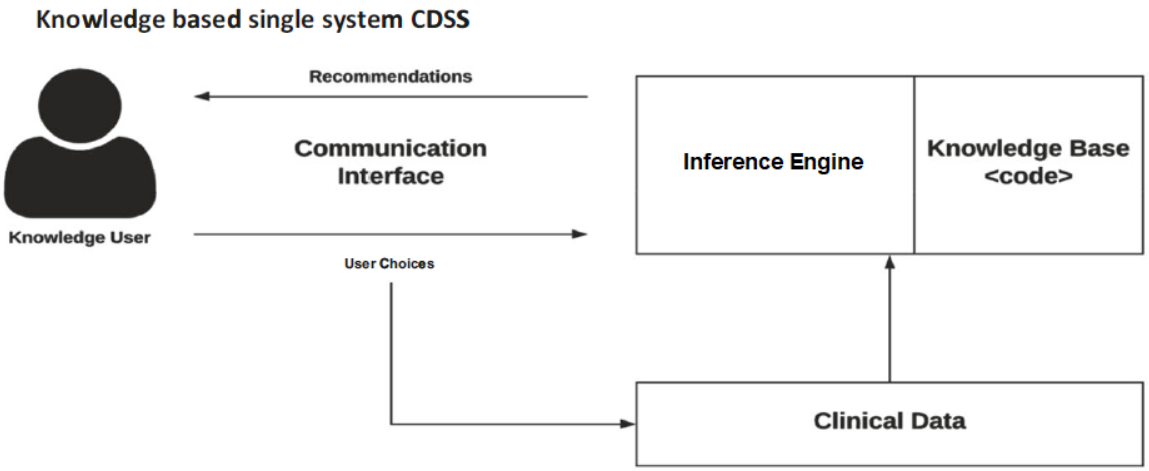

Figure 2.3: Key interactions in knowledge-based CDSS (Sutton et al., 2020)

The components of the knowledge-based CDSS architecture are:

1. **Knowledge base**: This component consists of a repository of structured medical knowledge, including clinical recommendations and procedures. The system contains programmed rules.
2. **Inference Engine**: This is the component that applies the programmed logical rules and algorithms to the data from the knowledge base and the patient's clinical data repository to generate clinical actions or recommendations.
3. **Communication interface**: The action or recommendation is presented to the user through a front-end interface or website, through which the user interacts with the system.

Sutton et al. (2020) explained that non-knowledge-based CDSS still need a data source, but instead of being programmed to follow expert medical knowledge, the decision is made using AI, ML, or statistical pattern recognition. Despite being a fast-expanding use of AI in medicine, non-knowledge-based CDSS are fraught with difficulties, such as difficulties deciphering the reasoning behind the AI's suggestions (black boxes), and issues with data accessibility. This type of CDSS has not yet been widely implemented. Most of the research on non-knowledge-based CDSS is conducted in developed countries, where these systems have been implemented much earlier than in developing countries. Figure 2.4 represents the structure and workflow of a non-knowledge-based CDSS, as described by Sutton et al. (2020). It illustrates how a non-knowledge-based CDSS leverages ML techniques to analyse large datasets, identify patterns, and provide clinical recommendations without relying on a predefined set of rules or knowledge base.

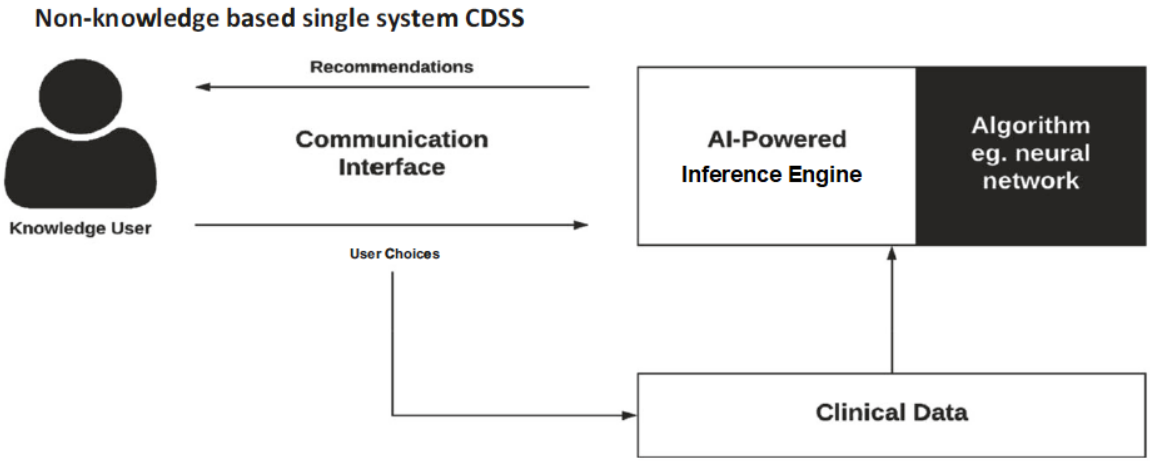

Figure 2.4: Key interactions in non-knowledge-based CDSS (Sutton et al., 2020)

Non-knowledge-based CDSS architecture consists of the following elements:

1. **Algorithms**: AI algorithms and ML techniques support clinical decision-making.
2. **AI-powered Inference Engine**: This component analyses clinical data using AI and ML algorithms to generate predictions or suggestions. This includes model training and inference.
3. **Communication Interface**: The action or recommendation is presented to the user through a front-end interface or website, through which the user interacts with the system.

Even while some developing countries have expanded their investments in health information technologies, these countries are confronted with considerably more difficult implementation issues than resource-rich countries do. Wang et al. (2021) mentioned that further limiting the adoption of AI CDSS systems in rural areas is the absence of training opportunities for the healthcare staff working in these outlying clinics to learn how to handle complex health information technology.

Reis et al. (2017) explained that the risk for potential errors in clinical decision-making exists when the medical histories of patients are incomplete, or patient load is high, or due to the inherent complexity of interpreting patient medical data. Mekonnen et al. (2018) added that medical errors are global problems, which can have huge economic cost implications, legal repercussions, and serious negative effects on patient health, which may sometimes result in

fatalities. CDSS can help mitigate these risks and improve patient safety by alerting healthcare providers to potential allergies and medical errors.

Medical professionals spend unnecessary time ordering medication and interpreting results. These routine tasks could be automated using CDSS, making more time available for patient care (Fanta and Pretorius, 2018). The up-to-date medical information provided by CDSS can help healthcare practitioners make more accurate clinical decisions (Dramburg et al., 2020).

The standardisation of clinical protocols and medical treatment guidelines is a function of CDSS that could be particularly beneficial in RLS (Mekonnen et al., 2018). Camacho et al. (2020) and Reis et al. (2017) asserted that CDSS could facilitate remote consultation and decision-making and be a cost-effective way to prevent or reduce medical errors and hospital readmissions, which are prevalent in RLS.

Fanta and Pretorius (2018) noted that the taking up of CDSS technologies in RLS remains low, despite the well-documented benefits of such electronic systems. Greenes et al. (2018), Horwood et al. (2023), and Marcolino et al. (2021) agreed that adapting these systems to the local conditions and resolving issues like unreliable power supply, inadequate internet connectivity, and costly hardware would help realise the full potential of CDSS in RLS.

2.4 Requirements Engineering (RE)

According to Melegati and Goldman (2016), an effective software system is one that accomplishes its purpose. Udousoro (2020) explained that requirements engineering (RE) is a process to discover high-quality relevant requirements for the development of a software system. RE ensures that the final product meets customer and business requirements and operates effectively in its target environment. Udousoro (2020) declared that RE is the most critical stage of software development. More et al. (2017) stated that RE is about understanding what various stakeholders need, transforming those needs into system requirements, and then ensuring those requirements are clear, complete, consistent, and can be implemented. Kabukye et al. (2020) described requirements as attributes, capabilities, or features that a software system, e.g., a CDSS, should have to be valuable and beneficial to the users. The requirements identified in the RE process act as a guideline towards the development of the desired software product. The quality and correctness of the requirements directly influence the success of the software project. More et al. (2017) concluded that the

benefits produced include error prevention, improved quality, and reduced risks throughout the software development process.

According to Melegati and Goldman (2016), a traditional process model consists of four phases: elicitation, development and analysis, documenting, and validation. Requirements elicitation focuses on discovering and collecting data and information from relevant stakeholders. The main objectives are to identify the problem to be solved and to define the boundaries and constraints of the proposed system. Communication, prioritisation and negotiation are some of the activities in the development and analysis phase. In the documentation phase, the requirements are uniquely identified, after which a requirements specifications document is produced. This document describes the software and its behaviour. Activities in the validation phase involve checking the system requirements against the raw requirements and ensuring the correctness of the documentation.

Melegati and Goldman (2016) go on to explain that the elicited raw requirements are often conflicting and inconsistent, and it is, therefore, necessary to analyse them and negotiate with stakeholders which requirements will be implemented given the prevailing constraints. The relative importance of the requirements is assessed against business objectives, needs of diverse stakeholders, technical feasibility, and operational limitations. An iterative prioritisation cycle should be used to allocate available resources effectively and manage conflicting requirements. Priority requirements must be addressed first, to reduce the risks associated with building the project and the system's quality.

Udousoro (2020) noted that many challenges need to be overcome in RE. These challenges include changed project scopes, ambiguous stakeholder expectations, and communication obstacles between multiple stakeholders. The implementation of appropriate tools and techniques to document and manage requirements effectively can help to formally address these challenges.

More et al. (2017) affirmed that effective requirements elicitation and prioritisation help in establishing agreement among stakeholders and identifying potential risks early in the software development process. It ensures software quality, reduces development costs, and guides the development team in delivering a product that aligns closely with user expectations.

2.4.1 Requirements Elicitation

Wohlin and Aurum (2005) asserted that planning of any project is a very important task in the development lifecycle. Designers and developers must be certain of what is required by the major stakeholders before commencing the actual building of the system. Requirements are characteristics that a software system must have for it to be of value to its users. Table 2.2 illustrates the classification of different types of requirements.

Table 2.2: Types of requirements (Wohlin & Aurum, 2005)

Requirements Classification
• Functional requirements – what the system will do • Non-functional requirements – constraints on the types of solutions that will meet the functional requirements e.g. accuracy, performance, security and modifiability
• Goal level requirements – related to business goals • Domain level requirements – related to the problem area • Product level requirements – related to the product • Design level requirements – what to build
• Primary requirements – elicited from stakeholders • Derived requirements – derived from primary requirements
Other classifications, e.g. • Business requirements versus technical requirements • Product requirements versus process requirements – i.e., Business needs versus how people will interact with the system • Role-based requirements – e.g., customer requirements, user requirements, IT requirements, system requirements, and security requirements

According to Pacheco et al. (2018), requirements elicitation is a critical phase in the RE process in which requirements are obtained from project stakeholders. Input is elicited from stakeholders in the proposed system to identify all expectations and requirements, functional and non-functional, to ensure that the software system meets its intended use and satisfies the expectations of the end-users. Pacheco et al. (2018) introduced several techniques that are available to perform requirements elicitation. These techniques can be categorised into traditional, cognitive, group, and contextual techniques.

1. **Traditional techniques** focus on structured and formal methods to gather requirements.

a) Interviews – detailed information is gathered from stakeholders through direct conversation. An in-depth understanding of the requirements can be obtained but it can be time-consuming.

b) Surveys/questionnaires – Structured forms can be distributed to a large audience to collect data quickly. The depth of information is, however, often limited.

2. **Cognitive techniques** focus on understanding the thought processes and mental models of users to elicit requirements that align with their cognitive needs.

a) Brainstorming – A wide range of ideas and requirements are generated by engaging stakeholders in creative discussions.

b) Repertory grid – Different aspects of the software are compared and contrasted to uncover implicit needs.

3. **Group techniques** emphasise the involvement of multiple stakeholders working together to elicit and refine requirements.

a) Focus groups – A wide range of stakeholders are gathered together to discuss requirements. This enables the generation of a wide variety of ideas and viewpoints.

b) Joint application development (JAD) – Stakeholders and software developers are involved in intensive workshops to define requirements collaboratively.

4. **Contextual techniques** prioritise real-world context and user interaction.

a) Observation – users of the current system are observed to identify requirements and problems of the proposed system.

b) Ethnographic studies – users are observed in their environment for an extended period.

These methods differ, and each method is better suited to specific projects. Tiwari et al. (2012) proposed a framework to select appropriate elicitation techniques based on the influencing factors of the software product. Examples of these factors are sources of domain knowledge, information available in the knowledge base, project situational factors, and the software domain. Practical understanding of the requirements ensures that the final product satisfies the expectations and demands of the stakeholders. Pacheco et al. (2018) noted several convincing reasons why effective requirements elicitation is crucial:

1. **Reduces Miscommunication**: Clear and precise requirements minimise misunderstandings between stakeholders and developers, reducing the risk of project failure.

2. **Improves Project Planning**: Accurate requirements help in better planning and estimation of project timelines and resources.

3. **Enhances Quality and Usability**: By understanding the actual needs of users, the software can be designed to be more user-friendly and effective.

4. **Mitigates Risks**: Early identification of potential issues through thorough requirements gathering helps in mitigating risks and avoiding costly changes later in the development process.

5. **Increases Stakeholder Satisfaction**: Engaging stakeholders throughout the elicitation process ensures their needs are met, leading to higher satisfaction with the final product.

Requirements elicitation is a vital part of the software development lifecycle. It involves various techniques, each with its own advantages and disadvantages, to acquire thorough and accurate requirements. Pacheco et al. (2018) suggested that the adequacy of these techniques significantly influences the success of software projects. Selecting and employing appropriate techniques is essential to satisfy stakeholders' needs effectively.

2.4.2 Requirements Prioritisation (RP)

RP refers to the ranking process of requirements to determine their relative priority and order of execution. The most critical and viable features are delivered first. Hudaib et al. (2018) contended that RP is necessary to ensure stakeholder requirements are delivered while time and resource constraints are adequately resolved.

There are many RP approaches, each of which has its advantages. Research has identified some of the most widely used methods:

1. Analytic Hierarchy Process (AHP): Stakeholders rank the relative importance of criteria through pair-wise comparison against each other. This technique converts pair-wise comparisons into a number priority. It's a complex method that takes time and tends to be problematic (Khan, 2006).

2. MoSCoW: This is a method in which requirements are put into one of four categories: must-have, should-have, could-have, and won't-have (or won't have yet). The idea is that things are categorised at the beginning of a project to separate what is purely necessary, what it would be pleasant to have, and what the project can do without. But it doesn't consider circumstances that can influence priorities for when to accomplish work. Be

cause the categorisation process is not numerical, it allows personal interpretation (Khan et al., 2015).

3. 100-Dollar Test: Stakeholders are presented with a hypothetical budget of 100 dollars to be distributed across various requirements to demonstrate their priority. This method is straightforward in determining the most valued needs. It is natural, intuitive, and instills team collaboration (Khan, 2006).

4. Ranking: The stakeholders assign a priority number to various requirements. The method is fast and straightforward to use but may lack accuracy and can be influenced by personal biases (Khan, 2006).

5. Priority Groups: Stakeholders assign requirements to one of three groups: high, medium, and low priority. It is a simple and flexible method, at the expense of detail and precision (Hudaib et al., 2018).

Sufian et al. (2019) and Khan et al. (2015) state that there are numerous factors to be considered when prioritising requirements. It is difficult to achieve consensus in priority decisions because stakeholders are human beings with subjective biases. Priorities may be difficult to determine when dynamic and ever-evolving requirements may require frequent analysis and revisions. Time and resource limitations can make it impossible to achieve a fully correct and complete outcome. This may lead to compromises.

RP plays a significant role in the software development lifecycle as it invests limited time and resources in requirements that contribute most to value. This leads to a clearer development plan, making planning, scheduling, and risk management more effective. If high-value requirements are addressed, user satisfaction and participation will be significantly enhanced (Hudaib et al., 2018). Incremental and iterative development can be supported using this approach, as well as the ability to adapt to changes in needs. Pacheco et al. (2018) concurred that the most critical requirements must be addressed during the initial phase to detect and eliminate risks to predict and stabilise project results. Effective RP supports a successful pilot project that meets the expectations of significant stakeholders.

2.5 Related Work

Köktaş and Duin (2008) investigated the effectiveness of a CDSS that incorporated machine learning models and algorithms for gait analysis. They measured the accuracy of the CDSS interpretation of automated gait data. The results of the experiments showed that automated GA was very effective in the treatment of patients with Osteoarthritis (OA).

Köktaş and Duin (2010) conducted a study to investigate if statistical analysis of gait data could contribute to supporting clinical decision-making processes. The authors directed their focus on the clinical environment in which gait analysis is highly significant, e.g. rehabilitation centers or hospitals. Data was collected and analysed in a rehabilitation gait laboratory at one of the universities in Turkey. The authors applied statistical methods, with various techniques of quantifying gait data and identifying trends that would be beneficial in guiding clinical decision-making. The results show that using gait data analysis as a clinical diagnosis tool for treating patients with mobility disorders is likely to be positive and successful for future use.

Greenes et al. (2018) investigated why some CDSS failed, and others were successful. Each of the frameworks investigated had been successful in addressing some of the factors, but not all of them. It was found that different models may be appropriate for addressing various factors at different stages of the CDSS development cycle.

Khairat et al. (2018) investigated the effect of meaningful engagement of physicians in the design and development of CDSS on user acceptance of the technology. Their context was the American healthcare system, in which CDSS has been adopted but resisted by physicians. The authors critically reviewed literature in knowledge databases such as MEDLINE/PubMed, CINAHL, PsycINFO, IEEE Xplore, and Web of Science. They conducted task analysis to help identify and describe the goals, user input, system output, knowledge requirements, and constraints to better understand the problems associated with CDSS. The study found that user acceptance of CDSS could be improved by including the physicians in the design process.

Marcolino et al. (2021) conducted a study with the following objectives:

1) Develop a CDSS to manage the treatment of hypertension and diabetes.
2) Implement the CDSS in an RLS in Brazil.
3) Evaluate the system's perceived feasibility, usability, utility, and user satisfaction.

The authors reviewed studies on hypertension and diabetes to establish the software's functional requirements and used a Likert-scale questionnaire to evaluate the system's perceived feasibility and user satisfaction. They found that the CDSS was effective in managing the treatment of diabetes and hypertension. User satisfaction was reported to have improved.

Zakane et al. (2017) organised a workshop for nurses, nurse assistants, and midwife assistants who worked at peripheral maternal healthcare facilities in rural Burkina Faso. The authors aimed to understand why CDSS usage was so poor. Data was collected in three parts: 1) participants completed questionnaires to show their CDSS usage patterns; 2) participants were given guiding questions to capture their experiences of the CDSS during group discussions, and 3) participants expressed their opinions about the CDSS in a plenary session. The participants expressed a lack of motivation to use the system. Some of the reasons for this demotivation were inadequate training, poor integration with workflow, inadequate infrastructure, and lack of incentives to motivate staff. Technical challenges like poor maintenance support and unreliable electricity supply were identified as important factors that needed to be considered. The study concluded that CDSS usage could be improved by involving users during the early design phases, as well as the development and pilot-testing phases. These results cannot be generalised as this was a qualitative study. However, they may be applicable and transferable to similar environments and context.

Horwood et al. (2023) conducted a study to monitor CDSS uptake in a rural district in KZN, SA. The aim was to establish the experiences and challenges faced by newly trained nurses when using the system. Data collection was conducted through 1) quantitative questionnaires; 2) electronic tracking of CDSS uptake at the participating clinics; 3) in-depth interviews (IDI) with some participants, and 4) focus group discussions (FGDs). Some of the positive feedback received was that the system was helpful and easy to use. However, some reported that use of the system disrupted their workflow. They also reported that they were unable to resolve hardware and technological issues due to inadequate training.

Fanta and Pretorius (2018) used a design science research (DSR) approach to investigate the factors that influence the success and sustainability of CDSS implementation in RLS in Africa. Factors that determine the long-term sustainability of eHealth were revealed to be relevance and user-friendliness of technology (technological), the availability of funds (financial), user involvement (organisational), executive support (political), and ICT infrastructure (environmental). The success of CDSS implementation is contingent on meeting the objectives of the stakeholders.

Peiffer-Smadja et al. (2020) arranged a workshop for healthcare workers who practiced in hospitals and medical institutes across nine West African countries. The aim of the study was to analyse the barriers and facilitators of CDSS implementation. The authors hoped that the findings could provide a solution for the sustainable use and adaptability of such systems. Data was collected through round-table discussions and questionnaires. The participants highlighted the positive impact of CDSS on healthcare and identified barriers. The findings revealed that stakeholder engagement in the design phase is crucial if a system is to be sustainable and acceptable in a local context.

Kabukye et al. (2017) chose a qualitative approach to elicit and analyse user requirements for an effective CDSS for oncology care. The purpose of this explorative study was to improve the usability and adoption of such systems in RLS. The authors arranged a workshop for healthcare workers at the Uganda Cancer Institute (UCI) in Kampala. They used 1) focus group discussions (FGD) to properly understand the workflow of routine tasks of the participants, and 2) in-depth interviews (IDI) to clarify and explore the issues raised in the FGD. The participants identified user-friendliness, improved patient information management, better communication between health practitioners, and adaptability to resource constraints in RLS as important requirements. Addressing and meeting these requirements could lead to a more usable and acceptable CDSS.

Kabukye et al. (2020) conducted a follow-up study in Uganda to prioritise oncology CDSS requirements and then compare them to those from developed countries. They included information technology (IT) experts along with oncology healthcare workers as participants in their data collection. The authors used a mixed-methods approach called concept mapping which included FGDs, surveys to cluster and rank the requirements, and statistical methods for prioritisation. The prioritised requirements were then presented as concept maps, which are visual summaries of the data. The findings highlighted critical needs such as user-friendly interfaces, efficient data entry processes, and the ability to track patient outcomes. The study concluded that EHR requirements for use in oncology in RLS are similar to those in developed countries. However, systems in RLS must be adaptable to resource constraints while still meeting the clinical demands of oncology care. Overcoming basic infrastructural and contextual barriers in RLS is important to sustain and advance the technology.

Table 2.3 highlights the research features of each of the related studies in terms of objective, context, methodology, focus, findings, inclusion of requirements elicitation and prioritisation.

Table 2.3: Summary of related studies

Authors	Objective/Goal	Location/Context	Methodology Used	Focus of the Study	Findings	Requirements Elicitation	Requirements Prioritisation
Köktaş et al. (2008)	Develop an intelligent CDSS for neuromusculoskeletal disorders.	Turkey: general clinical settings	AI techniques and clinical data analysis	Intelligent CDSS for neuromusculoskeletal disorders	AI-powered CDSS effectively supports accurate diagnosis and treatment recommendations for neuromusculoskeletal conditions.	No	No
Köktaş & Duin (2010)	Use statistical analysis of gait data to support clinical decisions.	Turkey: general clinical settings	Statistical analysis	Gait data analysis to aid clinical decision-making	Statistical analysis of gait data helps distinguish patient groups, identify abnormalities, and monitor rehabilitation progress.	No	No
Zakane et al. (2017)	Explore CDSS opportunities and obstacles for maternal care in Burkina Faso.	Rural Burkina Faso	Mixed methods (interviews, surveys)	CDSS for maternal healthcare	CDSS showed potential but faced challenges like infrastructure issues, lack of training, and system integration problems.	No	No
Kabukye et al. (2017)	Identify user requirements for an oncology EMR system in Uganda.	Uganda: Low-resource settings	Case study (interviews, surveys, observations)	EMR systems for oncology in low-resource settings	Critical need for user-friendly systems, comprehensive patient data management, and adaptability to resource-constrained healthcare settings.	Yes	No

Greenes et al. (2018)	Analyse CDSS implementation successes and failures.	General (not specific)	Literature review and comparative analysis	CDSS implementation successes and failures	CDSS success depends on user engagement, workflow integration, and adaptability to different healthcare settings.	No	No
Khairat et al. (2018)	Investigate reasons for physicians' reluctance to adopt CDSS.	U.S.A.: healthcare system	Qualitative (surveys, interviews)	Barriers to CDSS adoption	Non-adoption linked to workflow disruption, lack of trust in technology, and usability challenges.	No	No
Fanta and Pretorius (2018)	Develop a sustainable eHealth implementation framework.	Africa: resource-constrained settings	Conceptual and analytical	Sustainable eHealth framework in low-resource areas	Proposed a multi-dimensional framework considering technical, socio-cultural, and economic factors for sustainable eHealth implementation.	No	No
Kabukye et al. (2020)	Identify and prioritise requirements for EHRs in oncology in low-resource settings.	Uganda: Low-resource settings	Concept mapping	EHRs for oncology	Key requirements included user-friendly design, efficient data entry, and patient outcome tracking; prioritisation of requirements was critical.	Yes	Yes
Peiffer-Smadja et al. (2020)	Facilitate CDSS implementation for antibiotic prescribing in West Africa.	West Africa	Co-design workshops	CDSS for antibiotic prescribing	Physician involvement in CDSS co-design was essential for practical implementation and acceptance.	Yes	No

Marcolino et al. (2021)	Develop and implement CDSS for hypertension and diabetes in Brazil.	Brazil: resource-constrained area	Mixed methods (quantitative and qualitative)	CDSS for chronic disease management	CDSS improved control of chronic diseases but required adaptation to the local resource-constrained environment.	No	No
Wang et al. (2021)	Explore challenges in deploying AI-powered CDSS in rural China.	Rural China	Qualitative (field observations, interviews)	AI-powered CDSS in rural healthcare	Challenges included trust issues, concerns about AI accuracy, and difficulties integrating the system into healthcare workflows.	No	No
Horwood et al. (2023)	Investigate nurses' experiences using CDSS in rural South Africa.	Rural South Africa	Longitudinal mixed methods	CDSS in rural primary healthcare	Nurses experienced technical problems, inadequate training, and poor system integration, affecting the effectiveness of CDSS use in rural healthcare.	No	No

Table 2.3 reveals a clear research gap in the context of studies focusing on CDSS for gait-related diseases, particularly in resource-limited settings. While several studies address CDSS implementation and challenges (e.g., for chronic diseases, maternal care, or antibiotic prescribing), none of them specifically focuses on gait-related diseases or includes comprehensive requirements elicitation and prioritisation in this domain. Only a few studies, such as Kabukye et al. (2020), prioritised requirements for healthcare systems, but these focused on oncology rather than gait disorders. This highlights a gap in the literature for studies that aim to elicit and prioritise requirements for a CDSS tailored to gait-related diseases, especially in resource-constrained environments.

2.6 Summary

The literature review in this chapter provided a theoretical background on gait analysis, gait-related diseases, resource-limited settings, and CDSS. The two phases of requirements engineering that were elaborated on are requirements elicitation and requirements prioritisation. Several other related studies were referenced in terms of their context and objectives of the work, the approaches used, and the findings thereof.

CHAPTER 3: RESEARCH METHODOLOGY

This chapter outlines the methodological choices made for conducting the research.

3.1 Research Philosophy

This study aims to identify the requirements for a CDSS and evaluate their quality. It addresses and attempts to solve a real-world, practical problem. Based on descriptions by Kelly and Cordeiro (2020) and Goldkuhl (2012), a pragmatist philosophy is therefore appropriate for determining the practical impacts of these requirements on the design and implementation of CDSS especially in light of issues such as lack of resources, poor infrastructure, and healthcare accessibility constraints.

3.2 Research Approach

In a deductive approach: 1) a hypothesis is developed based on existing theory, 2) the hypothesis is tested by applying quantitative methods, and 3) the outcomes of the tests are analysed to confirm or reject the theory (Burney and Saleem, 2008). This study aims to assess the quality of prioritised requirements by testing the hypothesis that requirements for a CDSS in RLS can successfully be elicited and prioritised. The hypothesis can be tested with a measurable expectation, thus verifying the effectiveness of the requirements elicitation and prioritization process. Deduction was the methodology used for this study.

3.3 Research Methodology

Research methods can be categorised into three types: qualitative, quantitative, and mixed methods research (Creswell, 2013). Qualitative research methodology discusses the way to do things and involves the collection and analysis of primary textual data. Qualitative data analysis involves identifying patterns or themes from which generalisations or theories can be developed. With quantitative research methodology, theories are tested to prove or disprove a hypothesis. A mixed-method design combines a qualitative and a quantitative approach to data collection and analysis (Robinson, 2007). This is a two-stage design in which qualitative findings from Stage one guide the quantitative Stage two. Quantitative techniques are used to confirm the qualitatively established hypothesis (Halcomb and Hickman, 2015). Mixed-methods allow for more comprehensive and detailed data and provide a richer interpretation of the results.

A mixed-methods methodology was employed for this study. Data was collected using a qualitative literature review and then analysed to develop an understanding of the research gap. The data gathered included the elicited requirements along with a specific set of criteria for selecting a suitable prioritisation technique as outlined in objective One and Two. A survey questionnaire was distributed to stakeholders with extensive knowledge in the areas of gait analysis, physiology, biomechanics, and physiotherapy. Respondents were required to use a requirements prioritisation (RP) process on the elicited requirements. Subsequently, experts in software engineering conducted a quantitative analysis of the prioritisation outcome, assessing the quality of the prioritised requirements.

3.4 Research Strategy

A research strategy is a plan of activities for searching for and assessing information that guides a researcher (Malhotra, 2017). The strategy includes elements of data collection and analysis that are derived from the objectives and research questions of the research project.

3.4.1 Design Science Research

The focus of Design Science Research methodology (DSR) is developing artefacts intended to address and resolve design problems to advance the knowledge bases of technology and science (vom Brocke et al., 2020). It is a strategy aimed at creating practical solutions for real-world problems (Goldkuhl, 2012). This supports the decision to use design science as a research strategy for this study, considering its objectives. The phases of DSR are outlined as follows:

Awareness of the problem: Necessary data was gathered about the problem to be solved, to provide greater definition, insight and understanding of the problem domain.

Suggestions: The data collected was investigated and analysed to determine their strengths, weaknesses and relevance.

Development: The artefact was developed and implemented.

Evaluation: The quality of the artefact was evaluated to determine to what extent it fits the purpose.

Conclusion: In this phase, a consensus was reached on whether the research results are effective or not.

3.5 Research Design

The DSR activity plan for achieving the objectives is outlined as follows:

Phase 1 – Awareness of the Problem:

In the initial phase, document reviews and literature reviews were used for data collection to identify the requirements and available RP techniques. Sources of documents and literature included scholarly articles and journals, health policy reports, physician guidelines, and regulation reports.

Phase 2 – Suggestions:

RP techniques identified in phase 1 were compared to determine their relevance and suitability to the subject under consideration. One technique was selected from a shortlist of the most suitable techniques based on document reviews and comparative feature analysis.

Phase 3 – Development:

Researchers, practitioners, and academics in the fields of gait analysis (GA), physiology, biomechanics, physiotherapy, or neuro-mechanics applied the selected RP technique to the requirements. They were also allowed to propose any extra requirements they believed should be added to the list.

Phase 4 – Evaluation:

This phase involves the evaluation of the quality of the prioritised requirements generated in phase three. Respondents rated the set of requirements using attributes and criteria. The quality rating is guided by quality metrics as proposed by Wiegers' Quality Model (Wiegers, 1999) and Pohl's Quality Model (Pohl, 2010). The objective of this phase is to determine whether the output of the prioritisation process is accurate and of acceptable quality.

Phase 5 – Conclusion:

The outcome of the evaluation phase was used to derive a conclusion to the study.

An overview of the steps of the selected research design, based on DSR, is illustrated in Figure 3.1. A mapping of the objectives and the adopted research design is shown in Table 3.1.

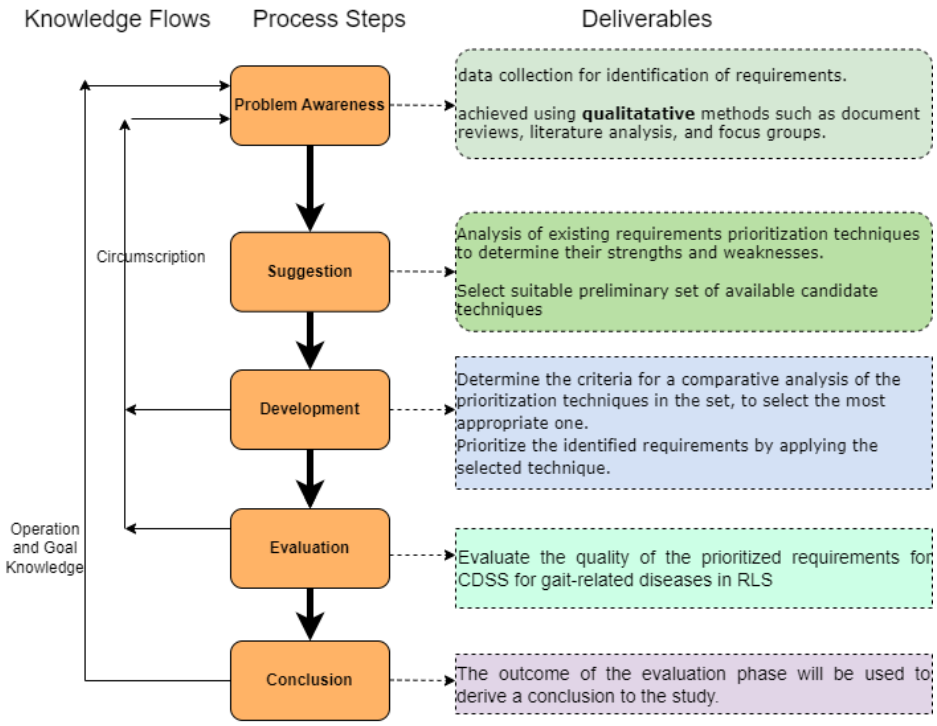

Figure 3.1: Overview of selected research design (Adapted from Vaishnavi & Keuchler, 2004)

Table 3.1: Research Design process mapping

Objective	Research design phase	Methods/activities	Output
Identify the requirements for a CDSS for gait-related diseases in RLS.	DSR - 1	Qualitative methods such as document reviews, literature analysis, and focus groups with medical experts and other related stakeholders, to identify requirements	Identified requirements
Develop a framework for comparative analysis of RP techniques for CDSS for gait-related diseases in RLS	DSR - 2, 3	literature analysis, feature analysis and comparison	Suitable prioritisation technique identified
Apply a selected RP process for CDSS for gait-related diseases in RLS	DSR – 3	Ranking/rating of requirements according to principles of selected technique	Prioritised requirements
Evaluate the quality of the prioritised requirements for CDSS for gait-related diseases in RLS	DSR – 4	Assessment of key aspects such as alignment with objectives, stakeholder validation, impact and benefit analysis.	Quantitative rating of quality of prioritised requirements

3.6 Ethical Considerations

Ethical clearance was obtained from CPUT. The Ethics Approval Certificate is shown in Appendix A. In this research dissertation, no actual patient data will be considered. However, human participants are a source of data. “Researchers have a duty to protect the life, health, dignity, integrity, right to self-determination, privacy and confidentiality of personal information of research subjects” (Yip, Han & Sng, 2016).

Taking the three basic ethical principles into account, namely, respect for persons, beneficence, and justice, as stated in the Belmont Report (States National Commission for the Protection of Human Subjects of Biomedical & Research, 1978), all appropriate steps have been undertaken to adhere to strict ethical guidelines to maintain the privacy, confidentiality, dignity, rights, and anonymity of all participants. Strict adherence to all the ethical guidelines serves as a measure of the honesty and trustworthiness of the data collected and the accompanying data analysis.

All prospective participants were provided with a letter of consent for the collection of data. This letter is to inform participants of the purpose and objectives of the research and how collected data will be stored and secured. They are assured that none of their responses were misinterpreted; moreover, a copy of the final completed thesis can be made available, on request. The researcher guarantees that no participants are put in a situation where they might be harmed because of their participation, physically or psychologically. All ethical measures are implemented in accordance with POPIA.

Informed consent: The researcher ensured that the participants were informed of the purpose, nature, data collection methods, and extent of the research before commencement. Participants were informed that the research is for academic purposes only and their participation in it is completely voluntary.

Privacy/confidentiality: The researcher ensured that the confidentiality and anonymity of the participants would be maintained. Questionnaires used for data collection were completed anonymously. Where participants’ names are known to the researcher it was emphasised that their names would not be used for any other purposes, nor would information be shared that reveals their identity in any way.

Management of data acquisition: To limit the confidentiality risk, the researcher attempted to reduce the amount of sensitive data being collected in the first place.

Data protection: All data collected from participants was stored in password-protected files. These files are stored on devices and repositories that are secured and only the researcher has authorised access to them. All data storage devices are protected using anti-virus software.

Disposal of data: All data collected for this study will be appropriately disposed of after completing the study.

3.7 Summary

This chapter detailed the methodology employed in the study and described the procedures used to do the research to achieve its objectives. The details of the various phases of the DSR strategy and why it was selected as an appropriate strategy for this study were outlined. The steps taken to reduce the ethical risks associated with this research are also described.

CHAPTER 4: REQUIREMENTS IDENTIFICATION AND PRIORITISATION

In this chapter, the research activities of requirements identification/elicitation, analysis, and prioritisation are described within the framework of Design Science Research (DSR).

4.1 Requirements Identification: Awareness of the Problem (Phase 1)

In the first phase of the DSR strategy, a literature review was conducted to identify user requirements that can be utilised in the implementation of clinical decision support systems (CDSS) for the treatment of gait-related diseases in resource-limited settings (RLS). This technique is appropriate when research objectives are focused on the identification or discovery of common themes. It can provide an overall insight into topics related to user requirements.

A literature analysis was employed to search for and identify how and why certain functional and non-functional requirements were defined for a CDSS useful for the treatment of gait-related diseases in resource-limited settings. Five articles were discovered and reviewed to determine requirements for CDSS based on their applicability to this research. All the papers discussed different aspects of healthcare systems, with a focus on electronic health records (EHR) and CDSS.

Blank et al. (2013) reported on an extensive study conducted at rural primary healthcare centers in Ghana, Burkina Faso, and Tanzania. Healthcare resources in these countries are scarce, and there is a significant healthcare knowledge-practice gap. The aim of the project was to create and implement a knowledge-based CDSS to improve the quality of healthcare in low-income countries. The study targeted four areas of interest: upgrading the competency of healthcare providers, improving the performance of health facilities, strengthening the healthcare system, and increasing community engagement in the provision of maternal and prenatal care. The authors employed a mixed-methods methodology, using both qualitative and quantitative data collection, to design and roll out a CDSS. The system was intended to support healthcare professionals by providing them with contextually relevant decision-making aid based on prevailing guidelines at the time.

Software developers created an open-source implementation of a CDSS, designed with an understanding of the unique challenges and cultural nuances of the low-income countries where it was deployed.

The system is a single, standalone Java 6 application. The software requires at least 1 GB of random-access memory (RAM), platform-independent Java software, and a display screen resolution of 1024 x 768. The number of prerequisites was kept to a minimum to enable future utilization and sharing. The system includes a user interface, patient database, and filtering algorithms to inspect values entered in the database. The user interface facilitates use by healthcare workers with little or no computer experience. Users can input and view patient data, which is saved in an XML database. The XML data could be used for data analysis or other project requirements. Knowledge of the decision support is derived from the World Health Organization (WHO) guidelines.

This is the type of CDSS that was envisaged for this study. Overall, a CDSS that is appropriate for low-income countries should be affordable, easy to use, scalable, customisable, interoperable, available offline, and localised to meet the needs of the local population (Jian et al., 2015). Key requirements identified in this study include user-friendly interfaces, context-specific content, integration with existing healthcare workflows, offline functionality, and training for healthcare providers.

Kabukye et al. (2020) conducted a study aimed at eliciting and prioritising requirements for Electronic Health Record systems (EHR) in oncology care in RLS. This digital medical information system stores patients' medical history in a systematic format. They are typically paired with CDSS, providing information readily available to healthcare providers. EHR systems also offer reporting and insights into the data that is retained. The authors used concept mapping as an interactive technique for eliciting and prioritising EHR requirements from stakeholders in at least 11 low- and middle-income African countries, where healthcare faces poor infrastructure and limited access to electronic healthcare systems. Physicians, nurses, and other healthcare practitioners generated and grouped ideas that represented their needs and expectations. Some of the identified requirements were comprehensive patient records, usability, clinical decision support, integration with laboratory and radiology systems, and flexibility to accommodate the local environment.

A study by Joukes et al. (2016) investigated the implementation of a new Electronic Health Record (EHR) system in two university hospitals in the Netherlands. The objective of the study was to determine the usability of the concept mapping method for collecting EHR requirements and understanding end-user stakeholders' expectations. Concept mapping was used to elicit end-user requirements. The method involved brainstorming sessions, clustering ideas, and ranking the feasibility and importance of the different requirements. Some of the identified

requirements included user-friendly interfaces, customisation options, support for other systems, reliable training programmes, and support for clinical workflow.

Jian et al. (2015) aimed to learn more about the difficulties encountered when implementing CDSS in areas with limited resources, as well as the benefits thereof. The objective was to determine whether the implementation and efficacy of these systems would have a positive impact on healthcare outcomes, despite the resource challenges that exist in RLS. The context for the study was developing countries with limited healthcare and technological infrastructure, where the demand for systems to aid clinical decision-making is high. The study emphasised the value of CDSS as a tool to assist healthcare practitioners in making evidence-based clinical decisions. A qualitative research design was used to evaluate the use of CDSS in developing countries. Literature review was conducted on CDSS implementation in various developing countries. The papers used were based on case studies and reports that documented the successes and pitfalls of such systems. A comparison of case studies from different developing nations was reviewed, with a view to establishing common factors that influence the success of CDSS. Literature that compared CDSS implementations in developing nations with those in more developed countries was also reviewed. This was done to highlight the differences and similarities in requirements and outcomes. Some critical prerequisites for the successful implementation of CDSS in developing countries were identified. These include user training and support, localisation and customisation, affordability and cost-effectiveness, compatibility with current infrastructure, and reliability and accuracy of data.

Timotijevic et al. (2020) conducted a study with the objective of creating a mobile health (mHealth) CDSS for the care management of Parkinson's disease (PD). This system was developed based on a deep understanding of user needs. The study focused on the care management of PD, and aimed to design a CDSS that could be used in various settings, such as home care. The authors employed a user-centered design approach, merging theoretical models and empirical research to guide the identification of user needs. These included literature reviews, stakeholder interviews, and repeated prototype testing. Requirements that were clarified included personal care plans, integration of wearable devices, real-time data tracking, patient engagement features, and ease of use for both patients and caregivers.

Participants in these studies also highlighted money, infrastructure (power and computer networks), managers' positive attitudes, the system's usability, and stakeholder involvement as other requirements that are related to the business or environment rather than the CDSS. These business and environmental requirements are crucial for the successful deployment

and use of the CDSS in addition to having a system that satisfies the functional requirements. In RLS, they might pose a significant obstacle and so need to be prioritised.

The identified requirements from each study were analysed to find common themes. The recurring themes across the studies were user-friendly interfaces, integration with existing systems, and context-specific content. They were also grouped into categories such as technical (e.g., system integration, offline functionality), user-centric (e.g., ease of use, customisation, training), and context-specific (e.g., local adaptability, support for specific diseases). In this way, a robust and contextually appropriate set of requirements was developed. This approach ensures that the requirements identification process is comprehensive and well-aligned with the specific challenges and opportunities of the healthcare environment of this study.

Table 4.1 shows the essential aspects and scope covered by the selected papers for CDSS requirements.

Table 4.1: Aspects and scope of the selected papers for CDSS requirements

Study	Context	Type of Healthcare System	Functional Requirements	Non-Functional Requirements
Blank et al. (2013)	RLS (Sub-Saharan Africa)	CDSS for prenatal care	- Context-specific content - Offline functionality	- User-friendly interface - Integration with existing workflows - Training for healthcare providers
Kabukye et al. (2020)	RLS	EHR for Oncology care	- Comprehensive patient records - Integration with lab/radiology systems - Support for clinical decision-making	- Ease of use - Adaptability to local context
Joukes et al. (2016)	High-Income country	EHR for General healthcare	- Customizable system - Interoperability with other systems - Support for clinical workflows	- User-friendly interface - Robust training programs - Alignment with user expectations
Timotijevic et al. (2020)	High-Income country	CDSS for Parkinson's disease management	- Personalised care plans - Real-time data monitoring - Integration with wearable devices	- Ease of use for patients and caregivers - Patient engagement features

Jian et al. (2015)	RLS	CDSS for General healthcare	- CDSS tailored to local health conditions - Data accuracy and reliability - Integration with existing systems	- Affordability - Customisation and localisation - Infrastructure compatibility

4.1.1 Identified Requirements

The identified functional and non-functional requirements were adapted from the set of requirements identified in the five selected articles. Table 4.2 shows the functional requirements that are categorised into gait analysis, general CDSS functionalities, and decision support. Table 4.3 shows the non-functional requirements, which include security and usability.

Table 4.2: Functional CDSS requirements adapted from selected papers

	Functional Requirements	Adapted from
Id	**Gait analysis**	
G1	The symptom outputs need to be in a graphical format	Timotijevic et al. (2020)
G2	The capability for the identification and comparison of changes in symptoms over time	Timotijevic et al. (2020)
G3	The provision of video capture data to observe uncontrolled patients' movements	Timotijevic et al. (2020)
G4	The provision for flexibility when a clinician with patient determines which symptoms and data collection options are most suitable for a particular patient leading to an integrated data output	Timotijevic et al. (2020)
G5	The need to provide clinicians and caregivers with data on the patient's adherence to pharmacological and supporting therapy care plans over time in a preferred language	Timotijevic et al. (2020)
G6	The need for Integration with existing healthcare infrastructure and complementary local healthcare ecosystem so that the clinician and patient caregiver can have access to an up-to-date list all other treatment plan of the patient	Timotijevic et al. (2020)
G7	The need for effective monitoring of the step-by-step changes made to pharmacological care plans of a patient during face-to-face and remote consultations to determine if the outcome of the change has been positive or negative.	Timotijevic et al. (2020)

G8	The need for clinicians and patient caregivers to have offline access to patient data while at home or away from the hospital environment	Timotijevic et al. (2020)
G9	The clinician should be able to prescribe supportive therapies that patients can engage with at home in their own time (including cognitive activities, speech and nutritional activities, and gamification of physiotherapy).	Timotijevic et al. (2020)
G10	The need for a communication platform that enables information sharing and alerts between clinicians during patient care	Timotijevic et al. (2020)
G11	The need to alert patients and caregivers on time to take their medication.	Timotijevic et al. (2020)
Id	**General CDSS functionalities**	
C1	The need to provide thorough routine Clinical Documentation that includes patient personal and demographics data, medical history, and treatment plans.	Kabukye et al. (2020)
C2	The need for accurate and comprehensive patient identification using biometrics and personal contact information details.	Kabukye et al. (2020)
C3	The ability to enable the scheduling of patient appointments and follow-up visits (e.g. when to come for physiotherapy and other follow-up checks)	Kabukye et al. (2020)
C4	The ability to ensure thorough and accurate record keeping of medications in terms of when they are prescribed, dispensed and stopped, and tracking of cumulative doses.	Kabukye et al. (2020)
C5	The need for data quality control mechanisms such as ensuring that all mandatory fields are provided and in the correct input format during data entry into the system.	Kabukye et al. (2020)
C6	The capacity for inventory Tracking for equipment, drugs, and supplies related to patient care.	Kabukye et al. (2020)
C7	The need for patient reminders in the form of visual aids, icons, and audio cues so that appointments and follow-up are not missed.	Kabukye et al. (2020)
C8	The provision of offline access for patients to make appointments so that patients can participate in their care (e.g. make appointments, get care instructions, report symptoms/side effects) even without internet such offline request should store locally on the system (logged) and delivered when internet connectivity is available.	Kabukye et al. (2020)
Id	**Decision support**	

D1	The need for computerised clinical decision support including scheduling, assigning diagnosis, alerts and warnings during prescription, and enforcing quality operational assurance (such as a rule that disallows prescribing without providing a diagnosis).	Kabukye et al. (2020)
D2	The need to enable uploading and storage of disease-specific documentation (e.g. diagnosis, risk factors, therapy details including side effects.	Kabukye et al. (2020)
D3	The need for the system to incorporate specific care/ treatment protocols and guidelines in its operations.	Blank et al. (2013), Jian et al. (2015)

Table 4.3: Non-functional CDSS requirements adapted from selected papers

	Non-Functional Requirements	Adapted from
Id	**Security**	
S1	The need for robust security authentication and authorisation features that enable verification of usernames and passwords, and user access levels.	Kabukye et al. (2020)
S2	The need for data backup capability that copies data to a cloud storage server daily.	Kabukye et al. (2020)
S3	The need to ensure changes to information or rules can only be made by authorised people, at the same time keeping an audit trail/log of all the changes made.	Kabukye et al. (2020)
Id	**Usability**	
U1	The need for quick and easy data entry features using appropriate form widgets such as dropdown menus, dropdown lists, checkboxes, and option buttons.	Kabukye et al. (2020), Joukes et al. (2016)
U2	The design of the system interface should be user-friendly, affording easy login, none/minimal password management complexity, eliminating redundancy (possibility to skip irrelevant (non-required) fields).	Kabukye et al. (2020)
U3	The need for a user interface that is simple and enables the logical flow and presentation of information to be done intuitively (viz. enabling the logical presentation of information on patient's registration, medical history, and clinician's diagnosis).	Kabukye et al. (2020), Blank et al. (2013)
U4	The need to provide multiple and multimodal data entry options such as text (keyboard), touch screen, voice, and barcode readers.	Kabukye et al. (2020)
U5	The need to support ubiquitous (remote and offsite) access by doctors while away from the office/hospital environment.	Kabukye et al. (2020)
U6	The need to support multiple local (native) languages spoken in the region where the system is deployed	Blank et al. (2013)
U7	The need for a user interface that friendly, intuitive and simple for non-literate persons to use.	Joukes et al. (2016), Jian et al. (2015)

4.2 Requirements Prioritisation (RP)

Numerous techniques for prioritising requirements have been developed, some of which are better suited to projects with a limited number of requirements while others are better suited to projects with multiple decision-makers and factors.

Berander et al. (2006) explained that prioritisation techniques assist decision-makers in examining needs and allocating numbers or symbols that reflect their importance. Budget, time, resources, technological limitations, the requirement for professional skills to apply these strategies, and the necessity to meet the expectations of the clients are only a few of the difficulties these techniques must overcome.

Hudaib et al. (2018) added that techniques for prioritising requirements rely on subject-matter specialists, require extensive engagement with stakeholders, and can be reliant on other requirements. This makes the task of suggesting the proper approach more challenging.

4.2.1 Selection of Prioritisation Technique: Suggestion (Phase 2)

Mead (2006) contended that some potential prioritising strategies need to be compared using certain evaluation criteria. Below are some examples of comparison criteria to help developers reach a recommendation to use a specific technique:

i. Steps that are clearly defined: The prioritising process has distinct phases or steps.
ii. Quantitative measurement: The numerical output of the prioritising approach makes the client's priorities for every requirement clear.
iii. High maturity: The technique has received a lot of exposure and study in the community of RE.
iv. Low labour intensity: The prioritising approach may be correctly carried out in a reasonable amount of time.
v. Shallow learning curve: It should not take long for stakeholders and requirements engineers to completely understand the process.

A comparative study by (Hudaib et al., 2018) identified the following prioritisation techniques as the most common or popular being used:

i. Numerical assignment (grouping)
ii. MoSCoW
iii. Priority groups
iv. Bubble sort

v. BST
vi. Analytic Hierarchy Process (AHP)
vii. Hundred dollar
viii. Minimal spanning tree

A general model developed to determine the best-suited prioritization technique for a specific project identified the following factors (Hudaib et al., 2018):

i. Ease of use
ii. Speed of results
iii. Size of requirement set
iv. Accuracy of results
v. Level of stakeholder involvement

Table 4.4 is a summary of the suitability of different prioritisation techniques based on different relevant criteria, as derived from the findings of the comparative study by Hudaib et al. (2018). The values for the ‘ease of use’ factor range from 1 to 8, where the smaller the number, the higher the degree of ease. The values for the ‘speed of results’ factor range from 1 to 8, where the smaller the number, the faster the speed to obtain results. The accuracy of a technique is measured as being high, medium, or low when compared to other techniques. Stakeholder involvement is categorised into three levels of participation: low, medium and high. The columns for the size of the requirements sets indicate whether a technique is best suited for a large, medium or small number of requirements.

Table 4.4: Summary of the suitability of prioritisation techniques based on key criteria

Prioritisation Technique	Ease of use	Speed of results	Accuracy of results	Size of requirements set	Stakeholder involvement
AHP	8	8	medium	small	high
Hundred dollar	5	3	high	small	high
Numerical assignment	2	1	low	small	high
MoSCoW	1	2	medium	Small, medium	high
Priority group	3	4	medium	small	high
Bubble sort	6	6	low	small, medium	medium
BST	4	5	high	small, medium, large	medium
Minimal spanning tree	7	7	low	medium, large	low
Data mining	8	7	high	medium, large	medium

In one comparative study by Vestola (2010), the author referenced two other comparative studies with conflicting results for the effectiveness of the MoSCoW technique when the number of requirements is low (20 or less). While one study found MoSCoW ineffective when dealing with small numbers of requirements, the other showed that users had the most faith in it because it was the simplest and fastest. The author also noted that MoSCoW is probably most effective when applied in the early phases of projects when requirements are less well-defined.

Wohlin and Aurum (2005) prescribe a general rule that one should use the simplest applicable prioritising approach and use more complex ones when a more sensitive analysis is required to resolve disputes or to support the most important decisions. The simplest approach provides cost-effective decisions since more complex procedures often take more time.

Many comparative studies of requirements prioritisation techniques noted that MoSCoW can help identify essential features that need to be included in the system, which is critical in low-resource settings. These studies provide evidence that MoSCoW is a useful and simple technique for prioritising software requirements for projects with limited resources and time. A review of the comparative studies also shows that MoSCoW can provide adequately accurate results for the small to medium-sized requirements set identified in this study. In RLS, the prioritisation of requirements using the MoSCoW method can help ensure that the most critical and relevant requirements are identified and addressed first.

4.2.2 MoSCoW Prioritisation Technique

The outcomes of the MoSCoW prioritisation technique fall under the nominal scale. This method separates the requirements into four categories, as described by Hudaib et al. (2018) in Table 4.5.

Table 4.5: MoSCoW prioritisation categories

Priority	Description
Must Have	Fundamental requirements that are essential for the product to function. The success of the product depends on these items. Without them, the project will be useless.
Should Have	Important requirements but without them, the product is still usable. They can enhance the value of the product but not necessarily its basic functionality.
Could Have	Negotiable requirements. They are considered nice to have but not urgent. They can be implemented if time and resources permit.
Won't Have	These requirements are considered not important, urgent or necessary. They don't provide any measurable value to the project and excluding these components won't jeopardise the project's success. They could be implemented in future releases or not at all.

4.3 Prioritisation Process: Development (Phase 3):

Experts in the fields of gait analysis (GA), physiology, biomechanics, physiotherapy or neuro-mechanics were required to apply the MoSCoW prioritisation technique to the identified set of requirements. Several researchers, practitioners, and academics in the fields were approached and six agreed to participate. Only five completed the task. Table 4.6 presents a summary of the roles and fields of interest/expertise of the participants.

Table 4.6: Overview of fields of experience of experts

Respondent	Role	Summary of role
R1	human movement scientist at Stellenbosch University in the Neuromechanics Unit	Completed their Master of Science in Sports Science (cum laude) in running biomechanics and gained extensive experience using modern motion capture technologies. Focused on biomechanics and motion data.
R2	physiotherapy academic at Stellenbosch University	Has skills and expertise in physical rehabilitation and musculoskeletal disorders.
R3	academic at the University of Pretoria and also a physiotherapist	Has a special interest in biomechanics, prevention, assessment, and treatment of sports and musculoskeletal injuries.
R4	academic at Victoria University in Australia	Holds a PhD in Sports Science. Has a special focus on biomechanics of musculoskeletal disorders and human movement.
R5	academic at the University of Pretoria	Has experience in biomechanics, exercise physiology, and GA in a sports performance setting.

The list of requirements to be prioritised was delivered to respondents electronically via the Internet. This method was chosen because it is fast and inexpensive to conduct. Respondents could complete the ranking at a time that is convenient for them. It also ensures no personal contact between the researcher and the respondents, which complies with current pandemic safety protocols.

Table 4.7 shows a sample of the MoSCoW prioritisation responses for all the identified functional requirements that were provided to the participants. Table 4.8 shows a sample of the prioritisation responses for all the identified non-functional requirements. Additionally, participants were requested to suggest any other requirements which they felt should have been included in the list provided to them. None of the participants provided any additional requirement statements. No weighting factor was applied to any of the participants' responses in the decision-making process.

Table 4.7: Sample of MoSCoW prioritisation responses for functional requirements

	Functional Requirements				
Id	**Gait analysis**	**Must have**	**Should have**	**Could have**	**Won't have**
G1	The CDSS shall present the symptom outputs in simple and understandable graphical format.		YES		
G2	The CDSS shall make it easy to track and compare symptom changes over time, with the ability to explore specific time periods based on the patient's needs.	YES			
G3	The CDSS shall possess video capture features that enable monitoring of uncontrolled movements of patients.	YES			
G4	The CDSS user interface shall allow the clinician and the patient to collaboratively determine which symptoms and data collection options are most suitable for the patient, leading to an integrated data output.		YES		
G5	The CDSS shall enable the clinician and caregiver to gain access to data on the patient's adherence to pharmacological and supporting therapy care plans over time, in a preferred language.			YES	
G6	The CDSS shall be integrated with existing healthcare infrastructure and complementary local healthcare ecosystem so that the clinician and patient caregiver can have access to an up-to-date list of all other treatment plans of the patient. For example, a physiotherapist should be able to see the occupational therapy plans that had been prescribed for the patient and on that basis gain a better understanding of the overall care being provided by the multidisciplinary team (MDT).		YES		
G7	The CDSS shall enable effective monitoring of the step-by-step changes made to pharmacological care plans of a patient during face-to-face and remote consultations to determine if the outcome of the change has been positive or negative.		YES		
G8	The CDSS shall allow clinician and patient caregiver to have offline access to patient data			YES	

	while at home, and away from the immediate hospital environment.				
G9	The CDSS shall enable the clinician to prescribe supportive therapies that patients can engage with at home in their own time (including cognitive activities, speech and nutritional activities, and gamification of physiotherapy).			YES	
G10	The CDSS shall have a communication platform that enables information sharing and alerts between clinicians during patient care.		YES		
G11	The CDSS shall be capable of notifying patients and caregivers when it is time to take their medication.			YES	
Id	**General CDSS functionalities**	**Must have**	**Should have**	**Could have**	**Won't have**
C1	The CDSS shall enable comprehensive routine Clinical Documentation that includes patient personal and demographics data, medical history, and treatment plans.	YES			
C2	The CDSS shall enable accurate and comprehensive patient identification through the use of biometrics and personal contact information details.	YES			
C3	The CDSS shall ensure the scheduling of patient appointments and follow-up visits (e.g. when to come for physiotherapy and other follow-up checks).			YES	
C4	The CDSS shall ensure thorough and accurate record keeping of medications in terms of when they are prescribed, dispensed and stopped, and tracking of cumulative doses.		YES		
C5	The CDSS shall possess data quality control mechanisms such as ensuring that all mandatory fields are provided and in the correct input format during data entry into the system.	YES			
C6	The CDSS shall be able to track the inventory of equipment, drugs, and other vital supplies related to patient care.				YES
C7	The CDSS shall be able to provide patient reminders in the form of visual aids, icons, and audio cues so that appointments and follow-up are not missed.			YES	

C8	The CDSS shall provide offline access for patients to make appointments so that patients can participate in their care (e.g. make appointments, get care instructions, report symptoms/side effects) even without internet connectivity. Such offline requests should be stored locally on the system (logged) and delivered when internet connectivity is available.			YES	
Id	**Decision support**	**Must have**	**Should have**	**Could have**	**Won't have**
D1	The CDSS shall provide computerised clinical decision support including scheduling, assigning diagnosis, alerts and warnings during prescription, and enforcing quality operational assurance (such as a rule that disallows prescribing without providing a diagnosis)		YES		
D2	The CDSS shall enable uploading and storage of disease-specific documentation (e.g. diagnosis, risk factors, therapy details including side effects).	YES			
D3	The CDSS shall incorporate specific care/treatment protocols and guidelines in its operations.			YES	

Table 4.8: Sample of MoSCoW prioritisation for non-functional requirements

	Non-Functional Requirements				
Id	**Security**	**Must have**	**Should have**	**Could have**	**Won't have**
S1	The CDSS shall have robust security authentication and authorisation features that enable verification of usernames and passwords, and user access levels.	YES			
S2	The CDSS shall possess data backup capability that enables data to be copied to a cloud storage server daily.	YES			
S3	The CDSS shall ensure that changes to information or rules can only be made by authorised persons, at the same time keeping an audit trail/log of all the changes made.	YES			
Id	**Usability**	**Must have**	**Should have**	**Could have**	**Won't have**
U1	The CDSS shall enable quick and easy data entry using appropriate form widgets such as dropdown menus, dropdown lists, checkboxes, and option buttons.	YES			
U2	The CDSS's interface shall be user-friendly, affording easy login, no/minimal password management complexity, and eliminating redundancy (it should be possible to skip irrelevant, and non-essential fields).	YES			
U3	The CDSS shall have a user interface that is simple and enables the logical flow and presentation of information to be done intuitively (viz. enabling the logical presentation of information patient's registration, medical history, and clinician's diagnosis).	YES			
U4	The CDSS shall provide multiple and multimodal data entry options such as text (keyboard), touch screen, voice, and barcode readers.			YES	
U5	The CDSS shall enable ubiquitous (remote and offsite) access by doctors while away from the office/hospital environment.		YES		
U6	The CDSS shall support multiple local (native) languages spoken in the region where the system is deployed			YES	

U7	The CDSS shall have a user interface that friendly, intuitive and simple for non-literate persons to use.	YES			

4.4 Results of Requirements Prioritisation Process

Tables 4.9 and 4.10 show the MoSCoW prioritisation responses of each of the respondents for the functional requirements and the non-functional requirements. Each of the respondents is labelled as R1, R2, etc.

Table 4.9: Prioritisation responses of experts for functional requirements

Id	Functional Requirements	Respondents				
	Gait analysis	**R1**	**R2**	**R3**	**R4**	**R5**
G1	The CDSS shall present the symptom outputs in simple and understandable graphical format.	MH	MH	MH	SH	SH
G2	The CDSS shall make it easy to track and compare symptom changes over time, with the ability to explore specific time periods based on the patient's needs.	SH	SH	MH	CH	MH
G3	The CDSS shall possess video capture features that enable monitoring of uncontrolled movements of patients.	MH	MH	MH	CH	MH
G4	The CDSS user interface shall allow the clinician and the patient to collaboratively determine which symptoms and data collection options are most suitable for the patient, leading to an integrated data output.	CH	SH	SH	CH	SH
G5	The CDSS shall enable the clinician and caregiver to gain access to data on the patient's adherence to pharmacological and supporting therapy care plans over time, in a preferred language.	SH	CH	SH	SH	CH
G6	The CDSS shall be integrated with existing healthcare infrastructure and complementary local healthcare ecosystem so that the clinician and patient caregiver can have access to an up-to-date list of all other treatment plans of the patient. For example, a physiotherapist should be able to see the occupational therapy plans that had been prescribed for the patient and on that basis	SH	SH	SH	SH	SH

	gain a better understanding of the overall care being provided by the multidisciplinary team (MDT).					
G7	The CDSS shall enable effective monitoring of the step-by-step changes made to pharmacological care plans of a patient during face-to-face and remote consultations to determine if the outcome of the change has been positive or negative.	MH	CH	MH	SH	SH
G8	The CDSS shall allow clinician and patient caregiver to have offline access to patient data while at home, and away from the immediate hospital environment.	MH	SH	MH	SH	CH
G9	The CDSS shall enable the clinician to prescribe supportive therapies that patients can engage with at home in their own time (including cognitive activities, speech and nutritional activities, and gamification of physiotherapy).	SH	MH	CH	MH	CH
G10	The CDSS shall have a communication platform that enables information sharing and alerts between clinicians during patient care.	CH	CH	MH	MH	SH
G11	The CDSS shall be capable of notifying patients and caregivers when it is time to take their medication.	SH	CH	SH	SH	CH
	General CDSS functionalities	**R1**	**R2**	**R3**	**R4**	**R5**
C1	The CDSS shall enable comprehensive routine Clinical Documentation that includes patient personal and demographics data, medical history, and treatment plans.	SH	MH	MH	MH	MH
C2	The CDSS shall enable accurate and comprehensive patient identification using biometrics and personal contact information details.	SH	MH	SH	SH	MH
C3	The CDSS shall ensure the scheduling of patient appointments and follow-up visits (e.g. when to come for physiotherapy and other follow-up checks).	MH	CH	SH	MH	CH
C4	The CDSS shall ensure thorough and accurate record keeping of medications in terms of when they are prescribed, dispensed and stopped, and tracking of cumulative doses.	MH	CH	MH	MH	SH

C5	The CDSS shall possess data quality control mechanisms such as ensuring that all mandatory fields are provided and in the correct input format during data entry into the system.	MH	MH	MH	CH	MH
C6	The CDSS shall be able to track the inventory of equipment, drugs, and other vital supplies related to patient care.	CH	WH	CH	SH	WH
C7	The CDSS shall be able to provide patient reminders in the form of visual aids, icons, and audio cues so that appointments and follow-up are not missed.	SH	CH	SH	SH	CH
C8	The CDSS shall provide offline access for patients to make appointments so that patients can participate in their care (e.g. make appointments, get care instructions, report symptoms/side effects) even without internet connectivity. Such offline requests should be stored locally on the system (logged) and delivered when internet connectivity is available.	MH	SH	SH	SH	CH
	Decision support	**R1**	**R2**	**R3**	**R4**	**R5**
D1	The CDSS shall provide computerised clinical decision support including scheduling, assigning diagnosis, alerts and warnings during prescription, and enforcing quality operational assurance (such as a rule that disallows prescribing without providing a diagnosis)	SH	SH	SH	MH	SH
D2	The CDSS shall enable uploading and storage of disease-specific documentation (e.g. diagnosis, risk factors, therapy details including side effects).	SH	MH	SH	MH	MH
D3	The CDSS shall incorporate specific care/treatment protocols and guidelines in its operations.	SH	MH	CH	MH	CH
MH — “must-have”; SH— “should-have”; CH — “could-have” WH— “won't-have						

Table 4.10: Prioritisation responses of experts for non-functional requirements

Id	Non-Functional Requirements	Respondents				
	Security	**R1**	**R2**	**R3**	**R4**	**R5**
S1	The CDSS shall have robust security authentication and authorisation features that enable verification of usernames and passwords, and user access levels.	MH	SH	MH	SH	MH
S2	The CDSS shall possess data backup capability that enables data to be copied to a cloud storage server on a daily basis.	SH	MH	MH	SH	MH
S3	The CDSS shall ensure that changes to information or rules can only be made by authorised persons, at the same time keeping an audit trail/log of all the changes made.	MH	MH	MH	MH	MH
	Usability	**R1**	**R2**	**R3**	**R4**	**R5**
U1	The CDSS shall enable quick and easy data entry using appropriate form widgets such as dropdown menus, dropdown lists, checkboxes, and option buttons.	SH	MH	MH	SH	MH
U2	The CDSS's interface shall be user-friendly, affording easy login, no/minimal password management complexity, and eliminating redundancy (it should be possible to skip irrelevant, and non-essential fields).	MH	SH	MH	SH	MH
U3	The CDSS shall have a user interface that is simple and enables the logical flow and presentation of information to be done intuitively (viz. enabling the logical presentation of information patient's registration, medical history, and clinician's diagnosis).	MH	MH	MH	SH	MH
U4	The CDSS shall provide multiple and multimodal data entry options such as text (keyboard), touch screen, voice, and barcode readers.	CH	MH	MH	SH	CH
U5	The CDSS shall enable ubiquitous (remote and offsite) access by doctors while away from the office/hospital environment.	SH	MH	MH	SH	SH
U6	The CDSS shall support multiple local (native) languages spoken in the region where the system is deployed	MH	MH	MH	SH	CH
U7	The CDSS shall have a user interface that friendly, intuitive and simple for non-literate persons to use.	MH	MH	MH	SH	MH
MH — "must-have"; SH— "should-have"; CH — "could-have" WH—"won't-have						

After consolidating and analysing the identified and prioritised requirements, the aggregated prioritisation results were determined and are represented in Table 4.11 and Table 4.12. The majority rule was applied to assign priority to each requirement. This principle postulates that the decision selected is the one the majority of people endorse. The MoSCow categories were assigned an order of precedence. The precedence order ranging from highest to lowest priority is Must-have, then Should-have, followed by Could-have, and then Won't-have. In cases where there was an equal split between the priority responses for any requirement, the aggregated priority was promoted to the rating with the higher precedence. For example, if the priority ratings are split equally between "Should have" and "Could have", the aggregate priority rating assigned to the requirement would be "Should have", as it has higher precedence.

Table 4.11: Final set of prioritised functional requirements

Id	Functional Requirements	
	Gait analysis	**Decision**
G1	The CDSS shall present the symptom outputs in simple and understandable graphical format.	**MUST HAVE**
G2	The CDSS shall make it easy to track and compare symptom changes over time, with the ability to explore specific time periods based on the patient's needs.	**MUST HAVE**
G3	The CDSS shall possess video capture features that enable monitoring of uncontrolled movements of patients.	**MUST HAVE**
G4	The CDSS user interface shall allow the clinician and the patient to collaboratively determine which symptoms and data collection options are most suitable for the patient, leading to an integrated data output.	**SHOULD HAVE**
G5	The CDSS shall enable the clinician and caregiver to gain access to data on the patient's adherence to pharmacological and supporting therapy care plans over time, in a preferred language.	**SHOULD HAVE**
G6	The CDSS shall be integrated with existing healthcare infrastructure and complementary local healthcare ecosystem so that the clinician and patient caregiver can have access to an up-to-date list of all other treatment plans of the patient. For example, a physiotherapist should be able to see the occupational therapy plans that had been prescribed for the patient and on that basis gain a better understanding of the overall care being provided by the multidisciplinary team (MDT).	**SHOULD HAVE**
G7	The CDSS shall enable effective monitoring of the step-by-step changes made to pharmacological care plans of a patient during face-to-face and remote consultations to determine if the outcome of the change has been positive or negative.	**MUST HAVE**
G8	The CDSS shall allow clinician and patient caregiver to have offline access to patient data while at home, and away from the immediate hospital environment.	**MUST HAVE**

G9	The CDSS shall enable the clinician to prescribe supportive therapies that patients can engage with at home in their own time (including cognitive activities, speech and nutritional activities, and gamification of physiotherapy).	**MUST HAVE**
G10	The CDSS shall have a communication platform that enables information sharing and alerts between clinicians during patient care.	**MUST HAVE**
G11	The CDSS shall be capable of notifying patients and caregivers when it is time to take their medication.	**SHOULD HAVE**
	General CDSS functionalities	**Decision**
C1	The CDSS shall enable comprehensive routine Clinical Documentation that includes patient personal and demographics data, medical history, and treatment plans.	**MUST HAVE**
C2	The CDSS shall enable accurate and comprehensive patient identification through the use of biometrics and personal contact information details.	**SHOULD HAVE**
C3	The CDSS shall ensure the scheduling of patient appointments and follow-up visits (e.g. when to come for physiotherapy and other follow-up checks).	**MUST HAVE**
C4	The CDSS shall ensure thorough and accurate record keeping of medications in terms of when they are prescribed, dispensed and stopped, and tracking of cumulative doses.	**MUST HAVE**
C5	The CDSS shall possess data quality control mechanisms such as ensuring that all mandatory fields are provided and in the correct input format during data entry into the system.	**MUST HAVE**
C6	The CDSS shall be able to track the inventory of equipment, drugs, and other vital supplies related to patient care.	**COULD HAVE**
C7	The CDSS shall be able to provide patient reminders in the form of visual aids, icons, and audio cues so that appointments and follow-up are not missed.	**SHOULD HAVE**
C8	The CDSS shall provide offline access for patients to make appointments so that patients can participate in their care (e.g. make appointments, get care instructions, report symptoms/side effects) even without internet connectivity. Such offline requests should be stored locally on the system (logged) and delivered when internet connectivity is available.	**SHOULD HAVE**
	Decision support	**Decision**
D1	The CDSS shall provide computerised clinical decision support including scheduling, assigning diagnosis, alerts and warnings during prescription, and enforcing quality operational assurance (such as a rule that disallows prescribing without providing a diagnosis)	**SHOULD HAVE**
D2	The CDSS shall enable uploading and storage of disease-specific documentation (e.g. diagnosis, risk factors, therapy details including side effects).	**MUST HAVE**
D3	The CDSS shall incorporate specific care/treatment protocols and guidelines in its operations.	**MUST HAVE**

Table 4.12: Final set of prioritised non-functional requirements

Id	Non-Functional Requirements	
	Security	**Decision**
S1	The CDSS shall have robust security authentication and authorisation features that enable verification of usernames and passwords, and user access levels.	**MUST HAVE**
S2	The CDSS shall possess data backup capability that enables data to be copied to a cloud storage server daily.	**MUST HAVE**
S3	The CDSS shall ensure that changes to information or rules can only be made by authorised persons, at the same time keeping an audit trail/log of all the changes made.	**MUST HAVE**
	Usability	**Decision**
U1	The CDSS shall enable quick and easy data entry using appropriate form widgets such as dropdown menus, dropdown lists, checkboxes, and option buttons.	**MUST HAVE**
U2	The CDSS's interface shall be user-friendly, affording easy login, no/minimal password management complexity, and eliminating redundancy (it should be possible to skip irrelevant, and non-essential fields).	**MUST HAVE**
U3	The CDSS shall have a user interface that is simple and enables the logical flow and presentation of information to be done intuitively (viz. enabling the logical presentation of information patient's registration, medical history, and clinician's diagnosis).	**MUST HAVE**
U4	The CDSS shall provide multiple and multimodal data entry options such as text (keyboard), touch screen, voice, and barcode readers.	**MUST HAVE**
U5	The CDSS shall enable ubiquitous (remote and offsite) access by doctors while away from the office/hospital environment.	**MUST HAVE**
U6	The CDSS shall support multiple local (native) languages spoken in the region where the system is deployed	**MUST HAVE**
U7	The CDSS shall have a user interface that friendly, intuitive and simple for non-literate persons to use.	**MUST HAVE**

Table 4.11 reveals that most of the requirements in the Gait Analysis category are "must have," with a few "should have" and no "could have" requirements. There is a more balanced priority distribution in the General CDSS Functionalities category, with more "must have" requirements, several "should have" requirements, and one "could have" requirement. In the Decision Support category, the priority is mainly "must have", a single "should have" requirement, with no "could have" requirements. In Table 4.12, the unanimous assignment of "must have" priorities in the "Security" and "Usability" categories, emphasises the critical importance of all the listed requirements.

4.5 Summary

This chapter described the research activities that were conducted within the framework of DSR. A literature analysis was conducted to investigate and understand the identification of functional and non-functional requirements for a CDSS designed for treating gait-related diseases in RLS. Literature analysis was also used for comparative analysis in identifying a suitable RP technique. Experts in GA, physiology, biomechanics, physiotherapy, and neuro-mechanics applied the selected prioritisation technique to the identified set of requirements.

CHAPTER 5: EVALUATION OF QUALITY OF REQUIREMENTS

This chapter presents phase 4 of the DSR process. Software development experts were requested to evaluate the quality of the set of prioritised requirements. They based their evaluation on attributes derived from established quality models.

5.1 Evaluation of Quality of Requirements: Phase 4

Software development projects' success and failure depend largely on the quality of requirements (Tamai and Kamata, 2009). Software development experts were asked to evaluate the quality of the prioritised requirements as shown in Tables 4.11 and 4.12. Measuring the quality of the requirements is a complex and difficult task and it is therefore recommended that prescribed quality models be used (Saavedra et al., 2013). Combining aspects of Wiegers model (Wiegers, 1999) and Pohl model (Pohl, 2010), a set of quality attributes was developed for determining the quality of the requirements in the study. The quality attributes used for the individual requirements evaluation are listed in Table 5.1, and the ones used for the set of requirements are listed in Table 5.2.

Table 5.1: Quality attributes for evaluating individual requirement statements

Criterion	Description
Complete	Each requirement must fully describe the functionality to be delivered.
Traceable	Each requirement must have a unique identifier for ease of referencing.
Correct	Each requirement contributes to a particular need of the system.
Unambiguous	Each requirement statement should be understood in a single, consistent way by all readers.
Comprehensible	The content of each requirement is easily understandable.
Consistent	There should not be any conflict or contradictions between requirements.
Verifiable	It should be possible to determine or test whether each requirement is properly implemented in the system.
Prioritised	Each requirement must be rated to show how essential it is to the implementation of the product.
Atomic	Each requirement represents a single, logical fact.

Table 5.2: Quality attributes for evaluating the set of requirements statements

Criterion	Description
Completeness	All requirements and necessary information must be present in the set.
Traceability	Each requirement in the set can be traced back to its origin and forwarded to processes that verify its correct implementation.
Modifiability	Each requirement in the set must be atomic and uniquely identified to facilitate any modification of the requirements.
Readability	The set of requirement statements is readable and understandable.
Consistency	The requirements in the set are consistently defined and do not conflict with business-level requirements sets or system or user requirements sets.

A group of software development experts evaluated the quality of the prioritised requirements. The roles and work experience of the experts are presented in Table 5.3.

Table 5.3: Profiles of software development experts

	Employment role/position	Years of professional working experience	Years of experience in RE
Expert A	Senior Software Developer	15	15
Expert B	Software Developer	10	8
Expert C	Software Developer	12	10
Expert D	Technology consultant	11	8
Expert E	quality assurance engineer	10	9
Expert F	Lead developer	8	7
Expert G	Senior Data Engineer	13	10

The experts were presented with an evaluation document to be used to rate the prioritised requirements individually and as a set. The contents of the document are shown in Table 5.4 and Table 5.5.

Table 5.4: Requirements quality evaluation document for individual requirements

Evaluation of individual requirements						
Criterion	**Description**	**Excellent(5)**	**Good(4)**	**Average(3)**	**Poor(2)**	**Very poor(1)**
Complete	Each requirement for the CDSS fully describes the functionality to be delivered.					
Traceable	Each requirement for the CDSS has a unique identifier for ease of referencing.					
Correct	Each requirement for the CDSS contributes to a particular need of the system.					
Unambiguous	Each requirement statement for the CDSS should be understood in a single, consistent way by all readers.					
Comprehensible	The content of each requirement for the CDSS is easily understandable.					
Consistent	There should not be any conflict or contradictions between requirements for the CDSS.					
Verifiable	It should be possible to determine or test whether each requirement for the CDSS is properly implemented in the system.					
Prioritised	Each requirement for the CDSS must be rated to show how essential it is to the implementation of the product.					
Atomic	Each requirement for the CDSS represents a single, logical fact.					

Table 5.5: Requirements quality evaluation document for the set of requirements

Evaluation of requirements set						
Criterion	**Description**	**Excellent(5)**	**Good(4)**	**Average(3)**	**Poor(2)**	**Very poor(1)**
Completeness	All requirements for the CDSS and necessary information are present in the set.					
Traceability	Each requirement for the CDSS in the set can be traced back to its origin and forwarded to processes that verify its correct implementation.					
Modifiability	Each requirement for the CDSS in the set is atomic and uniquely identified to facilitate any modification of the requirements.					
Readability	The set of requirement statements for the CDSS is readable and understandable.					
Consistent	The requirements for the CDSS in the set are consistently defined and do not conflict with business-level requirements sets or system or user requirements sets.					

5.2 Results of Quality Evaluation

The evaluation documents were sent to seven software development experts, but only five completed the task. The evaluation of the quality of the requirements, as performed by these experts, is shown in Tables 5.6 and 5.7. A Likert scale rating system was used, with rating values ranging from 5 (excellent) to 1 (very poor). The aggregated rating was determined by calculating the average of the values scored per criterion.

Table 5.6: Results of evaluation of individual requirements

Results of Evaluation of Individual Requirements						
Criterion	**Expert A**	**Expert B**	**Expert C**	**Expert D**	**Expert E**	**Average rating**
Complete	4	4	5	5	4	4
Traceable	5	5	5	5	5	5
Correct	4	5	4	5	5	5
Unambiguous	3	4	4	5	4	4
Comprehensible	4	4	5	4	4	4
Consistent	4	5	5	5	5	5
Verifiable	5	5	5	5	5	5
Prioritised	5	5	5	5	5	5
Atomic	4	4	5	5	5	5

The ratings by experts are consistent for the most part across most criteria. Criteria like "Traceable", "Verifiable", and "Prioritised", all have a top rating of 5 by the experts. There are slight differences in ratings for criteria like "Complete", "Correct", "Unambiguous", and "Comprehensible". For instance, "Unambiguous" has a rating of 3 from one expert, indicating some difference of opinion on this criterion. The average scores concur with the individual expert scores, indicating that the overall perception of each criterion is the same for all the experts. The criteria that were evaluated tended to be given high scores on average, indicating a positive review of the requirements based on being complete, correct, traceable, and other quality attributes. These comments indicate that the requirements tend to receive very high approval from the experts with slight differences in certain areas. One of the experts noted that there ought to be additional security requirements aimed at guaranteeing the integrity and confidentiality of individuals' personal data.

Table 5.7: Results of evaluation of requirements set

Results of Evaluation of Requirements Set						
Criterion	**Expert A**	**Expert B**	**Expert C**	**Expert D**	**Expert E**	**Average rating**
Completeness	4	5	5	4	5	5
Traceability	4	5	5	5	5	5
Modifiability	5	4	4	5	5	5
Readability	5	5	5	5	5	5
Consistent	5	5	5	5	4	5

"Traceability," "Readability," and "Modifiability" were rated unanimously high by the experts. Experts A and D rated "Completeness" slightly lower (4) than the rest. Expert E scored a lower rating (4) for "Consistent", showing some slight uncertainty on that criterion. "Readability" was highly rated, with all the experts giving a score of 5, indicating that the requirements are presented well and are easy to read. All the criteria have an average score of 5 across the board, which implies that the experts consider the requirements set to be of good quality. These results suggest that the requirements set is rated positively, with minor variations in completeness and consistency.

5.3 Summary

In this chapter, an explanation of the evaluation criteria was provided, with a description of how they were used to evaluate the quality of the prioritised requirements. Overall, the quality of the requirements received an excellent or good rating. The set of requirements could therefore be included as part of the specifications in future related studies.

CHAPTER 6: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

An overview of the research activities completed to achieve the study's objectives is presented. This chapter summarises the findings, highlights the contributions, and proposes future research directions.

6.1 Research Summary

Chapter 1 provides background to the research area, gait analysis (GA), requirements elicitation, requirements prioritisation (RP), and resource-limited settings (RLS). The chapter explained the benefits of using Clinical Decision Support Systems (CDSS) in healthcare. The chapter highlighted the importance of identifying and prioritising requirements in CDSS design and development. The importance of requirements identification and prioritisation for implementing CDSS, particularly in RLS, was discussed and explored. The study aims to determine the effectiveness and efficiency of an RP process for a CDSS addressing gait-related diseases in RLS. Based on this, a problem statement, objectives, and research questions were formulated.

Chapter 2 reviews relevant literature. It emphasises the significance of CDSS and their use in RLS to improve healthcare for conditions associated with atypical gait. The importance of requirements engineering (RE) in the software development process is explained.

The research methodology used in the study was presented in Chapter 3, which includes philosophy, approach, methods, and design. All ethical considerations were strictly adhered to, to ensure the confidentiality and integrity of the participants throughout the research.

Chapter 4 focusses on identifying and prioritising requirements for CDSS for gait-related diseases for RLS. The first step was a literature review to identify prominent functional and non-functional requirements of CDSS derived from studies on implementation of CDSS in low-income countries. Prioritisation techniques were evaluated in the second phase. The chapter concluded with experts in gait analysis, biomechanics, and physiotherapy applying the MoSCoW prioritisation process to the identified requirements.

Chapter 5 describes the evaluation of the prioritised requirements. After aggregating the results of the MoSCoW prioritization process, software development practitioners were asked to rate the quality of the requirements. The evaluation was based on attributes of the quality models proposed by Wiegers (Wiegers, 1999) and Pohl (Pohl, 2010).

The following research objectives were achieved in the study:

Objective 1: Identify the requirements for a CDSS for gait-related diseases in RLS.

A literature review was performed to identify functional and non-functional requirements. The researcher analysed five studies relevant to electronic healthcare systems in RLS. Blank et al. (2013) emphasised the need for a scalable, user-friendly CDSS that is context-sensitive to RLS. Kabukye et al. (2020) and Joukes et al. (2016) stated the significance of comprehensive patient history, seamless integration, and alignment with user needs. Jian et al. (2015) considered localisation, cost-effectiveness, and data accuracy vital when developing CDSS for implementation in less-developed countries. Timotijevic et al. (2020) highlighted patient empowerment, monitoring in real-time, and tailored care plans. The results of the literature review helped create a customised set of requirements for CDSS for RLS.

Objective 2: Perform a comparative analysis of requirements prioritisation techniques for CDSS for gait-related diseases in RLS.

The researcher compared and assessed various prioritisation techniques to determine how they apply to specific evaluation criteria. Berander et al. (2006) and Hudaib et al. (2018) offered suggestions for selecting appropriate techniques. Some of the challenges encountered in the selection process included stakeholder engagement and the availability of resources. The comparative analysis produced a shortlist of suitable prioritisation techniques for this study, which included Numerical Assignment (clustering), MoSCoW, Priority Group, Bubble Sort, Binary Search Tree (BST), Analytic Hierarchy Process (AHP), Hundred-Dollar Technique, and Minimal Spanning Tree. Further analysis revealed that MoSCoW was the most suitable technique based on ease of use, effectiveness, and ability to identify prominent features, especially in RLS. MoSCoW prioritization, with its easy categorization of requirements and affordability, worked well for small to medium-sized collections of requirements.

Objective 3: Apply a selected requirements prioritisation process for CDSS for gait-related diseases in RLS.

Experts in gait analysis, physiology, biomechanics, physiotherapy, and neuro-mechanics were engaged to prioritise the identified requirements using the MoSCoW technique. Six experts were invited, with five completing the task electronically to ensure convenience and safety. The prioritisation results for both functional and non-functional requirements were documented, revealing that most gait analysis and CDSS functionalities were classified as

"must have" or "should have," with very few “could have" requirements. Notably, all security and usability requirements were considered essential ("must have"), highlighting their critical importance. None of the participants suggested additional requirements, and no weighting factors were applied to their responses.

Objective 4: Evaluate the quality attributes of the prioritised requirements for CDSS for gait-related diseases in RLS.

The prioritised requirements were sent to software development experts for quality rating. The experts were provided with a document where the ranking of the quality of the requirements could be captured using a Likert scale, with values ranging from 1 to 5. A ranking value of 5 indicated ‘Excellent’ quality, while a value of 1 was ‘Very Poor’. Wiegers (Wiegers, 1999) and Pohl (Pohl, 2010) established quality models from which the evaluation criteria were constructed. The requirements were assessed as a requirements set, and individual requirements. The evaluation of the individual requirements revealed that the following quality attributes, complete, unambiguous, and comprehensible, had an average rating of 4. The mean rating for the remaining quality attributes was 5. According to the evaluation of the requirements, all the quality attributes received an average rating of 5. The requirements received ratings of "Excellent" and "Good" overall.

6.2 Contributions of the Study

Overall, the study improves the understanding of how to identify and prioritise CDSS requirements for the implementation of such systems in low-resource settings. It also provides practical insights and methodological contributions to the field.

6.2.1 Theoretical Contribution

The focus of this study will provide a basis for a better understanding of the importance of requirements analysis and CDSS prioritisation in RLS. It is expected to provide an opportunity to expand on what is currently known about the development of CDSS for gait-related diseases, in the context of RLS.

6.2.2 Practical Contribution

CDSS have been shown to support and improve the delivery of quality healthcare. The results of studies documenting their implementation and success rates in developing countries have

been encouraging. The framework produced by this study can be used to facilitate the design and development of such systems in RLS, where the limited required resources need to be utilised efficiently.

6.3 Limitations of the Study

The list of requirements is not complete but could evolve as technological infrastructure and medical technology improve and become more accessible and CDSS implementation and usage rates increase in RLS. Due to the inaccessibility of medical experts currently practising in rural areas, respondents approached for RP are all academics who focus on and have extensive experience in the fields of GA, physiology, biomechanics, physiotherapy or neuro-mechanics. The sample of selected participants is vocationally and geographically narrow and this could limit the generalisability of the results of the study to other RLS.

6.4 Recommendations

The potential for CDSS to improve healthcare will increase as technology keeps developing. It is recommended that industry and government focus on developing CDSS solutions specifically tailored to resource-limited settings. Key non-functional requirements such as security, usability, and offline functionality should be prioritised, with a strong emphasis on training and support for healthcare providers. For implementation to be successful, developers, providers, and legislators must work together, and engage stakeholders. To ensure alignment with healthcare demands and improve outcomes, governments should also fund research and regularly assess CDSS.

6.5 Future Research

Future research should focus on tailoring CDSS to the requirements of different healthcare settings, i.e., variability in disease prevalence, local medical practice, and health infrastructure. This focus would necessitate tailoring software functionality and ensuring the content and recommendations conform to local medical guidelines and practices. For instance, a CDSS may need to be localised for other geographical areas by including local languages, adjusting clinical guidelines for alignment with local protocols, and ensuring region-specific disease conditions. Research can also focus on maximising stakeholders' buy-in and incorporating their views during CDSS design. To observe the value of CDSS over an extended period, long-term trials can track its impact on patient outcomes, health care effectiveness, and

system performance over years. To determine whether the CDSS is making measurable long-term improvements in health or reducing costs, researchers could evaluate improvements in decision-making and health care delivery to ensure sustainability. These areas of study have the potential to enhance the performance and adaptability of CDSS in various environments towards ultimately enhancing healthcare outcomes and promoting more effective use of resources.

REFERENCES

Ali Khan, J., Ur Rehman, I., Hayat Khan, Y., Javed Khan, I. & Rashid, S. 2015. Comparison of Requirement Prioritization Techniques to Find Best Prioritization Technique. *International Journal of Modern Education and Computer Science*, 7(11): 53–59.

van Aswegen, H., Roos, R., McCree, M., Quinn, S. & Mer, M. 2019. Investigation of physical and functional impairments experienced by people with active tuberculosis infection: A feasibility pilot study. *African Journal of Disability*, 8: 1–12.

Berander, P., Khan, K.A. & Lehtola, L. 2006. Towards a research framework on requirements prioritization. *Sixth Conference on Software Engineering Research and Practice in Sweden, 18-19 October (SERPS'06)*: 39–48.

Blank, A., Prytherch, H., Kaltschmidt, J., Krings, A., Sukums, F., Mensah, N., Zakane, A., Loukanova, S., Gustafsson, L.L., Sauerborn, R. & Haefeli, W.E. 2013. Quality of prenatal and maternal care: Bridging the know-do gap (QUALMAT study): An electronic clinical decision support system for rural Sub-Saharan Africa. *BMC Medical Informatics and Decision Making*, 13(1), 1-16.

vom Brocke, J., Hevner, A. & Maedche, A. 2020. Introduction to Design Science Research., (September): 1–13.

Burney, S.M.A. & Saleem, H. 2008. Inductive and Deductive Research Approach. Lecture delivered at Auditorium of Faculty of Arts and Science, University of Karachi, Pakistan, 6 March 2008.

Camacho, J., Zanoletti-Mannello, M., Landis-Lewis, Z., Kane-Gill, S.L. & Boyce, R.D. 2020. A conceptual framework to study the implementation of clinical decision support systems (BEAR): Literature review and concept mapping. *Journal of Medical Internet Research*, 22(8). 10.2196/18388.

Carcreff, L., Gerber, C.N., Paraschiv-Ionescu, A., De Coulon, G., Newman, C.J., Aminian, K. & Armand, S. 2020. Comparison of gait characteristics between clinical and daily life settings in children with cerebral palsy. *Scientific Reports*, 10(1).

Chia, K., Fischer, I., Thomason, P., Graham, H.K. & Sangeux, M. 2020. A Decision Support System to Facilitate Identification of Musculoskeletal Impairments and Propose Recommendations Using Gait Analysis in Children With Cerebral Palsy. *Frontiers in Bioengineering and Biotechnology*, 8(November): 1–15.

Cicirelli, G., Impedovo, D., Dentamaro, V., Marani, R., Pirlo, G. & D'Orazio, T.R. 2022. Human Gait Analysis in Neurodegenerative Diseases: A Review. *IEEE Journal of Biomedical and Health Informatics*, 26(1): 229–242.

Creswell, J. 2013. Steps in Conducting a Scholarly Mixed Methods Study Abstract for DBER Group Discussion on 2013 - 11 - 14. *Steps in Conducting a Scholarly Mixed Methods Study*: 1–54. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1047&context=dberspeakers

Dekker, M.C.J., Coulibaly, T., Bardien, S., Ross, O.A., Carr, J. & Komolafe, M. 2020. Parkinson's Disease Research on the African Continent: Obstacles and Opportunities. *Frontiers in Neurology*, 11, 512.

Deriel, E., Puttkammer, N., Hyppolite, N., Diallo, J., Wagner, S., Honoré, J.G., Balan, J.G., Celestin, N., Vallès, J.S., Duval, N., Thimothé, G., Boncy, J., Coq, N.R.L. & Barnhart, S. 2018. Success factors for implementing and sustaining a mature electronic medical record in a low-resource setting: A case study of iSanté in Haiti. *Health Policy and Planning*, 33(2): 237–246.

Di Biase, L., Di Santo, A., Caminiti, M.L., De Liso, A., Shah, S.A., Ricci, L. & Di Lazzaro, V. 2020. Gait analysis in parkinson's disease: An overview of the most accurate markers for diagnosis and symptoms monitoring. *Sensors (Switzerland)*, 20(12): 1.

Dramburg, S., Marchante Fernández, M., Potapova, E. & Matricardi, P.M. 2020. The Potential of Clinical Decision Support Systems for Prevention, Diagnosis, and Monitoring of Allergic Diseases. *Frontiers in Immunology*, 11, 2116.

Esquenazi, A. & Talaty, M. 2011. *Gait analysis, technology and clinical applications*. http://www.minervamedica.it [23 February 2021].

Fanta, G.B. & Pretorius, L. 2018. A conceptual framework for sustainable ehealth implementation in resource-constrained settings. *South African Journal of Industrial Engineering*, 29(3 Special Edition): 132–147.

Fritz, F., Tilahun, B. & Dugas, M. 2015. Success criteria for electronic medical record implementations in low-resource settings: A systematic review. *Journal of the American Medical Informatics Association*, 22(2): 479–488.

Goldkuhl, G. 2012. Design research in search for a paradigm: Pragmatism is the answer. *Communications in Computer and Information Science*, 286 CCIS(June): 84–95.

Greenes, R.A., Bates, D.W., Kawamoto, K., Middleton, B., Osheroff, J. & Shahar, Y. 2018. Clinical decision support models and frameworks: Seeking to address research issues underlying implementation successes and failures. *Journal of Biomedical Informatics*, 78(July 2017): 134–143.

Halcomb, E.J. & Hickman, L. 2015. Mixed methods research. *Nursing Standard: promoting excellence in nursing care*, 29(32): 41–47.

Horwood, C., Luthuli, S., Mapumulo, S., Haskins, L., Jensen, C., Pansegrouw, D. & McKerrow, N. 2023. Challenges of using e-health technologies to support clinical care in rural Africa: a longitudinal mixed methods study exploring primary health care nurses' experiences of using an electronic clinical decision support system (CDSS) in South Africa. *BMC Health Services Research*, 23(1): 1–11.

Hudaib, A., Masadeh, R., Qasem, M.H. & Alzaqebah, A. 2018. Requirements Prioritization Techniques Comparison. *Modern Applied Science*, 12(2): 62.

Hulleck, A.A., Menoth Mohan, D., Abdallah, N., El Rich, M. & Khalaf, K. 2022. Present and future of gait assessment in clinical practice: Towards the application of novel trends and technologies. *Frontiers in Medical Technology*, 4.

Jawhari, B., Ludwick, D., Keenan, L., Zakus, D. & Hayward, R. 2016. Benefits and challenges of EMR implementations in low resource settings: A state-of-the-art review. *BMC Medical Informatics and Decision Making*, 16(1).

Jian, Z., Jian'er, Y., Shuang, T. & Jianxia, Q. 2015. Analysis of the clinical decision support system in developing country.

Joukes, E., Cornet, R., de Bruijne, M.C. & de Keizer, N.F. 2016. Eliciting end-user expectations to guide the implementation process of a new electronic health record: A case study using concept mapping. *International Journal of Medical Informatics*, 87(87): 111–117.

Kabukye, J.K., de Keizer, N. & Cornet, R. 2020. Elicitation and prioritization of requirements for electronic health records for oncology in low resource settings: A concept mapping study. *International Journal of Medical Informatics*, 135(December 2019): 17–20.

Kabukye, J.K., Koch, S., Cornet, R., Orem, J. & Hägglund, M. 2017. *User Requirements for an Electronic Medical Records System for Oncology in Developing Countries: A Case Study of Uganda*. http://clinicmaster.net/.

Kang, M., Park, E., Cho, B.H. & Lee, K.S. 2018. Recent patient health monitoring platforms incorporating Internet of Things-enabled smart devices. *International Neurourology Journal*, 22: S76–S82.

Kelly, L.M. & Cordeiro, M. 2020. Three principles of pragmatism for research on organizational processes. *Methodological Innovations*, 13 (2).

Khairat, S., Marc, D., Crosby, W. & Al Sanousi, A. 2018. Reasons for physicians not adopting clinical decision support systems: Critical analysis. *JMIR Medical Informatics*, 6 (2). 10.2196/medinform.8912.

Khan, K.A. 2006. A Systematic Review of Software Requirements Prioritization, 56(October): 93.

Köktaş, N.Ş. & Duin, R.P.W. 2010. Statistical analysis of gait data to assist clinical decision making. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. 61–68.

Köktaş, N.Ş., Yalabik, N. & Yavuzer, G. 2008. An intelligent clinical decision support system for analyzing neuromusculoskeletal disorders. *Pattern Recognition in Information Systems - Proceedings of the 8th International Workshop on Pattern Recognition in Information Systems, PRIS 2008; In Conjunction with ICEIS 2008*: 29–37.

Laka, M., Milazzo, A. & Merlin, T. 2020. Factors that impact the adoption of clinical decision support systems (CDSS) in healthcare settings for evidence-based decision making.: 1–21. https://doi.org/10.21203/rs.3.rs-34358/v1

Lofterød, B., Terjesen, T., Skaaret, I., Huse, A.B. & Jahnsen, R. 2007. Preoperative gait analysis has a substantial effect on orthopedic decision making in children with cerebral palsy: Comparison between clinical evaluation and gait analysis in 60 patients. *Acta Orthopaedica*, 78(1): 74–80.

Mafukidze, A.T., Calnan, M. & Furin, J. 2016. Peripheral neuropathy in persons with tuberculosis. *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, 2: 5–11.

Malhotra, G. 2017. Impact factor: 4.295 Strategies in Research. *International Journal of Advance Research*, 3: 1137–1144.

Marcolino, M.S., Oliveira, J.A.Q., Cimini, C.C.R., Maia, J.X., Pinto, V.S.O.A., Sá, T.Q.V., Amancio, K., Coelho, L., Ribeiro, L.B., Cardoso, C.S. & Ribeiro, A.L. 2021. Development and Implementation of a Decision Support System to Improve Control of Hypertension and Diabetes in a Resource-Constrained Area in Brazil: Mixed Methods Study. *Journal of Medical Internet Research, 23(1).* 10.2196/18872.

Maredza, M. & Chola, L. 2016. Economic burden of stroke in a rural South African setting. *eNeurologicalSci*, 3: 26–32.

Marýn, J., Blanco, T., Marín, J.J., Moreno, A., Martitegui, E. & Aragüés, J.C. 2019. Integrating a gait analysis test in hospital rehabilitation: A service design approach. *PLoS ONE*, 14(10): 1–23.

Matizirofa, L. & Chikobvu, D. 2021. Analysing and quantifying the effect of predictors of stroke direct costs in South Africa using quantile regression. *BMC Public Health*, 21, 1-9.

Mead, N. 2006. Requirements prioritization introduction. *Software Engineering Institute*, (September): 1–7.

Mekonnen, A.B., Alhawassi, T.M., McLachlan, A.J. & Brien, J. anne E. 2018. Adverse Drug Events and Medication Errors in African Hospitals: A Systematic Review. *Drugs - Real World Outcomes*, 5(1): 1–24.

Melegati, J. & Goldman, A. 2016. Requirements engineering in software startups: A grounded theory approach. *2016 International Conference on Engineering, Technology and Innovation/IEEE International Technology Management Conference, ICE/ITMC 2016 - Proceedings*.

More, N.T., Sapre, B.S. & Chawan, P.M. 2017. An Insight into the Importance of Requirements Engineering. *International Journal of Computer and Communication Technology*, (January 2011): 29–31.

Moyaert, M., Viljoen, J., Viviers, P., Derman, W. & De Villiers, R. 2018. Sacroiliac tuberculosis masquerading as mechanical lower back pain in a collegiate basketball athlete: a case presentation. *South African Journal of Sports Medicine*, 30(1): 1–3.

Pacheco, C., Garcia, I. & Reyes, M. 2018. Requirements elicitation Techniques: A systematic literature review based on the maturity of the techniques. *IET Software*, 12(4): 365–378.

Peiffer-Smadja, N., Poda, A., Ouedraogo, A. S., Guiard-Schmid, J. B., Delory, T., Le Bel, J., … Lescure, F. X. 2020. Paving the way for the implementation of a decision support system for antibiotic prescribing in primary care in West Africa: Preimplementation and co-design workshop with physicians. *Journal of Medical Internet Research*, *22*(7). https://doi.org/10.2196/17940 [9 December 2021].

Pohl, K. 2010. Requirements engineering: fundamentals, principles, and techniques. Heidelberg: Springer. https://doi.org/10.1007/978-3-642-12578-2. [21 July 2024]

Porat, T., Delaney, B. & Kostopoulou, O. 2017. The impact of a diagnostic decision support system on the consultation: perceptions of GPs and patients. *BMC Medical Informatics and Decision Making*, 17(1): 1–9.

Prajapati, N., Kaur, A. & Sethi, D. 2021. A Review on Clinical Gait Analysis. In *Proceedings of the 5th International Conference on Trends in Electronics and Informatics, ICOEI 2021*. Institute of Electrical and Electronics Engineers Inc.: 967–974.

Qiu, S., Wang, Z., Zhao, H., Liu, L., Li, J., Jiang, Y. & Fortino, G. 2019. Body Sensor Network-Based Robust Gait Analysis: Toward Clinical and at Home Use. *IEEE Sensors Journal*, 19(19): 8393–8401.

Raza, M.A., Chaudry, Q., Zaidi, S.M.T. & Khan, M.B. 2017. Clinical decision support system for Parkinson's disease and related movement disorders. *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP) 2017*: 1108–1112.

Reis, W.C., Bonetti, A.F., Bottacin, W.E., Reis, A.S., Souza, T.T., Pontarolo, R., Correr, C.J. & Fernandez-Llimos, F. 2017. Impact on process results of clinical decision support systems (CDSSS) applied to medication use: Overview of systematic reviews. *Pharmacy Practice*, 15(4): 1–8.

Robinson, P. 2007. Designing and Conducting Mixed Methods Research. *Australian and New Zealand Journal of Public Health*, 31(4): 388.

Saavedra, R., Ballejos, L. & Ale, M. 2013. Software Requirements Quality Evaluation: State of the art and research challenges.: 1850–2792.

Schluger, N.W., Sherman, C.B., Binegdie, A., Gebremariam, T., Kebede, D., Worku, A., Carter, E.J. & Brändli, O. 2018. Creating a specialist physician workforce in low-resource settings: reflections and lessons learnt from the East African Training Initiative. *BMJ Global Health*, 3(5): e001041.

Seo, M., Shin, M.J., Park, T.S. & Park, J.H. 2020. Clinometric gait analysis using smart insoles in patients with hemiplegia after stroke: Pilot study. *JMIR mHealth and uHealth*, 8(9): 1–11.

Shawahna, R. 2019. Merits, features, and desiderata to be considered when developing electronic health records with embedded clinical decision support systems in Palestinian hospitals: A consensus study. *BMC Medical Informatics and Decision Making*, 19(1): 1–21.

States National Commission for the Protection of Human Subjects of Biomedical, U. & Research, B. 1978. *The Belmont Report Ethical Principles and Guidelines for the Protection of Human Subjects of Research. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research*.

Sutton, R.T., Pincock, D., Baumgart, D.C., Sadowski, D.C., Fedorak, R.N. & Kroeker, K.I. 2020. An overview of clinical decision support systems: benefits, risks, and strategies for success. *npj Digital Medicine*, 3(1): 1–10.

Tamai, T. & Kamata, M.I. 2009. *Impact of Requirements Quality on Project Success or Failure*. *Design Requirements Workshop, LNBIP 14*, 258-275.

Timotijevic, L., Hodgkins, C.E., Banks, A., Rusconi, P., Egan, B., Peacock, M., Seiss, E., Touray, M.M.L., Gage, H., Pellicano, C., Spalletta, G., Assogna, F., Giglio, M., Marcante, A., Gentile, G., Cikajlo, I., Gatsios, D., Konitsiotis, S. & Fotiadis, D. 2020. Designing a mHealth clinical decision support system for Parkinson's disease: A theoretically grounded user needs approach. *BMC Medical Informatics and Decision Making*, 20(1): 1–21.

Tiwari, S., Rathore, S.S. & Gupta, A. 2012. Selecting requirement elicitation techniques for software projects. *2012 CSI 6th International Conference on Software Engineering, CONSEG 2012*, (September).

Udousoro, I. 2020. Effective Requirement Engineering Process Model in Software Engineering, 8(1): 1–5.

Vestola, M. 2010. A Comparison of Nine Basic Techniques for Requirements Prioritization. *Helsinki University of Technology*: 1–8.

Wagner, M., Slijepcevic, D., Horsak, B., Rind, A., Zeppelzauer, M. & Aigner, W. 2019. KAVAGait: Knowledge-assisted visual analytics for clinical gait analysis. *IEEE Transactions on Visualization and Computer Graphics*, 25(3): 1528–1542.

Wang, Dakuo, Wang, L., Zhang, Z., Wang, Ding, Zhu, H., Gao, Y., Fan, X. & Tian, F. 2021. 'Brilliant AI Doctor' in Rural China: Tensions and Challenges in AI-Powered CDSS Deployment.

Wiegers, K.E. 1999. *Writing Quality Requirements 1*. www.processimpact.com.

Wohlin, C. & Aurum, A. 2005. What is important when deciding to include a software requirement in a project or release? *2005 International Symposium on Empirical Software Engineering, ISESE 2005*, (January 2005): 246–255.

Yip, C., Han, N.L.R. & Sng, B.L. 2016. Legal and ethical issues in research. *Indian Journal of Anaesthesia*, 60(9): 684–688.

Zakane, S.A., Gustafsson, L.L., Sie, A., Tomson, G., Loukanova, S. & Bastholm-Rahmner, P. 2017. Opportunities and obstacles using a clinical decision support system for maternal care in Burkina Faso. *Online Journal of Public Health Informatics*, 9(2).

APPENDICES

Appendix A: Ethics Approval Certificate

Cape Peninsula University of Technology
creating futures

PO Box 1906, Bellville,7535 Symphony Way, Bellville, Cape Town, South Africa
+ 27 (0)21 959 6767 www.facebook.com/cput.ac.za info@cput.ac.za www.cput.ac.za

Office of the Research Ethics Committee
Faculty of Informatics and Design
Room 2.09
80 Roeland Street
Cape Town
Tel: 021-469 1012
Email: ndedem@cput.ac.za
Secretary: Mziyanda Ndede

22 August 2022

Mr Radford Burger
c/o Department of Information Technology
CPUT

Reference no: 195026365/2022/18

Project title: Identification and Prioritization of Requirements of a Clinical Decision Support System for Gait-related Diseases in Resource-limited Settings

Approval period: 22 August 2022 – 31 December 2023

This is to certify that the Faculty of Informatics and Design Research Ethics Committee of the Cape Peninsula University of Technology conditionally approves the methodology and ethics of Mr Radford Burger (195026365) for Master of ICT.

Any amendments, extension or other modifications to the protocol must be submitted to the Research Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

Dr Blessing Makwambeni
Acting Chair: Research Ethics Committee
Faculty of Informatics and Design
Cape Peninsula University of Technology

Appendix B: Individual Consent Letter

Introductory letter for the collection of research data

Radford Burger is registered for the Master of Technology: Information Technology at CPUT (195026365). The thesis is titled **Identification and Prioritization of Requirements of a Clinical Decision Support System for Gait-related Diseases in Resource-limited Settings**, and aims to determine the effectiveness and efficiency of a requirements prioritization process for a CDSS for gait-related diseases in RLS. The supervisor(s) for this research is/are:

Prof Justine Olawande Daramola

e-mail: wande.daramola@up.ac.za

Cell: 0618618287

In order to meet the requirements of the university's Higher Degrees Committee (HDC) the student must get consent to collect data from individuals and organisations which they have identified as potential sources of data.

If you agree to this, you are requested to complete the attached form (an electronic version can be made available to you).

Please note that no data will be gathered until the researcher has received ethics clearance from CPUT.

For further clarification on this matter, please contact either the supervisor(s) identified above, or the Faculty Research Ethics Committee secretary (Mziyanda Ndede) at 021 469 1014 or ndedem@cput.ac.za

Yours sincerely,

Prof Justine Olawande Daramola

13 September 2023

Cape Peninsula
University of Technology

FID/REC/ICv0.1

FACULTY OF INFORMATICS AND DESIGN

Individual Consent for Research Participation

Title of the study: Identification and Prioritization of Requirements of a Clinical Decision Support System for Gait-related Diseases in Resource-limited Settings.

Name of researcher: Radford Burger

Contact details: email: burgerr@cput.ac.za phone: 0837223501

Name of supervisor: Prof Justine Olawande Daramola

Contact details: email: wande.daramola@up.ac.za phone: 061861 8287

Purpose of the Study: The aim of this research is to determine the effectiveness and efficiency of a requirements prioritization process for a Clinical Decision Support System (CDSS) for gait-related diseases in resource-limited settings (RLS).

Participation: My participation will essentially entail looking at a set of requirements (MS Excel document) and ranking them in terms of their perceived level of importance (must have, should have, could have, not have) and providing feedback on them. In addition, I may also suggest additional requirements that should have been included but omitted/missing from the list of requirements provided to me.

Confidentiality: I have received assurance from the researcher that the information I will share will remain strictly confidential unless noted below. I understand that the contents will be used only for MTech thesis, and journal article publication and that my confidentiality will be protected using pseudonyms.

Anonymity will be protected in the following manner (unless noted below): Real names will not be used; no photographs bearing the respondents images will be used; the workplace of the respondents will not be disclosed.

Conservation of data: The data collected will be kept in a secure manner. Data collected via audio/visual recording, and written notes will be stored on a password-protected laptop, and files will be encrypted. Only the researcher and the supervisor, in some cases, will have access to this data. All data will be conserved for as long as is necessary for completion of this study. Thereafter, all data will be disposed of.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed.

Additional consent: I make the following stipulations (please tick as appropriate):

	In thesis	**In research publications**	**Both**	**Neither**
My image may be used:				✓
My name may be used:				✓
My exact words may be used:				✓
Any other (stipulate):				

Acceptance:

I, (print name)_____

agree to participate in the above research study conducted by Radford Burger of the Faculty of Informatics and Design, Information Technology department at Cape Peninsula University of Technology, which is under the supervision of Prof Justine Olawande Daramola.

If I have any questions about the study, I may contact the researcher or the supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the secretary of the Faculty Research Ethics Committee at 021 469 1012, or email naidoove@cput.ac.za.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____