# AN INVESTIGATION INTO DIGITAL VACCINATION RECORDS FOR MINORS IN GAUTENG, SOUTH AFRICA

---


**by**

**WESLEY MOONSAMY**

**Student Number: 41179609**


**submitted in accordance with the requirements**

**for the degree of**

**MASTER OF SCIENCE**

**in the subject**

**COMPUTING**

**at the**

**UNIVERSITY OF SOUTH AFRICA**

**SUPERVISOR: PROFESSOR S SINGH**

**2020**

# ABSTRACT

The design and development of "*e-Vaccination*" applications are not extensively researched within developing economies, in part because of the difficulty in gaining access to government officials and medical experts. Vaccination cards have been used to keep track of minors' immunisation records in South Africa for over 30 years. The South African government is moving towards the use of electronic systems for the storage of such information.

South Africa has a clearly defined electronic health strategy, which is to utilise information and communications technologies in healthcare to inter alia, engage in medical research, promote health education, monitoring of diseases and tracking public health. Supporting this strategy means digitising current paper-based systems. The result would be information that can be stored safely, backed up and analysed more easily than paper-based journals, documents and vaccination cards.

The purpose of this research is to develop a better understanding of key stakeholders' perceptions to the replacement of paper-based vaccination cards with an electronic system. This is important because digital records can be considered as a more effective method of storing vaccination data.

This study is quantitative in nature and primary data in the form of Likert scale questionnaires were collected from 118 key stakeholders being nurses, doctors, parents and school administration staff. The Likert scale questionnaire data was analysed using the following statistical techniques: Cronbach Alpha Test, Chi-Square Test, Analysis of Variance Test and Principle Component Analysis. The analysis provided a deeper understanding of the key stakeholder's perceptions to the use of e-Vaccination applications.

e-Vaccination applications are affected by user friendliness of the application, the graphical design of the application, practicality of the application, user experience of the application as well as the usability of the application.

The practical implications of this research on e-Vaccination applications is that designers, developers, policymakers and government have a deeper understanding of nurses, doctors, parents and school administration staff perceptions to the use of e-Vaccination.

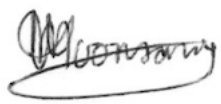


**Keywords:** e-Vaccination, Vaccination cards, e-Health, Electronic Health Record, Electronic Medical Record

## DECLARATION

Student Number: 41179609

I, Wesley Moonsamy, declare that this research project is my own work except as indicated in the references and acknowledgements. It is submitted in full requirement for the degree of Master of Science in Computing. This research has not been submitted previously for any degree or examination to this or any other university.



27 November 2020

---

---

Signature

Date

Mr Wesley Moonsamy

## DEDICATION

I dedicate this research to my wife Prelini Moonsamy. I could not have asked for a more understanding wife during this research project. You held the fort when I was in front of my laptop day and night. Your innovative ideas challenged my thinking and helped me to enhance this research. Thank you.

To our precious daughters Kayla and Mirelle, you taught me how to type with one hand and carry you with the other. I know this was hard on you too but remember, it was you who inspired me to take up this research and to make a difference.

## ACKNOWLEDGEMENTS

My sincere thanks and gratitude go to my research supervisor, Professor Shawren Singh. Your guidance, advice and concepts were vital in aiding me to complete this research.

I would also like to thank Professor Gaetan Kabera for aiding in the enrichment of the statistical analysis.

I would like to thank my family and friends for their assistance and support during this research. I am grateful to you for going above and beyond to help me during those times when I really needed it.

# LIST OF PUBLICATIONS AND CONFERENCES

## Peer Reviewed Paper

1. Moonsamy, W., & Singh, S. (2019). An investigation into electronic vaccination cards for minors in Gauteng, South Africa. In *IEEE International Multidisciplinary Information Technology and Engineering Conference (IMITEC) 2019* (pp. 452–455). https://doi.org/978-1-7281-0040-1

## Conferences

1. IEEE International Multidisciplinary Information Technology and Engineering Conference (IMITEC) 2019 (21 – 22 November 2019). See Appendix 2 (participation certificate).
2. Ekurhuleni Annual Health Research Conference (27 November 2019). See Appendix 3 (Best Poster Presentation Certificate).

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| Abbreviation | Description |
|---|---|
| BRIC | Brazil, Russia, India and China |
| BRICS | Brazil, Russia, India, China and South Africa |
| CAES | College of Agriculture and Environmental Sciences |
| CDC | Centers for Disease Control and Prevention |
| *df* | Degrees of freedom |
| e-Government | Electronic Government (systems) |
| eHealth | Electronic Health (systems) |
| EHR | Electronic Health Record |
| EMR | Electronic Medical Record |
| ePrescription | Electronic Prescription |
| Govt. | Government |
| HTML5 | Hyper Text Mark-up Language version 5 |
| IBM | International Business Machines |
| ICT | Information and Communications Technology |
| KSI Blockchain | Keyless Signature Infrastructure Blockchain |
| mHealth | Mobile Health |
| NIP | National Immunisation Programme |
| NIR | National Immunisation Register |
| PCV13 | Pneumococcal Conjugate Vaccine |
| PHP | Hypertext Pre-processor |
| SMS | Short Message Service |
| STIKO | German Standing Committee on Vaccinations |
| UNISA | University of South Africa |
| WHO | World Health Organisation |

# LIST OF DEFINITIONS

| Definition | Description |
|---|---|
| Advertising banner | An area on a mobile application or website where the creator of the application can place adverts usually for commercial purposes. |
| Artefact | Refers to the prototype (e-Vaccination) |
| Blockchain | A digital ledger of information that is store in a distributed manner by adding new entries into the ledger |
| Child | A natural person who is under the age of 18 |
| Digitisation | Moving from analogue to digital form. In the enterprise context it is moving from paper-based systems to digital systems |
| Electronic vaccination record | Refers to a non-paper based or digital vaccination record |
| e-Vaccination | An electronic vaccination record system proposed at part of this research |
| In-App purchases | Purchases that can be made while using a mobile app with the aim of enhancing the mobile apps functionality |
| Minor | A natural person who is under the age of 18 |

# CHAPTER 1: INTRODUCTION

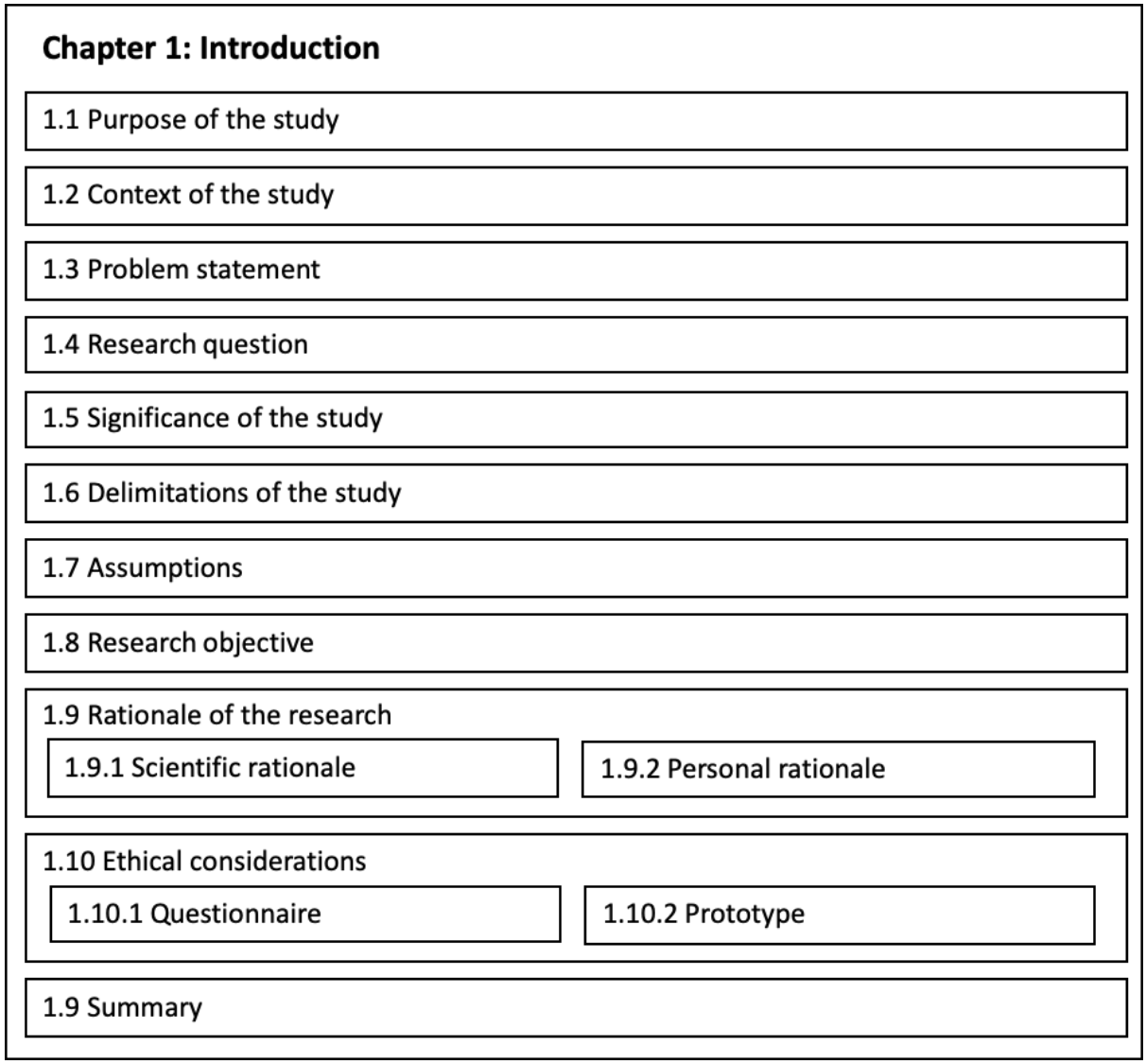



***Figure 1.1:*** *Structure of Chapter 1*

## 1.1 PURPOSE OF THE STUDY

The purpose of this research is to review the current paper-based vaccination record management mechanism in Gauteng in order to determine whether this system should be digitised.

“One of the best ways to protect your children is to make sure they have all of their vaccinations” (Department of Health, 2019b). A person is immunised against an infectious disease usually by being administered a vaccine. This process is called immunisation (WHO, 2019a). Immunisation of children in South Africa starts when they are born and the last vaccination is administered at 12 years of age (Department

of Health, 2019b). In South Africa, the immunisation records of children are managed by a mixture of paper-based and electronic systems (van den Heever, 2012).

Gauteng is the economic hub of South Africa (Stats SA, 2018b) with a population of around 13 399 724 (Stats SA, 2016). In Gauteng 528 922 households live in informal settlements ("Gauteng: Informal Settlements Status," 2012). Informal settlements are susceptible to natural disasters such as flooding and heavy winds and are also prone to damage from fires. These disasters make physical documents such as vaccination cards susceptible to loss or damage.

When a child's immunisation card is lost or damaged, there is no immediate way to determine which diseases the child has been immunised against. This poses a challenge to parents as well as healthcare professionals when examining children for illnesses. Several countries have therefore implemented electronic vaccination record systems to manage these vital records. As part of this research, the vaccination record mechanisms of 16 countries will be investigated.

## 1.2 CONTEXT OF THE STUDY

Converting paper-based records into an electronic format in the healthcare sector has led to an increase in the quality of the data (Botha, 2015). In countries such as Estonia, 95% of healthcare records have already been digitised (e-Estonia, 2016). This high rate of digitisation implies high data quality of healthcare records.

South Africa's eHealth strategy aims to utilise information in its digital form, together with the relevant ICTs as a medium and storage for the information, to monitor public health as well as to treat patients, according to the Department of Health (2012). In 2017, Gauteng experienced a Measles outbreak (Mdhluli, 2017). Monitoring of the public's health with accurate and up to date information, such as determining if children have been vaccinated against such a disease, can be critical during such outbreaks.

South Africa is not ready for a national electronic health record (Kleynhans, 2011). This research does not provide a view on a national level but rather focuses on the Gauteng province in particular.

## 1.3 PROBLEM STATEMENT

Countries in Europe and North America are moving towards Electronic Health Records as part of their eHealth Strategies (Kleynhans, 2011). In Gauteng, the immunisation record system is primarily paper-based and not yet fully automated as information still requires manual input from reports and not directly by the healthcare practitioner into digital systems (van den Heever, 2012). No South African Government based (Electronic Health Record) EHR system has been designed with the view of making children's immunisation records available to various stakeholders' viz. parents, medical practitioners and the government itself.

Systems that store vaccination records as a mixture of electronic systems and paper-based records can result in inconsistences which can have an effect on vaccination statistics.

The safe storage of physical documents such as vaccination cards is challenging in Gauteng due to a high number of households living in informal settlements. Vulnerabilities such as fire and flooding in these types of dwellings magnifies the risk of paper-based vaccination cards.

During the outbreak of diseases such as the Gauteng Measles outbreak in 2017, as well as the recent Coronavirus disease (COVID-19) pandemic in 2020, paper-based records might not be sufficient in determining who is immunised against diseases and who is not.

This calls for a better understanding of vaccination record systems in Gauteng, and the possible replacement of the current paper-based vaccination card with an electronic vaccination records system by understanding the perceptions of the key stakeholders who are involved with vaccination records.

## 1.4 RESEARCH QUESTION

The perception of converting the existing paper-based vaccination card system to an electronic vaccination records management system will be determined by responses to the research questionnaire from key stakeholders. The question this research aims to answer is:

"*What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system?*"

## 1.5 SIGNIFICANCE OF THE STUDY

The efficacy of electronic medical records and systems have been investigated in South Africa as well as other African countries such as Rwanda. The EMR implemented at the Ndera Hospital in Rwanda has had a positive outcome (Twizeyimana, 2016). There have been positive steps taken in South Africa that have led to securing the future of electronic health systems (Kleynhans, 2011).

The health records that have been investigated so far by other authors have concentrated on records that are stored by healthcare facilities. The onus of the safe and secure storage of vaccination records currently resides with the child's parents or guardians. Vaccination records were mentioned by Kleynhans (2011), as having the potential to be digitally stored but the semantics of converting from the paper-based system to an electronic one was not covered in-depth.

Based on the advantages of digital health records such as better storage and back up, effective reporting and other downstream applications, this research then builds on the foundations that have already been laid by other authors and will add to it by taking these "client-facing" records and converting them into a digital format that can be utilised by government to achieve their eHealth strategic aims.

## 1.6 DELIMITATIONS OF THE STUDY

This research focusses on the Gauteng province within South Africa. Gauteng was chosen because it is the province with the largest population and population density in South Africa (South African Government, 2018). Gauteng is also the economic hub of South Africa and attracts the most amount of migrants from other provinces seeking employment (Stats SA, 2018b).

The four groups of key stakeholders identified were parents, doctors, nurses and school administration staff. They were chosen due to their involvement with vaccinations and vaccination records. Other stakeholder types outside of these four groups were not considered. Respondents to the questionnaire were asked to select

their primary role as part of the research. If they embodied more than one stakeholder group, their secondary role was not considered.

## 1.7 ASSUMPTIONS

Assumptions made during the course of this research are:

- Stakeholders who want to participate in the research questionnaire have access to the Internet when filling in the questionnaire; and
- There is adequate Internet access at the healthcare facilities.

## 1.8 RESEARCH OBJECTIVE

The objective of this study is to understand the key stakeholders' perceptions of an electronic vaccination record system as a means of keeping track of immunisation records in Gauteng.

## 1.9 RATIONALE OF THE RESEARCH

This research is motivated by both a scientific and personal rationale, as further detailed below.

### 1.9.1 SCIENTIFIC RATIONALE

The research field of e-Government is concerned with transforming manually intensive and paper-based processes at government level into an electronic format. The accuracy of data in an electronic format can be superior to data that is stored in purely paper-based or a hybrid paper-based and electronic system (Department of Health, 2012).

This research considers how EHR systems can improve the data quality and usefulness of immunisation records in Gauteng.

### 1.9.2 PERSONAL RATIONALE

The researcher is an Information Systems consultant who has extensive experience in the digitising of paper-based systems. When the researcher became a father in 2014, he saw that the Department of Health still used paper-based vaccination cards. He soon embarked on an undertaking to determine whether an electronic based system would be more reliable and convenient to the various stakeholders in Gauteng.

## 1.10 ETHICAL CONSIDERATIONS

The ethical considerations for this research took into account the data collection processes (the questionnaire) as well as the use of the prototype that was designed for this research.

### 1.10.1 QUESTIONNAIRE

No personal or identifiable information of the respondents to the questionnaire was collected or published in this research. Respondents were not forced to complete the questionnaire and could have opted-out from completing the questionnaire before the response was submitted electronically or prior to the physical copy being handed in.

Ethical clearance has been received from the UNISA CAES department (Appendix 4). Permission was also received from the Ekurhuleni Health District Research Committee and the Tshwane Research Committee (Appendices 5 and 6).

### 1.10.2 PROTOTYPE

A generic login was created for the respondents, which ensured the anonymity of the respondents. No sensitive or personally identifiable information were required by the respondents.

## 1.11 SUMMARY

The subsequent six chapters in this dissertation are described in **Figure 1.2**.

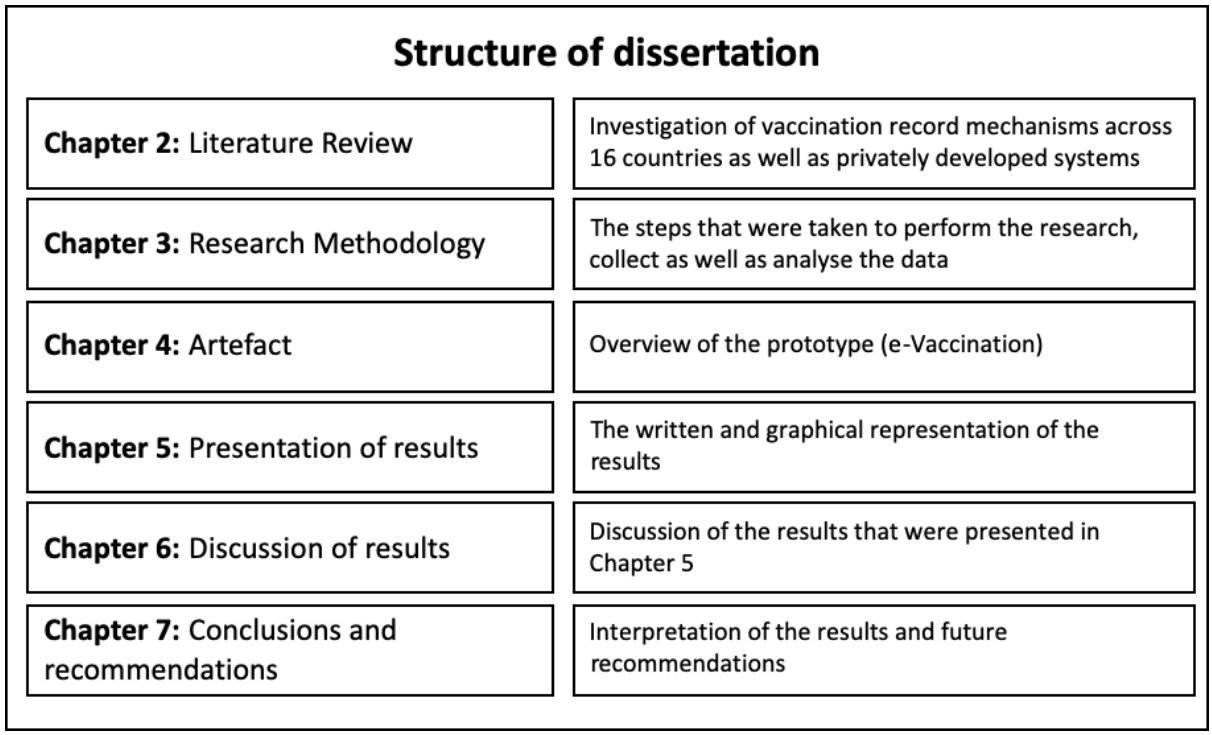



***Figure 1.2:*** *List of Chapters*

The structure of the dissertation as outlined in **Figure 1.2** is explained in greater detail below:

- **Chapter 2** (*Literature Review*) contains the investigation of various vaccination storage mechanisms globally as well as the eHealth aims of the Department of Health.
- **Chapter 3** (*Research Methodology*) details the data collection, sampling methods and statistical analysis techniques that were used in this research.
- **Chapter 4** (*Artefact*) is a detailed explanation of the prototype system (e-Vaccination) that was developed as part of this research. It contains the overall design as well as the rationale behind the features that were included.
- **Chapter 5** (*Presentation of results*) presents the results and outcomes of the statistical analysis that was performed on the data that was collected.
- **Chapter 6** (*Discussion of results*) is an explanation and interpretation of the results of the statistical analysis in relation to the research topic and research question.

- **Chapter 7** (*Conclusions and recommendations*) concludes the research by outlining the outcomes of the research in relation to the digitisation of vaccination records. Recommendations for future research as well as recommendations for the future of vaccination records in Gauteng, South Africa are presented.

In the next chapter (*Literature Review*), vaccination storage mechanisms will be discussed. The elements of the systematic literature review that was used in this research will also be discussed.

# CHAPTER 2: LITERATURE REVIEW

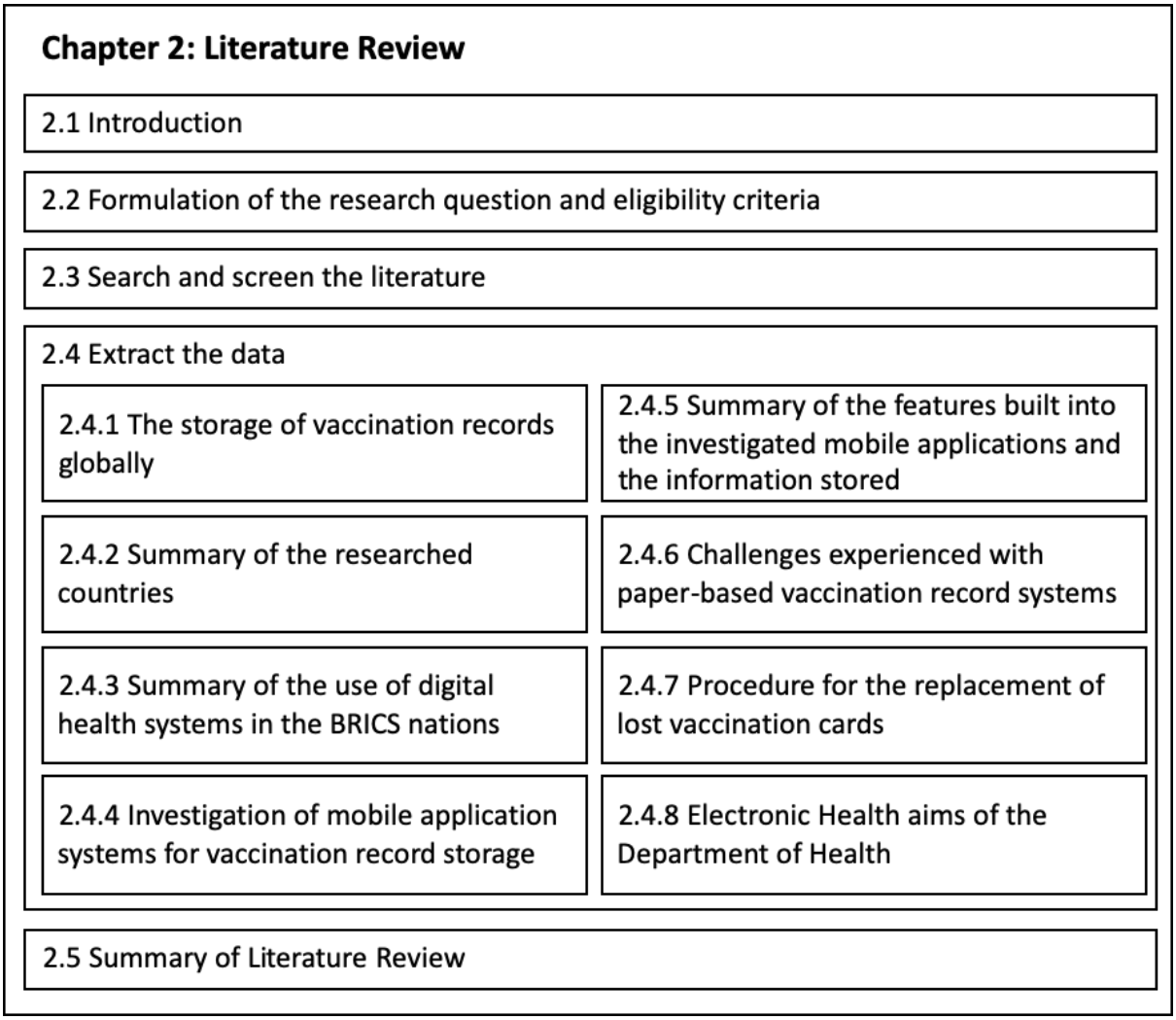



***Figure 2.1:*** *Structure of Chapter 2*

## 2.1 INTRODUCTION

Elements of a systematic literature review approach involving a review of the current published materials (Remenyi, 2017) was followed during this research. Some of the systematic literature review steps as described by the University of Sydney (The University of Sydney, 2019) were followed. These steps, together with a summary of their outcomes, are listed in **Figure 2.2**. A detailed review of the investigations performed during the literature review along with the respective outcomes, for each step as outlined in **Figure 2.2**, are discussed in the sections to follow.

| Step | Outcome (Summary) |
|---|---|
| **1. Formulate the research question** | What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system? |
| **2. Develop eligibility criteria** | **Location:** Gauteng, South Africa<br>**Stakeholders:** Parents, Doctors, Nurses, School Administration Staff<br>**Exclusions:** Travel vaccines |
| **3. Search the literature** | **Peer reviewed journals:** Multiple digital sources were searched including:<br>http://encore.unisa.ac.za<br>https://www.ebsco.com<br>https://www.researchgate.net<br>**Digital health strategies:** Global and the Department of Health |
| **4. Screen the literature** | No less than 10 peer reviewed papers were screened to determine their relevance. From this, four vital concepts were identified<br>The global digital health advances pertaining to immunisation records were filtered<br>The BRICS nations were considered due to their relevance to South Africa |
| **5. Extract the data** | Global assessment<br>Mobile applications<br>Challenges with physical vaccination cards<br>Procedure for the replacement of a lost vaccination card<br>Electronic health aims of the Department of Health |

***Figure 2.2:*** *A summary of the five steps taken to compile a literature review as outlined by the University of Sydney, (The University of Sydney, 2019), together with the outcomes of each step*

## 2.2 FORMULATION OF THE RESEARCH QUESTION AND ELIGIBILITY CRITERIA

Steps one (*Formulate the research question*) and two (*Develop eligibility criteria*) took place in parallel due to a close linkage between the research question and the identification of the stakeholders (**Figure 2.3**).

| | |
|---|---|
| **1. Formulate the research question** | What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system? |
| **2. Develop eligibility criteria** | **Location:** Gauteng, South Africa<br>**Stakeholders:** Parents, Doctors, Nurses, School Administration Staff<br>**Exclusions:** Travel vaccines |

***Figure 2.3:*** *Steps 1 and 2 - Formulate the research question and develop the eligibility criteria*

The accuracy of data in an electronic format can be superior to data that is stored purely paper-based or in a hybrid paper-based and electronic system (Department of Health, 2012). This research therefore needed to be more refined and led to the following question, "*Could an electronic based system be used to manage vaccination records in Gauteng?*" The investigation of electronic and paper-based systems therefore supported the scientific rationale.

Use-Case models are used in software development for capturing and describing features of a system (Anda, Dreiem, Sjøberg, & Jørgensen, 2001). Use cases were therefore used to determine the features of an electronic vaccination record system. Upon examination of the physical vaccination card, three potential use cases for an electronic based system were identified, that is,

- Creating a vaccination record by a nurse or parent;
- Viewing vaccination records by nurses, doctors and parents; and
- Requesting vaccination records by school administration staff.

These use cases indirectly determined the four key stakeholders involved with the physical vaccination card, these are:

- Parents;
- Nurses;
- Doctors; and
- School administration staff.

Increasing stakeholder participation has become a key focus area in the improvement of digital systems such as decision support systems (Ingram & Gaskell, 2018). It was therefore vital to include the identified stakeholders in the research by understanding their perceptions towards managing vaccination records using a digital system.

The inclusion of the key stakeholders in the research therefore led to further refinement of the research question, with the final research question being: "*What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system?*"

During the refinement of the research question, parallel conclusions drawn in relation to the eligibility criteria became apparent. Gauteng was the province in which the researcher resided, and it is South Africa's economic hub (Stats SA, 2018b) and the

destination for most of South Africa's migrants (Stats SA, 2018b). Gauteng was therefore selected as the only province that the research would be conducted in and would be the geographical location of the research. To enhance the focus of the research, we decided to include only vaccination records pertaining to general child health (Department of Health, 2019a) within Gauteng. Vaccinations are also required when travelling to certain countries (Netcare, 2016) however, these vaccinations were excluded from this research.

## 2.3 SEARCH AND SCREEN THE LITERATURE

A search for relevant literature was conducted (**Figure 2.4**) to determine the extent of use of electronic health records in South Africa and globally.


***Figure 2.4:*** *Step 3 - Search the literature*

**Table 2.1** shows the digital sources that were searched together with the search terms used. The search terms were not necessarily used in each digital source.

***Table 2.1:*** *Summary of the digital sources that were searched together with some of the search terms used*

| Digital source | Search terms included |
|---|---|
| http://encore.unisa.ac.za<br>https://www.ebsco.com<br>https://www.researchgate.net | • Electronic vaccination cards<br>• Vaccination cards<br>• Immunisation records<br>• Electronic medical record<br>• Electronic health records<br>• South Africa and Medical records<br>• eHealth |

The matrix in **Table 2.2** was constructed based on the concept matrix demonstrated by Klopper & Lubbe (2011). The matrix illustrates the authors that were referenced during this research along with the key concepts that each author presented in their papers.

***Table 2.2:*** *Concept matrix showing the 4 emerging concepts determined by the various authors researched*

| Concepts / References | Data Quality | Digital Records | Digital Reminders | Immunisation Rates |
|---|---|---|---|---|
| (Botha, 2015) | ✓ | ✓ | | |
| (Chachou et al., 2015) | | | ✓ | ✓ |
| (Sanftenberg et al., 2016) | | | | ✓ |
| (Chan et al., 2017) | | ✓ | | |
| (Ndirangu et al., 2009) | | | | ✓ |
| (Liu et al., 2017) | ✓ | ✓ | | |
| (Tozzi et al., 2016) | | ✓ | | ✓ |
| (Westley et al., 2014) | | ✓ | | ✓ |
| (LeardMann et al., 2007) | | ✓ | | |
| (Fontanesi et al., 2002) | | ✓ | ✓ | |
| (Nolen et al., 2018) | | ✓ | | |
| (Wang et al., 2015) | | ✓ | | |

The concept matrix in **Table 2.2** provides a holistic view of the key concepts that were identified by the referenced authors. It places emphasis on or grouping by *concepts* rather than emphasis on or grouping by the authors (Klopper & Lubbe, 2011). These key concepts influenced the focus of this literature review and were incorporated into e-Vaccination and the research questionnaire. The literature was then screened to assess its relevance in relation to the use of electronic health records in Gauteng (**Figure 2.5**).

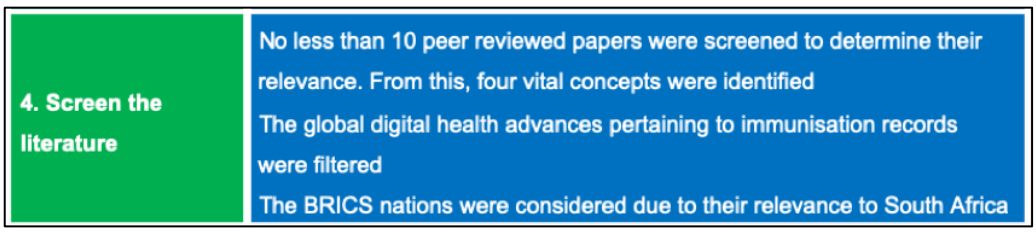



***Figure 2.5:*** *Step 4 – Screen the literature*

Countries are increasingly moving towards electronic health records (Botha, 2015; Kleynhans, 2011) as part of their eHealth strategies.

The literature review therefore explored this trend in other countries, with particular emphasis on the storage of vaccination records. To ensure that a range of

comparisons regarding the storage of vaccination records was used, the literature review included an analysis of 16 countries, spread across all of the inhabited continents, to form a global picture. The countries were also selected based on their country classification as either *developed*, *developing* or *countries in transition* (United Nations, 2014). Of these 16 countries, the BRICS nations were further subjected to more in-depth research, in light of South Africa having joined these nations in December 2010 (About BRICS, 2017), and as a result of to their similarity and cooperation with South Africa in terms of economics, health, science and technology (About BRICS, 2017).

Digital health systems pertaining to immunisation records within the BRICS nations were therefore investigated with particular emphasis. **Table 2.3** illustrates the classification (developed, developing or countries in transition), geographical location (Africa, North America, South America, Europe, Asia or Australia) and BRICS association of the 16 countries that were researched. For the purposes of this research, Russia is considered to be part of Asia and not Europe.

***Table 2.3:*** *The classification, location and BRICS association of the assessed countries*

| Country | Developed | Economies in transition | Developing | North America | South America | Europe | Asia | Africa | Australia/ Oceania | BRICS Nation |
|---|---|---|---|---|---|---|---|---|---|---|
| Brazil | | | ✓ | | ✓ | | | | | ✓ |
| Russia | | ✓ | | | | | ✓ | | | ✓ |
| India | | | ✓ | | | | | | | ✓ |
| China | | | ✓ | | | | ✓ | | | ✓ |
| South Africa | | | ✓ | | | | | ✓ | | ✓ |
| Estonia | ✓ | | | | | ✓ | | | | |
| Norway | ✓ | | | | | ✓ | | | | |
| The Netherlands | ✓ | | | | | ✓ | | | | |
| Australia | ✓ | | | | | | | | ✓ | |
| New Zealand | ✓ | | | | | | | | ✓ | |
| Sierra Leone | | | ✓ | | | | | ✓ | | |
| Tanzania | | | ✓ | | | | | ✓ | | |
| Mongolia | | | ✓ | | | | ✓ | | | |
| Vietnam | | | ✓ | | | | ✓ | | | |
| New Mexico | | | ✓ | ✓ | | | | | | |
| Uruguay | | | ✓ | | ✓ | | | | | |

Upon tallying the numbers in each category, the representation is as follows: *Developed Countries: 5; Economies in Transition: 1; Developing Countries: 10; North America: 1; South America: 2; Europe: 3; Asia: 4; Africa: 3; Australia/Oceania: 2; and BRICS: 5*.

The peer reviewed papers revealed that countries have become less reliant on paper-based systems as a result of the large-scale conversion of paper-based records to digital records (Botha, 2015).

When reviewing the literature in relation to South Africa, it was found that measures are being taken to create an Electronic Health Record in South Africa (Kleynhans, 2011) and that immunisation is a type of clinical data relating to patient care in South Africa (Botha, 2015). Neither of these studies however, placed specific emphasis on how vaccination records could be digitised within Gauteng. In addition, it was found that no South African Government-based electronic health system had been designed with the view to making minors' vaccination records easily available to the identified stakeholder groups viz. parents, doctors, nurses and school administration staff.

Upon further investigation, it was confirmed that in Gauteng, the immunisation record system is primarily paper-based and not yet fully automated (van den Heever, 2012). This called for a better understanding of vaccination record systems in Gauteng and a possible replacement of the current paper-based vaccination card with an electronic vaccination record system.

These literature findings supported the relevance of this research, as the research focuses on both the conversion of the paper-based vaccination card into a digital record and making it accessible to the various stakeholders.

**Figure 2.6** demonstrates the literature research flow in terms of the vaccination storage systems.

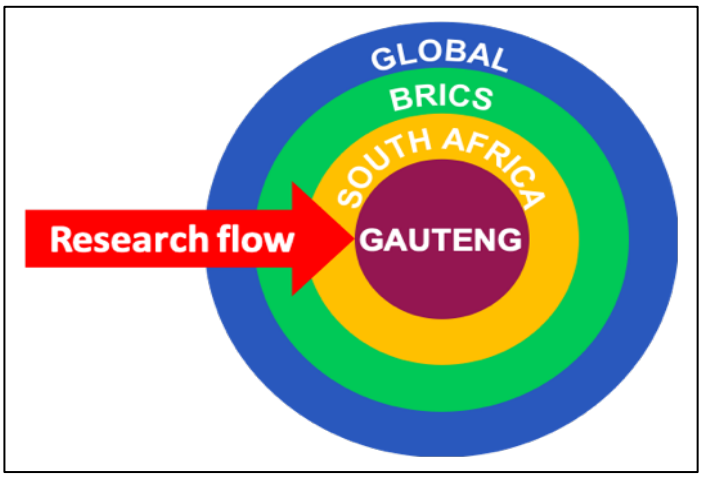



***Figure 2.6:*** *Summary of the literature research flow honing-in on Gauteng*

A global view was done with 16 countries including the BRICS nations. The BRICS nations provided input that could also be relevant to South Africa. South Africa and Gauteng took into account the systems of storage, reporting and the eHealth aims of the Department of Health.

## 2.4 EXTRACT THE DATA

Pertinent information on the management of vaccination records was summarised and presented as described in **Figure 2.7**.

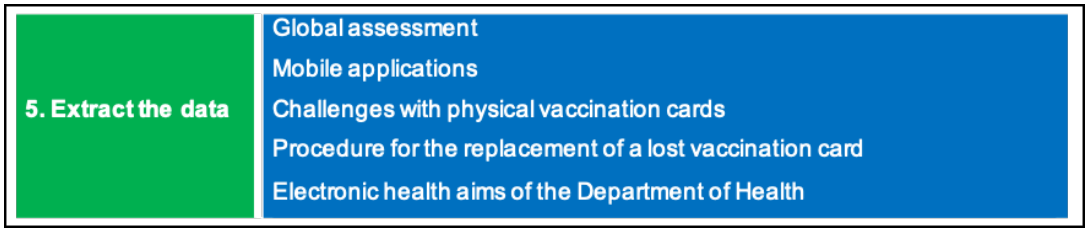



***Figure 2.7:*** *Step 5 – Extract the data*

Data extracted during this stage were grouped into the following categories:

- The storage of vaccination records globally – This provides a view of the 16 countries;
- Investigation of mobile application systems for vaccination record storage – These are systems that parents can use to keep track of their child's vaccination records;
- Challenges experienced with paper-based vaccination record systems – three main challenges were identified;

- Procedure for the replacement of lost vaccination cards – The steps that parents in Gauteng need to follow if their child's vaccination card is lost; and
- Electronic health aims of the Department of Health – The aims of the Department of Health were used to further justify this research and to design e-Vaccination.

**Figure 2.8** is a graphic representation of the data that was researched and summarised. Each section has been linked to the concepts as described in **Table 2.2.**

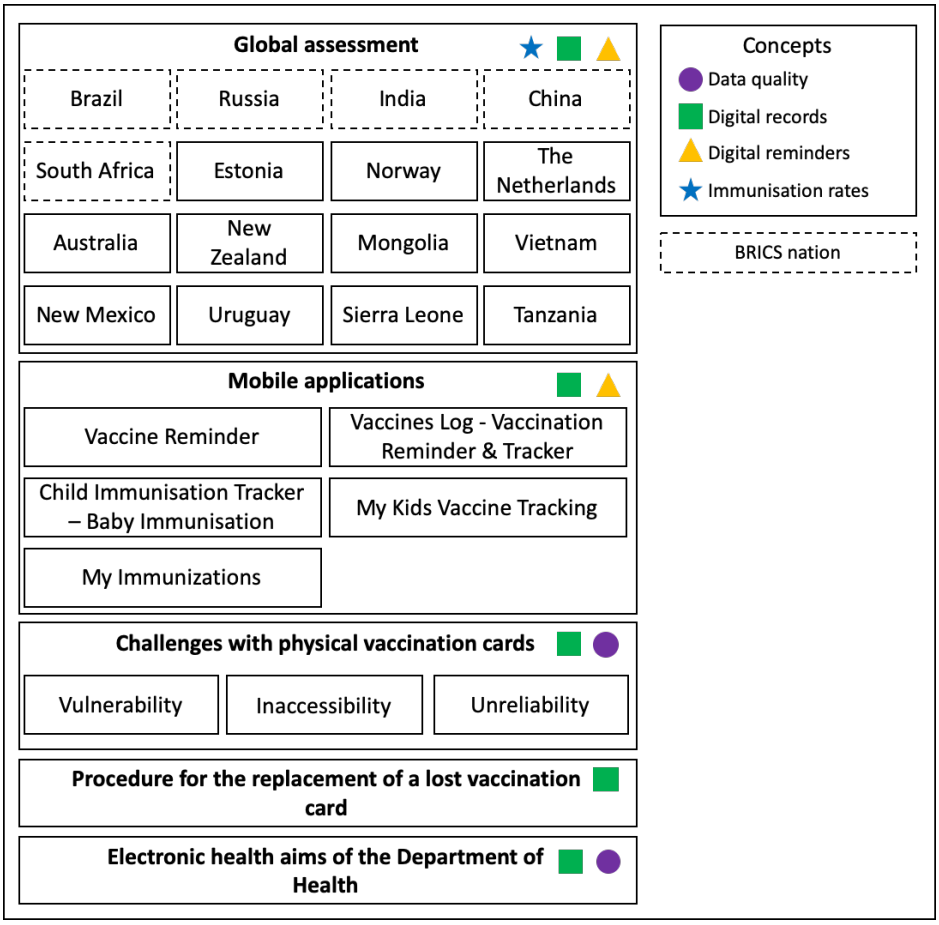



***Figure 2.8:*** *Illustration of the link between this research and the concepts identified by other authors as mentioned in* ***Table 2.2***

### 2.4.1 THE STORAGE OF VACCINATION RECORDS GLOBALLY

To eliminate vaccine-preventable diseases, an appropriate vaccination coverage rate must be achieved (Tozzi et al., 2016). The appropriate number of doses must also be administered according to the German Standing Committee on Vaccinations (STIKO) for example, two doses for Measles (Sanftenberg et al., 2016). Global immunisation rates are however sub-optimal (Chachou et al., 2015). Vaccination coverage is

especially lower in developing countries, which leads to preventable mortality (Ndirangu et al., 2009). Digital tools can be used for immunisation registries as well as dose tracking (Tozzi et al., 2016). Another possible intervention to ensure that immunisations are carried out on time is to use reminders (Chachou et al., 2015). This research shows that some countries as well as some privately developed vaccination record systems support the use of immunisation registries, dose tracking and vaccination reminders.

The European Union Health Commissioner, Vytenis Andriukaitis, stated that the European Commission is in support of an electronic immunisation record system that can help the European Union member states to improve their cross-border collaboration and help to prevent infectious diseases (Michalopoulos, 2017). This follows the outbreak of Measles in Europe during 2016/2017 which resulted in 42 deaths. There are five European (developed) nations covered in this study to determine the status of their digital vaccination records.

BRIC was an association of four of the World's major emerging economies which was founded in 2006 (About BRICS, 2017). South Africa was invited to join the association in 2010 by China. The acronym was thereafter changed from BRIC to BRICS. The BRICS nations have similar economies and challenges such as poverty. Considering the similarities of the BRICS nations, the use and success of electronic vaccination cards in any of these nations might yield similar results in Gauteng. The BRICS nations were therefore included in the research.

To better understand the impact of managing vaccination records using digital systems, other countries were considered in this study. For each country the following data sets were considered:

- Population;
- Vaccination coverage; and
- System used to manage the vaccination records (digital, physical or hybrid of both).

To include diversity into this study, at least one country from each continent as well as two other African countries were considered as part of this research. The results of the research per country have been detailed below.

**Estonia**

| | |
|---|---|
| Continent: | Europe |
| Economic status: | Developed |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 1 323 000 |
| Vaccination coverage (2018): | 91% |

The information above is based on the World Health Organization (2019b).

Estonia is the first country globally to have implemented a nationwide EHR system (Nicholson, 2012). The system contains nearly all of the resident's medical records from birth to death. Since 2008, health data in Estonia is 95% digitised (e-Estonia, 2016) and (e-Estonia, 2018). The Estonian National Health Information System has over 20 000 000 health documents (records) including vaccination records. Toomas Hendrik Ilves, the former president of Estonia, stated that the effective use of electronic health solutions will allow Estonia to make healthcare services more flexible (e-Estonia, 2016). The consequence of this will be improved health of Estonians, increased awareness of the patients and savings in billions of Euros. The key to Estonia's EHR system is their electronic ID-card system which was built using KSI Blockchain technology. This ensures the integrity of the country's vital health data as well as the residents' personal data.

**Norway**

| | |
|---|---|
| Continent: | Europe |
| Economic status: | Developed |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 5 338 000 |
| Vaccination coverage (2018): | 97% |

The information above is based on the World Health Organization (2019c).

In 2016, Norway had already implemented EMR systems such as the National Health Portal, Norwegian Health Net, Summary Care Record and e-Prescription (Roland, 2016). Such systems store information such as medicines prescribed, hospitalisation, doctor's visits, emergencies as well as vaccination records.

**The Netherlands**

| | |
|---|---|
| Continent: | Europe |
| Economic status: | Developed |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 17 060 000 |
| Vaccination coverage (2018): | 93% |

The information above is based on the World Health Organization (2019d).

Starting in 2008, the Netherlands moved from paper-based records to electronic reporting in certain areas of national health care (Alberts et al., 2013). By 2013, all vaccinations administered within the National Immunisation Programme (NIP) were registered in a centralised electronic database for each citizen (Alberts et al., 2013). Based on the information available electronically, the Ministry for Health, Welfare and Sport were able to determine that vaccination coverage for the NIP was between 92% and 99%.

**Australia**

| | |
|---|---|
| Continent: | Australia / Oceania |
| Economic status: | Developed |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 24 898 000 |
| Vaccination coverage (2018): | 93% |

The information above is based on the World Health Organization (2019e).

Australia developed the Australian Immunisation Register, which is an electronic system that stores children's immunisation records. Parents can view their child's immunisation records by accessing the Immunisation History Statement on their Medicare online account (Department of Human Services, 2018). The Immunisation History Statement can be used for school admission requirements.

The Queensland Government developed a mobile app that parents can use to keep track of their children's immunisation records (Queensland Government, 2018). The mobile app called VacciDate is available on the Apple App Store and Google Play. The app keeps track of the child's vaccine schedule and does not interface with the

Australian Government. All the data is stored on the mobile devices local database based on the Terms and Conditions (Apple Inc., 2018a).

The VaxOnTime mobile app was developed by the Victorian Department of Health and Human Services to remind parents when their child's vaccinations are due (Victoria State Government, 2015). This app is available on the Google Play Store as well as the Apple App Store, (Google Play, 2018) and (Apple Inc., 2018c).

**New Zealand**

| | |
|---|---|
| Continent: | Australia/Oceania |
| Economic status: | Developed |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 4 743 000 |
| Vaccination coverage (2018): | 84% |

The information above is based on the World Health Organization (2019f).

New Zealand has developed a National Immunisation Register (NIR). The NIR is an electronic information system that stores the immunisation records of adults and children (Ministry of Health, 2015). The aim of the NIR is to increase immunisation rates in New Zealand. To ensure that immunisations are given on time, authorised healthcare professionals can use the NIR to access a child's immunisation records. Parents and guardians can request their child's immunisation records from their local District Health Board (DHB) (Ministry of Health, 2016) which uses the NIR. Only authorised health care professionals can update the NIR.

**Mongolia**

| | |
|---|---|
| Continent: | Asia |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 3 170 000 |
| Vaccination coverage (2018): | 98% |

The information above is based on the World Health Organization (2019g).

Electronic registers should accompany quality assurance procedures for the monitoring of vaccination programmes (Chan et al., 2017). In Mongolia, an electronic

system was used to capture vaccination records. Data were gathered from 06 June 2016 to 24 August 2016 and showed that a total of 19 879 PCV13 vaccinations were recorded. The system has not yet been rolled out across the entire country.

**Vietnam**

| | |
|---|---|
| Continent: | Asia |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 95 546 000 |
| Vaccination coverage (2018): | 84% |

The information above is based on the World Health Organization (2019h).

In 2012, Vietnam's National Expanded Immunization Program collaborated with PATH to find ways to improve the immunisation coverage in women and children. They developed a pilot system called ImmReg, which is a digital database that housed and tracked immunisation records in the Ben Tre province (PATH, 2017). Within five years, the success of this pilot system led to its evolution into the Vietnam's National Immunization Information System. **Figure 2.9** shows the piles of paper-based records created prior to the implementation of the digital system.

***Figure 2.9:*** *A photograph of how the immunisation records were captured in the previous paper-based immunisation record system in Vietnam (PATH, 2017)*

**Mexico**

| | |
|---|---|
| Continent: | North America |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 126 191 000 |
| Vaccination coverage (2018): | 90% |

The information above is based on the World Health Organization (2019i).

Vaccination cards are used in Mexico to store children's vaccination records (Hospital CMQ, 2020). In 2016, the Electronic Immunization Record, CEV, (*Cartilla Electrónica de Vacunación*) was created to capture and store real time vaccination records (Fundacion Carlos Slim, 2016). The system stores vaccination records for life, including adult vaccines such as the Influenza vaccine. A hybrid system of both paper-based and electronic is therefore used in Mexico.

**Uruguay**

| | |
|---|---|
| Continent: | South America |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 3 449 000 |
| Vaccination coverage (2018): | 94% |

The information above is based on the World Health Organization (2019j).

Uruguay released a National Immunization Program Register (SNNI) in 1987, which was a hybrid paper-based and electronic system (Westley et al., 2014). A physical vaccination record form is filled in at the healthcare facility where the vaccine is administered. These forms were collected and captured into a national computerised database. The SNNI system produced great results due to its high data quality and was touted as a great success by the Pan American Health Organization. Since 2005, the SNNI has been moving towards a fully electronic model. This would include electronic data entry and removing the need for a physical vaccination form.

**Sierra Leone**

| | |
|---|---|
| Continent: | Africa |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 7 650 000 |
| Vaccination coverage (2018): | 91% |

The information above is based on the World Health Organization (2019k).

Vaccine-preventable diseases constitute 30% of the causes of death among children under the age of 5 in Sierra Leone (eHealth Africa, 2018). This lead to the launching of an Electronic Vaccination Record and Tracking Project called VaxTrac, which was an electronic registry of children's immunisations in 2016 (Kombian, 2017). The pilot phase of VaxTrac ran from November 2016 to June 2017. There were 110 health officials and 50 workers from 50 health care facilities that were trained on the use of VaxTrac. Biometric indicators such as fingerprints are used by caregivers to generate patient profiles. Quick Response code stickers on the paper-based vaccination cards are also used. Over 20 000 patients have been registered on VaxTrac.

**Tanzania**

| | |
|---|---|
| Continent: | Africa |
| Economic status: | Developing |
| BRICS association: | Non-BRICS nation |
| Population (2018): | 56 313 000 |
| Vaccination coverage (2018): | 95% |

The information above is based on the World Health Organization (2019l).

In 2015, Tanzania embarked on a project with PATH and BID Initiative to launch an immunisation registry (Intrahealth, 2015). The aim of the project was to digitise the stock management, service delivery and administration for the vaccination of 2 000 000 babies per year. The system would keep track of all of the children's vaccine encounters and share the information with Tanzania's other health information systems.

**Brazil**

| | |
|---|---|
| Continent: | South America |
| Economic status: | Developing |
| BRICS association: | BRICS nation |
| Population (2018): | 209 469 000 |
| Vaccination coverage (2018): | 85% |

The information above is based on the World Health Organization (2019m).

Brazil has an area of approximately 8 500 000 Square kilometres, making it the fifth largest country in the World (Statista - The Statistics Portal, 2018).

Brazil has a highly effective National Immunization Programme (NIP) with a routing vaccination coverage above 95% (WHO, 2017). The recommended coverage by the WHO is 90%. Annually, Brazil provides more than 300 000 000 vaccination dosages. One of the major challenges that the Brazil NIP faces is access to remote communities deep within the Amazon jungle. Nevertheless, these communities are still reached and the children therein are vaccinated (WHO, 2017). **Figure 2.10** illustrates the transport mechanisms used to send vaccines to remote locations in Brazil. Some locations cannot be access via road.

***Figure 2.10:*** *Depiction of the transport mechanisms used to send vaccines to remote areas in Brazil* (WHO, 2017)

At the clinic, a mother will receive a vaccination card the first time a child is vaccinated. The nurse writes down the necessary details on the vaccination card which the mother will then keep. The Nurse also captures the information from these vaccination cards into Brazil's NIP even in these remote areas. The nurses are also able to determine whether the child's vaccinations are up to date using Brazil's NIP (WHO, 2017).

### Russia

| | |
|---|---|
| Continent: | Asia |
| Economic status: | Economy in transition |
| BRICS association: | BRICS nation |
| Population (2018): | 145 734 000 |
| Vaccination coverage (2018): | 95% |

The information above is based on the World Health Organization (2019n).

Russia has an area of 17 000 000 Square kilometres making it the largest country in the World.

In 2012, Russia turned to IBM to create digital medical records for healthcare facilities outside of their largest cities such as Moscow and St. Petersburg (IBM, 2012). Though there has been progress in Russia's digital healthcare (Health Information Translations, 2016), parents are still required to bring their child's vaccination card to the healthcare facility for recording of immunisations.

**India**

| | |
|---|---|
| Continent: | Asia |
| Economic status: | Developing |
| BRICS association: | BRICS nation |
| Population (2018): | 1 352 642 000 |
| Vaccination coverage (2018): | 83% |

The information above is based on the World Health Organization (2019o).

India has an area of 3 287 240 Square kilometres (Office of the Registrar General & Census Commissioner India, 2001). India is the 7$^{th}$ largest country in the World (National Portal of India, 2018).

India aims to immunize approximately 156 000 000 women and children annually (Cilliers, 2017). Increasing immunisation compliance will result in a large decrease in the death and disability rates in India due to vaccine preventable diseases. As at 2016, over 2 000 000 children die each year and a further 1 000 000 children are disabled each year due to vaccine preventable diseases.

Immunize India is the World's largest vaccination reminder service (Immunize India, 2016). It is national non-profit initiative supported by the Indian Academy of Paediatrics, available to parents in India at no charge. Vaccination reminder services in other countries have increased compliance by 20% (Immunize India, 2016). Vaccination reminders will be sent to the registered mobile numbers until the child is 12 years old. There are three reminders, sent two days apart for each for each vaccination.

Based on the design of the system, each child is not uniquely identified, and a complete record cannot be captured. Once a registered child has been vaccinated, the child's vaccination records is not updated. This system is therefore not an end to end solution.

**China**

| | |
|---|---|
| Continent: | Asia |
| Economic status: | Developing |
| BRICS association: | BRICS nation |
| Population (2018): | 1 427 648 000 |
| Vaccination coverage (2018): | 99% |

The information above is based on the World Health Organization (2019p).

China is approximately 9 600 000 Square kilometres (The State Council of the People's Republic of China, 2005). It is the World's 4$^{th}$ largest country (Worldatlas, 2018).

China has not made the digital advances that healthcare consultants had hoped for (Shobert, 2017) and m-Health is still in its infancy (Lam, 2017). Some of the reasons that the advances were not made are as follows (Shobert, 2017):

- Chinese families and healthcare professionals had challenges with access and affordability of digital systems;
- Digital m-Health start-up companies monetised their platforms by offering advertising on the applications;
- The benefit to healthcare professionals who needed to use the digital systems was not always clear; and
- Many of the healthcare professionals were not trained in the use of the applications and therefore did not use them correctly.

China Mobile launched pilot m-Health studies in the Guangdong, Guizhou, and Tianjin provinces in partnership with the University of Cambridge (Lam, 2017). The following programmes were launched:

- Medical Link;
- Medicine Link;

- Vaccine Link; and
- Patient Link.

The aims of these pilot studies were:

- To deliver medical, health, and wellness information via SMS;
- Improve access to doctors via SMS communication;
- Provide vaccine-related information for families;
- Aid in self-diagnosis;
- Create a caller operating system for appointment bookings and a better system for managing patient information;
- Allow for mobile video consultations;
- Provide remote diagnosis and infectious disease tracking; and
- Enable radio-frequency identification tracking for drugs.

One of the reasons for the success of these pilots was the strong existing telecommunications infrastructure.

Though the pilots were successful, China is still in the research phase of their digital healthcare strategies for general medical care as well as vaccination records. There is no fully functioning electronic system for vaccination records.

**South Africa**

| | |
|---|---|
| Continent: | Africa |
| Economic status: | Developing |
| BRICS association: | BRICS nation |
| Population (2018): | 57 793 000 |
| Vaccination coverage (2018): | 79% |

The information above is based on the World Health Organization (2019q).

South Africa has an area of 1 220 813 Square kilometres (South African Government, 2018).

One of the Department of Health's eHealth strategic aims is to create a National Electronic Health Record System (Department of Health, 2012). This includes the

creation of an Electronic Health Record, which includes immunisation records (Kleynhans, 2011).

An information dissemination system called MomConnect was developed by the Department of Health to provide new and expectant mothers information on child healthcare via SMS (Department of Health, 2020). The information sent to the mothers, stops when the child turns one year old. The system does not remind mothers to have their child vaccinated.

There is currently no fully electronic end to end system in place.

### 2.4.2 SUMMARY OF THE RESEARCHED COUNTRIES

**Table 2.4** is a summary of the countries that were investigated. It highlights each country's BRICS association, economic status, continent, population, number of births per year, vaccination coverage and the type of system used to manage vaccination records.

***Table 2.4:*** *Summary of the vaccination records systems across the 16 countries that were researched*

| Country | BRICS nation | Economic status | Continent | Population (2018) | Vaccination coverage (2018) | Fully functioning electronic vaccination records system |
|---|---|---|---|---|---|---|
| Estonia | No | Developed | Europe | 1 323 000 | 91% | Yes |
| Norway | No | Developed | Europe | 5 338 000 | 97% | Yes |
| The Netherlands | No | Developed | Europe | 17 060 000 | 93% | Yes |
| Australia | No | Developed | Australia / Oceania | 24 898 000 | 95% | Yes |
| New Zealand | No | Developed | Australia / Oceania | 4 743 000 | 84% | Yes |
| Mongolia | No | Developing | Asia | 3 170 000 | 98% | No |
| Vietnam | No | Developing | Asia | 95 546 000 | 84% | Yes |
| New Mexico | No | Developing | North America | 126 191 000 | 90% | Hybrid of electronic and physical |
| Uruguay | No | Developing | South America | 3 449 000 | 94% | No |
| Sierra Leone | No | Developing | Africa | 7 650 000 | 91% | No |
| Tanzania | No | Developing | Africa | 56 313 000 | 95% | Yes |
| Brazil | Yes | Developing | South America | 209 469 000 | 85% | Hybrid of electronic and physical |
| Russia | Yes | Economy in transition | Asia | 145 734 000 | 95% | Hybrid of electronic and physical |
| India | Yes | Developing | Asia | 1 352 642 000 | 83% | No |
| China | Yes | Developing | Asia | 1 427 648 000 | 99% | No |
| South Africa | Yes | Developing | South Africa | 57 793 000 | 79% | No |

**Figure 2.11** highlights the various countries that were considered in this study. This visual depiction shows a representation from a global and continental perspective. It also represents the extent of the usage of digital systems for the management of vaccination records by highlighting them in either green, amber, red or grey.

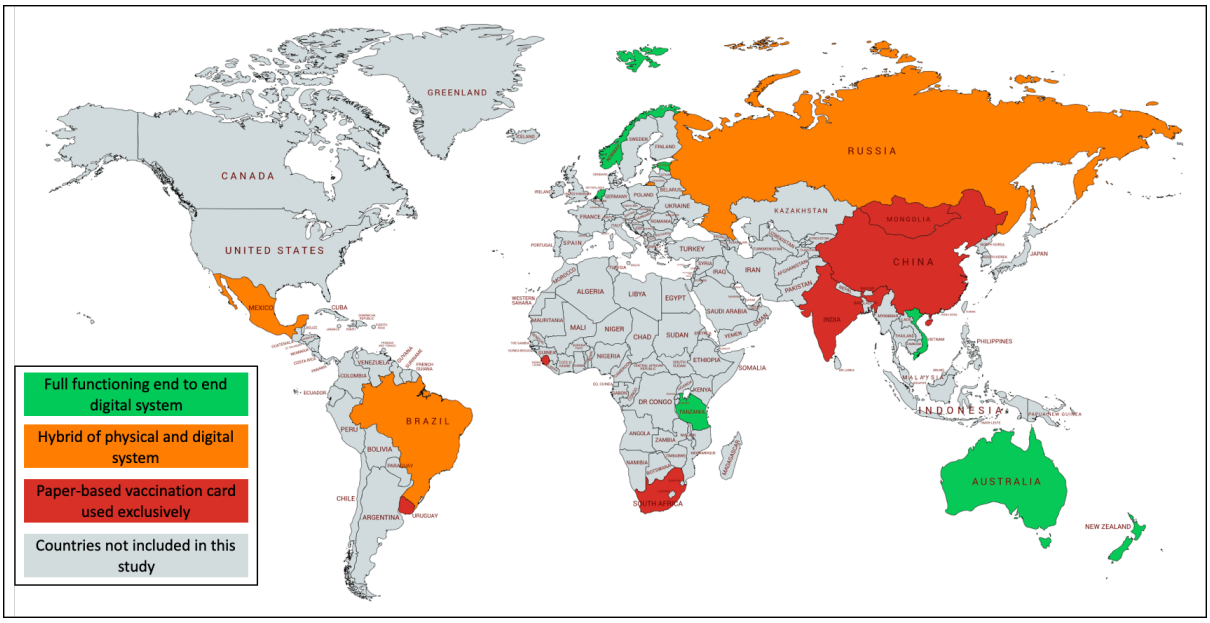



***Figure 2.11:*** *The vaccination record systems of the highlighted countries were investigated. This map was created by utilising the map chart tool created by mapchart.net (2019)*

### 2.4.3 SUMMARY OF THE USE OF DIGITAL HEALTH SYSTEMS IN THE BRICS NATIONS

The investigation of the use of digital health systems in the storage of vaccination records in the BRICS nations showed different trends amongst some of the countries. It was found that India, China and South Africa do not have a fully functioning end to end digital system that manages vaccination records. Brazil and Russia were found to have fully functioning end to end digital systems in place however, these countries still use the physical vaccination card in addition to these systems.

**Figure 2.12** depicts a summary of the review of the BRICS nations' vaccination record systems.

| Country | End to end digital system exists | Physical vaccination cards in use | Outcome |
|---|---|---|---|
| Brazil | Yes | Yes | Hybrid of physical vaccination card and digital system in use |
| Russia | Yes | Yes | Hybrid of physical vaccination card and digital system in use |
| India | No | Yes | Physical vaccination card in use exclusively as no end to end digital system exists. An SMS reminder system is in use |
| China | No | Yes | Physical vaccination card in use exclusively as no end to end digital system exists |
| South Africa | No | Yes | Physical vaccination card in use exclusively as no end to end digital system exists |

***Figure 2.12:*** *Summary of the outcomes of the investigation into the use of digital vaccination record management systems in the BRICS nations*

Although the BRICS nations are similar in economic growth and social challenges, 40% of them have a fully functioning end to end electronic vaccination record system. The Department of Health's eHealth aims discussed in later make it clear that South Africa aims to move to electronic records which includes vaccination records. The trend amongst the BRICS nations is to digitise vaccination records.

### 2.4.4 INVESTIGATION OF MOBILE APPLICATION SYSTEMS FOR VACCINATION RECORD STORAGE

Using a mobile app platform can potentially help to overcome certain health challenges such as oral diseases (Nolen et al., 2018). Since mobile apps can be used for the management of various types of health records, they were included in this study. Various non-government based mobile apps were investigated to determine what information was stored, where the information is stored and whether there are other automatic processes that could be beneficial to e-Vaccination. **Table 2.5** summarises the results of this investigation.

***Table 2.5:*** *Comparison of the investigated mobile applications based on their features*

| Vaccination Record System | Register child | Add vaccination records | View vaccination records | Share vaccination records | Vaccination reminders | Schedule-based vaccination records | Passcode protection |
|---|---|---|---|---|---|---|---|
| Vaccine Reminder | ✓ | ✓ | ✓ | × | ✓ | ✓ | × |
| Vaccines Log – Vaccination Reminder & Tracker | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Child Immunisation Tracker – Baby Immunisation | ✓ | ✓ | ✓ | × | × | × | × |
| My Kids Vaccine Tracking | ✓ | ✓ | ✓ | × | × | ✓ | × |
| My Immunizations | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |

The vaccination record systems summarised in **Table 2.5** show that not all the key features are built into every system. Based on the Department of Health's eHealth aims, it is important to have a system that centralises vaccination records and thereby allow for information to be easily accessed by appropriate authorities. None of the systems in **Table 2.5** send vaccination information to Government systems. In South Africa, there are four possible vaccination schedules (Fedhealth, 2019). It is therefore important to ensure that different schedules are catered for as the vaccination dates would differ. The investigated mobile applications are discussed below.

### Vaccine Reminder

Pediatric OnCall (Pediatric Oncall, 2019) is a child healthcare website that offers a mobile app developed by Pediatric Oncall Private Limited, to help parents keep track of their child's immunisations. The mobile app called Vaccine Reminder can be downloaded off the Apple App Store (Apple Inc., 2018b). This mobile app is private and does not interface with government systems. The features of the system are:

- Parents can register their child on the application;
- Parents can view their child's vaccination records;
- The Vaccination charts and schedules are based on the Centers for Disease Control and Prevention (CDC) vaccination schedule; and
- Parents who have registered for the app will also receive vaccine reminders a few days before their child's vaccines are due.

The data stored in the system are listed in **Table 2.6** and an overview of the system illustrated in **Figure 2.13**.

***Table 2.6:*** *Data stored in the Vaccine Reminder mobile application*

| Data Category | Field Name |
|---|---|
| Child | Name |
| | Age |
| | Gender |
| | Photograph |
| Parent | E-mail address |
| | Mobile phone number |
| Vaccine | Name |
| | Description |
| | Dose |
| | Due date |
| | Status |

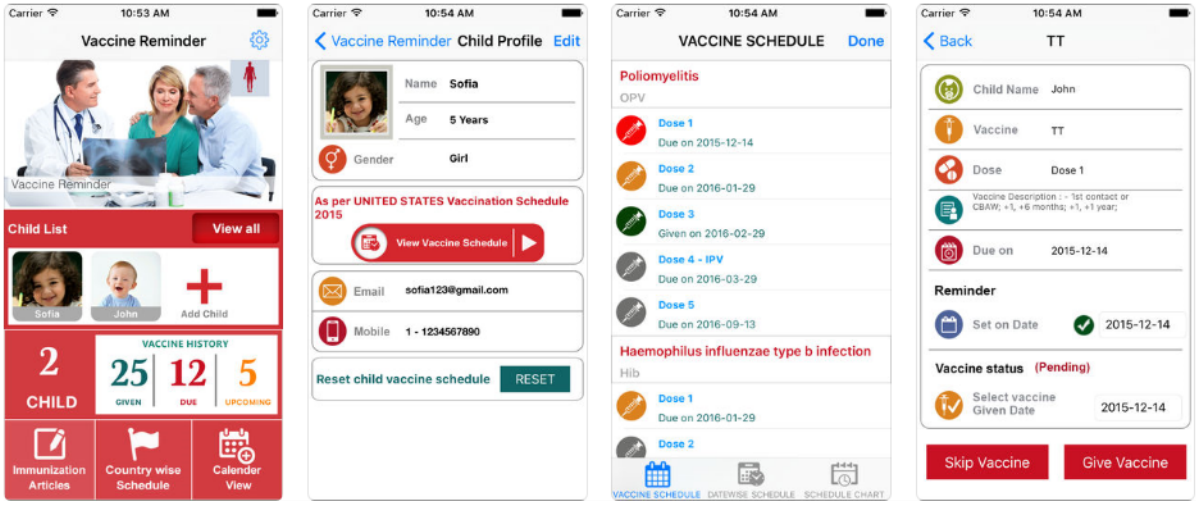



***Figure 2.13:*** *Screenshots of Vaccine Reminder*

### Vaccines Log – Vaccination Reminder & Tracker

Vaccines Log – Vaccination Reminder & Tracker is a mobile app developed by LINKLINKS LTD (LINKLINKS, 2018), available on the Apple App Store (Apple, 2018d). It is used to record children's vaccination records and to also check the vaccination schedule. The app can be downloaded for free and offers In-App purchases. Although the app can be downloaded for free, there is an advertising banner on the top of the app. There is no registration required for this app. All records created are stored on the mobile devices local database and not in a centralised cloud.

If the mobile app is deleted, the data will also be lost. The app has the following features:

- Parents can add an unlimited number of children to the app and check each child's schedule separately;
- Vaccination records can be logged on the app;
- Parents can view their child's vaccination record;
- Parents can set reminders for their child's next vaccine;
- Passcode protection;
- Vaccine logs can be exported via E-mail; and
- Parents can check the CDC program for each age group.

The data stored on the system are listed in **Table 2.7** and an overview of the system is provided in **Figure 2.14**.

***Table 2.7:*** *Data stored in the Vaccines Log mobile application*

| Data category | Field name |
|---|---|
| Child | Name |
| | Date of birth |
| | Gender |
| | Blood type |
| Family doctor | Name |
| | Contact number |
| Vaccine | Name |
| | Description |
| | Dose |
| | Due date |
| | Status |
| | Clinic |
| | Manufacturer |
| | Batch number |
| | Disease that the vaccine prevents against |


***Figure 2.14:*** *Screenshots of Vaccination Reminder and Tracker*

### Child Immunisation Tracker – Baby Immunisation

Child Immunisation Tracker – Baby Immunisation is a mobile app developed by Impressol (Impressol, 2018), also available on the Apple App Store (Apple, 2018a). The app can be downloaded and used at no cost. There are, however advertising pop-ups on the app. There is no registration required for this app. All records created are stored on the mobile devices local database and not in a centralized cloud. If the mobile app is deleted, the data will also be lost. The features of the system are listed below:

- Parents can register their child;
- Parents can add a vaccination record; and
- Parents can view their child's vaccination records.

The data stored on the system are listed in **Table 2.8**, followed by an overview of the system in **Figure 2.15**.

***Table 2.8:*** *Data stored in the Child Immunisation Tracker mobile application*

| Data Category | Field name |
|---|---|
| Child | Name |
| | Date of birth |
| | Gender |
| | Blood type |
| | Photo |
| | Area |
| Family Doctor | Name |
| | Contact number |

| Data Category | Field name |
|---|---|
| Vaccine | Name |
| | Description |
| | Dose |
| | Due date |
| | Status |
| | Disease that the vaccine prevents against |


***Figure 2.15:*** *Screenshots of Child Immunisation Tracker – Baby Immunisation*

### My Kids Vaccine Tracking

My Kids Vaccine Tracking is a mobile app available on the Apple App Store (Apple, 2018c). The app can be purchased for $0,99 internationally or for R14,99 from the South African Apple App Store. The features of the system are listed below:

- Parents can add an unlimited number of children;
- Parents can add a vaccination record;
- Parents can view their child's vaccination history; and
- Allows parents to track their child's vaccinations according to the CDC schedule.

Data stored on the system are listed in **Table 2.9** and an overview of the system is shown in **Figure 2.16**.

***Table 2.9:*** *Data stored in the My Kids Vaccine Tracking mobile application*

| Data category | Field name |
|---|---|
| Child | Name |
| | Date of birth |

| Data category | Field name |
|---|---|
| | Photo |
| Vaccine | Name |
| | Description |
| | Dose |
| | Due date |
| | Date of vaccine |
| | Status |
| | Disease that the vaccine prevents against |

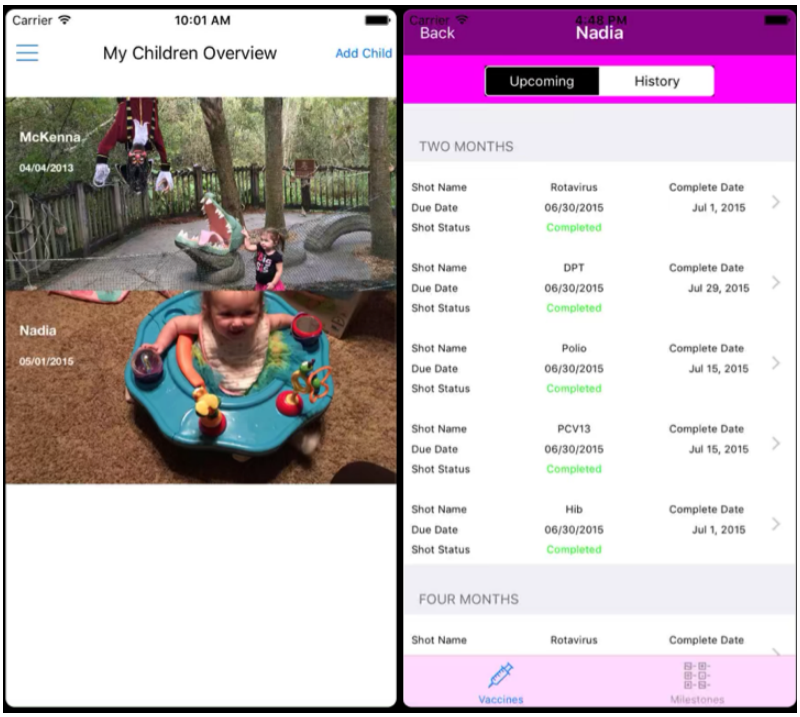



***Figure 2.16:*** *Sample upcoming vaccinations of My Kids Vaccine Tracking*

### My Immunizations

My immunizations is a mobile app that is available on the Apple App Store (Apple, 2018b). The features of the system are listed below:

- Parents can add their children to the app as members;
- Parents can add vaccination records for their children;
- Parents can view vaccination records;
- Parents can send PDF versions of their child's vaccination records themselves so that it can be printed as a physical paper copy; and
- Vaccination reminders.

The data stored on the system are listed in **Table 2.10** and in **Figure 2.17**, an overview of the system is provided.

***Table 2.10:*** *Data stored in the My Immunizations mobile application*

| Data Category | Field Name |
|---|---|
| Child | Name |
| | Date of birth |
| | Photo |
| Parent | Name |
| Vaccine | Name |
| | Description |
| | Due date |
| | Date of vaccine |
| | Status |
| | Disease that the vaccine prevents against |

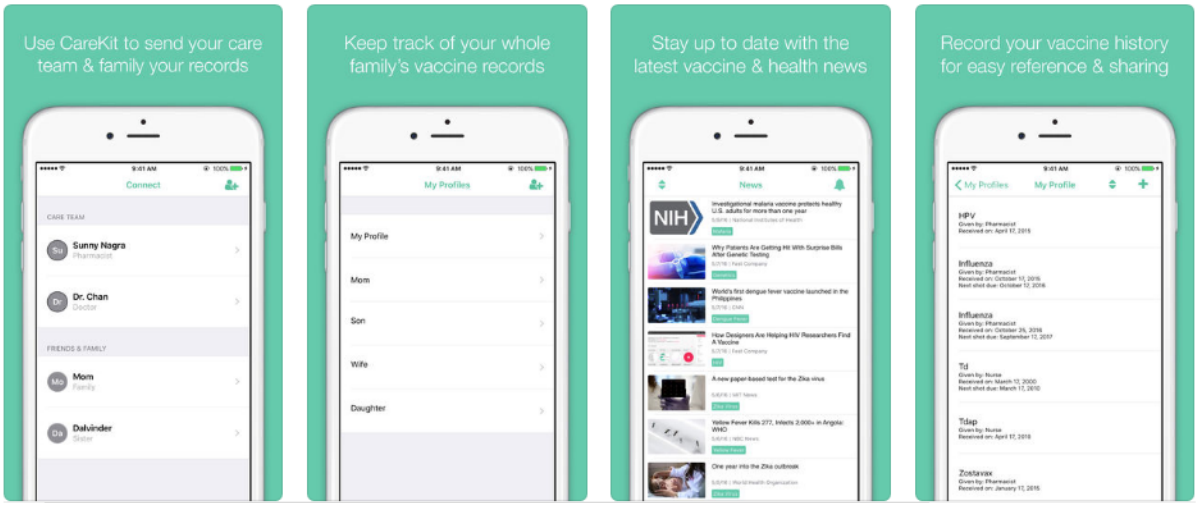



***Figure 2.17:*** *Screenshots of My Immunizations*

### 2.4.5 SUMMARY OF THE FEATURES BUILT INTO THE INVESTIGATED MOBILE APPLICATIONS AND THE INFORMATION STORED

**Table 2.11** contains a summary of the features available across the various mobile applications investigated.

***Table 2.11:*** *Summary of the features built into the investigated mobile applications*

| Feature | Description |
|---|---|
| Register child | Parents can register their children on the application and thereafter track their vaccination records |
| Add a vaccination record | Parents can create a new vaccination record when their child is immunised |

| Feature | Description |
|---|---|
| Share vaccination records | Parents can share their child's vaccination record via E-mail or print out a physical copy |
| View vaccination records | Parents can view their child's vaccination records |
| Set a vaccination reminder | Reminders can be set so that the parent is alerted before their child's vaccination is due |
| Track vaccinations according to CDC schedule | Vaccinations can be tracked based on the various CDC schedules |
| Passcode protection | The application can be protected via a passcode |

The features in **Table 2.11** were considered during the design and build of e-Vaccination. Not all the features were incorporated into e-Vaccination as prototypes are normally built with limited purposes (Houde & Hill, 1997). This is discussed in detail in Chapter 4.

**Table 2.12** contains all the data stored across the various mobile application systems. This information was considered in the development of e-Vaccination. For the purposes of making the prototype easier to use, not all the data fields were included in the final design.

***Table 2.12:*** *Summary of the data stored in the investigated mobile applications*

| Data Category | Field Name |
|---|---|
| Child | Name |
| | Date of birth |
| | Gender |
| | Area |
| | Photo |
| | Blood type |
| Parent | Name |
| | E-mail address |
| | Contact number |
| Family doctor | Name |
| | Contact number |
| Vaccine | Name |
| | Description |
| | Due date |
| | Date of vaccine |
| | Dose |
| | Status |

| Data Category | Field Name |
|---|---|
| | Disease that the vaccine prevents against |

### 2.4.6 CHALLENGES EXPERIENCED WITH PAPER-BASED VACCINATION RECORD SYSTEMS

In addition to the usage of paper-based versus electronic vaccination record systems, a review of the literature, journals and other artefacts revealed three main challenges experienced by paper-based vaccination record systems. These are; vulnerability, accessibility and reliability (**Figure 2.18**) along with the respective challenges faced by paper-based record systems.

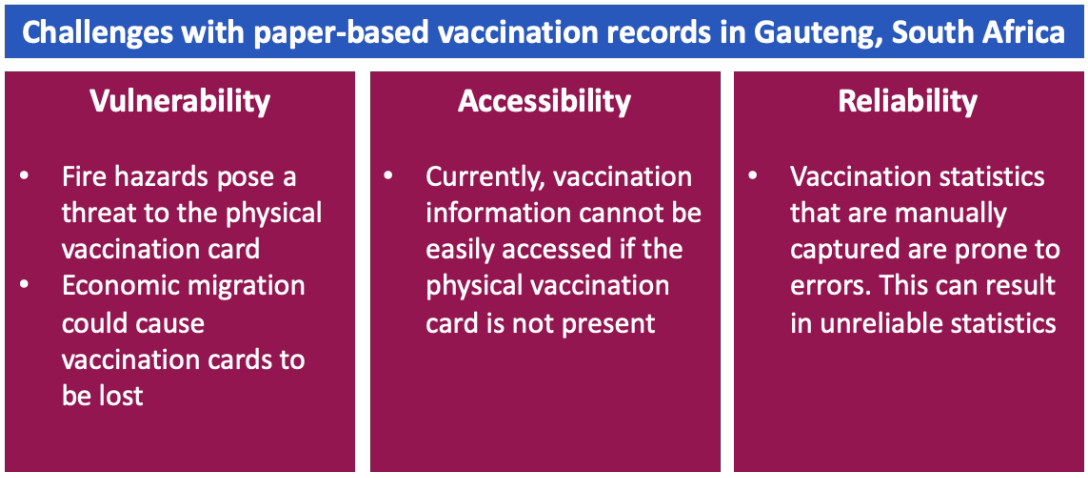



***Figure 2.18:*** *Summary of the three main challenges with the physical vaccination card in Gauteng*

The challenges were then explored in further detail, as summarised below:

- **Vulnerability**:
  - The vaccination record is susceptible to physical damage or loss.
- **Accessibility**:
  - Accessing the vaccination record requires that the physical vaccination card must be present. If the vaccination card is not present, the vaccination records cannot be accessed by any other means.
- **Reliability**:
  - The accuracy or correctness of the vaccination statistics cannot be totally relied upon due to the amount of manual entry by medical practitioners.

In 2013, there were 118 government clinics offering immunisations in the City of Johannesburg region alone (City of Johannesburg, 2018). When a child is born in Gauteng, the parents are given a physical vaccination card called the “Road to Health” card (Department of Health, 2019b). It is the responsibility of the parent to keep the vaccination card safe and to produce the card every time the child is vaccinated (Naidoo et al., 2018). The nurse who immunises the child is responsible for capturing the details of the vaccination on the vaccination card.

The Road to Health card in **Figure 2.19**, must be brought with the child to every clinic visit (Department of Health, 2018).

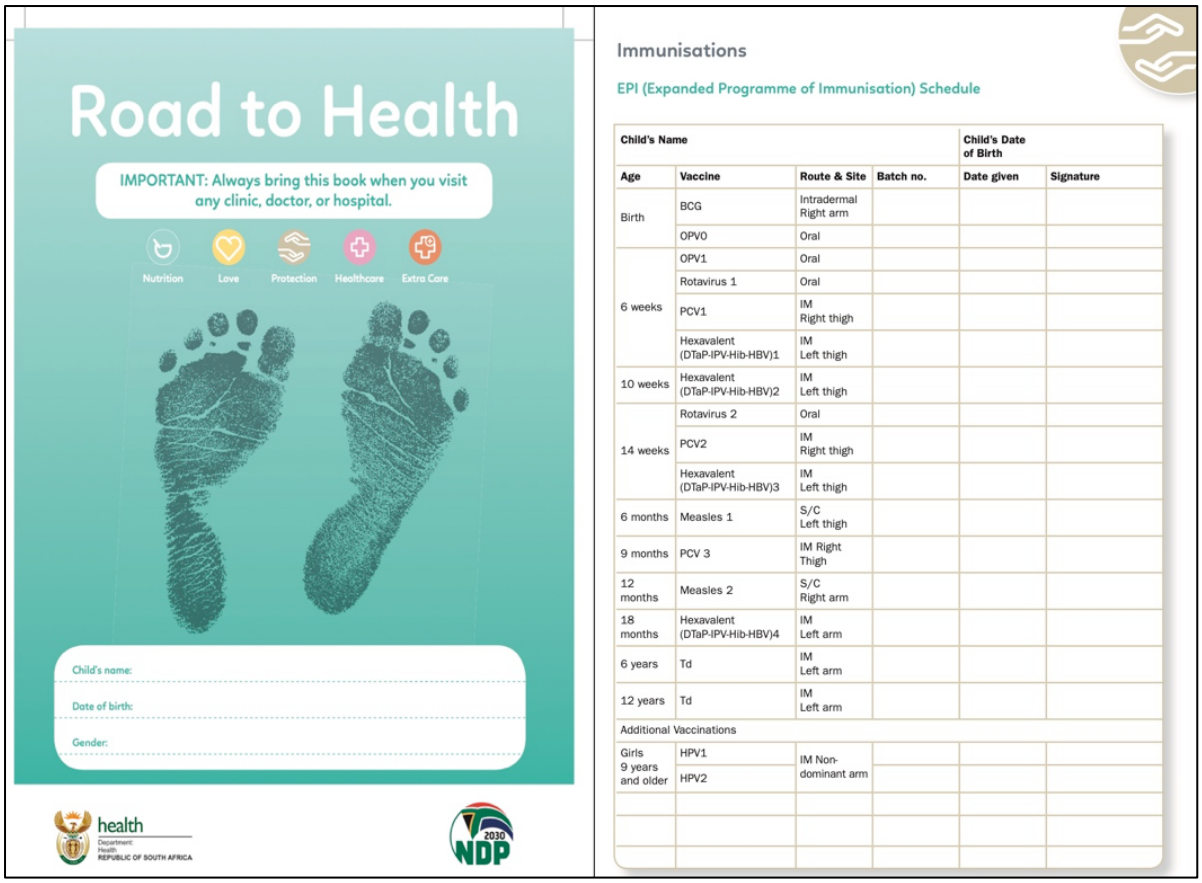



***Figure 2.19:*** *Road to health vaccination card for girls and boys used in Gauteng (Department of Health, 2018)*

This card stores the immunisation records of the child as well as clinic visits, clinic assessments such as signs of malnutrition, milestones such as dates for crawling, as well as tips for parents to keep their child healthy. This booklet stores a lot of information regarding the child’s health. Losing this booklet could mean losing this vital information.

Threats to the physical vaccination card within the context of this study (Gauteng) are discussed below.

### Vulnerability of Physical Vaccination Cards

In Gauteng, fire hazards pose a threat to physical vaccination cards. The Fire Protection Association of Southern Africa (Fire Protection Association, 2018) contains the reports on all fires that have occurred within South Africa. The latest report as at 13 July 2017 is for the year 2014. In 2014, there were 185 fires which affected informal dwellings in Johannesburg, Gauteng. Fires that result in the destruction of these dwellings together with their contents, will also result in the loss of documentation such as vaccination cards. Without another copy of the child's vaccination card, these records would be lost. About 2 642 dwellings were affected by fires from 2011 to 2014 (**Table 2.13)** (Fire Protection Association, 2018). This poses a threat to health documentation such as physical vaccination cards.

***Table 2.13:*** *The number of formal and informal dwellings in Johannesburg, Gauteng affected by fires from 2011 to 2014*

| Year | Number of formal dwellings | Number of informal dwellings | Total per year |
|---|---|---|---|
| 2011 | 390 | 345 | 735 |
| 2012 | 372 | 353 | 725 |
| 2013 | 412 | 373 | 785 |
| 2014 | 212 | 185 | 397 |

Gauteng is the economic hub of South Africa (Stats SA, 2018b). The Gauteng province attracts people from other provinces due to job prospects (economic migration). It is estimated that between 2016 and 2021, 1 048 440 people would have moved from other South African provinces to Gauteng (Stats SA, 2018a). This migration will result in families with minors being moved. This poses a threat to the paper-based records such as vaccination cards being lost during that migration.

### Inaccessibility of Vaccination Records

The physical vaccination card in Gauteng (the Road to Health card) is the single source of vaccination information for each child in Gauteng. As a result, this card has to be present to determine whether a child has been vaccinated in accordance with the vaccination schedule or not (**Figure 2.20**).

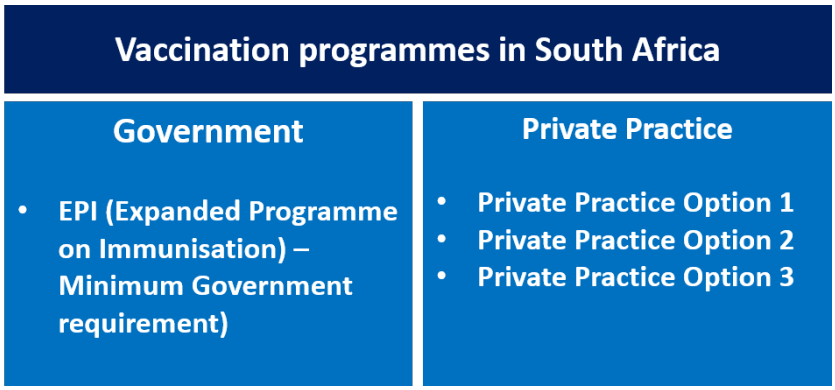



***Figure 2.20:*** *Summary of the South African vaccination programmes (Fedhealth, 2019)*

South Africa has four vaccination schedules or programmes that parents can adhere to when having their children immunised. These schedules are: *EPI* (Expanded Programme on Immunisation) schedule, *Private Practice Option 1*, *Private Practice Option 2* and *Private Practice Option 3*, (Fedhealth, 2019).

The minimum vaccination requirement in South Africa as described by Fedhealth on the image in **Figure 2.21,** consists of 19 vaccines which need to be administered to children from birth to 12 years of age.

# Vaccine schedules for South Africa

| Age of child | EPI schedule | Age of child | Private practice: Option 1 | Private practice: Option 2 | Age of child | Private practice: Option 3 |
|---|---|---|---|---|---|---|
| **At birth** | OPV (0)<br>BCG | **At birth** | OPV (0)<br>BCG | OPV (0)<br>BCG<br>HBV[1] | **At birth** | OPV (0)<br>BCG |
| **6 weeks** | OPV (1)<br>RV (1)<br>DTaP-IPV//Hib (1)<br>HBV (1)<br>PCV (1) | **6 weeks** | OPV (1)<br>RV (1)<br>DTaP-IPV//Hib (1)<br>HBV (1)<br>PCV (1) | OPV (1)<br>RV (1)<br>DTaP-IPV//Hib/HBV (1)<br>PCV (1) | **2 months** | OPV (1)<br>RV (1)<br>DTaP-IPV//Hib/HBV (1)<br>PCV (1) |
| **10 weeks** | DTaP-IPV//Hib (2)<br>HBV (2) | **10 weeks** | RV [2][2]<br>DTaP-IPV//Hib (2)<br>HBV (2)<br>PCV (2) | RV (2)[2]<br>DTaP-IPV//Hib/HBV (2)<br>PCV (2) | **3 or 4 months** | RV (2)[2]<br>DTaP-IPV//Hib/HBV (2)<br>PCV (2) |
| **14 weeks** | RV (2)<br>DTaP-IPV//Hib (3)<br>HBV (3)<br>PCV (2) | **14 weeks** | RV (2 or 3)[2]<br>DTaP-IPV//Hib (3)<br>HBV (3)<br>PCV (3) | RV (2 or 3)[2]<br>DTaP-IPV//Hib/HBV (3)<br>PCV (3) | **4 or 6 months** | RV (2 or 3)[2]<br>DTaP-IPV//Hib/HBV (3)<br>PCV (3) |
| **9 months** | Measles vaccine (1)<br>PCV (3) | **9 months** | Measles vaccine | Measles vaccine | **9 months** | Measles vaccine |
| **18 months** | DTaP-IPV//Hib (4)<br>Measles vaccine (2) | **12-15 months** | PCV (4)[3]<br>Chickenpox (varicella) vaccine (1)[4]<br>MMR (1) or MMRV[5]<br>Hepatitis A vaccine (repeat 6 months later) | PCV (4)[3]<br>Chickenpox (varicella) vaccine (1)[4]<br>MMR (1) or MMRV[5]<br>Hepatitis A vaccine (repeat 6 months later) | **12-15 months** | PCV (4)[3]<br>Chickenpox (varicella) vaccine (1)[4]<br>MMR (1) or MMRV[5]<br>Hepatitis A vaccine (repeat 6 months later) |
| | | **18 months** | DTaP-IPV//Hib (4) | DTaP-IPV//Hib or DTaP-IPV//Hib/HBV (4)[6] | **18 months** | DTaP-IPV//Hib or DTaP-IPV//Hib/HBV(4)[6] |
| **6 years** | Td vaccine | **5-6 years** | MMR (2) or MMRV[5]<br>Chickenpox (varicella) vaccine (2)<br>DTaP or TdaP-IPV | MMR (2) or MMRV[5]<br>Chickenpox (varicella) vaccine (2)<br>DTaP or TdaP-IPV | **5-6 years** | MMR (2) or MMRV[5]<br>Chickenpox (varicella) vaccine (2)<br>DTaP or TdaP-IPV |
| | | **9 years** | HPV (from 9 years)[7] | HPV (from 9 years)[7] | **9 years** | HPV (from 9 years)[7] |
| **12 years** | Td vaccine | **12 years** | TdaP-IPV | TdaP-IPV | **12 years** | TdaP-IPV |

COVERED BY FEDHEALTH MEDICAL AID | NOT COVERED BY FEDHEALTH MEDICAL AID

## Vaccine trade names

| Vaccine | Trade Name | Age Group |
|---|---|---|
| **BCG** | BCG® | Usually at birth only<br>In certain cases, up to 1 year |
| **Chickenpox** | Varilrix® | 9 months and older |
| **DTaP-IPV//Hib/HBV** | Infanrix-Hexa® | 8 weeks to 2 years |
| **DTaP-IPV/Hib[3]** | Pentaxim® | 6 weeks to 2 years |
| **Hepatitis A** | Avaxim 80®<br>Havrix Junior® | 1-15 years |
| **Hepatitis B (HBV)** | Heberbiovac HB®<br>Euvax®<br>Engerix-B® | Birth to adulthood<br>Dose according to age |
| **HPV** | Gardasil® (quadrivalent) | 9-26 years |
| | Cervarix® (bivalent) | 9 years and older |
| **Measles** | Rouvax® | 9 months and older |
| **MMR** | Trimovax®<br>Priorix® | 1 year to adulthood |
| **MMRV** | Priorix Tetra® | 9 months to 12 years |
| **OPV** | OPV-Merieux®<br>Polioral® | Birth to adulthood<br>Not generally recommended in adulthood, because of vaccine-associated paralytic polio (VAPP) |
| **PCV** | Prevenar-13®<br>Synflorix® | 6 weeks to 5 years<br>6 weeks to 2 years |
| **RV** | Rotarix® | First dose from 6 weeks,<br>second dose before 24 weeks |
| | Rotateq® | First dose from 6 weeks,<br>last dose before 32 weeks |
| **TdaP-IPV** | Adacel Quadra® | From 3 years |
| | Boostrix Tetra® | From 4 years |
| **Td** | Diftavax® | 6 years and older |

**Paediatric vaccines available for other situations**
- Hiberix® [Hib (Haemophilus influenzae type b)]: Up to 5 years of age.
- Infanrix® [DTaP (diphtheria, tetanus, acellular pertussis)]: Up to 7 years of age.
- Twinrix® (hepatitis A and B).

Family takes care of family

## Abbreviations

**(0):** Birth dose, which doesn't count as part of primary series
**(1):** First dose in a series
**(2):** Second dose in a series
**(3):** Third dose in a series
**(4):** Fourth dose (booster)
**BCG:** Bacille Calmette-Guérin (tuberculosis vaccine)
**DTaP-IPV//Hib/HBV (hexavalent):** Diphtheria, tetanus, acellular pertussis/inactivated polio vaccine/ Haemophilus influenzae type b and hepatitis B vaccine
**DTaP-IPV//Hib (pentavalent):** Diphtheria, tetanus, acellular pertussis/inactivated polio vaccine and influenzae type b vaccine
**EPI:** Expanded Programme of Immunisation
**HBV:** Hepatitis B vaccine
**HPV:** Human papillomavirus vaccine
**MMR:** Measles, mumps and rubella vaccine
**OPV:** Oral polio vaccine
**PCV:** Pneumococcal conjugated vaccine
**RV:** Rotavirus vaccine
**Tdap-IPV (quadrivalent):** Tetanus and reduced amount of diphtheria vaccine with acellular pertussis and inactivated polio vaccine.
**Td vaccine:** Tetanus and reduced amount of diphtheria vaccine

## Notes (superscripted numbers)

1. If the hexavalent vaccine (Infanrix-Hexa®) is given according to the EPI schedule (6, 10 and 14 weeks), a birth dose of HBV (not routinely given in South Africa) is required.
2. If pentavalent RV is given, three doses are required, at 6, 10 and 14 weeks. If monovalent vaccine is given, only two doses are required, at 6 and 14 weeks.
3. When Synflorix® is given, the fourth dose can be given from 9.5 months, provided it has been six months since the last dose.
4. Chickenpox (varicella) vaccine can be given at any time from 9 months of age, but is probably most effective if given after the age of 12 months. If not given on the same day as measles vaccines, the vaccines must be separated by at least one month. Varicella vaccine can now be given in combination with MMR as MMRV.
5. MMRV is an option if varicella vaccine has not been given yet. MMRV can be given in place of MMR and varicella vaccines.
6. A booster of HBV is not routinely recommended in South Africa.
7. HPV quadrivalent vaccine can be given to boys and girls; the course consists of three doses, at 0, 2 and 6 months. HPV bivalent vaccine can be given to girls only; the course consists of three doses, at 0, 1 and 6 months.

FEDHEALTH

***Figure 2.21:*** *The South African vaccination schedule (Fedhealth, 2019)*

Based on these vaccination schedules, the vaccination card must be kept updated and safe for a minimum period of 12 years. Even if a physical document such as a vaccination card is kept safe, there is a possibility of damage over the 12 year vaccination period. In addition, vaccination cards are printed and prepopulated based on the vaccines that are available at that point in time. The introduction of new vaccines therefore poses a challenge, as vaccination cards that have already been printed and distributed to parents cannot be accessed in order for the cards to be updated. Parents and guardians will also not be aware of the new vaccines that are available.

The vaccination card is required during the admissions process of children into public schools (Brand South Africa, 2015). In the case of private schools, this can differ from school to school. A random sample of 24 schools were investigated to determine whether vaccination cards were required upon admission. The results show that of the 24 schools investigated, 41,7% require a copy of the child's vaccination card upon admission or registration. In addition, minors in Gauteng can also be vaccinated in their school as part of the school health programme (Department of Health, 2019a).

A summary of the vaccination requirements in a random sample of 24 Gauteng schools is depicted below and further information is documented in Appendix 7.

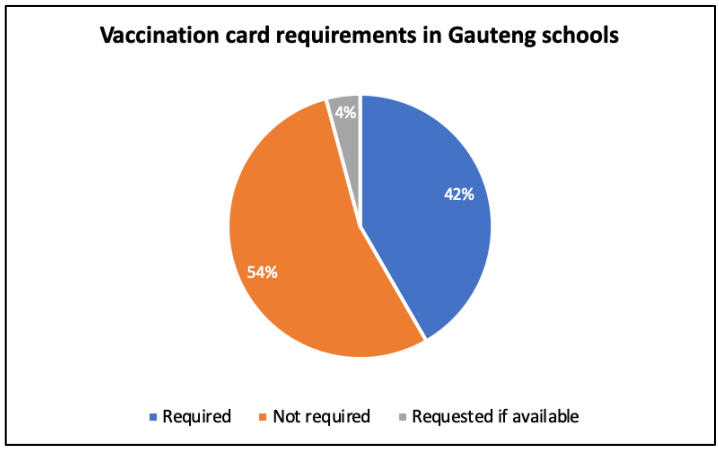



***Figure 2.22:*** *Summary of the vaccination card requirements based on a sample of 24 schools in Gauteng*

In each instance, that is, an adm0issions process or vaccinating a child at school, the vaccination record of each child will need to be present in order to determine the child's vaccination status and to update the vaccination record. If the card is not present, this could result in the child not being accepted at a particular school, in relation to the

admissions process; or being re-vaccinated or not vaccinated, in relation to vaccinating a child at school.

The lack of access to up to date information can pose a threat during epidemic outbreaks. From all the common childhood viral illnesses, Measles is the most serious (Health24, 2018). It forms a red rash on the skin and its symptoms include a high fever, cough and a runny nose. See Appendix 8 for an image of the Measles rash.

In May 2017, an outbreak of the Measles virus was detected in Gauteng with 17 cases detected as early as the 08th May 2017 (Mdhluli, 2017). The MEC for Health in Gauteng at the time, Dr Gwen Ramokgopa, said that immunisation centres would be setup at health facilities with the aim of immunising around 1 million children. The Department of Health undertook a mass Measles vaccination campaign (National Institute for Communicable Diseases, 2017). The aim was to vaccinate children from six months to five years of age. The Measles immunisation rates in South Africa are documented in Appendix 9.

In a situation such as this, where there is an outbreak of a vaccine preventable disease, a child's vaccine records are vital to determine whether the child has been vaccinated against this disease or not. It is possible that many children would have been revaccinated against the Measles virus which can be traumatic for small children (Orenius et al., 2018).

A study done in Shenzen, China (a BRICS economy) showed that the parental recollection of their children's vaccination status for the Measles virus slightly over estimated the actual vaccination status of the children (Liu et al., 2017). In that study, 163 children who had an electronic record of their vaccination status were considered. The study found that 48,5% of parents reported that their children were vaccinated against the Measles virus however the electronic records showed that 41,7% of the children were vaccinated against the Measles virus.

A similar study conducted in California, USA, took into account 54 066 participants, who were asked whether they had received the Smallpox vaccination (LeardMann et al., 2007). Their responses could be checked against their electronic vaccination record as there was an electronic system in place. When comparing the participants' recollection of whether they had been vaccinated against Smallpox and their electronic record, it was found that 84% of the responses matched.

In both these studies, there is a slight difference between information recalled by the participants and the electronic record of the child's vaccination status. It should be noted however, that in both instances, there was an electronic record of the vaccination with which to compare. In Gauteng there is no electronic record for parents to rely on in the event that a vaccination card is lost. In cases where a child's vaccination records are lost and the parents are unable to remember the vaccinations that the child has had, the child will have to be re-vaccinated (Child Healthcare, 2018).

There has not been any vaccination recall incidents in South Africa as yet. On 26 April 2010 however, the WHO and UNICEF (WHO and UNICEF, 2010) announced a recall of the Shan5 vaccine. The Shan5 vaccine was produced in India by Shantha Biotechnics. The WHO and UNICEF recommended that all Shan5 vaccines manufactured by Shantha Biotechnics be destroyed due to incidents of a white sediment sticking to vials. There were no reported side effects of the white sediment or the vaccine, the recall was just a precautionary measure.

Should a vaccine recall occur in Gauteng, the paper-based vaccine record system will not be adequate in immediately identifying the children who had received the vaccine from a specific batch. An electronic vaccine record storage system could be used to determine which children received vaccines from the affected batch of vaccines. Their parents could then be contacted so that they can take the necessary steps to revaccinate their child. The current paper-based system therefore poses a significant threat to children who have received a recalled vaccine as there is no easy way to access or identify these children.

**Unreliability and Limited Usability of Vaccination Data**

The information flow for paper-based vaccination records is one way. Once the medical professional administers the vaccine, the details are captured on the vaccination card. There is not always a mechanism that takes the details of the child or the record of the vaccination and sends it back to a central repository. As a result of this one-way information flow, the validity of vaccination data can be challenged by external or internal organisations.

The accuracy of vaccination statistics can be affected if the information that feeds into the reports is not up to date or accurate. **Figure 2.23** illustrates the flow of vaccination data from a health facility or clinic in South African to the WHO (van den Heever,

2012). The child's details are verified against the child register at the healthcare facility. From there, the data is tallied and compiled into a Health Facility report for each health facility. Data from the various health facilities within each district is then combined into District Tabulations. All the District Tabulations within each province are then grouped and combined into the Province Reports which then form part of the National Tabulations. This is compiled into a Joint report that is sent to the WHO.

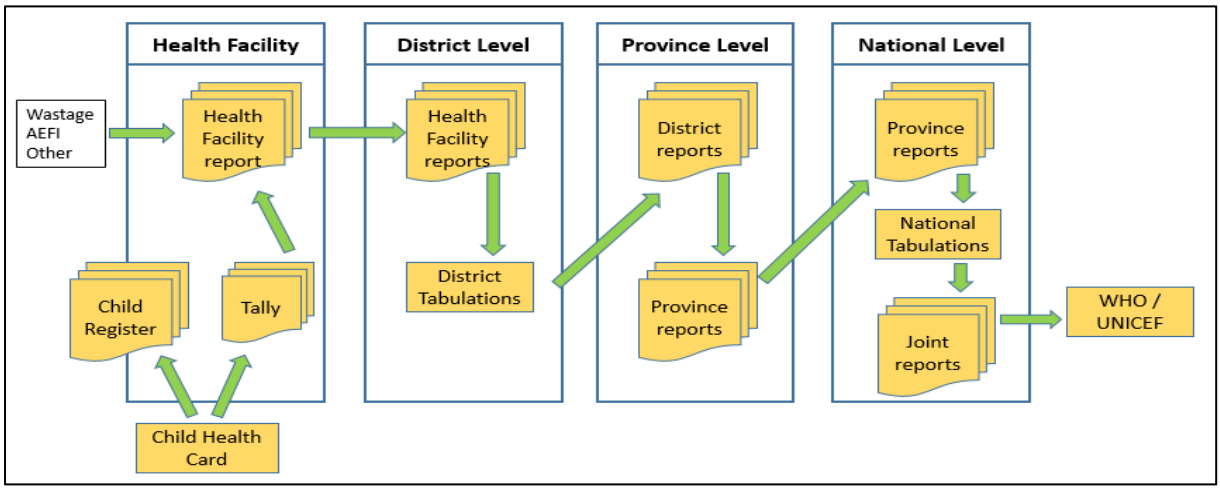



***Figure 2.23:*** *Depiction of the vaccination data flow from health facility to national level. The data flow cycle occurs every 45 days (van den Heever, 2012)*

Based on the flow in **Figure 2.23**, it appears that the vaccination statistics at a national level and at the WHO would be the same, but this is not the case. The Department of Health reported a 96% vaccination rate in South Africa whereas the WHO reported a rate of 64% (Dyosop, 2012). The vaccination statistics of South Africa reported by both the Department of Health and the WHO are flawed (Dyosop, 2012).

The Head of the Department of Health's Expanded Programme on Immunisation (EPI), Johann van den Heever also disputed the WHO/UNICEF vaccination coverage figures (van den Heever, 2012). He does however acknowledge that there are data discrepancies in the Department of Health data due to old data collection tools.

In a study conducted in Canada, it was found that the electronic vaccination record system allowed data to be collected, analysed and applied in a rapid fashion (Heidebrecht et al., 2014). Positive sentiments about the system were expressed by appointment clerks, nurses, registration, implementation and management staff. The system was used to record influenza vaccine uptake in addition to the standard

required vaccinations. The data were not just stored but also analysed to determine trends in immunisation.

The significant discrepancy in the estimated vaccination rates between the WHO and the Department of Health in South Africa demonstrates the high level of unreliability in the vaccination statistics of paper-based systems. In addition, when compared to an electronic vaccination record system, the usability of the vaccination data, that is, the ability to analyse and forecast using the data, is limited.

The data flow of vaccination records as detailed above is subject to human error at almost all points in the collection process. This poses a threat to the accuracy of vaccination related data. The manual interventions that arise from the paper-based system can result in unreliable and inaccurate data.

A country that has seen meaningful impact of moving from a paper-based system to an electronic records system is Vietnam. The previous paper-based system used in Vietnam was cumbersome (PATH, 2017). Generating reports from a paper-based system can lead to errors and can be time consuming. By moving from a paper-based system to an electronic system, the ImmReg system was able to reduce the amount of human errors in manual lists and increase the effectiveness of on-time delivery of certain vaccines by up to 20% (PATH, 2017).

Without the implementation of an electronic vaccination record system, Gauteng is unlikely to experience material increase in the accuracy of vaccination data.

### 2.4.7 PROCEDURE FOR THE REPLACEMENT OF LOST VACCINATION CARDS

Since there is no fully automated end to end vaccination record system in Gauteng (van den Heever, 2012), losing a vaccination card usually means losing a child's vaccination records. Parental recall can be used to recover the child's vaccination history. In the Measles vaccine study pointed out earlier (Liu et al., 2017), parental recall does slightly overestimate vaccination rates.

In the event of a physical vaccination card being lost or damaged in Gauteng, the following process must be followed (Child Healthcare, 2018):

- The mother should collect a new "Road-to-Health" immunisation card from a clinic. This card must be marked as a duplicate;

- The nurse should ask the mother which immunisations the child has had already;
- Based on the mother's recollection of the child's immunisations, the immunisation card will be updated accordingly; and
- If the mother is uncertain about certain vaccines, these vaccines will be administered to the child.

Provided that the child is not too old, repeating immunisations is not dangerous (Child Healthcare, 2018). Re-vaccinating a child can however have adverse psychological effects. Needle phobia is a condition that is more common in children and adolescents (within vaccination age) than in adults (Orenius et al., 2018). A condition called Resistive Needle phobia which is characterised by combativeness, can result in the dread of needles and a fear of being controlled (Orenius et al., 2018). Subjecting children to re-vaccination could therefore result in an increased fear of injections.

### 2.4.8 ELECTRONIC HEALTH AIMS OF THE DEPARTMENT OF HEALTH

The measure of success of a country's eHealth maturity is made up of five stages (Department of Health, 2012). These stages are summarised in **Table 2.14**.

***Table 2.14:*** *Summary of the five stages of eHealth maturity in developing countries*

| Stage | Description |
|---|---|
| Stage 1 | District health indicators are collected by means of paper-based systems |
| Stage 2 | The optimisation of the paper-based systems. This is achieved by the simplification of information and reducing the amount of duplication |
| Stage 3 | Converting the paper-based district health information systems into electronic storage and reporting |
| Stage 4 | Introducing working ICT systems as the source of data in the Health Information System |
| Stage 5 | Integrated and fully comprehensive National Health Information System |

Overall, South Africa is at Stage 3 of eHealth maturity (Department of Health, 2012). Some provinces however, are at Stage 4 in certain areas and other provinces at Stage 1, 2 and 3. The Department of Health has outlined the following steps for South Africa to reach Stage 4 and 5 of eHealth maturity:

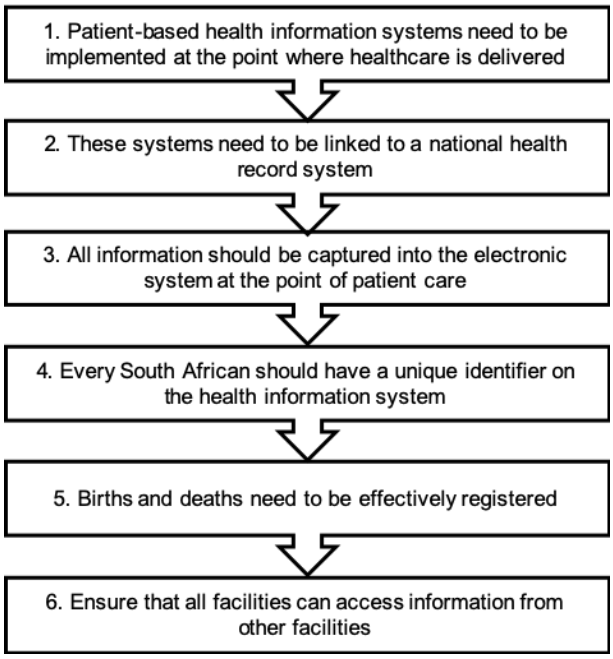



***Figure 2.24:*** *The six steps identified by the Department of Health to take South Africa into Stage 4 and 5 in terms of eHealth (Department of Telecommunications and Postal Services, 2017)*

A summary of the Department of Health's aims for eHealth are listed in **Figure 2.25**. This is based on a report by the Department of Telecommunications and Postal Services (Department of Telecommunications and Postal Services, 2017).

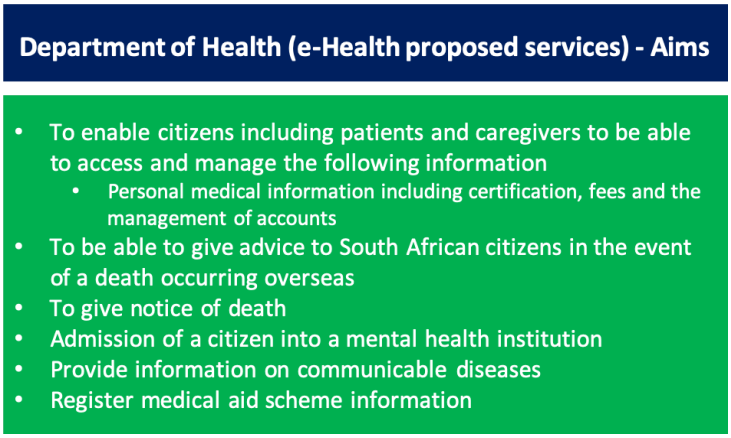



***Figure 2.25:*** *Summary of the Department of Health's aims regarding e-Health, (Department of Health, 2012)*

The first aim of the Department of Health's eHealth strategy relates to the accessibility challenge currently experienced with the physical vaccination card in Gauteng. The rest of the eHealth strategy aims in **Figure 2.25** are indirectly related to vaccination records.

South Africa still relies on the physical vaccination card to record children's immunisation details (Department of Health, 2019b). There is no fully electronic system that keeps track of individual children's vaccination records.

Though not mentioned in the eHealth aims above, the use of digital records could also contribute towards the reporting of herd immunity based on the physical location of the minors who have been vaccinated against certain diseases. Early warning systems could utilise digital vaccination records for further processing.

The objective of this research is therefore qualified as it is an extension of the existing research regarding electronic health records and supports the aims of the Department of Health's eHealth strategy.

## 2.5 SUMMARY OF LITERATURE REVIEW

The Literature Review is comprised of five main components. These are illustrated in **Figure 2.26**.

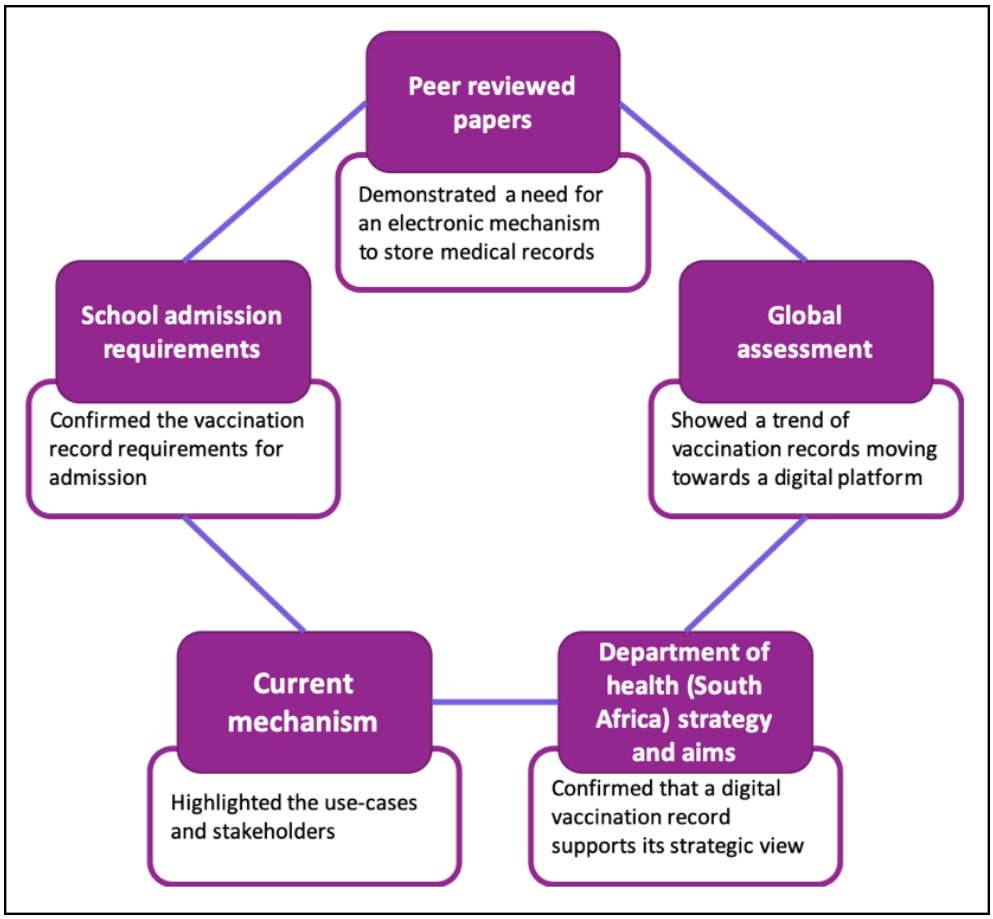



***Figure 2.26:*** *Summary of Chapter 2*

The five main components of the Literature Review as illustrated in **Figure 2.26** were Peer Reviewed Papers, Global Assessment, Department of Health Aims and Strategy, Current Mechanism and School Admission Requirements. These were investigated to determine the feasibility of using an electronic mechanism for the effective management of vaccination records in Gauteng. The outcome of this investigation is summarised as follows:

- **Peer Reviewed Papers –** Evidence shows that countries are moving towards digital systems for the management of medical health records. There is lack of research done in the area of medical records specifically aimed at vaccination records. These papers were listed in **Table 2.2**.
- **Global Assessment –** The assessment of the 16 countries shows that some countries are digitising their vaccination record systems. This trend is seen in countries regardless of their economic status, continental location or whether they are BRICS members or not. This was discussed in Section 2.4.1.

- **Department of Health –** The aims and strategies of the Department of Health support the digitising of medical records and to create an electronic health record for citizens. Since vaccination records form part of a child's medical history, it should also be included in the overall strategy. This was discussed in Section 2.4.8.
- **Current Mechanism –** The current paper-based record was used to determine the use cases or processes as well as to identify the key stakeholders involved with vaccination records. This information was used in the construction of the research question as well as the questionnaire that will be discussed in Chapter 3.
- **School Admission Requirements –** A random sample of schools in Gauteng revealed that vaccination cards are required upon admission by 41,7% of those schools. The school admission requirements were discussed in Section 2.4.6.

The Literature Review has demonstrated that an investigation on the current paper-based vaccination record system in Gauteng is warranted and that replacing it with a digital system is potentially feasible.

# CHAPTER 3: RESEARCH METHODOLOGY

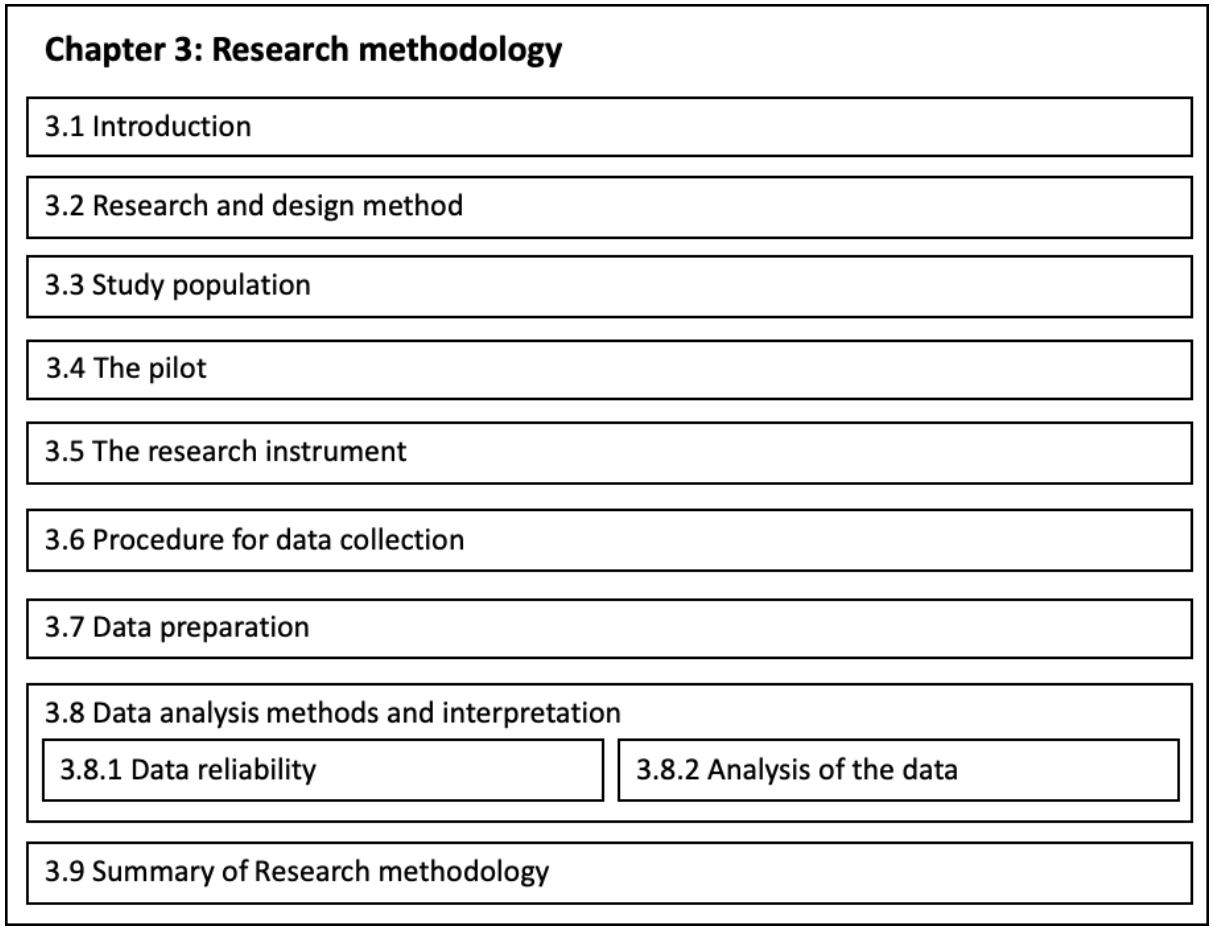



***Figure 3.1:*** *Structure of Chapter 3*

## 3.1 INTRODUCTION

Elements of a literature review were shared in Chapter 2. This showed that countries are moving towards an electronic health record for citizens. Based on the evidence presented in Chapter 2, it was found that the vaccination record system used in Gauteng, South Africa is largely paper-based. South Africa also aims to digitise medical records of its citizens and have identified the steps needed to do so.

To answer the research question, "*What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system?*" it was necessary to perform a quantitative research analysis by collecting relevant data and analysing it. This chapter shows where and how the data were collected. It also describes how the data were prepared and analysed.

## 3.2 RESEARCH AND DESIGN METHOD

A literature review was conducted to determine the relevance and feasibility of this study. It was found that there is not a fully automated system for vaccination records management for minors in Gauteng. Countries are increasingly moving towards digital systems for the management of medical information (Kleynhans, 2011). This led to the design of a prototype electronic vaccination record system (e-Vaccination). This is an appropriate method relating to a study involving eHealth (Botha, 2015). A prototype system is a way to explore designs for computer systems containing limited purposes (Houde & Hill, 1997). e-Vaccination therefore has limited features but can be used to demonstrate how an electronic vaccination records management system could function.

To assess the effectiveness of the prototype and to answer the research question, a questionnaire was designed to collect feedback from the relevant stakeholders. The prototype developed for this study was initially piloted by ten users who provided their feedback regarding the system. The prototype was thereafter refined and prepared for distribution to the relevant stakeholders.

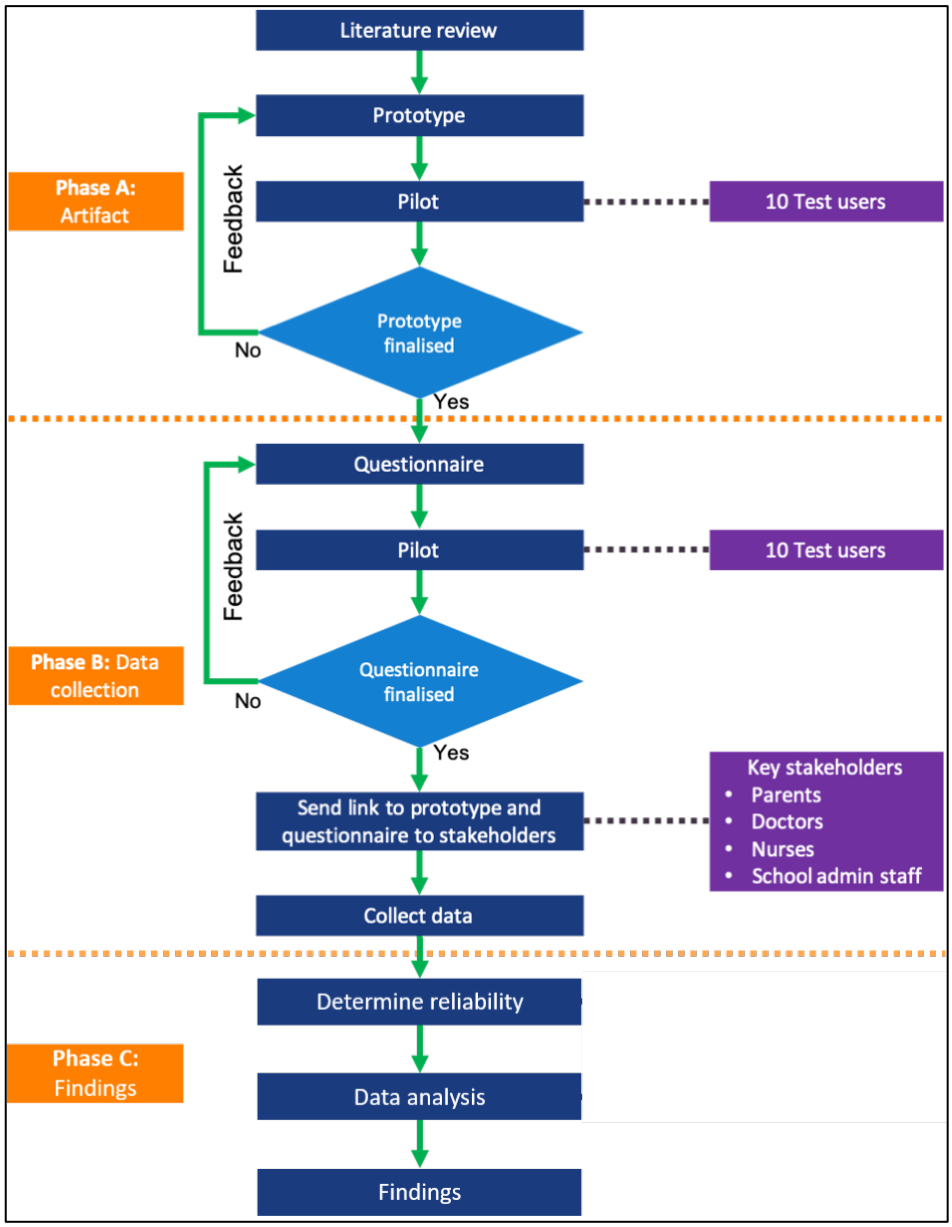



***Figure 3.2:*** *The Research Design Flow*

**Figure 3.2** is an illustration of the Research Design Flow. The steps are explained in detail below:

- **Literature review –** The steps taken in this phase of the research are illustrated in **Figure 2.2**.
- **Prototype –** The design and development of a prototype electronic system for the management of vaccination records followed an iterative process. The aim of the prototype was to demonstrate the usefulness and effectiveness of an electronic system with limited features as an end-to-end system is not required for a software prototype (Houde & Hill, 1997). It must be noted that although

this research involves elements of health informatics, the quasi intervention method was not utilised.

- **Pilot (Prototype) –** Once the prototype was developed, it was piloted with ten test users to ensure that there were no bugs in the system. As this was an iterative process, bugs that were identified were fixed and the process continued until the prototype was ready for use.
- **Questionnaire –** The questionnaire was designed to gather responses on the use of an electronic vaccination record system for minors in Gauteng.
- **Pilot (Questionnaire) –** The questionnaire was piloted on ten test users to ensure that the questions were understandable and worded in a manner that avoided ambiguity. Any issues identified with the questionnaire were corrected.
- **Send link to prototype and questionnaire to stakeholders –** Once the prototype and questionnaire were finalised, stakeholders from the four groups were contacted via E-mail, telephone call, instant messaging or by visit.
- **Collect Data –** Once the stakeholders completed the questionnaire, the responses were submitted electronically in the case of the online submission. Although physical questionnaire responses were catered for, all submissions were eventually done electronically.
- **Determine Reliability –** The Cronbach Alpha was used to determine the reliability of the responses.
- **Data Analysis –** The data were analysed using a Chi-Square, Analysis of Variance and a Principle Component Analysis.
- **Findings –** The results of the data analysis were then prepared for the conclusion.

## 3.3 STUDY POPULATION

A study conducted by Wang et al., (2015) involving three stakeholder types (physicians, medical record staff and patients) revealed that physicians (doctors) had the least amount of support in an information system that is used to share information between hospitals. We used an adapted approach in this research where four key stakeholder types were chosen based on their involvement with vaccination records. This is described in **Figure 3.3**.

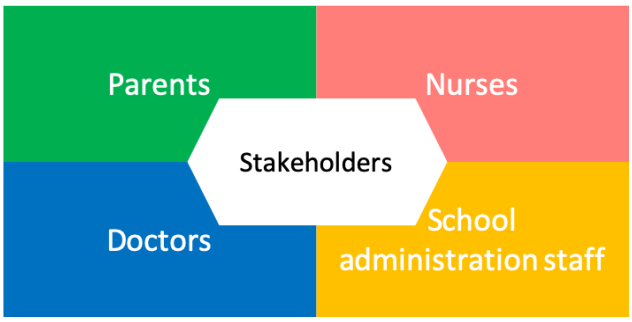



***Figure 3.3:*** *The four key stakeholder groups considered in this research*

- **Doctors (Non-specialists or specialists) –** Doctors sometimes administer vaccinations and have detailed knowledge of vaccinations as well as the consequences of losing a vaccination card.
- **Nurses –** Nurses administer vaccinations to children. They also work with the existing paper-based vaccination card on a daily basis and could provide the relevant insight into the use of a digital vaccination management system.
- **Parents (Those who have children under the age of 12) –** Parents are currently responsible for the storage of their children's paper-based vaccination records. They could also be future users of an electronic vaccination record storage system.
- **School administration staff –** School administration staff understand the entrance requirements of schools. They have insight into the procedures when dealing with children who either do not have a valid vaccination record or have an incomplete vaccination record.

The participants of this research were selected using a sample of convenience where subjective methods can be used to determine whether a participant should be included in the research or not (Battaglia, 2008).

## 3.4 THE PILOT

e-Vaccination was piloted on ten users to ensure that there were no defects. Feedback was also considered to refine e-Vaccination, contributing towards a better user experience. **Table 3.1** is a summary of the feedback received and actions taken.

***Table 3.1:*** *The feedback received from the pilot phase and the corresponding actions that were taken*

| Feedback | Action taken |
|---|---|
| Reduce the amount of typing required for the prototype | Sample parent profiles were created and populated in dropdown boxes. This allowed the stakeholders to easily select a child profile with which to experiment. |
| Do not display features that are not available in the menu | Features that are not available in the prototype were coloured in grey. |

During the pilot phase, no defects were reported.

## 3.5 THE RESEARCH INSTRUMENT

To answer the research question, it was necessary to collect and analyse data relating to e-Vaccination. A questionnaire with three sections was designed to collect Demographic Information; Perceptions towards vaccinations in Gauteng; Usefulness, Satisfaction and Ease of Use (based on the USE tool) (Lund, 2001) related information on e-Vaccination. The USE Tool is a method that is used to measure the usefulness, ease of use, ease of learning and satisfaction of a software tool from a users' perspective (Lund, 2001). The three sections are explained in further detail below:

1. **Section A: Respondent Information (Demographics)**
    a. This was to determine where the respondent lives and works. Since the research is relevant for Gauteng, the respondents needed to either live or work in Gauteng;
    b. To determine which of the four key stakeholder groups the respondent belonged to; and
    c. To determine whether the stakeholders had access to the Internet, a smartphone and an e-mail address. These resources are needed to access an electronic system of this nature.
2. **Section B: Vaccinations Records in Gauteng, South Africa**
    a. This section was used to determine the stakeholders' perceptions towards the paper-based vaccination card;
    b. To determine whether the stakeholder believed that vaccination records should be managed by the Parents/Guardians or Government; and
    c. To determine the stakeholders' perceptions towards the vaccination rate in Gauteng.

## 3. Section C: A Centralised Electronic Vaccination Record System in Gauteng, South Africa Managed by the Government

a. This section of the questionnaire was based on a 5-point Likert scale with the five possible responses as {Strongly agree = 5, Agree = 4, Neither agree nor disagree = 3, Disagree = 2, Strongly disagree = 1} (Andres & Borabo, 2015; Nolen et al., 2018;). These questions, based on the USE tool (Lund, 2001) were divided into five sub-categories, that is, Usefulness, Ease of Use, Ease of Learning, Satisfaction and, Design and Visual Aids. These sub-categories are explained in **Table 3.2**.

***Table 3.2:*** *Description of the categories in Section C of the questionnaire*

| Category | Description |
|---|---|
| Usefulness | The system is useful (Lund, 2001) |
| Ease of Use | The system is easy to use (Lund, 2001) |
| Ease of Learning | The system is easy to learn to use (Lund, 2001) |
| Satisfaction | The user is satisfied with the system and would recommend it to a friend (Lund, 2001) |
| Design and Visual Aids | The design and visual aids such as icons are helpful |

The complete research instrument is found in Appendix 10. The five categories in **Table 3.2** resulted in the hypotheses listed in **Table 3.3**.

***Table 3.3:*** *The five categories in the questionnaire with the associated null and alternate hypotheses*

| Category | Null Hypothesis | Null Hypothesis Description | Alternate Hypothesis | Alternate Hypothesis Description |
|---|---|---|---|---|
| Usefulness | $H_{0\text{- usefulness}}$ | e-Vaccination is useful | $H_{1\text{- usefulness}}$ | e-Vaccination is not useful |
| Ease of Use | $H_{0\text{- easy to use}}$ | e-Vaccination is easy to use | $H_{1\text{- easy to use}}$ | e-Vaccination is not easy to use |
| Ease of Learning | $H_{0\text{- easy to learn}}$ | e-Vaccination is easy to learn | $H_{1\text{- easy to learn}}$ | e-Vaccination is not easy to learn |
| Satisfaction | $H_{0\text{- satisfaction}}$ | The stakeholders are satisfied with e-Vaccination | $H_{1\text{- satisfaction}}$ | The stakeholders are not satisfied with e-Vaccination |
| Design and Visual Aids | $H_{0\text{- design and visual aids}}$ | The design and visual aids of e-Vaccination are helpful | $H_{1\text{- design and visual aids}}$ | The design and visual aids of e-Vaccination are not helpful |

## 3.6 PROCEDURE FOR DATA COLLECTION

The questionnaire was distributed to the key stakeholders electronically (via the prototype). The participants were asked to use e-Vaccination first and then respond to the questionnaire. A paper-based version of the questionnaire was also prepared (but never used). The responses were anonymous as per a similar study by Wang et al., (2015). No identifying details such as names, E-mail addresses or contact numbers was collected from the respondents. Respondents to the questionnaire were selected using a sample of convenience with their contact details obtained via the Internet in some cases. In other cases, word of mouth was used to distribute the link to the prototype and questionnaire. Permission to collect data was obtained from the institutions as listed in **Table 3.4.**

***Table 3.4:*** *Details of the research permission obtained for the data collection from the various institutes*

| Institute | Committee | Reference number |
|---|---|---|
| Gauteng Province Health Department | Tshwane Research Committee | GP_201812_018 |
| Gauteng Province Health Department | Ekurhuleni Health District | GP_201812_018 |

Ethics approval letters can be found in Appendix 4, 5 and 6.

## 3.7 DATA PREPARATION

Once the questionnaires were filled in and the data collected, the following steps were taken to prepare the data for analysis:

- Responses were filtered to ensure that only those stakeholders living/working in Gauteng were considered;
- Incomplete answers (not applicable) were replaced with the respective respondents' mean (Downey & King, 1998); and
- Responses to negatively worded Likert-type questions were reversed (Jozsa & Morgan, 2017).

Once these steps were taken, the data were considered ready for analysis.

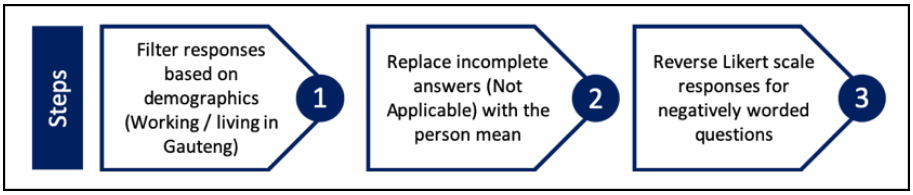



***Figure 3.4:*** *The steps taken to prepare the data collected for analysis*

## 3.8 DATA ANALYSIS METHODS AND INTERPRETATION

Once the dataset was ready for analysis and interpretation, the steps outlined in **Figure 3.5** were followed.

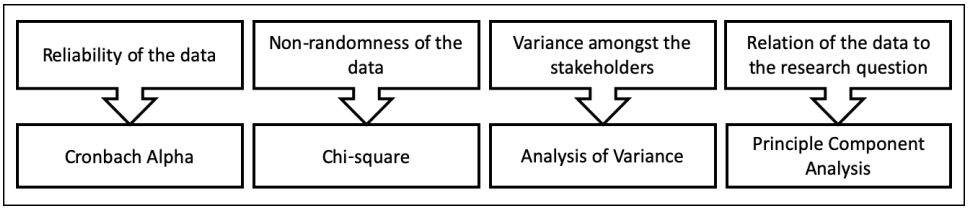



***Figure 3.5:*** *The data analysis steps that were followed*

The data had to be proven reliable before the analysis took place. A Cronbach Alpha was used to determine this. In order to confirm that the data collected was not a randomised occurrence, a Chi-Square goodness of fit test was followed as a subsequent step. Since there were four different stakeholder groups, a comparison of the data collected between these groups was done using an Analysis of Variance (ANOVA) test. Once it was proven that the data were reliable, not random and that stakeholder groups did not have a significant difference between them in their responses, a Principle Component Analysis (PCA) was done. The PCA was used to determine whether the responses to the questionnaire were related to the overall research question. These data analysis steps are discussed in detail below.

### 3.8.1 DATA RELIABILITY

The Cronbach Alpha is used to determine the reliability of a set of questions (Goforth, 2015). When using a Likert scale, it is imperative to use Cronbach's alpha to report the internal consistency reliability (Gliem & Gliem, 2003). Cronbach Alpha scores are expressed as a decimal value from 0 to 1 (Goforth, 2015). The scores are interpreted as per **Table 3.5**.

***Table 3.5:*** *The Cronbach alpha scores and ratings based on the scores (Gliem & Gliem, 2003)*

| Score | Rating |
|---|---|
| >0,9 | Excellent |
| >0,8 alpha <=0,9 | Good |
| >0,7 alpha <=0,8 | Acceptable |
| >0,6 alpha <=0,7 | Questionable |
| >0,5 alpha <=0,6 | Poor |
| alpha <0,5 | Unacceptable |

Once the data were collected, the Cronbach Alpha score was calculated for each category of Section C of the questionnaire. The score for each category was used to determine whether the data were reliable based on scores in **Table 3.5**.

### 3.8.2 ANALYSIS OF THE DATA

#### Chi-Square test

The Chi-Square test is used to determine the likelihood that, an observed distribution of categorical data, is due to chance (University of Pennsylvania School of Arts and Sciences, 2008). A similar study by McConachie et al., (2020) involving electronic health records, used the Chi-Square test to analyse the data. For purposes of this research, the Chi-Square test was used to determine if the results obtained were based on a random occurrence or whether the results were influenced by another variable, which formed the basis of the hypothesis for this test.

The null hypotheses and associated alternate hypotheses for the Chi-Square test per sub-category are listed in **Table 3.6**.

***Table 3.6:*** *The null and alternate hypotheses for the Chi-Square test*

| Category | Null Hypothesis | Null Hypothesis Description | Alternate Hypothesis | Alternate Hypothesis Description |
|---|---|---|---|---|
| Usefulness | $H_{0}$- usefulness Chi-Square | The proportions of scores for the usefulness category are the same between the observed and the expected responses | $H_{1}$- usefulness Chi-Square | At least 2 proportions of scores for the usefulness category are different between the observed and the expected responses |
| Ease of Use | $H_{0}$- easy to use Chi-Square | The proportions of scores for the ease of use category are the same between the observed and the expected responses | $H_{1}$- easy to use Chi-Square | At least 2 proportions of scores for the ease of use category are different between the observed and the expected responses |
| Ease of Learning | $H_{0}$- easy to learn Chi-Square | The proportions of scores for the ease of learning category are the same between the observed and the expected responses | $H_{1}$- easy to learn Chi-Square | At least 2 proportions of scores for the ease of learning category are different between the observed and the expected responses |
| Satisfaction | $H_{0}$- satisfaction Chi-Square | The proportions of scores for the satisfaction category are the same between the observed and the expected responses | $H_{1}$- satisfaction Chi-Square | At least 2 proportions of scores for the satisfaction category are different between the observed and the expected responses |
| Design and Visual Aids | $H_{0}$- design and visual aids Chi-Square | The proportions of scores for the design and visual aids category are the same between the observed and the expected responses | $H_{1}$- design and visual aids Chi-Square | At least 2 proportions of scores for the design and visual aids category are different between the observed and the expected responses |

A 5% significance level and four degrees of freedom were used in the calculation of the Chi-Square test. The null hypothesis was rejected if the Chi-Square value was greater than the critical value. The critical value is based on the table of Chi-Square Statistics (The University of Texas at Austin, 2004). Similarly, if the *p value* was less than the significance level, this means that the probability that random chance is causing the observed values to be different from the expected value is extremely small, there is therefore a statistical relationship between the variables (StatisticsSolutions, 2020).

**Analysis of Variance Test**

The Analysis of Variance (ANOVA) test was used because data was collected from more than two stakeholder types. The ANOVA test is used to determine if there are significant differences between different experimental conditions (Rutherford, 2000). This statistical method was used to analyse Likert-type scales in a similar study by Holtz & Krein (2011). In this research, the differences between the means of the different stakeholder groups were analysed to determine if the null hypothesis for each sub-category was accepted.

The null hypotheses and associated alternate hypotheses for the ANOVA test per sub-category are listed in **Table 3.7**.

***Table 3.7:*** *The null and alternate hypotheses for the ANOVA test*

| **Category** | **Null Hypothesis** | **Null Hypothesis Description** | **Alternate Hypothesis** | **Alternate Hypothesis Description** |
|---|---|---|---|---|
| Usefulness | $H_{0\text{- usefulness ANOVA}}$ | The mean scores for the usefulness category across the 4 stakeholder groups are the same | $H_{1\text{- usefulness ANOVA}}$ | At least 2 mean scores for the usefulness category across the 4 stakeholder groups are different |
| Ease of Use | $H_{0\text{- easy to use ANOVA}}$ | The mean scores for the ease of use category across the 4 stakeholder groups are the same | $H_{1\text{- easy to use ANOVA}}$ | At least 2 mean scores for the ease of use category across the 4 stakeholder groups are different |
| Ease of Learning | $H_{0\text{- easy to learn ANOVA}}$ | The mean scores for the ease of learning category across the 4 stakeholder groups are the same | $H_{1\text{- easy to learn ANOVA}}$ | At least 2 mean scores for the ease of learning category across the 4 |

| Category | Null Hypothesis | Null Hypothesis Description | Alternate Hypothesis | Alternate Hypothesis Description |
|---|---|---|---|---|
| | | | | stakeholder groups are different |
| Satisfaction | $H_{0\text{- satisfaction ANOVA}}$ | The mean scores for the satisfaction category across the 4 stakeholder groups are the same | $H_{1\text{- satisfaction ANOVA}}$ | At least 2 mean scores for the satisfaction category across the 4 stakeholder groups are different |
| Design and Visual Aids | $H_{0\text{- design and visual aids ANOVA}}$ | The mean scores for the design and visual aids category across the 4 stakeholder groups are the same | $H_{1\text{- design and visual aids ANOVA}}$ | At least 2 mean scores for the design and visual aids category across the 4 stakeholder groups are different |

The degrees of freedom between groups was determined as 3 and as 114 for degrees of freedom within groups. These results, together with a 5% level of significance were used to calculate the ANOVA test. If the p value was greater than the level of significance, it meant that the differences in the responses across the stakeholder types was not statistically significant (Minitab Express, 2019), the null hypothesis would then be accepted.

### Principle Component Analysis

A Principle Component Analysis (PCA) is a data reduction method (UCLA Institute for Digital Research & Education, 2020) that can be used to investigate a relationship between dependent variables (Syms, 2019). In this case, the relationship between the responses and the overall concept of digitising the vaccination card as well as the five sub-categories relating to Section C of the questionnaire. The dataset used in the PCA were the responses of the 118 participants to the 33 questions contained in Section C of the questionnaire. A PCA was also conducted in a similar study by Ndirangu et al., (2009).

Prior to conducting the PCA, the Kaiser-Meyer-Olkin (KMO) value was calculated in order to determine whether the data was suitable for a PCA, since the KMO value is a measure of sampling adequacy (UCLA Institute for Digital Research & Education, 2020). The KMO value should be greater than 0,5 (David & Jacobs, 2014).

Once it had been determined that the dataset was suitable for a PCA, the PCA was conducted and the Eigenvalues were calculated to determine the principle components of the dataset. Eigenvalues greater than 1 should be kept (UCLA Institute for Digital Research & Education, 2020). The Eigenvalues were then used to generate a scree plot that was used to determine which of the components identified from the PCA were significant.

## 3.9 SUMMARY OF RESEARCH METHODOLOGY

A quantitative analysis of the data was performed to determine the perceptions of the key stakeholders. **Figure 3.6** is a summary of the data preparation and analysis steps that were followed in this study.

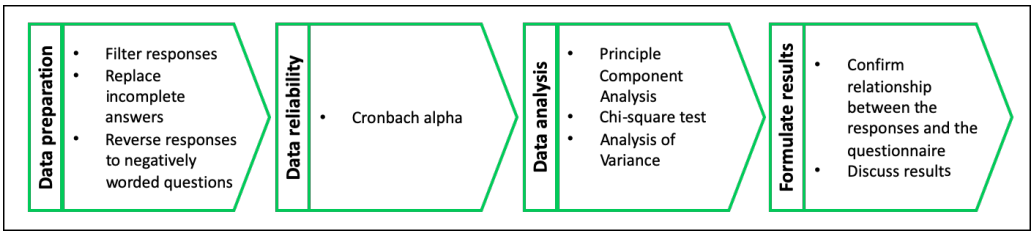



***Figure 3.6:*** *The steps taken to analyse the responses and formulate the results*

# CHAPTER 4: ARTEFACT

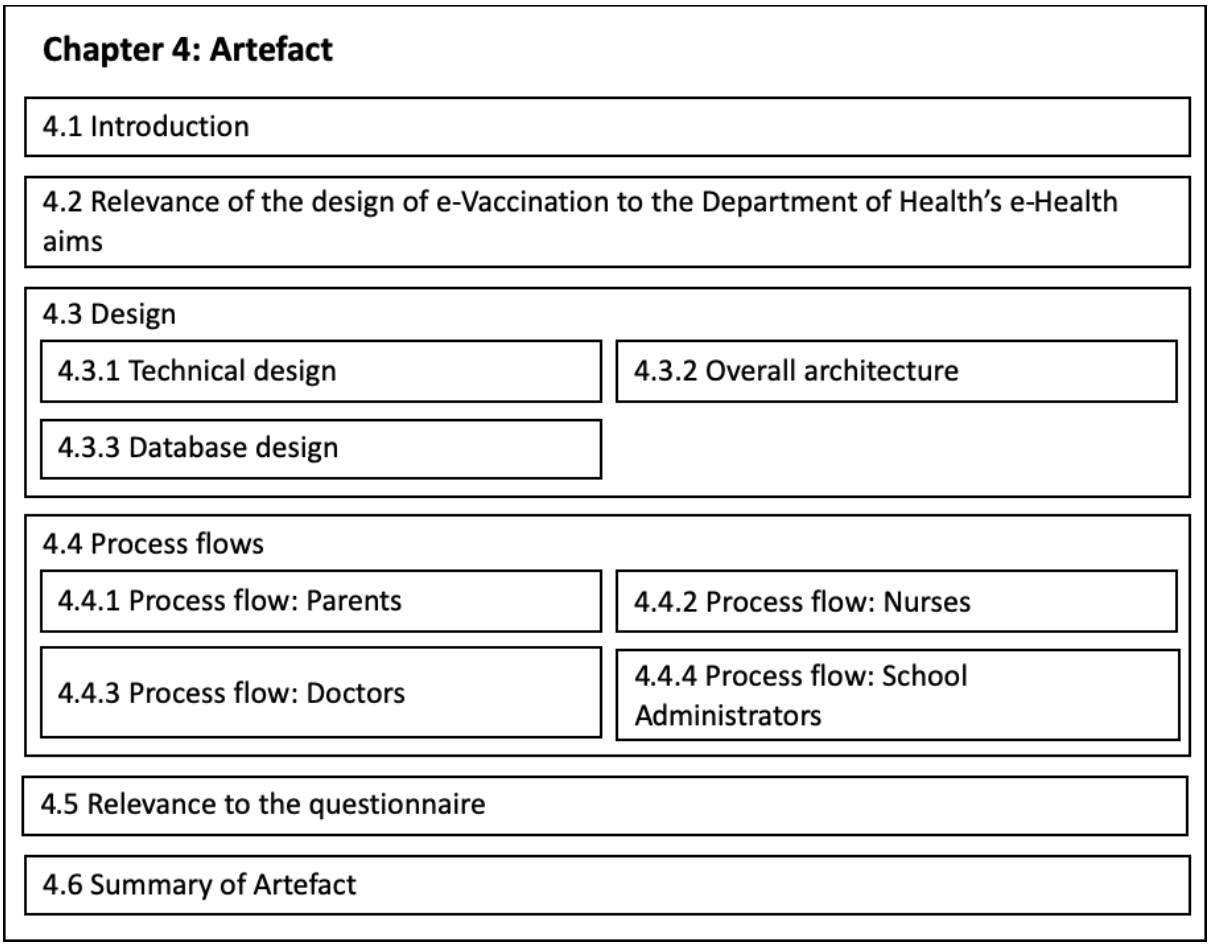



***Figure 4.1:*** *Structure of Chapter 4*

## 4.1 INTRODUCTION

The prototype (e-Vaccination) was created to demonstrate an electronic version of a vaccination record system. Its functionality and design were centred on the four key stakeholders (Parents, Doctors, Nurses and School Administrators). The phase in the research where e-Vaccination was used is detailed in **Figure 3.2**.

## 4.2 RELEVANCE OF THE DESIGN OF E-VACCINATION TO THE DEPARTMENT OF HEALTH'S E-HEALTH AIMS

The five stages of eHealth maturity in developing countries (Department of Health, 2012) were introduced in Section 2.4.8 together with the steps identified by the South African Department of Health to move South Africa from Stage 3 to Stage 4 and 5 (Department of Health, 2012). The design of e-Vaccination took into account the eHealth maturity stages and the steps needed to move South Africa to Stages 4 & 5

(**Figure 4.2**). e-Vaccination therefore supports 5 out of the 6 steps (**Figure 4.2**), the respective features that support these steps are elaborated in **Table 4.1**.

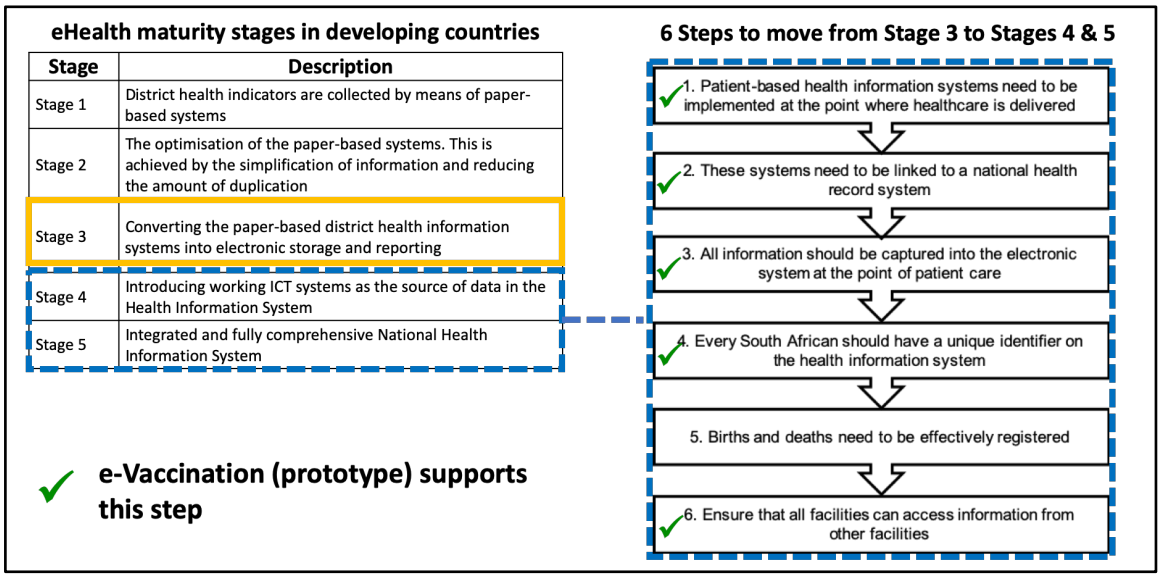



***Figure 4.2:*** *Summary of the eHealth maturity stages for developing countries together with the steps that the Department of Health has identified to move South Africa to stages 4 and 5*

***Table 4.1:*** *Summary of the e-Vaccination features that support the steps identified in Figure 4.2*

| Step Number | Description of e-Vaccination Feature |
|---|---|
| 1 | e-Vaccination is a cloud-based system that can be accessed and used at the healthcare facility where the vaccination is being administered, provided there is an Internet connection. |
| 2 | With the use of systems integration e-Vaccination can be linked to a national health record system. |
| 3 | The electronic vaccination record can be created at the healthcare facility. |
| 4 | e-Vaccination ensures that every minor has a unique identifier. |
| 6 | Since e-Vaccination is a cloud-based system, the information can be accessed from anywhere provided there is an Internet connection. |

## 4.3 DESIGN

The features built into the investigated mobile applications are detailed in **Table 4.2** as well as whether or not such feature was incorporated into the design of e-Vaccination or not.

***Table 4.2:*** *Influence of the researched systems on e-Vaccination, with the rationale for each feature*

| Feature | Included in e-Vaccination | Rationale |
|---|---|---|
| Register child | No | Sample parent and child profiles were created for the stakeholders to use. This would ensure that the stakeholders could get straight into the key features of the system. |
| Add a vaccination record | Yes | Adding a vaccination record is currently an important part of vaccination records management. |
| Share vaccination record | No | The downloading and sharing of vaccination records was not included in e-Vaccination to keep the prototype lean. |
| View a vaccination record | Yes | The 4 stakeholder types are able to view vaccination records based on the sample profiles. |
| Set a vaccination reminder | No | To keep e-Vaccination lean, this feature was not built. |
| Track vaccinations according to CDC schedule | Yes | The vaccinations in e-Vaccination were based on the South African EPI schedule. |
| Passcode protection | Yes | e-Vaccination requires a passcode to log in. |

As seen in **Table 4.2**, four out of the seven researched features were included into the design and build of e-Vaccination.

### 4.3.1 TECHNICAL DESIGN

In a study conducted by Wang et al., (2015) involving three stakeholder types (physicians, medical record staff and patients), it was concluded that policy makers should consider incorporating a Cloud-based Healthcare Information System. A cloud-based system that houses the application and data in a centralised location was therefore created. That system has been hosted by Uniwebserve since 2017 and will terminate at the end of 2020.

e-Vaccination was created using the PHP programming language as a server-side scripting language that allows for dynamic content to be displayed on a web page. The data is stored on a MySQL database. HTML5 was used to display the information. Both these systems are open source, so no development license costs were incurred during the development of the prototype.

The front-end (user interface) is mobile responsive and has been adapted to mobile devices. The system therefore renders the best application or usability on a mobile device instead of desktop computers.

### 4.3.2 OVERALL ARCHITECTURE

**Figure 4.3** illustrates the overall architecture of e-Vaccination.

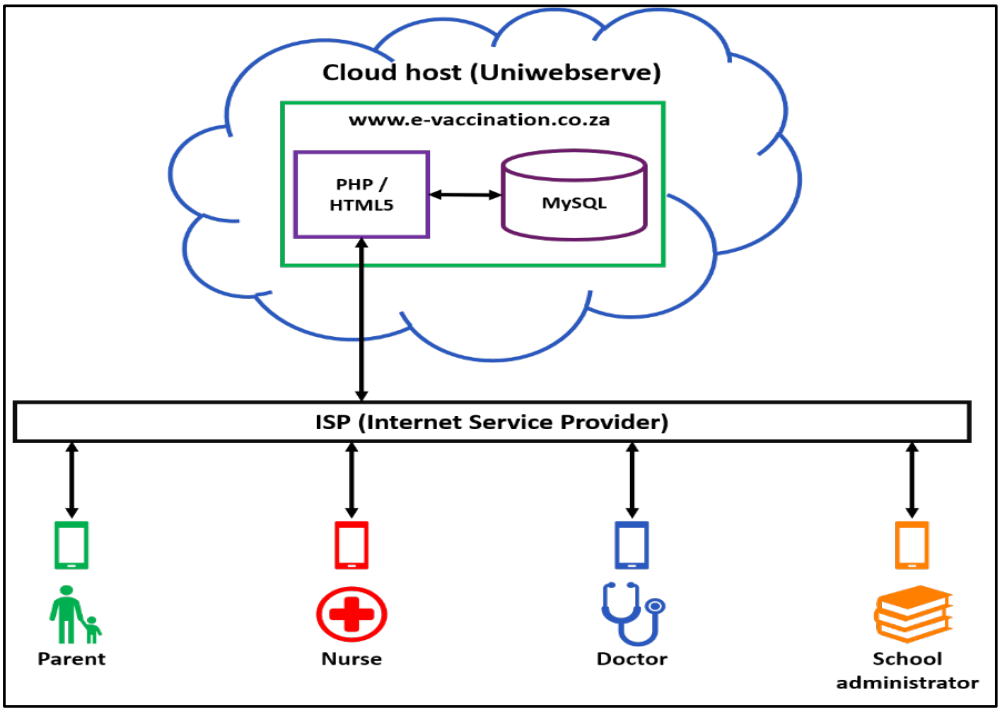



***Figure 4.3:*** *An illustration of the architecture of e-Vaccination*

As seen in **Figure 4.3**, the stakeholders can use their Internet enabled devices to access e-Vaccination. A request is sent from their device which goes via their ISP (Internet Service Provider) by going to www.e-vaccination.co.za in their web browser. The e-Vaccination home page will then be displayed.

Once they enter an access code which was provided along with the link to the system, it will be verified, and the stakeholder will be logged in. All the patient and other statistics data reside on the MySQL database which is accessed using PHP and displayed using HTML5. If the stakeholder's Internet connection is interrupted, the pages will no longer display, and the stakeholder will have to log in once the Internet connection is up.

### 4.3.3 DATABASE DESIGN

The database design was based on the data that needed to be stored. The data were grouped into tables based on some of the designs of the investigated mobile applications as previously summarised in **Table 2.12**.

An Entity Relationship Diagram (ERD), shows a relationship between database entities, in this case the tables. It also depicts the relationship types (one to one, one to many, many to one, many to many) (w3schools, 2019). **Figure 4.4** is an ERD which represents the database tables that make up e-Vaccination and how they relate to each other. Not all the tables are linked to others, some exist independently.

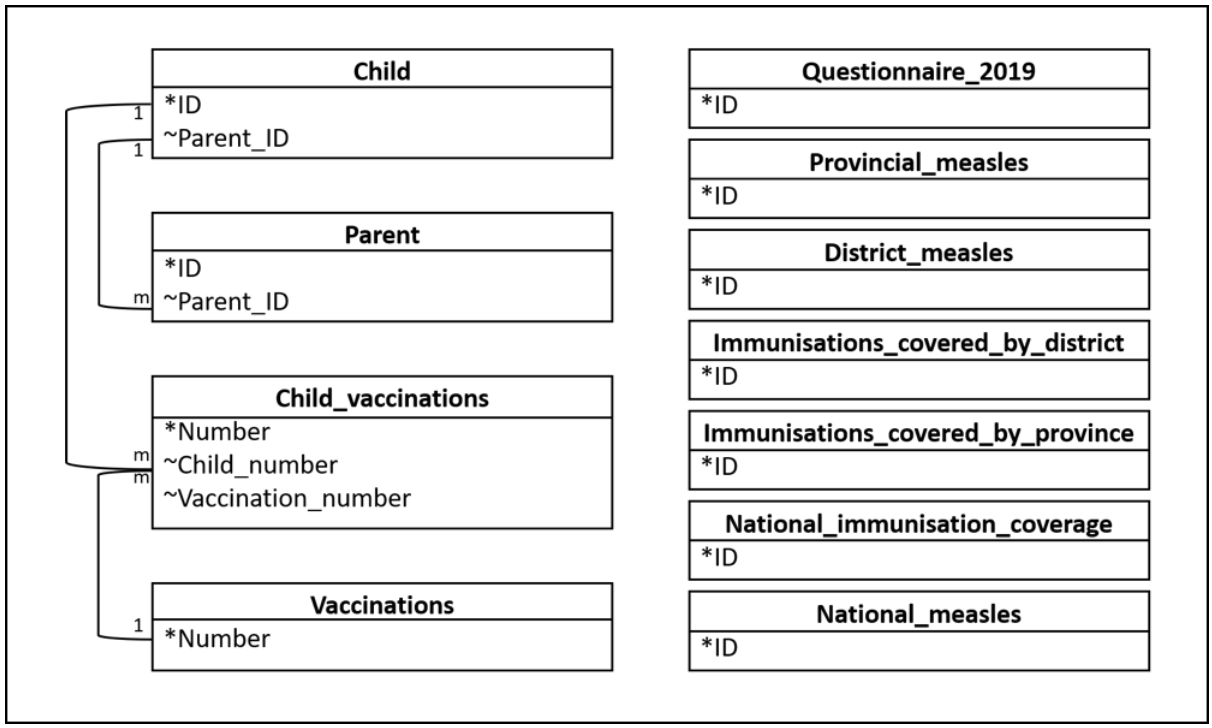



***Figure 4.4:*** *The Entity Relationship Diagram of the e-Vaccination database tables*

The Child table stores the demographic information about the child such as name and surname. This table is linked to the Parent table via the Parent_ID field. The Parent table stores the parents' demographic information such as name and surname. The link to the Child table via the Parent_ID field works both ways.

When a vaccination record is created by a stakeholder, a record is added to the Child_vaccinations table. This record is linked to the Child record. The Vaccinations table contains a list of all the vaccinations. When the stakeholder views the vaccinations in a dropdown list, they are being accessed from this table.

Statistical reports that are available on e-Vaccination are stored in the following tables:

- Provincial_measles – Measles vaccination rates by province;
- District_measles – Measles vaccination rates by district;
- Immunisations_covered_by_district – Overall vaccination rates by district;

- Immunisations_covered_by_province – Overall vaccination rates by province;
- National_immunisation_coverage – Overall vaccination rates at the national level; and
- National_measles – Overall Measles vaccination rates at the national level.

Once the stakeholder completes the online questionnaire and submits the information, this is stored in the Questionnaire_2019 table.

## 4.4 PROCESS FLOWS

The following section details the process flows for each of the stakeholder types. Since the stakeholders' approach vaccination records from different perspectives such as adding a vaccination record versus viewing only, different process flows were created.

### 4.4.1 PROCESS FLOW: PARENTS

**Figure 4.5** outlines the overall process flow for the "Parent" stakeholder type. At the highest level, parents can view a child's vaccination record, add a vaccination record and view vaccination reports produced by the government. Since prototypes offer limited functionality (Houde & Hill, 1997), registering a child, E-mailing records and downloading records are not catered for.

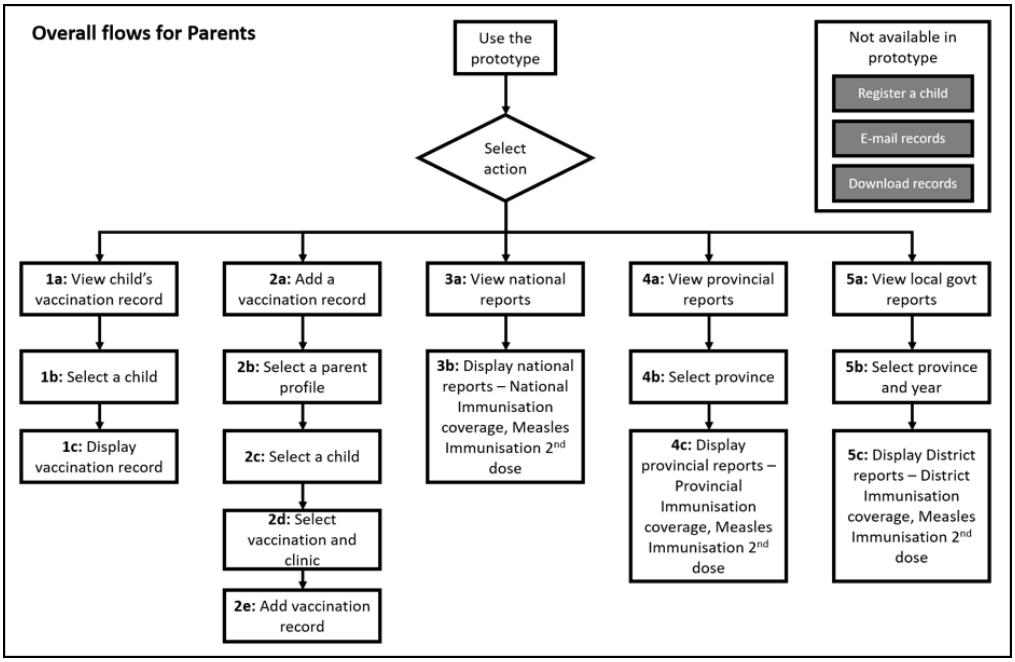
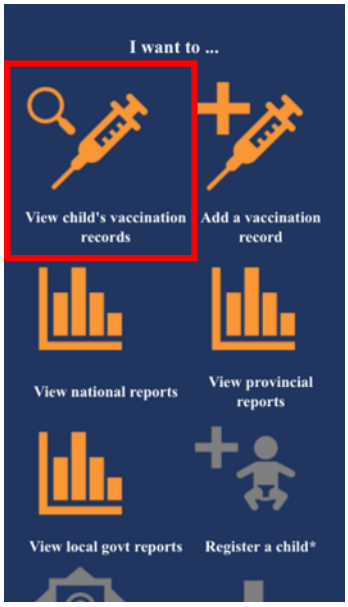
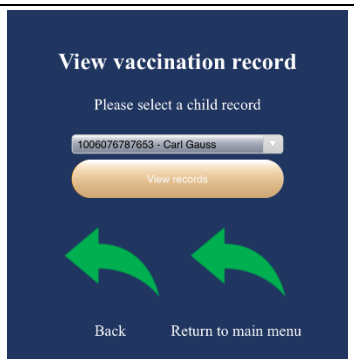
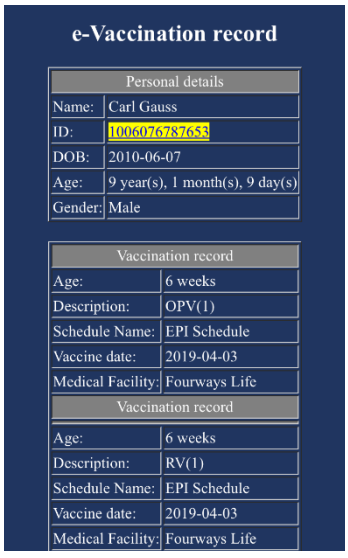
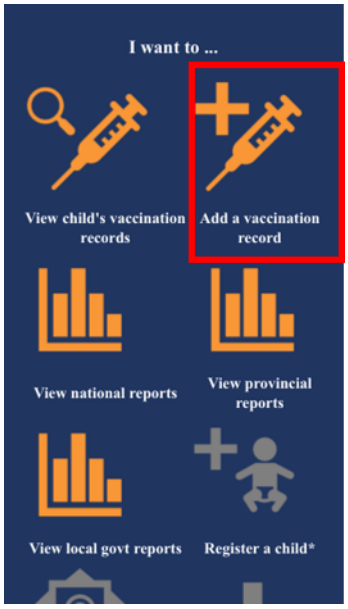
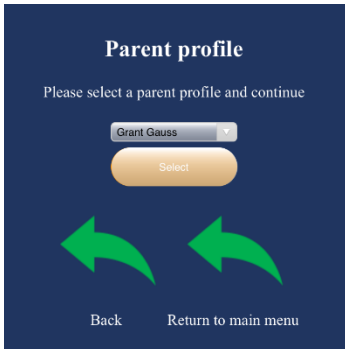
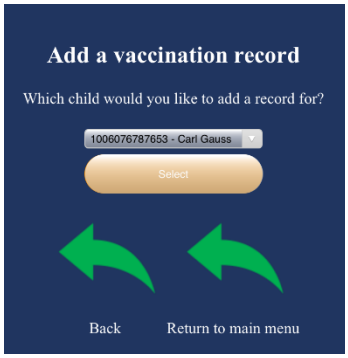
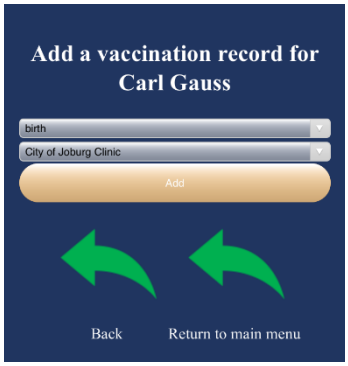
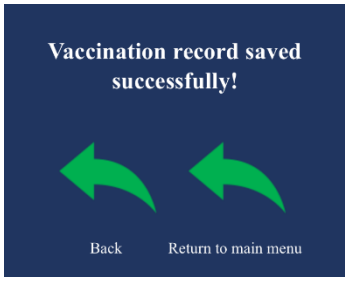
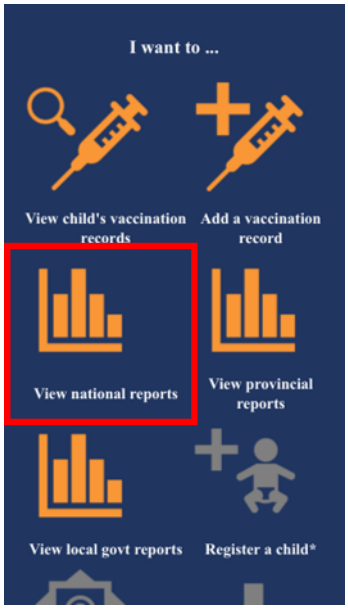
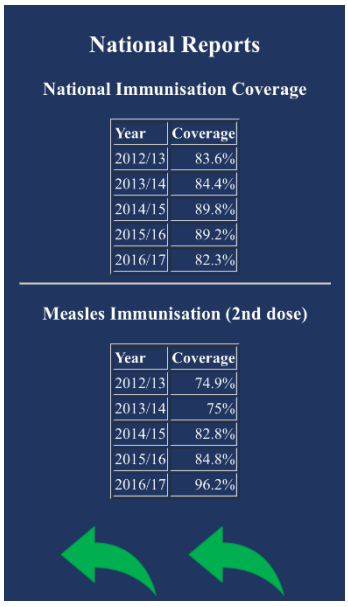


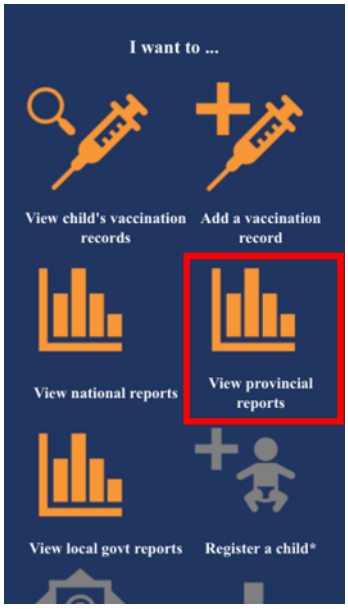
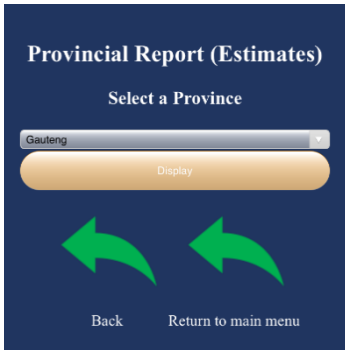
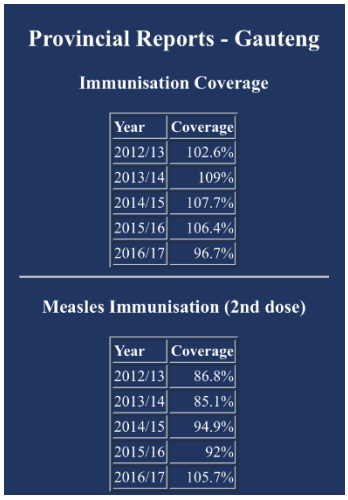

***Figure 4.5:*** *Overall process flows for Parents*

**Figure 4.6** explains the process flows for the "Parent" stakeholder type included in e Vaccination in further detail.

| ID | Screenshot | Description |
|---|---|---|
| 1a |  | **View child's vaccination record -** Parents can use their mobile phone or other devices to log into e-Vaccination and access their child's vaccination records instead of searching for a physical vaccination record that might be misplaced. |
| 1b |  | **Select a child -** e-Vaccination has child profiles loaded onto it to limit the amount of input required by the parents using this prototype. The child profiles appear in a dropdown menu that the parents can choose from. |
| 1c |  | **Display vaccination record -** Once a child's profile has been selected and the parent clicks on the "View records" button, the selected child's vaccination record is displayed. The personal details of the child such as Name, ID Number, Date of birth, Age and Gender are displayed at the top of the page. This is followed by the details of vaccines administered to the child. |

| ID | Screenshot | Description |
|---|---|---|
| 2a |  | **Add a vaccination record -** e-Vaccination allows parents to add a vaccination record to the selected child's profile. |
| 2b |  | **Select a parent profile -** The "Add a vaccination record" function within e-Vaccination has a "Parent profile" pre-populated dropdown menu that the parent can choose from. |
| 2c |  | **Select a child -** Each parent profile contains a unique set of respective child profiles that the parent who is using e-Vaccination can select. |
| 2d |  | **Select vaccination and clinic -** Once the child's profile has been selected, the parent can then select the vaccine (based on the child's age) as well as the clinic that the vaccine will be administered at. |

| ID | Screenshot | Description |
|---|---|---|
| 2e |  | **Add vaccination record -** Once the parent clicks on "Add", the vaccination record is successfully added to the child's profile. |
| 3a |  | **View national reports -** The National immunisation reports were made available in e-Vaccination as an added feature for purposes of making that information easily accessible to the parents. |
| 3b |  | **Display national reports – National Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the National Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017. |

| ID | Screenshot | Description |
|---|---|---|
| 4a |  | **View provincial reports -** Provincial reports were made available in e-Vaccination as an added feature for purposes of making the information therein easily accessible to the parents. |
| 4b |  | **Select province -** The provincial reports are displayed per province. The parent will have to select the province that he/she wishes to view and then click “Display”. |
| 4c |  | **Display provincial reports – Provincial Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Provincial Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017 for the selected province. |

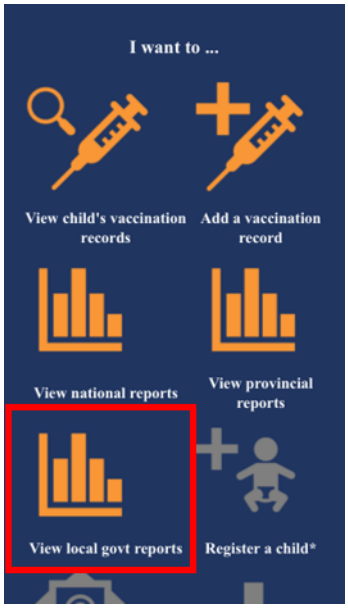
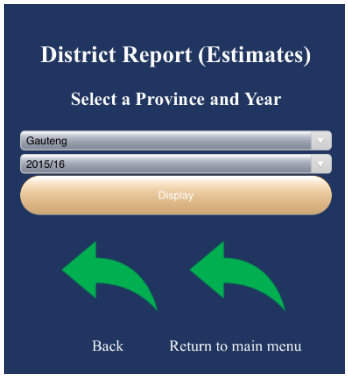
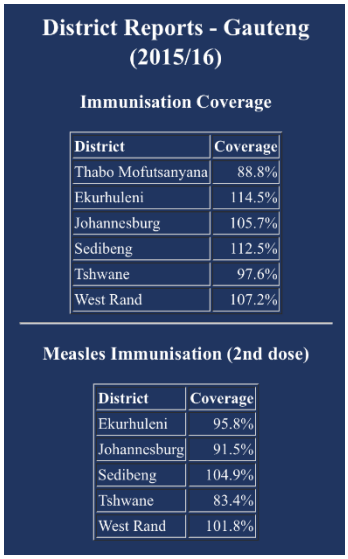
| ID | Screenshot | Description |
|---|---|---|
| 5a |  | **View local govt. reports -** Local Government (District) reports were made available in e-Vaccination as an added feature for purposes of making that information easily accessible to the parents. |
| 5b |  | **Select province and year -** The Local Government reports are grouped by their respective provinces. The parent will select the province as well as the report year. |
| 5c |  | **Display District reports – District Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Local Government (District) Immunisation coverage and the Measles Immunisation (2nd dose) for the districts based on the selected province and year. |

***Figure 4.6:*** *Detailed process flows for Parents*

### 4.4.2 PROCESS FLOW: NURSES

**Figure 4.7** contains the overall processes that have been built for the Nurse stakeholder type. A nurse can view a child's vaccination record (adding a record has been built with the view that parents will add the record) and view vaccination reports produced by the government. Verifying a vaccination record has not been built as part of the prototype.

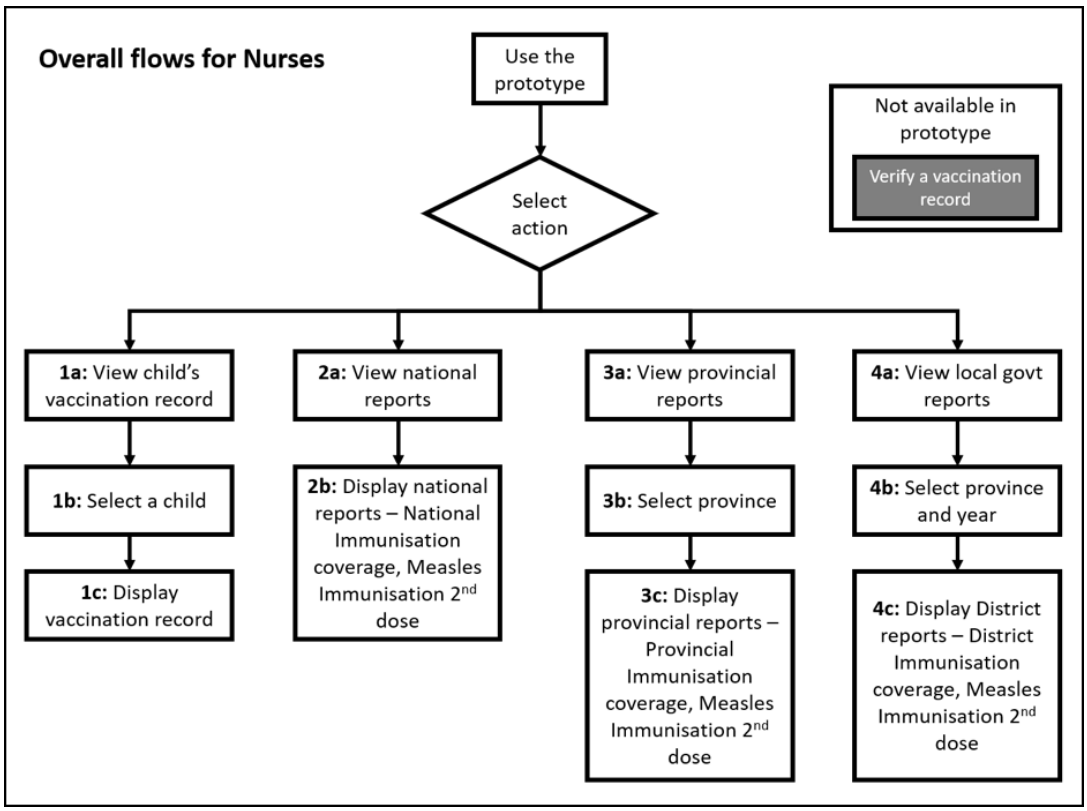
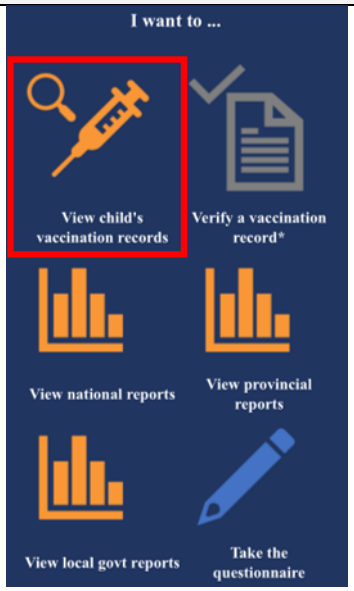
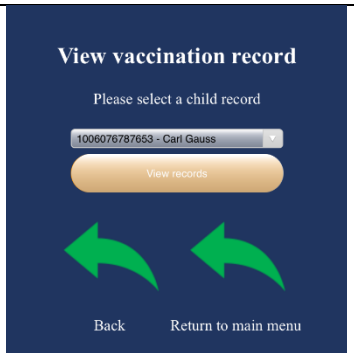
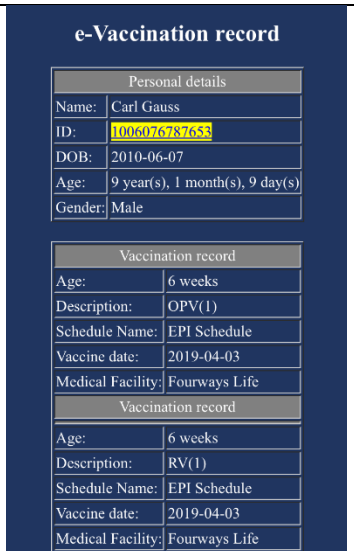
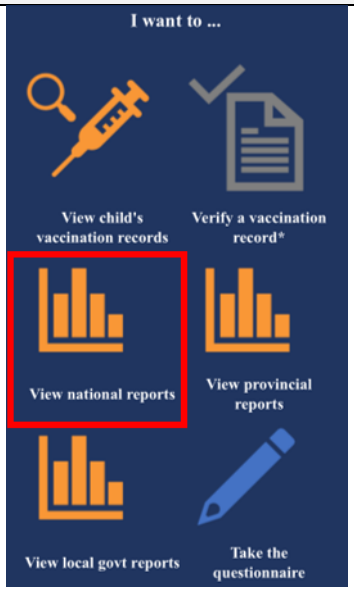
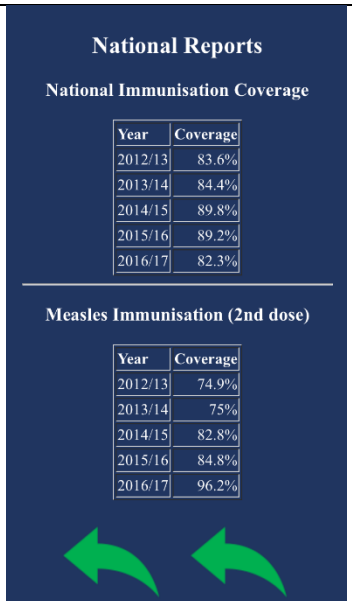
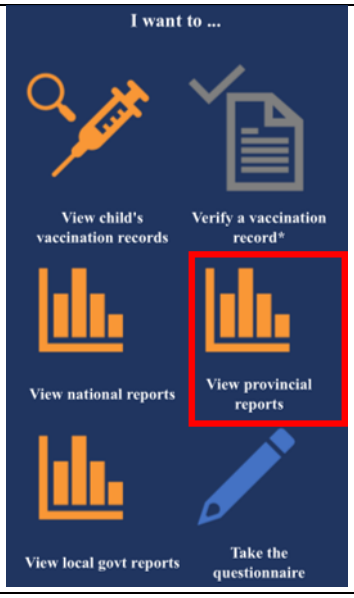
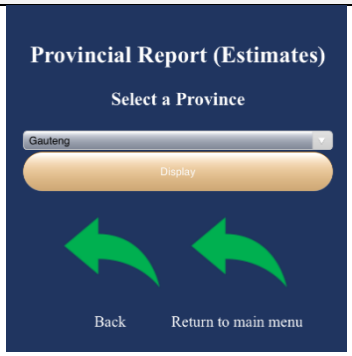
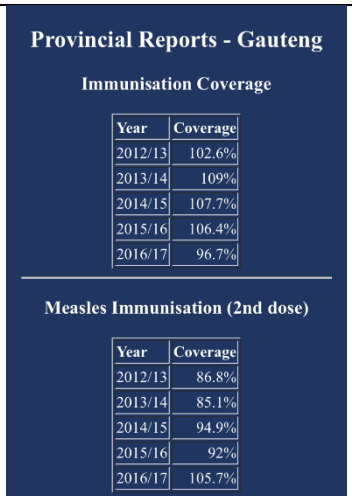
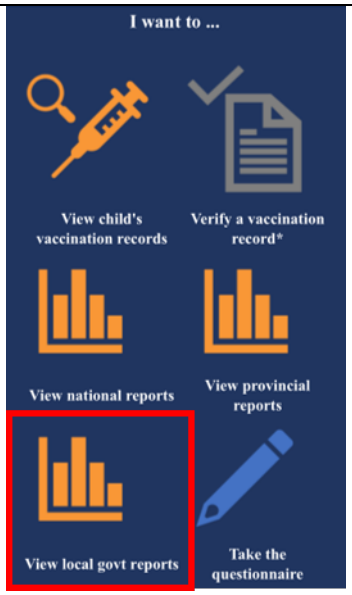
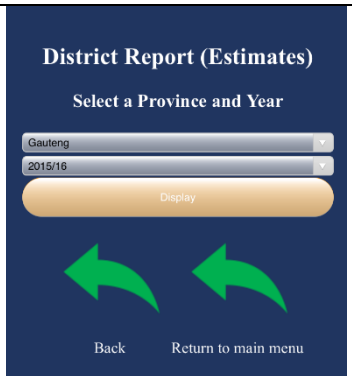



***Figure 4.7:*** *Overall process flows for Nurses*

**Figure 4.8** details the process flows for the "Nurse" stakeholder type included in e-Vaccination in further detail.

| ID | Screenshot | Description |
|---|---|---|
| 1a |  | **View child's vaccination record -** Nurses can use their mobile phone or other devices to log into e-Vaccination and access a child's vaccination records in the event that the physical vaccination record is not available. |
| 1b |  | **Select a child -** e-Vaccination has child profiles loaded onto it to limit the amount of input required by the nurses using this prototype. The child profiles appear in a dropdown menu that the nurses can choose from. |
| 1c |  | **Display vaccination record -** Once a child profile has been selected and the nurse clicks on the "View records" button, the selected child's vaccination record is displayed. The personal details of the child such as Name, ID Number, Date of birth, Age and Gender are displayed at the top of the page, followed by details of the vaccines administered to the child. |

| ID | Screenshot | Description |
|---|---|---|
| 2a |  | **View national reports -** The National immunisation reports were made available in e-Vaccination as an added feature for purposes of making their contents easily accessible to the nurses. |
| 2b |  | **Display national reports – National Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the National Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017. |
| 3a |  | **View provincial reports -** Provincial reports were made available in e-Vaccination as an added feature for purposes of making the information therein easily accessible to the nurses. |

| ID | Screenshot | Description |
|---|---|---|
| 3b |  | **Select province -** The provincial reports are displayed per province. The nurse will have to select the province that he/she wishes to view and then click “Display”. |
| 3c |  | **Display provincial reports – Provincial Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Provincial Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017 for the selected province. |
| 4a |  | **View local govt. reports -** Local Government (District) reports were made available in e-Vaccination as an added feature for purposes of making the respective information easily accessible to the nurses. |
| 4b |  | **Select province and year -** The Local Government reports are grouped by their respective provinces. The nurse will select the province as well as the report year. |

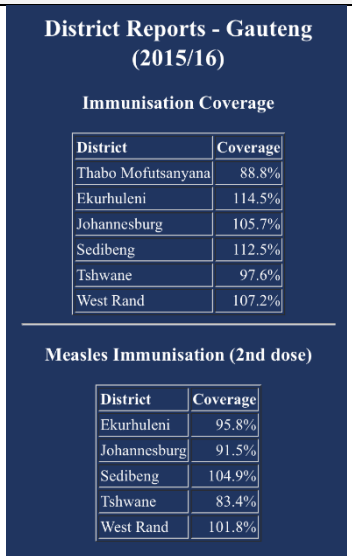
| ID | Screenshot | Description |
|---|---|---|
| 4c |  | **Display District reports – District Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Local Government (District) Immunisation coverage and the Measles Immunisation (2nd dose) for the districts, based on the selected province and year. |



***Figure 4.8:*** *Detailed process flows for Nurses*

### 4.4.3 PROCESS FLOW: DOCTORS

**Figure 4.9** depicts an overall process that has been built for the "Doctor" stakeholder type. A doctor can view a child's vaccination record and view vaccination reports produced by the government. Verifying a vaccination record has not been built as part of the prototype.

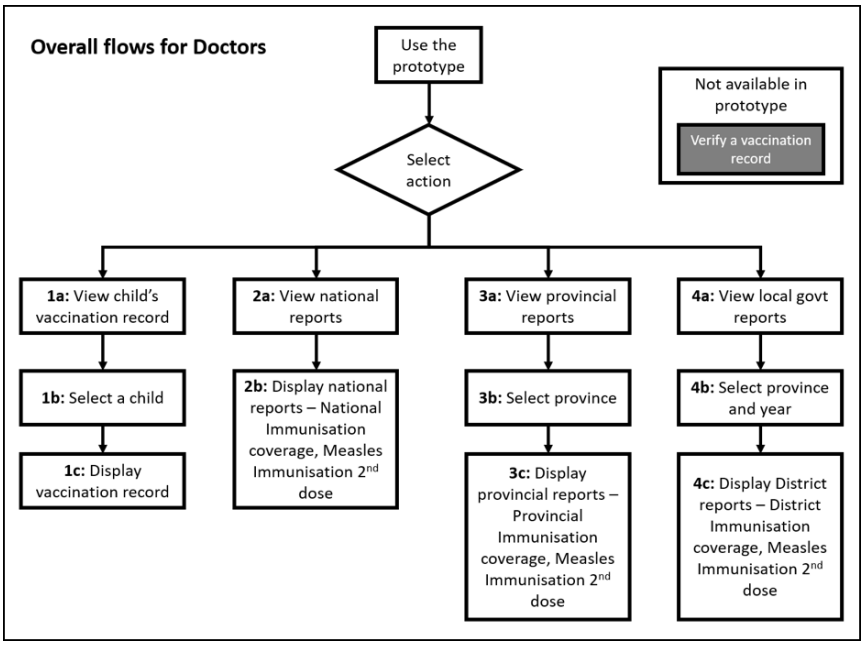
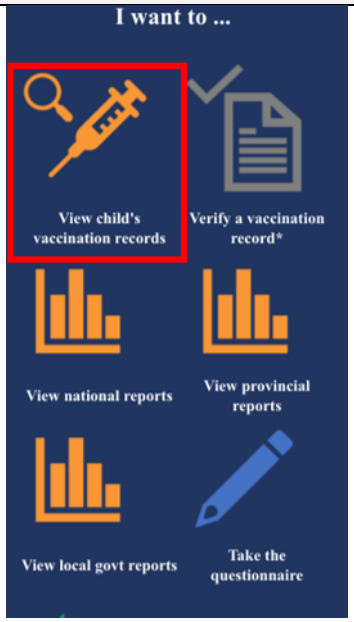
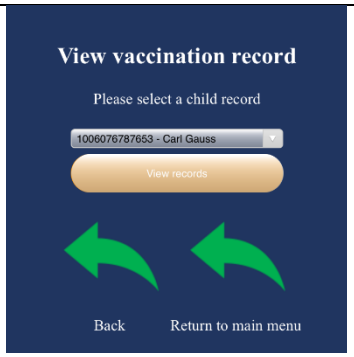
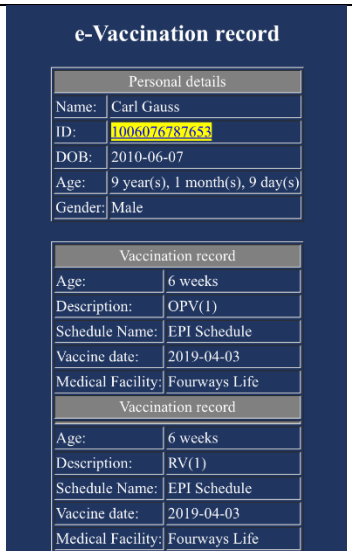
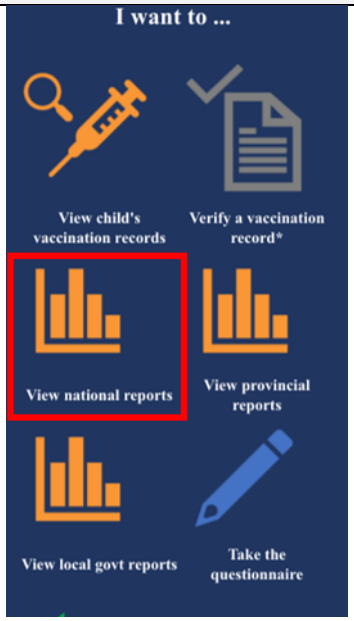
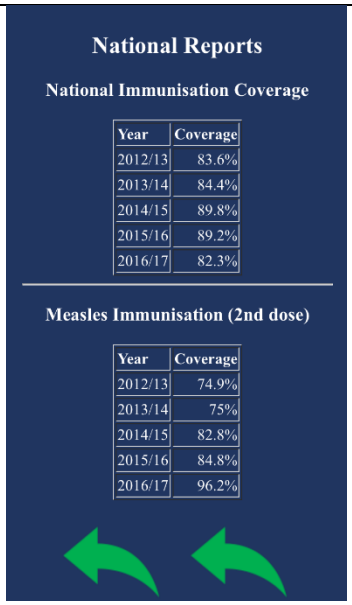
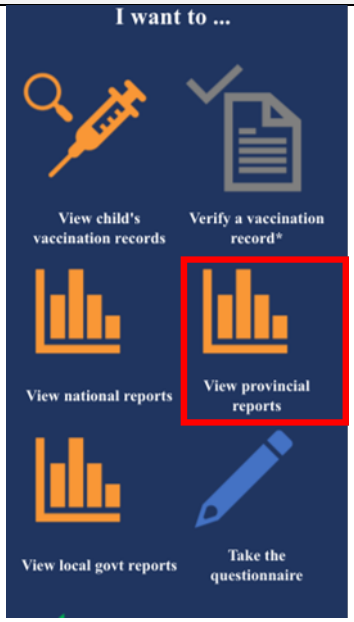
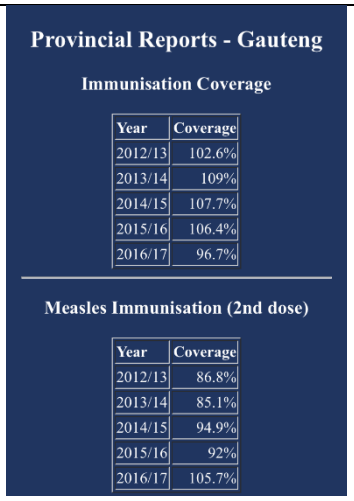



***Figure 4.9:*** *Overall process flows for Doctors*

**Figure 4.10** explains the process flows for the "Doctor" stakeholder type included in e-Vaccination in further detail.

| ID | Screenshot | Description |
|---|---|---|
| 1a |  | **View child's vaccination record -** Doctors can use their mobile phone or other devices to log into e-Vaccination and access a child's vaccination records in the event that the physical vaccination record is not available. |
| 1b |  | **Select a child -** e-Vaccination has child profiles loaded onto it to limit the amount of input required by the doctor using this prototype. The child profiles appear in a dropdown menu that the doctors can choose from. |
| 1c |  | **Display vaccination record -** Once a child profile has been selected and the doctor clicks on the "View records" button, the selected child's vaccination record is displayed. Personal details of the child such as Name, ID Number, Date of birth, Age and Gender are displayed at the top of the page, followed by details of the vaccines administered to this child. |

| ID | Screenshot | Description |
|---|---|---|
| 2a |  | **View national reports -** The National immunisation reports were made available in e-Vaccination as an added feature for purposes of making the information easily accessible to the doctors. |
| 2b |  | **Display national reports – National Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the National Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017. |

| ID | Screenshot | Description |
|---|---|---|
| 3a |  | **View provincial reports -** Provincial reports were made available in e-Vaccination as an added feature for purposes of making that information easily accessible to the doctors. |
| 3b |  | **Select province -** The provincial reports are displayed per province. The doctor will have to select the province that he/she wishes to view and then click "Display". |
| 3c |  | **Display provincial reports – Provincial Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Provincial Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017 for the selected province. |

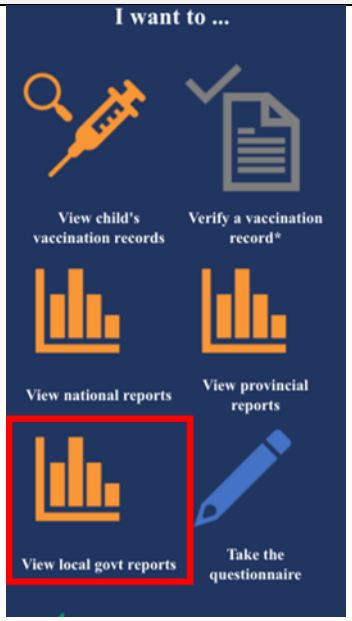
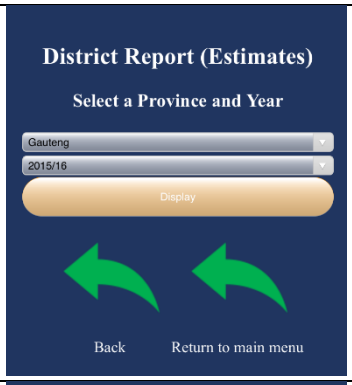
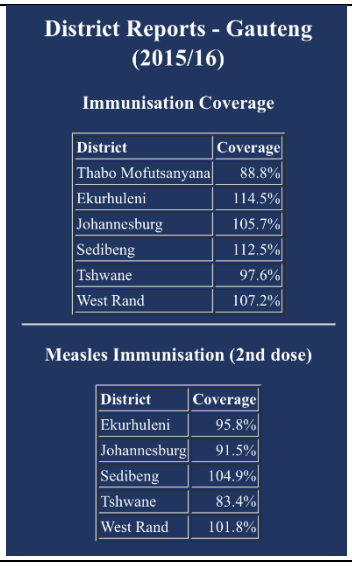
| ID | Screenshot | Description |
|---|---|---|
| 4a |  | **View local govt. reports -** Local Government (District) reports were made available in e-Vaccination as an added feature for purposes of making the information therein easily accessible to the doctors. |
| 4b |  | **Select province and year -** The Local Government reports are grouped by their respective provinces. The doctor will select the province as well as the report year. |
| 4c |  | **Display District reports – District Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Local Government (District) Immunisation coverage and the Measles Immunisation (2nd dose) for the Districts based on the selected province and year. |

***Figure 4.10:*** *Detailed process flows for Doctors*

### 4.4.4 PROCESS FLOW: SCHOOL ADMINISTRATORS

**Figure 4.11** outlines the overall process that has been built for the "School Administrator" stakeholder type. A school administrator can request a child's vaccination record on the system. Since the prototype has been built with limited functionality, the requesting of a child's vaccination record does not require approval. The records are automatically displayed. The school administrator can also view vaccination reports produced by the government.

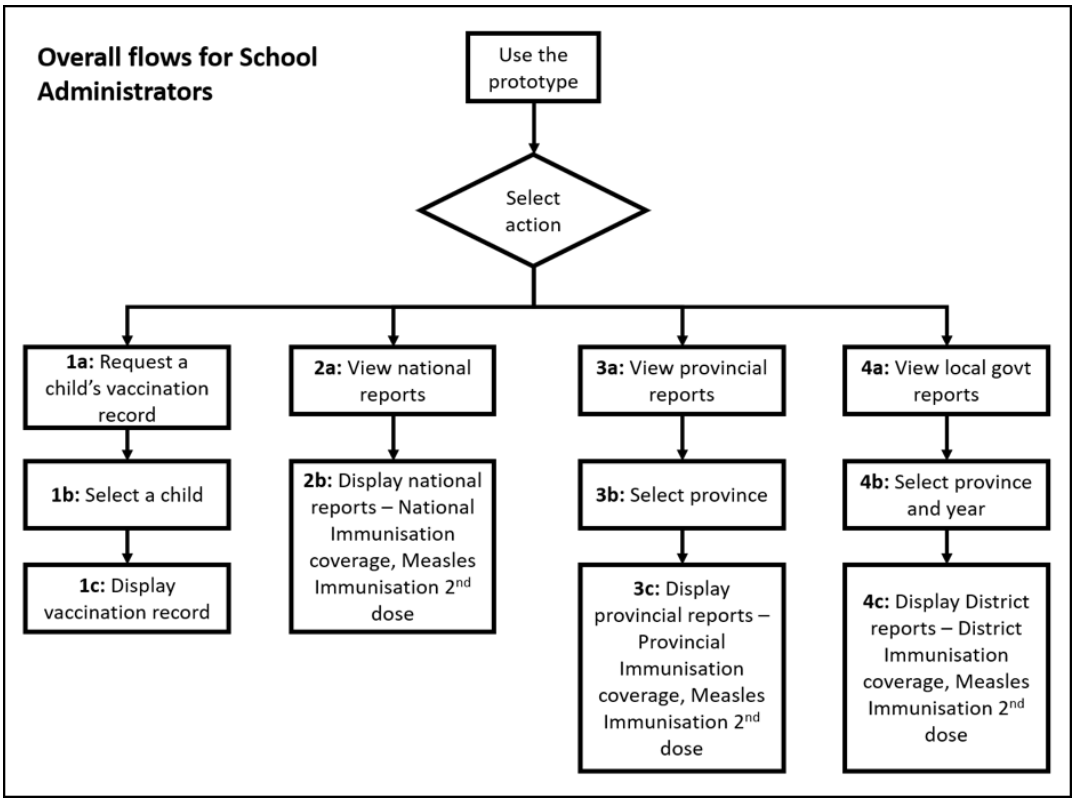
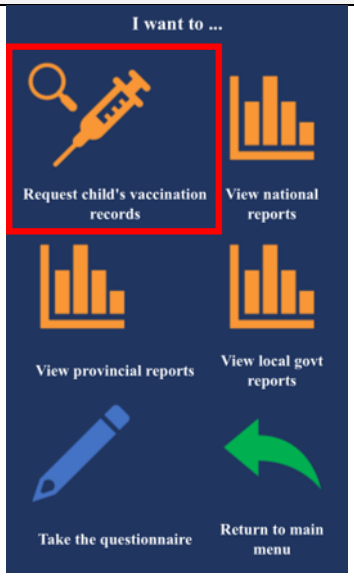
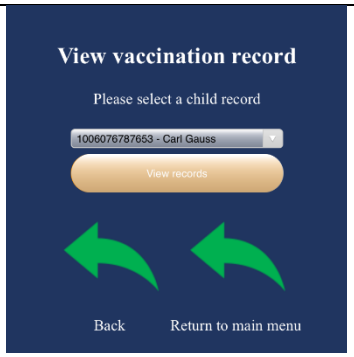
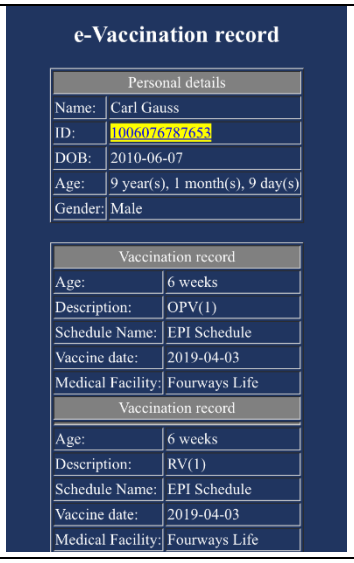
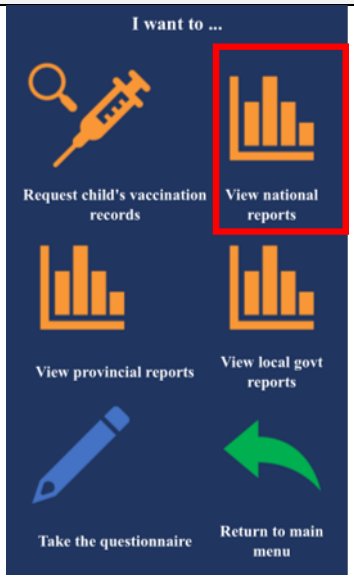
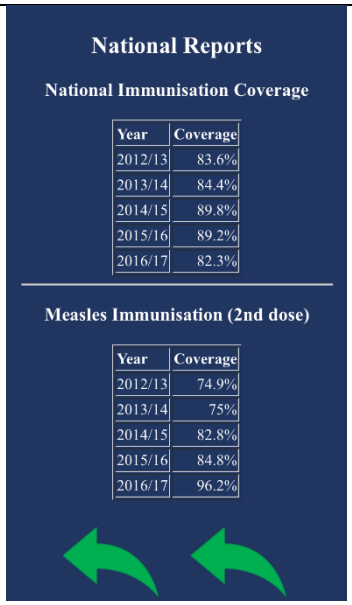
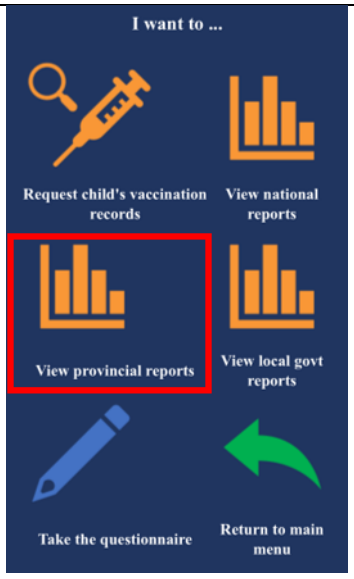
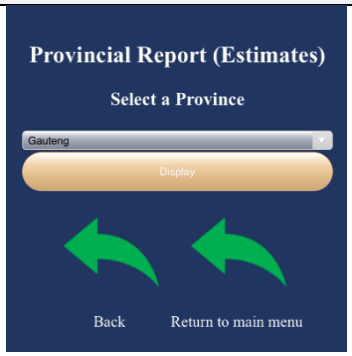
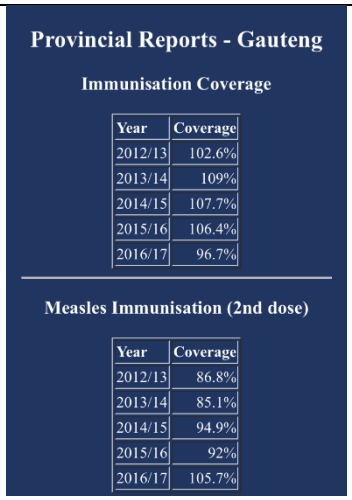
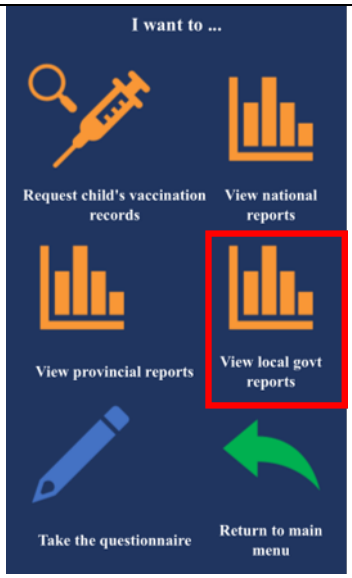
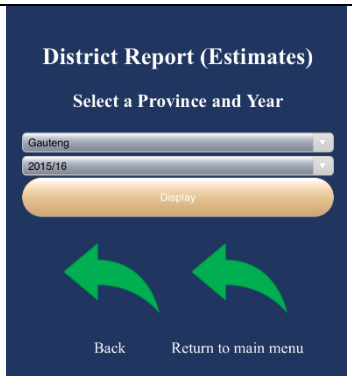



***Figure 4.11:*** *Overall process flows for School Administrators*

**Figure 4.12** explains the process flows for the "School Administrator" stakeholder type included in e-Vaccination in further detail.

| ID | Screenshot | Description |
|---|---|---|
| 1a |  | **Request a child's vaccination record -** School Administrators can use their mobile phone or other devices to log into e-Vaccination and access a child's vaccination records in the event that the physical vaccination record is not available. For purposes of making the prototype easier to use, the School Administrator can request a child's vaccination record. In a real-world scenario, a form of authentication would be used as follows:<br>1. A School Administrator will enter a child's ID number and request the record,<br>2. A parent will then receive notification via E-mail,<br>3. The parent will then either approve or decline the request from the School Administrator by clicking on the appropriate link, and<br>4. The School Administrator will then receive the child's vaccination record or a notification that the request was declined via E-mail. |
| 1b |  | **Select a child -** e-Vaccination has child profiles loaded onto it to limit the amount of input required by the School Administrator using this prototype. Child profiles appear in a dropdown menu that the School Administrators can choose from. |
| 1c |  | **Display vaccination record -** Once a child profile has been selected and the School Administrator clicks on the "View records" button, the selected child's vaccination record is displayed. Personal details of the child such as Name, ID Number, Date of birth, Age and Gender are displayed at the top of the page, followed by details of the vaccines administered to this child. |

| ID | Screenshot | Description |
|---|---|---|
| 2a |  | **View national reports -** The National immunisation reports were made available in e-Vaccination as an added feature for purposes of making the information easily accessible to the School Administrators. |
| 2b |  | **Display national reports – National Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the National Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017. |
| 3a |  | **View provincial reports -** Provincial reports were made available in e-Vaccination as an added feature for purposes of making the information easily accessible to the School Administrators. |

| ID | Screenshot | Description |
|---|---|---|
| 3b |  | **Select province -** Provincial reports are displayed per province. The School Administrator will have to select the province that he/she wishes to view and then click “Display”. |
| 3c |  | **Display provincial reports – Provincial Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Provincial Immunisation coverage from 2012 to 2017 as well as the Measles Immunisation (2nd dose) from 2012 to 2017 for the selected province. |
| 4a |  | **View local govt. reports -** Local Government (District) reports were made available in e-Vaccination as an added feature for purposes of making the information easily accessible to the School Administrators. |
| 4b |  | **Select province and year -** Local Government reports are grouped by their respective provinces. The School Administrator will select the province as well as the report year. |

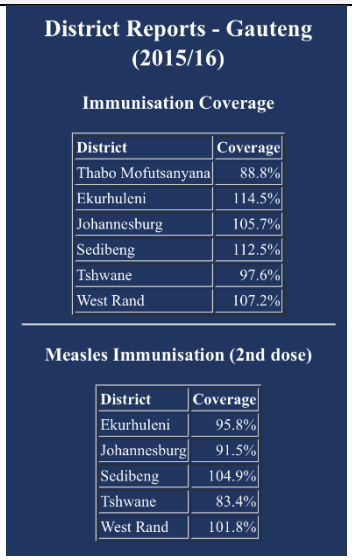
| ID | Screenshot | Description |
|---|---|---|
| 4c |   | **Display District reports – District Immunisation coverage, Measles Immunisation 2nd dose -** The reports displayed in the system are the Local Government (District) Immunisation coverage and the Measles Immunisation (2nd dose) for the districts, based on the selected province and year. |

***Figure 4.12:*** *Detailed process flows for School Administrators*

## 4.5 RELEVANCE TO THE QUESTIONNAIRE

The questionnaire (discussed in Section 3.5) was designed to collect data from the relevant stakeholders on their perceptions of e-Vaccination. **Table 4.3** shows the association of the question from each category and the rationale behind the question.

***Table 4.3:*** *Summary of the rationale behind the USE tool questions in the questionnaire*

| Category | Question | Rationale |
|---|---|---|
| **Usefulness** | The e-Vaccination application can help me to be more effective when handling vaccination records | e-Vaccination allows for the stakeholder to log in and perform the same functions offered by paper-based vaccination cards. In addition to this, other functions such as viewing vaccination statistics is also possible. |
| | The e-Vaccination application can help me to be more productive when using the vaccination functions | e-Vaccination could save you time by accessing the child's profile even if the physical vaccination card is not available at that time. |
| | The e-Vaccination application is useful for managing vaccination records | e-Vaccination allows the appropriate stakeholder to capture a vaccination at the time that it occurs. |
| | The e-Vaccination application will save me time when storing vaccination records | Once the vaccination record has been saved, there is no need to safely store a physical card away. |
| | The e-Vaccination application will save me time when accessing vaccination records | Since e-Vaccination is cloud based, a stakeholder can use a web-enabled device such as their mobile phone or desktop computer to access the child's records instead of looking for the physical vaccination card which may result in someone having to physically go to a location where the card is stored. |
| | The e-Vaccination application meets my needs in terms of storing vaccination records | The stakeholders can save a vaccination record which demonstrates how a record could be saved in an actual system. |
| | The e-Vaccination application saves my inputs as required | Once a stakeholder saves a record, they are able to go into the child's profile to verify whether the record was saved. |
| | The e-Vaccination application displays vaccination records in a way that I can understand | The layout of the vaccination record of e-Vaccination differs from that of the physical vaccination card. |
| **Ease of Use** | The e-Vaccination application is easy to use | e-Vaccination was aimed at being usable to stakeholders with varying degrees of experience with digital systems. |
| | The e-Vaccination application is not a complicated system to use | If the complexity of using e-Vaccination is too high, the stakeholder adoption might be low. |
| | The e-Vaccination application is user friendly as it minimises the amount of input I need to enter | e-Vaccination offers more drop-down options for entering information rather than expecting the stakeholder to input information via a textbox. |

| Category | Question | Rationale |
|---|---|---|
| | Any action on the e-Vaccination application is completed with the minimum number of possible steps | e-Vaccination aims to reduce the number of steps and screen loads taken to perform a task. |
| | Using the e-Vaccination application is effortless | Since many of the scenarios are story-based, the stakeholder can read the heading and instinctively determine which icon to click on next. |
| | I can use the e-Vaccination application without written instructions | e-Vaccination aims to reduce the amount of help needed by a stakeholder to complete the required function. |
| | There are no inconsistencies within the e-Vaccination application | e-Vaccination performs the functions expected by the stakeholders. |
| | I can recover from mistakes easily when using the e-Vaccination application | If a stakeholder makes a mistake, they are able to go back and navigate to the function they required. |
| | I can use the e-Vaccination application successfully every time | The stakeholder can use e-Vaccination consistently by performing different tasks with success. |
| **Ease of Learning** | I quickly understood how to use the e-Vaccination application | e-Vaccination is a story and icon-based system allowing for the stakeholders to navigate to the required function easily by reducing the amount of learning needed. |
| | I easily remember how to use the e-Vaccination application | The steps to perform different functions on e-Vaccination are similar. The stakeholders can use a function and then move to another function by remembering how the previous one worked. |
| | I quickly became skilful with the e-Vaccination application | e-Vaccination promotes reduced time needed to perform functions as the stakeholder uses the system more often. |
| | I quickly learned how to navigate through the e-Vaccination application | The menu of e-Vaccination is a central point to each stakeholder allowing them to move from menu to function and back to the menu. |
| | I quickly learned what the colour coding of the visual aids (icons) meant | The use of a colour-based icon system differentiates between the functions that are offered by e-Vaccination and those that are concepts that could be incorporated into an actual system. The amber colour icons are available whereas the grey icons are not available. |

| Category | Question | Rationale |
|---|---|---|
| **Satisfaction** | I am satisfied with the e-Vaccination application | e-Vaccination meets the stakeholders' expectations of an electronic vaccination record system. |
| | I would recommend the e-Vaccination application to a friend | The adoption and popularity of such a system could increase with word of mouth distribution of the system. |
| | The e-Vaccination application works the way I want it to work | e-Vaccination works correctly and performs all the available functions. |
| | I am satisfied with the overall appearance of the e-Vaccination application | The colours and icons used in e-Vaccination are visually appealing to the stakeholder. |
| | I am satisfied with how the navigation of the e-Vaccination application works | The stakeholder can navigate to different parts of the system without getting stuck at one point. |
| **Design and Visual Aids** | The use of visual aids (icons) are helpful when using the e-Vaccination application | The visual aids limit the amount of reading required by the stakeholder. The icons appeal to the instinct of the stakeholder to click on the appropriate item. |
| | I would prefer written instructions on the e-Vaccination application instead of visual aids (icons) | The stakeholder prefers more words to be used rather than visual aids. |
| | The visual aids (icons) help me navigate the e-Vaccination application easily | The visual aids assist the stakeholder in finding the relevant function. |
| | The colour coding of the visual aids (icons) helps me to determine what the link means | The amber and grey coloured icons assist the stakeholder in knowing which functions are available and which are not. |
| | The vaccination statistics provided are useful | e-Vaccination offers historic statistics aimed at bringing at the relevant vaccination information closer to the stakeholder. |

**Table 4.3** confirms the relevance of the question in the research instrument by identifying the feature of e-Vaccination that is relevant to that question.

## 4.6 SUMMARY OF ARTEFACT

**Figure 4.13** shows the vaccination record systems and the Department of Health aims that influenced the design of e-Vaccination. The technical design, overall architecture, database field design, process flows, and functionality were taken into consideration when designing e-Vaccination.

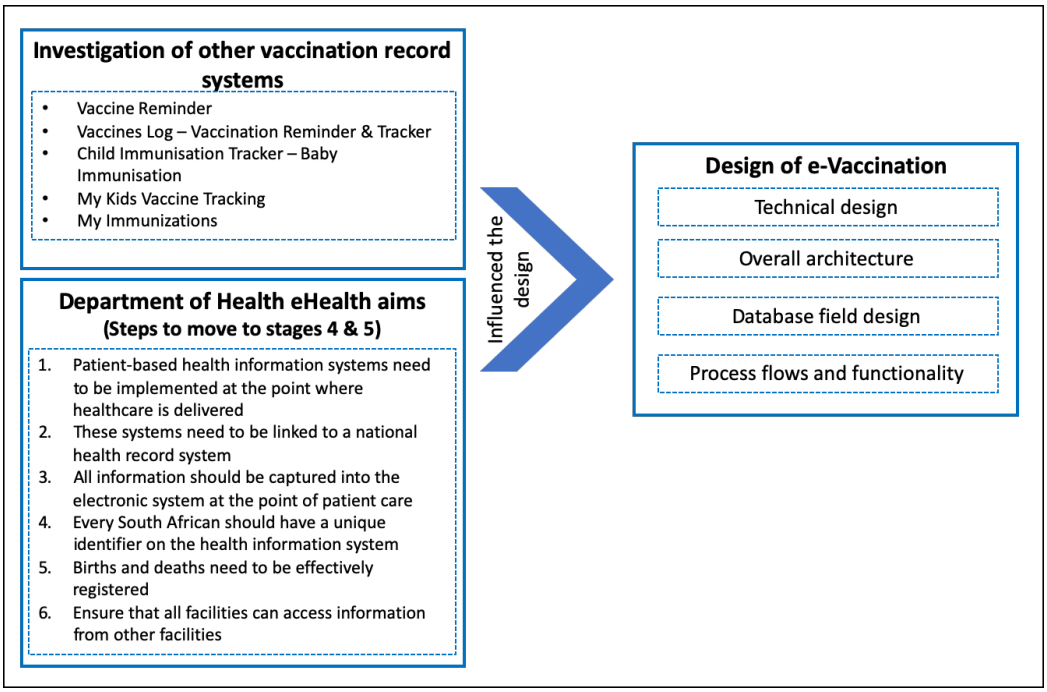



***Figure 4.13:*** *Summary of Chapter 4*

# CHAPTER 5: PRESENTATION OF RESULTS

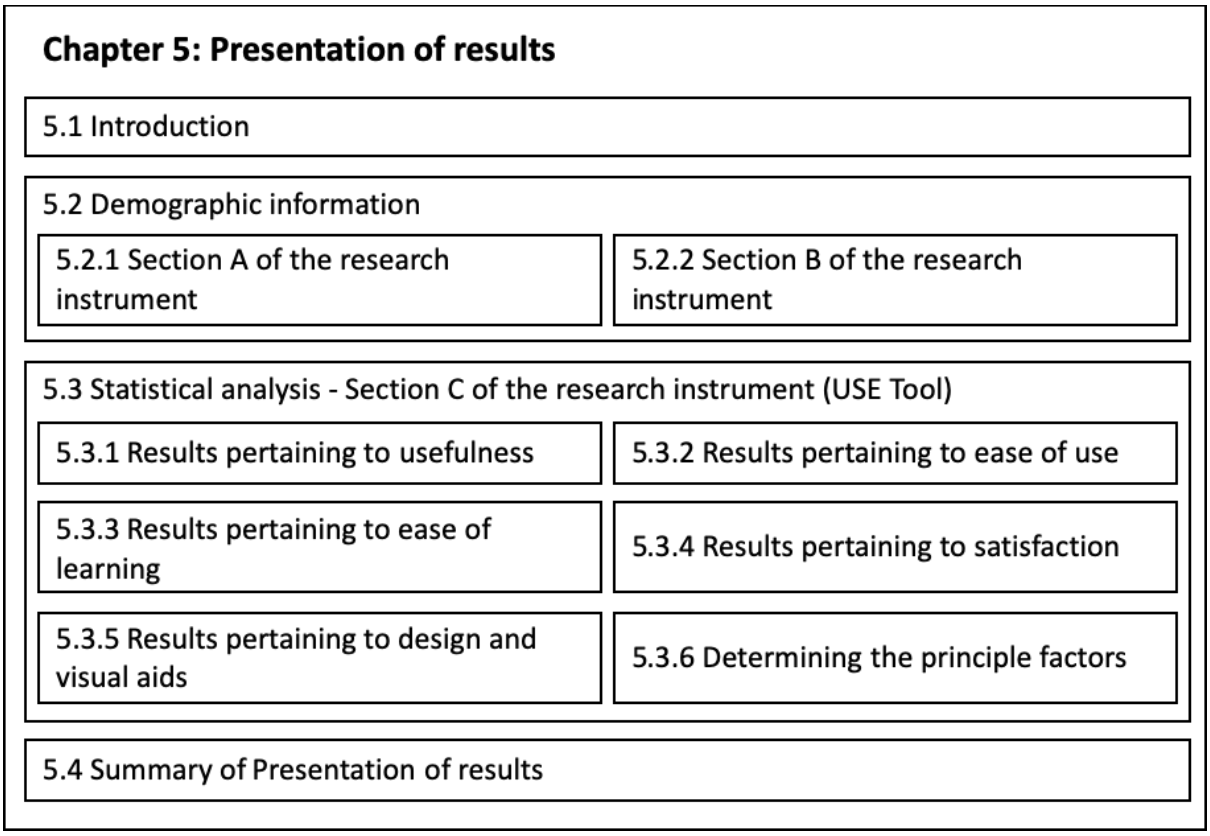



***Figure 5.1:*** *Structure of Chapter 5*

## 5.1 INTRODUCTION

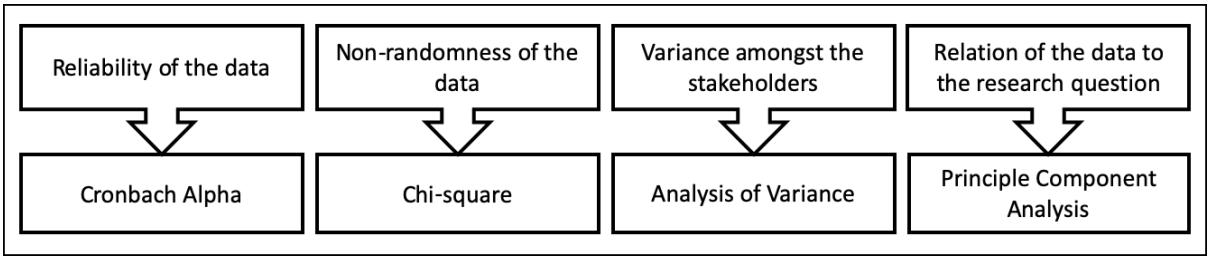



***Figure 5.2:*** *A recap of the data analysis steps that were followed*

**Figure 5.2** above as discussed in Chapter 3 outlines the data analysis steps that were followed. In this chapter, the results of these data analysis steps are presented. The data collected from the research instrument is broken into 2 parts, these are demographic information and the scores from the USE tool. The demographic information has been presented in the form pie and bar charts. The USE tool part of the research instrument was used to determine the answer to the research question, "*What are the perceptions of the key stakeholders towards replacing the paper-based*

*vaccination card with an electronic vaccination record system?*" The perceptions were based on the following five categories that were introduced in **Table 3.2**:

- Usefulness;
- Ease of Use;
- Ease of Learning;
- Satisfaction; and
- Design and Visual Aids.

The results will be presented according to the following parameters:

- Sample size;
- Cronbach alpha;
- Chi-Square test:
    - Critical value;
    - Chi-Square value displayed as an exponent;
    - Outcome (Whether Chi-Square value > or < critical value); and
    - Result (Reject or not reject the null hypothesis);
- ANOVA:
    - *F value*;
    - *p value*;
    - *f crit*;
    - Significance;
    - Outcome of calculation; and
    - Result (Accept or reject the null hypothesis).
- Principle Component Analysis
    - KMO value
    - Eigenvalues
    - Percentage contribution of factors

## 5.2 DEMOGRAPHIC INFORMATION

As mentioned in Chapter 3, responses to the research questionnaire were collected from four stakeholder types. These are parents, doctors, nurses and school

administration staff. This is due to their interaction with vaccinations and/or vaccination records.

### 5.2.1 SECTION A OF THE RESEARCH INSTRUMENT

There was a total of 118 respondents for the four stakeholder groups in a spread as depicted on the pie chart in **Figure 5.3**. All the respondents lived and/or worked in Gauteng. The questions asked in the questionnaire were whether respondents had access to a smartphone, Internet and Email addresses.

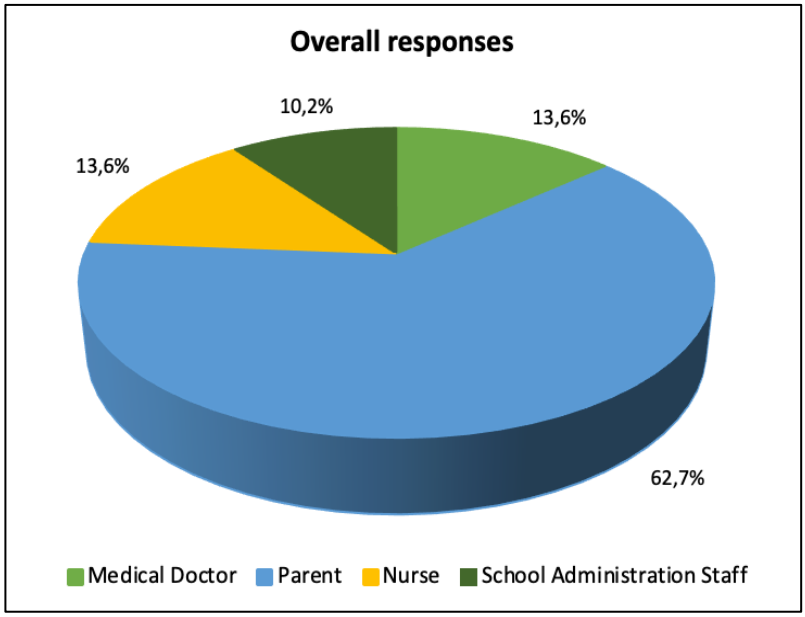



***Figure 5.3:*** *Pie chart depicting the percentage responses per stakeholder type*

Of the 118 respondents to the questionnaire, 95% had access to a smartphone and at least 96% had Internet access. The breakdown of these responses by stakeholder type is provided in a bar chart in **Figure 5.4** (smartphone access) and **Figure 5.5** (Internet access).

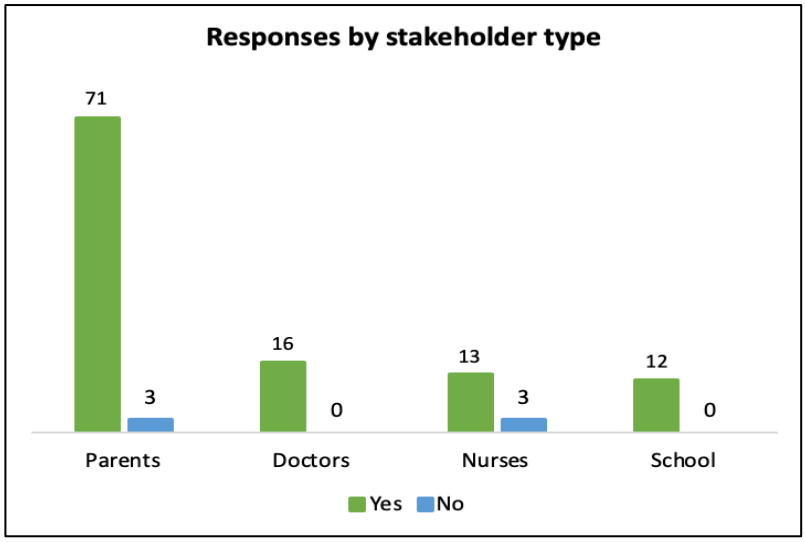



***Figure 5.4:*** *Bar chart depicting the number of respondents that have access to a smartphone versus those that did not have access to a smartphone, broken down by stakeholder type*

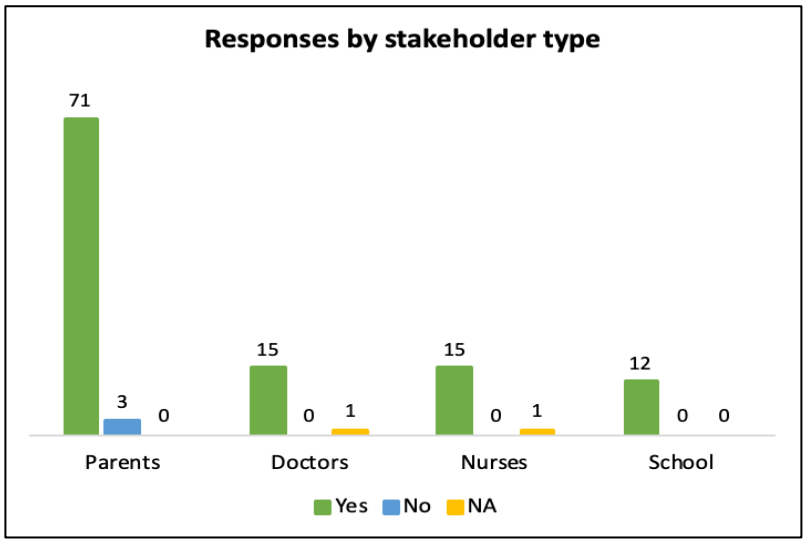



***Figure 5.5:*** *Bar chart depicting the number of respondents that have access to the Internet versus those that did not have access to the Internet, broken down by stakeholder type*

**Figure 5.5** is a bar chart depiction of Internet access by stakeholder type. It was noted that 96% of the respondents had access to the Internet.

**Figure 5.6** is a bar chart depiction of participants that did or did not have an email address, shown by stakeholder type. It was noted that 96% of the respondents have an E-mail address.

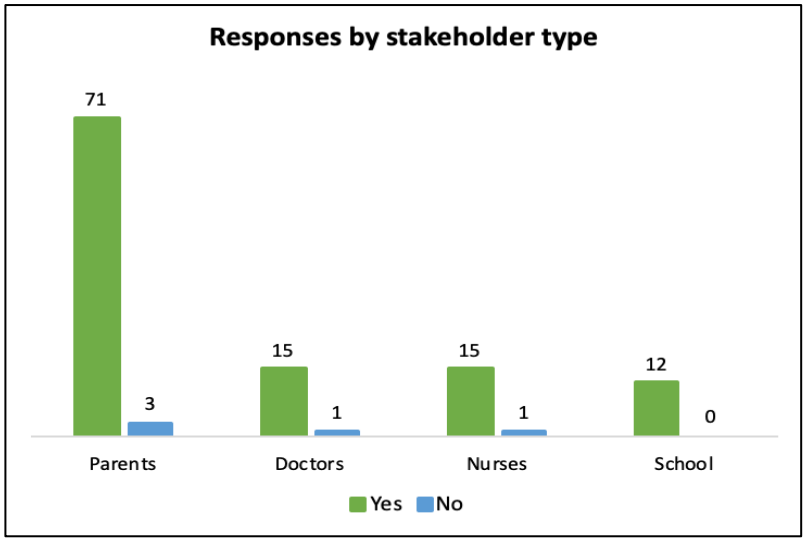



***Figure 5.6:*** *Bar chart depicting the number of respondents that have an E-mail address versus those that did not have an E-mail address, broken down by stakeholder type*

### 5.2.2 SECTION B OF THE RESEARCH INSTRUMENT

Section B of the questionnaire related to the respondent's perceptions regarding vaccinations and vaccination record storage mechanisms in Gauteng.

Approximately 91% of the respondents indicated that vaccination records in Gauteng are stored on the paper-based vaccination card. Perceptions on electronic systems storage was at 5%, while 3% were unsure about how vaccination records were stored and 1% indicated that no records were kept. **Figure 5.7** shows the actual figures illustrated in a bar chart per stakeholder type.

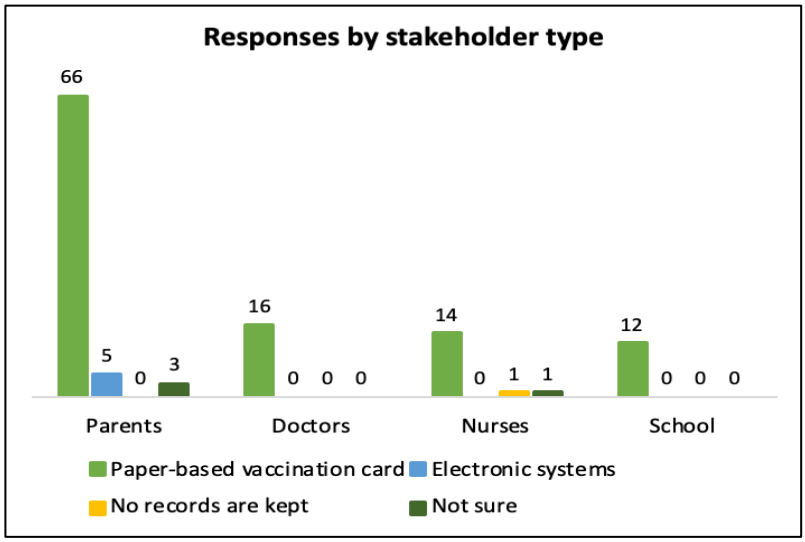



***Figure 5.7:*** *Bar chart depicting the responses to the vaccination storage medium used in Gauteng, broken down by stakeholder type*

Experiences with a lost vaccination card or record was recorded by 47% of the respondents. For those who administer vaccinations and work closely with these records, that is, doctors and nurses, 94% indicated that they were aware of lost vaccination cards or records. **Figure 5.8** is a bar chart that shows the breakdown by stakeholder type.

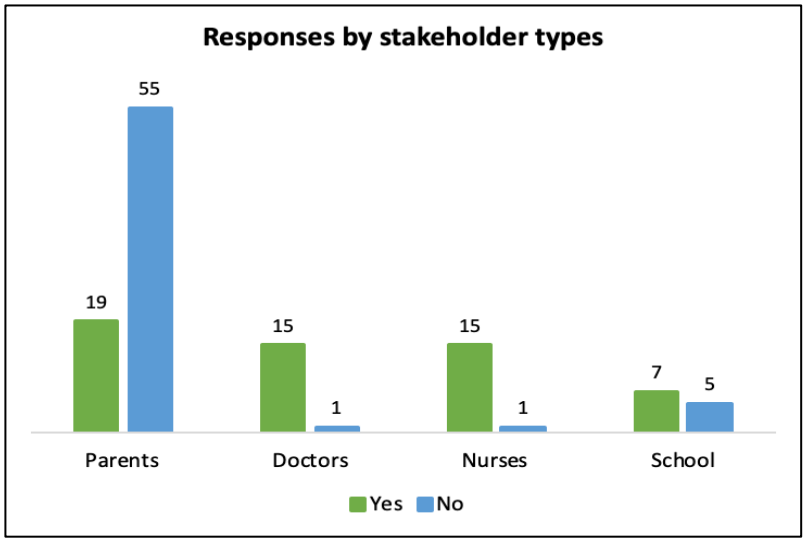



***Figure 5.8:*** *Bar chart depicting the number of respondents that have experience with a lost vaccination card, broken down by stakeholder type*

For those stakeholders who have experience with a lost vaccination card, the measures that were taken to recover the lost vaccination records are provided in **Figure 5.9**.

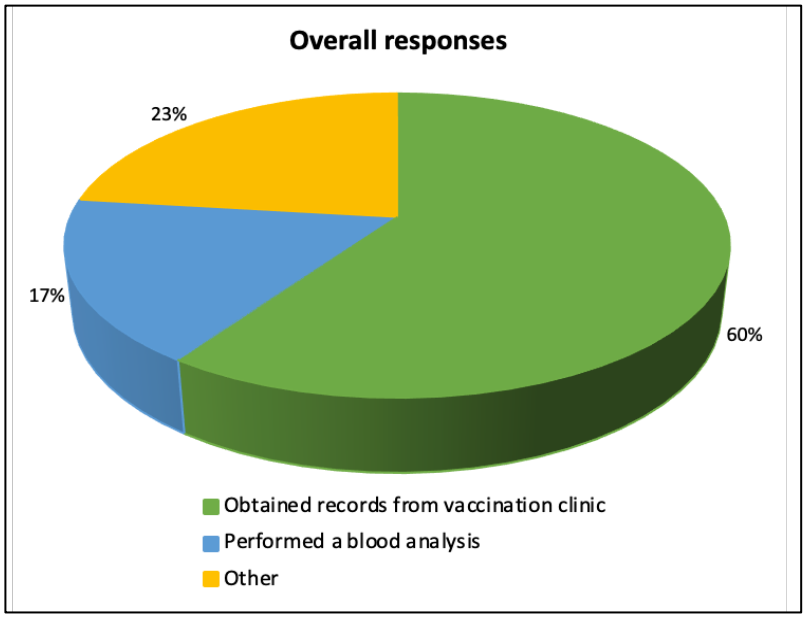



***Figure 5.9:*** *Pie chart depicting the percentage break down of the actions taken to retrieve the lost vaccination information*

Of the 56 respondents who indicated that they had experienced a lost or damaged vaccination card, 52 selected an appropriate method taken to recover the lost information. Responses indicated that more than half (60%) of the lost records were obtained from a vaccination clinic. In other instances, a blood analysis would typically be done to recover records, as indicated by 17% of respondents while 23% indicated that records were recovered using other methods. **Figure 5.10** is a bar chart that illustrates the breakdown by stakeholder type.

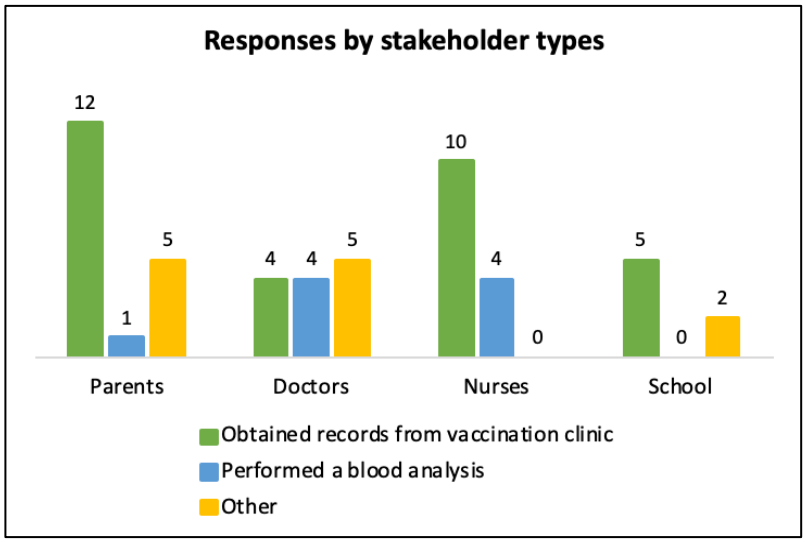



***Figure 5.10:*** *Bar chart depicting the actions taken to retrieve the lost vaccination information, broken down by stakeholder type*

A free-text field was provided to allow the respondents to enter the steps taken to recover the information if the dropdown field provided did not contain a measure that they had taken. The “Other” measures are listed below:

- History was never recovered, but we remembered what was given due to the structure order of the vaccines on the card;
- Usually unable to obtain a record and rely on the mothers’ history;
- Parent submitted a copy they had made;
- Visiting the facility where the vaccinations had been done initially;
- Parent went to the clinic to ask about another vaccination card with no luck;
- Usually there is no way, unless a record was kept by the clinic;
- Don't know what measures were taken to recover the lost detail;
- We have to open new files for my child;

- Often the family try to get another Road to Health Booklet from the hospital where the child was born in my experience;
- In the cases I witnessed, new records were given, and vaccinations continued from where mom said they had ended; and
- Obtain duplicate card from local clinic.

The safe and secure storage of vaccination records for minors in Gauteng should be the responsibility of the parents or guardians according to 69% of the respondents. The remaining 30% indicated that this should be the responsibility of government. **Figure 5.11** reflects these responses and in **Figure 5.12** a bar chart shows these responses by stakeholder type.

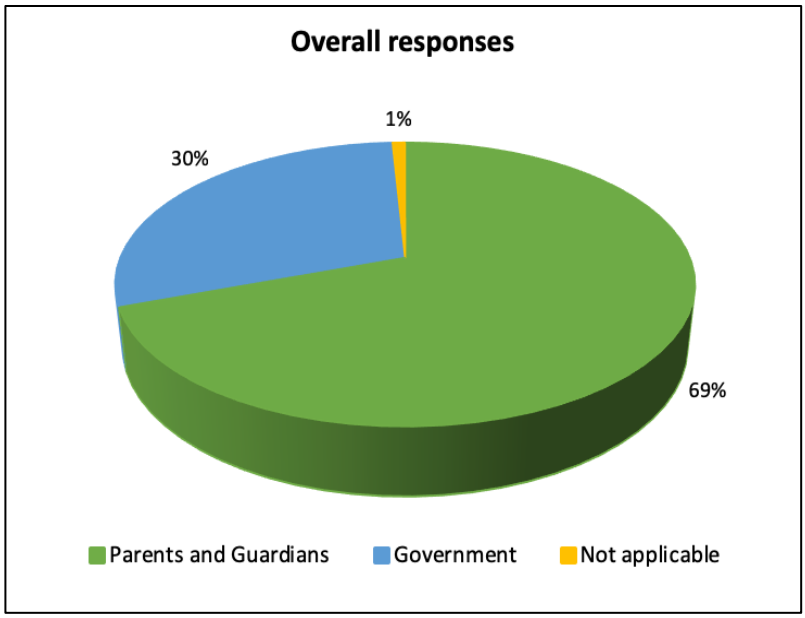



***Figure 5.11:*** *Pie chart depicting the percentage breakdown of who should be responsible for storing minors' vaccination records in Gauteng based on the stakeholders' responses*

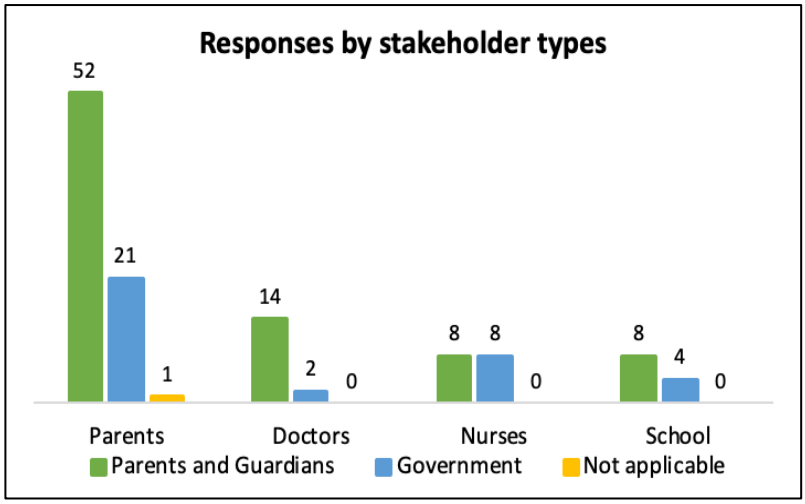



***Figure 5.12:*** *Bar chart depicting who should be responsible for storing minors' vaccination records in Gauteng, broken down by stakeholder type*

**Figure 5.12** indicates that 52 parents, 14 doctors, 8 nurses and 8 school admin staff (82 in total) believe that parents and guardians should be responsible for the safe storage of vaccination records. The government should be responsible, according to 21 parents, 2 doctors, 8 nurses and 4 school admin staff (35 in total). The remaining 1 parent selected "not applicable."

**Figure 5.13** is a pie chart that shows the stakeholders perceptions of whether minors in Gauteng receive their vaccinations on time and in Figure **5.14**, a bar chart that illustrates the breakdown of these responses by stakeholder type is provided.

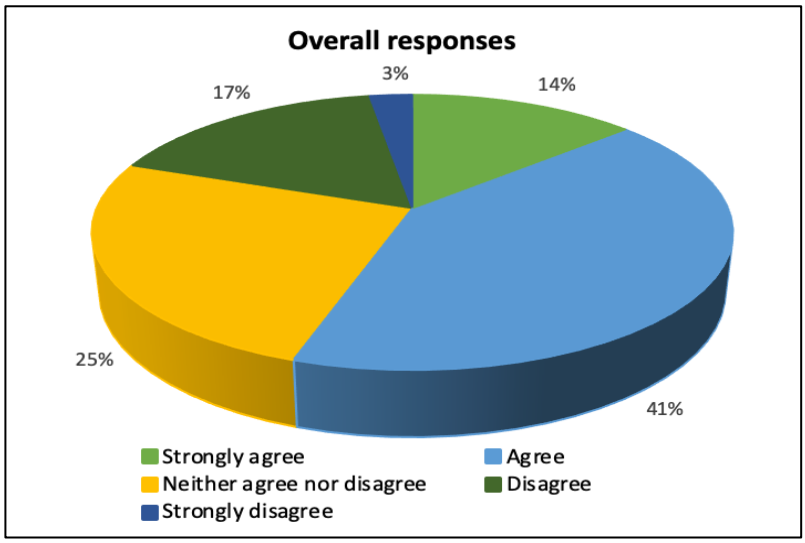



***Figure 5.13:*** *Pie chart depicting the percentage break down of whether minors in Gauteng receive their vaccinations on time based on the stakeholders' responses*

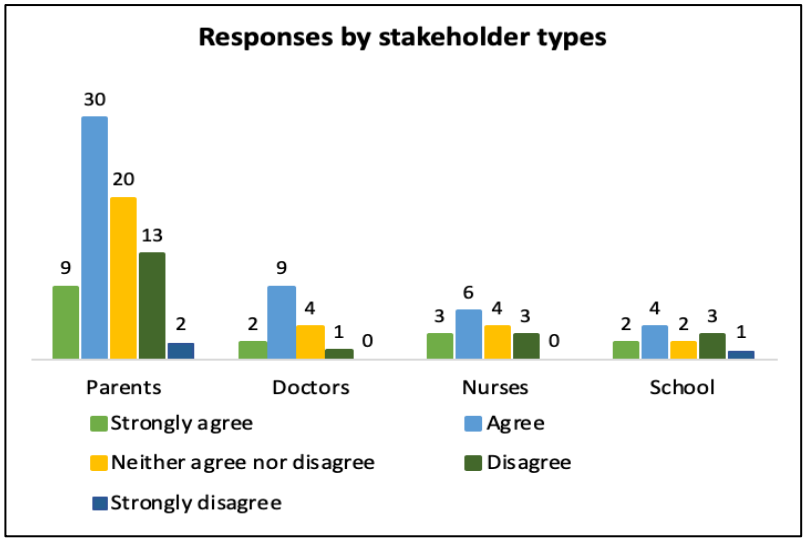



***Figure 5.14:*** *Bar chart depicting the responses received regarding whether minors in Gauteng receive their vaccinations on time, broken down by stakeholder type*

Most of the respondents, 59%, believe that the paper-based vaccination card is a reliable way to store vaccination records. This question was however phrased in a negative way (indirectly favouring the physical vaccination card as a storage mechanism). Wording questions in this way can result in the respondents not reading the question well which poses problems with the responses, (Jozsa & Morgan, 2017).

**Figure 5.15** is a pie chart that illustrates the overall stakeholders' perceptions of whether the paper-based vaccination card is a reliable way to store vaccination records and the corresponding bar chart in **Figure 5.16**, shows the responses by stakeholder type.

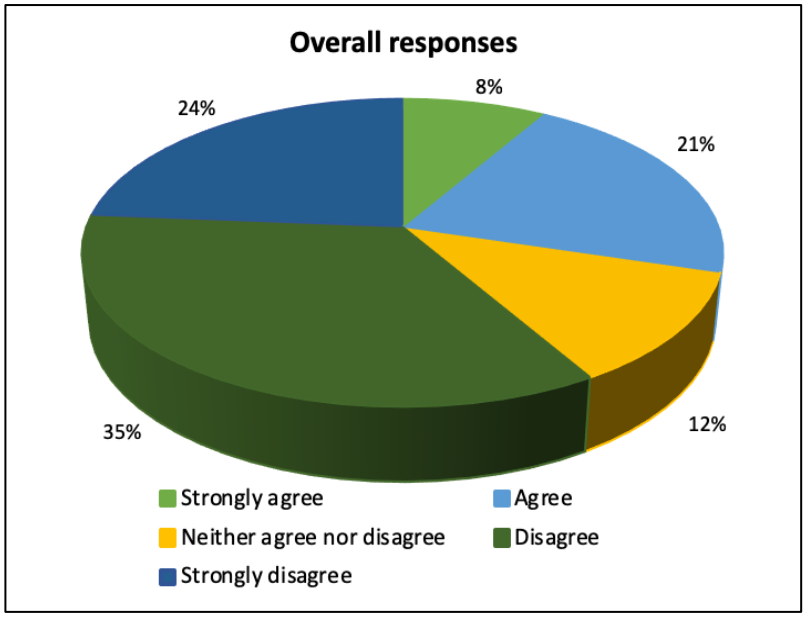



***Figure 5.15:*** *Pie chart depicting the percentage break down of whether the paper-based vaccination card is a reliable way to store vaccination records based on the stakeholders' responses*

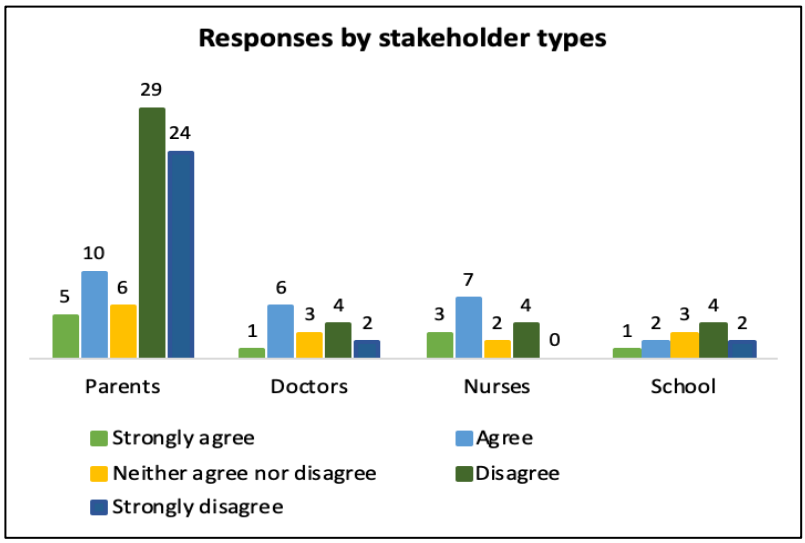



***Figure 5.16:*** *Bar chart depicting whether the paper-based vaccination card is a reliable way to store vaccination records, broken down by stakeholder type*

## 5.3 STATISTICAL ANALYSIS - SECTION C OF THE RESEARCH INSTRUMENT (USE TOOL)

Section C of the questionnaire gathered responses regarding e-Vaccination. The questions were grouped into the categories: *Usefulness*, *Ease of use*, *Ease of learning*, *Satisfaction* and *Design and visual aids* as discussed in Chapter 3. The questions in each section were combined into composite values by calculating the mean values for each respondent. These values were then checked for reliability using

the Cronbach alpha which is a measure of reliability and internal consistency (Goforth, 2015). The score for every category was greater than or equal to 0,67, higher than the recommended minimum of 0,65 (Goforth, 2015).

### 5.3.1 RESULTS PERTAINING TO USEFULNESS

The "Usefulness" section of the questionnaire was broken up into nine questions based on a 5-point Likert scale. These nine questions were combined into composite values by calculating their means.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,91 was obtained. Based on the Cronbach alpha scores and ratings in **Table 3.5**, this score has a rating of "excellent".

#### Chi-Square test

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the "*participants' perceptions of the usefulness of e-Vaccination*". The related null hypothesis and alternate hypothesis were presented in **Table 3.6**.

The frequency distribution table for the single variable Chi-Square calculation has been provided in **Table 5.1**.

***Table 5.1:*** *Observed and expected frequencies for the usefulness category data*

| Likert-scale options | Observed | Expected |
|---|---|---|
| Strongly Agree | 51 | 23,60 |
| Agree | 61 | 23,60 |
| Neutral | 6 | 23,60 |
| Disagree | 0 | 23,60 |
| Strongly Disagree | 0 | 23,60 |
| **Total** | **118** | **118,00** |

If the data for this category was completely random, as per $H_{0\text{- usefulness Chi-Square}}$, then the number of responses for each option listed in **Table 5.1** would have been equal and in this instance, would be approximately 23,60. These values were then used in the Chi-Square analysis. The results have been summarised in **Table 5.2**.

***Table 5.2:*** *Chi-Square results table for the usefulness category data*

| | |
|---|---|
| Chi-Square value† | 151,41 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 151,41† > 9,49‡ |
| Result | $H_{0\text{- usefulness Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The Chi-Square value for four degrees of freedom at a 5% level of significance was 151,41. The critical Chi-Square value was 9,49; 151,41 > 9,49 which means that the difference between what we expected, and our observations was too great to be explained by chance alone. $H_{0\text{- usefulness Chi-Square}}$ is therefore rejected. Similarly, the *p value* was less than 0,001 for four degrees of freedom and a Chi-Square value of 151,41 based on the Chi-Square f table. This means that the probability that random chance is causing the observed values to be different from the expected value is extremely small and we can conclude that the differences between the observed values and expected values are statistically significant.

### Analysis of Variance Test

An ANOVA test was used to determine if the variances in the responses between the four stakeholder groups was statistically significant for the “Usefulness” category. The related null hypothesis and alternate hypothesis were presented in **Table 3.7**.

**Table 5.3** shows the detailed breakdown of responses by stakeholder type and **Table 5.4** a summary of the ANOVA calculations.

***Table 5.3:*** *Summary of responses for the usefulness category by stakeholder type*

| Stakeholder types | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Parents | 35 | 36 | 3 | 0 | 0 |
| Doctors | 4 | 10 | 2 | 0 | 0 |
| Nurses | 6 | 9 | 1 | 0 | 0 |
| School Administrators | 6 | 6 | 0 | 0 | 0 |

***Table 5.4:*** *Results of the ANOVA calculation for the usefulness category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,91 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,48 |
| *p value* ¦ | 0,23 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,23¦ > 0,05§ |
| Result | $H_{0\text{- usefulness ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

**"Usefulness" Category**: Degrees of freedom (3†, 114‡) = 1,48; *p value* = 0,23 > 0,05 (Not significant, since the *p value* is higher than the level of significance. $H_{0\text{- usefulness ANOVA}}$ is accepted).

**Result**: The mean scores were not statistically different between the stakeholder groups.

### 5.3.2 RESULTS PERTAINING TO EASE OF USE

The "Ease of Use" section of the questionnaire was broken up into nine questions based on the 5-point Likert scale. These nine questions were combined into composite values by calculating the means.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,92 was obtained. Based on the Cronbach alpha scores and ratings in **Table 3.5**, this score has a rating of "excellent".

#### Chi-Square test

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being "*the participants' perceptions of the ease of use of e-Vaccination*". The related null hypothesis and alternate hypothesis were previously presented in **Table 3.6**.

The frequency distribution table for the single variable Chi-Square calculation has been provided in **Table 5.5**.

***Table 5.5:*** *Observed and expected frequencies for the ease of use category data*

| Likert-scale options | Observed | Expected |
|---|---|---|
| Strongly Agree | 31 | 23,60 |
| Agree | 75 | 23,60 |
| Neutral | 10 | 23,60 |
| Disagree | 2 | 23,60 |
| Strongly Disagree | 0 | 23,60 |
| **Total** | **118** | **118,00** |

If the data for this category were completely random, as per $H_{0\text{- easy to use Chi-Square}}$, then the number of responses for each option listed in **Table 5.5** would have been equal, and this instance, approximately 23,60. These values were then used in the Chi-Square analysis. The results have been summarised in **Table 5.6**.

***Table 5.6:*** *Chi-Square results table for the ease of use category data*

| | |
|---|---|
| Chi-Square value† | 165,47 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 165,47† > 9,49‡ |
| Result | $H_{0\text{- easy to use Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The Chi-Square value for four degrees of freedom at a 5% level of significance was 165,47. The critical Chi-Square value was 9,49; 165,47 > 9,49 which means that the difference between what we expected, and our observations was too great to be explained by chance alone. $H_{0\text{- easy to use Chi-Square}}$ is therefore rejected. Similarly, the *p value* was less than 0,001 for four degrees of freedom and a Chi-Square value of 165,47 based on the Chi-Square f table. This means that the probability that random chance is causing the observed values to be different from the expected value is extremely small and we can conclude that the differences between the observed values and expected values are statistically significant.

### Analysis of Variance Test

An ANOVA test was used to determine if the variances in the responses between the four stakeholder groups was statistically significant for the “Ease of Use” category. The related null hypothesis and alternate hypothesis were previously presented in **Table 3.7**.

**Table 5.7** shows a detailed breakdown of responses by stakeholder type, followed by a summary of the ANOVA calculations in **Table 5.8**.

***Table 5.7:*** *Summary of responses for the ease of use category by stakeholder type*

| Stakeholder types | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Parents | 19 | 47 | 7 | 1 | 0 |
| Doctors | 2 | 12 | 2 | 0 | 0 |
| Nurses | 6 | 9 | 0 | 1 | 0 |
| School administrators | 4 | 7 | 1 | 0 | 0 |

***Table 5.8:*** *Results of the ANOVA calculation for the ease of use category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,92 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* freedom within groups ‡ | 114 |
| *F value* | 0,54 |
| *p value* ¦ | 0,66 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,66¦ > 0,05§ |
| Result | $H_{0\text{- easy to use ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

**“Ease of Use” Category**: Degrees of freedom (3†, 114‡) = 0,54; *p value* = 0,66 > 0,05 (Not significant, since the *p value* is higher than the level of significance. $H_{0\text{- easy to use ANOVA}}$ is accepted).

**Result**: The mean scores were not statistically different between the stakeholder groups.

### 5.3.3 RESULTS PERTAINING TO EASE OF LEARNING

The “Ease of Learning” section of the questionnaire was broken up into five questions based on the 5-point Likert scale. These five questions were combined into composite values by calculating the means.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,9 was obtained. Based on the Cronbach alpha scores and ratings in **Table 3.5**, this score has a rating of “excellent”.

#### Chi-Square test

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the “*participants’ perceptions of the ease of learning of e-Vaccination*”. The related null hypothesis and alternate hypothesis were previously presented in **Table 3.6**.

The frequency distribution table for the single variable Chi-Square calculation has been provided in **Table 5.9**.

***Table 5.9:*** *Observed and expected frequencies for the ease of learning category data*

| Likert-scale options | Observed | Expected |
|---|---|---|
| Strongly Agree | 33 | 23,60 |
| Agree | 72 | 23,60 |
| Neutral | 13 | 23,60 |
| Disagree | 0 | 23,60 |
| Strongly Disagree | 0 | 23,60 |
| **Total** | **118** | **118,00** |

If the data for this category was completely random, as per $H_{0\text{- easy to learn Chi-Square}}$, then the number of responses for each option listed in **Table 5.9** would have been equal and in this instance, approximately 23,60. These values were then used in the Chi-Square analysis. The results have been summarised in **Table 5.10**.

***Table 5.10:*** *Chi-Square results table for the ease of learning category data*

| | |
|---|---|
| Chi-Square value† | 154,97 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 154,97 > 9,49‡ |
| Result | $H_{0\text{- easy to learn Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The Chi-Square value for four degrees of freedom at a 5% level of significance was 154,97. The critical Chi-Square value was 9,49; 154,97 > 9,49 which means that the difference between what we expected, and our observations was too great to be explained by chance alone. $H_{0\text{- easy to learn Chi-Square}}$ is therefore rejected. Similarly, the *p value* was less than 0,001 for 4 degrees of freedom and a Chi-Square value of 154,97 based on the Chi-Square f table. This means that the probability that random chance is causing the observed values to be different from the expected value is extremely small and we can conclude that the differences between the observed values and expected values are statistically significant.

### Analysis of Variance Test

An ANOVA test was used to determine if the variances in the responses between the four stakeholder groups was statistically significant for the "Ease of Learning" category. The related null hypothesis and alternate hypothesis were presented in **Table 3.7**.

**Table 5.11** shows a detailed breakdown of responses by stakeholder type followed by a summary of the ANOVA calculations **Table 5.12**.

***Table 5.11:*** *Summary of responses for the ease of learning category by stakeholder type*

| **Stakeholder types** | **Strongly agree** | **Agree** | **Neither agree nor disagree** | **Disagree** | **Strongly disagree** |
|---|---|---|---|---|---|
| Parents | 21 | 45 | 8 | 0 | 0 |
| Doctors | 3 | 11 | 2 | 0 | 0 |
| Nurses | 6 | 9 | 1 | 0 | 0 |
| School administrators | 3 | 7 | 2 | 0 | 0 |

***Table 5.12:*** *Results of the ANOVA calculation for the ease of learning category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,90 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 0,55 |
| *p value* ¦ | 0,65 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,65¦ > 0,05§ |
| Result | $H_{0\text{- easy to learn ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

**"Ease of Learning" Category**: Degrees of freedom (3†, 114‡) = 0,55; *p value* = 0,55 > 0,05 (Not significant, since the *p value* is higher than the level of significance. $H_{0\text{- easy to learn ANOVA}}$ is accepted).

**Result**: The mean scores were not statistically different between the stakeholder groups.

### 5.3.4 RESULTS PERTAINING TO SATISFACTION

The "Satisfaction" section of the questionnaire was broken up into five questions based on the 5-point Likert scale. These five questions were combined into composite values by calculating the means.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,90 was obtained. Based on the Cronbach alpha scores and ratings in **Table 3.5**, this score has a rating of "excellent".

#### Chi-Square test

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the "*participants' perceptions of the satisfaction of e-Vaccination*". The related null hypothesis and alternate hypothesis were previously presented in **Table 3.6**.

The frequency distribution table for the single variable Chi-Square calculation has been provided in **Table 5.13**.

***Table 5.13:*** *Observed and expected frequencies for the satisfaction category data*

| Likert-scale options | Observed | Expected |
|---|---|---|
| Strongly Agree | 39 | 23,60 |
| Agree | 64 | 23,60 |
| Neutral | 14 | 23,60 |
| Disagree | 1 | 23,60 |
| Strongly Disagree | 0 | 23,60 |
| **Total** | **118** | **118,00** |

If the data for this category was completely random, as per $H_{0\text{- satisfaction Chi-Square}}$, then the number of responses for each option listed in **Table 5.13** would have been equal and approximately 23,60. These values were then used in the Chi-Square analysis. The results have been summarised in **Table 5.14**.

***Table 5.14:*** *Chi-Square results table for the satisfaction category data*

| | |
|---|---|
| Chi-Square value† | 128,36 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 128,36† > 9,49‡ |
| Result | $H_{0\text{- satisfaction Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The Chi-Square value for four degrees of freedom at a 5% level of significance was 128,36. The critical Chi-Square value was 9,49; 128,36 > 9,49 which means that the difference between what we expected, and our observations was too great to be explained by chance alone. $H_{0\text{- satisfaction Chi-Square}}$ is therefore rejected. Similarly, the *p value* was less than 0,001 for four degrees of freedom and a Chi-Square value of 128,36 based on the Chi-Square f table. This means that the probability that random chance is causing the observed values to be different from the expected value is extremely small and we can conclude that the differences between the observed values and expected values are statistically significant. This result shows that $H_{0\text{-satisfaction}}$ could therefore not be rejected.

### Analysis of Variance Test

An ANOVA test was used to determine if the variances in the responses between the four stakeholder groups were statistically significant for the "Satisfaction" category. The related null hypothesis and alternate hypothesis were previously presented in **Table 3.7**.

A detailed breakdown of responses by stakeholder type is provided in **Table 5.15**, followed by **Table 5.16** with a summary of the ANOVA calculations.

***Table 5.15:*** *Summary of responses for the satisfaction category by stakeholder type*

| Stakeholder types | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Parents | 27 | 39 | 7 | 1 | 0 |
| Doctors | 3 | 8 | 5 | 0 | 0 |
| Nurses | 6 | 9 | 1 | 0 | 0 |
| School Administrators | 3 | 8 | 1 | 0 | 0 |

***Table 5.16:*** *Results of the ANOVA calculation for the satisfaction category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,90 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,54 |
| *p value* ¦ | 0,21 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,21¦ > 0,05§ |
| Result | $H_{0\text{- satisfaction ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

**"Satisfaction" Category**: Degrees of freedom (3†, 114‡) = 1,54; *p value* = 0,21 > 0,05 (Not significant, since the *p value* is higher than the level of significance. $H_{0\text{- satisfaction ANOVA}}$ is accepted).

**Result**: The mean scores were not statistically different between the stakeholder groups.

### 5.3.5 RESULTS PERTAINING TO DESIGN AND VISUAL AIDS

The “Design and visual aids” section of the questionnaire was broken up into five questions based on the 5-point Likert scale. These five questions were combined into composite values by calculating the means.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,67 was obtained. Based on The Cronbach alpha scores and ratings from **Table 3.5,** this score has a rating of “questionable”. This lower score could have been the result of question 30 being worded in a negative way favouring written instructions over the use of visual aids. Some of the respondents might not have noted that the question was worded negatively when inserting their responses (Jozsa & Morgan, 2017). This could have negatively affected the outcome of this question therefore the results of this section could possibly have been higher. The score of 0,67 is however higher than the recommended minimum of 0,65 (Goforth, 2015).

#### Chi-Square test

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the “*participants’ perceptions of the design and visual aids in of e-Vaccination*”. The related null hypothesis and alternate hypothesis were previously presented in **Table 3.6**.

The frequency distribution table for the single variable Chi-Square calculation has been provided in **Table 5.17**.

***Table 5.17:*** *Observed and expected frequencies for the design and visual aids category data*

| Likert-scale options | Observed | Expected |
|---|---|---|
| Strongly Agree | 19 | 23,60 |
| Agree | 78 | 23,60 |
| Neutral | 18 | 23,60 |
| Disagree | 3 | 23,60 |
| Strongly Disagree | 0 | 23,60 |
| **Total** | **118** | **118,00** |

If the data for this category were completely random, as per $H_{0\text{- design and visual aids Chi-Square}}$, then the number of responses for each option listed in **Table 5.17** would have been equal and in this instance, approximately 23,60. These values were then used in the Chi-Square analysis to give results as summarised in **Table 5.18**.

***Table 5.18:*** *Chi-Square results table for the design and visual aids category data*

| | |
|---|---|
| Chi-Square value† | 169,20 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 169,20† > 9,49‡ |
| Result | $H_{0\text{- design and visual aids Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The Chi-Square value for four degrees of freedom at a 5% level of significance was 169,20. The critical Chi-Square value was 9,49; 169,20 > 9,49 which means that the difference between what we expected, and our observations was too great to be explained by chance alone. $H_{0\text{- design and visual aids Chi-Square}}$ is therefore rejected. Similarly, the *p value* was less than 0,001 for four degrees of freedom and a Chi-Square value of 169,20 based on the Chi-Square f table. This means that the probability that random chance is causing the observed values to be different from the expected value is extremely small and we can conclude that the differences between the observed values and expected values are statistically significant. This result shows that $H_{0\text{- design and visual aids}}$ could therefore not be rejected.

### Analysis of Variance Test

An ANOVA test was used to determine if the variances in the responses between the four stakeholder groups was statistically significant for the "Design and Visual Aids" category. The related null hypothesis and alternate hypothesis were previously presented in **Table 3.7**.

**Table 5.19** shows a detailed breakdown of responses by stakeholder type followed by a summary of the ANOVA calculations in **Table 5.20**.

***Table 5.19:*** *Summary of responses for the design and visual aids category by stakeholder type*

| Stakeholder types | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| Parents | 10 | 56 | 6 | 2 | 0 |
| Doctors | 1 | 10 | 5 | 0 | 0 |
| Nurses | 7 | 5 | 3 | 1 | 0 |
| School Administrators | 1 | 7 | 4 | 0 | 0 |

***Table 5.20:*** *Results of the ANOVA calculation for the design and visual aids category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,67 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,45 |
| *p value* ¦ | 0,23 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,23¦ > 0,05 § |
| Result | $H_{0\text{- design and visual aids ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

**"Design and Visual Aids" Category**: Degrees of freedom (3†, 114‡) = 1,45; *p value* = 0,23 > 0,05 (Not significant, since the *p value* is higher than the level of significance. $H_{0\text{- design and visual aids ANOVA}}$ is accepted).

**Result**: The mean scores were not statistically different between the stakeholder groups.

### 5.3.6 DETERMINING THE PRINCIPLE FACTORS

Section C of the questionnaire was designed to answer the research question "*What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system?*"

To determine whether the responses to the 33 questions in this section of the questionnaire related to the five categories identified in **Table 3.2** and the overall concept of digitising the vaccination card, a Principle Components Analysis (PCA) was performed. A PCA is a data reduction method which can reduce correlated variables into a few principle components (UCLA Institute for Digital Research & Education, 2020). The outputs of this analysis are discussed below. The PCA calculations were done using XLSTAT version 2020.3.1.15.

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy is used to determine whether the data is suitable to be used in a PCA (UCLA Institute for Digital Research & Education, 2020). The KMO value varies between 0 and 1 with a minimum suggested value of 0,6 (UCLA Institute for Digital Research & Education, 2020). The KMO value calculated was 0,91 and it is above the minimum recommended value.

The data were therefore suitable for the PCA. The specific results of the KMO can be found in Appendix 11.

Eigenvalues were used to determine the main factors of the 33 questions. Generally, the factors with Eigenvalues greater than 1 should be kept (UCLA Institute for Digital Research & Education, 2020). These factors are considered significant and form the principle components of a dataset. The factors with Eigenvalues greater than 1 are displayed in **Table 5.21**.

***Table 5.21:*** *Summary of the top six principle components as determined by the PCA*

| Factors | Eigenvalue | Variability (%) | Cumulative % |
|---|---|---|---|
| 1 | 16,93 | 51,30 | 51,30 |
| 2 | 2,05 | 6,22 | 57,52 |
| 3 | 1,78 | 5,38 | 62,91 |
| 4 | 1,38 | 4,19 | 67,10 |
| 5 | 1,22 | 3,69 | 70,79 |
| 6 | 1,05 | 3,19 | 73,98 |

From **Table 5.21**, it can be seen that almost 74% of the total variability of all the data collected related to these 6 factors. The variability of the remaining factors (7 to 33 based on the 33 questions) can be seen in Appendix 12. These six factors had Eigenvalues greater than 1. The Eigenvalues were then plotted on a scree plot as shown in **Figure 5.17**.

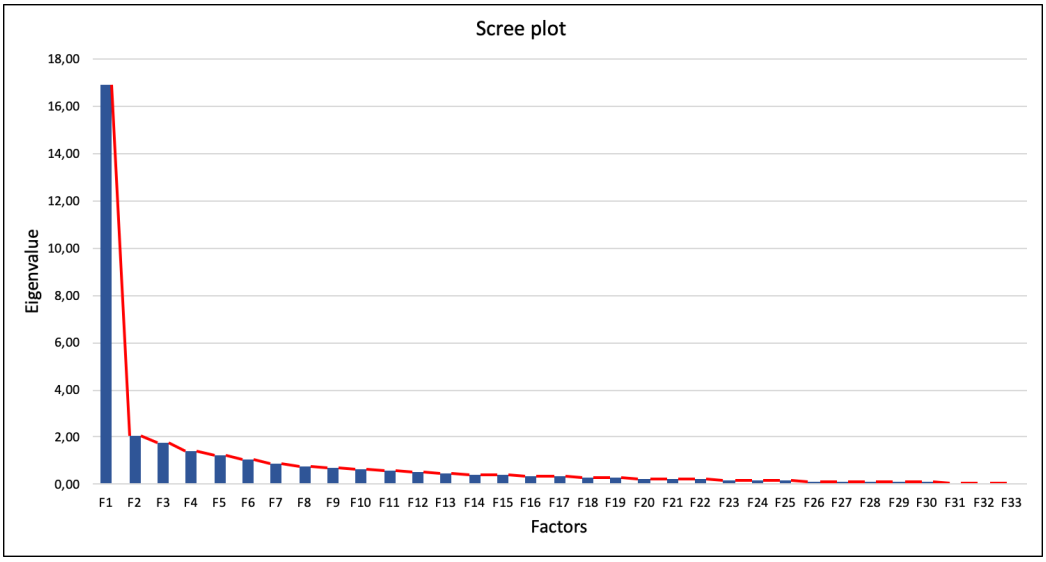



***Figure 5.17:*** *Scree plot showing all 33 identified factors from highest to lowest*

The factor with the steepest gradient in the scree plot denotes the principle component. As seen from **Figure 5.17,** there is 1 principle factor (F1) which represents the overall concept of digitising the vaccination card.

The remaining factors 2 to 6 though with gentler gradients, had Eigenvalues that were greater than 1. To determine which categories contributed to factors 2 to 6, a PCA was done on the composite values (the mean of the scores for each of the five categories). The results of the percentage contributions are given in **Table 5.22**.

***Table 5.22:*** *Summary of the percentage category contributions to the five factors*

| Categories | F1 (%) | F2 (%) | F3 (%) | F4 (%) | F5 (%) |
|---|---|---|---|---|---|
| Usefulness | 18,608 | 17,457 | 60,125 | 3,225 | 0,584 |
| Ease of Use | 23,421 | 0,000 | 9,301 | 3,367 | 63,911 |
| Ease of Learning | 21,340 | 0,229 | 17,994 | 52,903 | 7,533 |
| Satisfaction | 21,586 | 8,105 | 4,648 | 39,850 | 25,810 |
| Design and Visual Aids | 15,045 | 74,208 | 7,931 | 0,654 | 2,162 |

## 5.4 SUMMARY OF PRESENTATION OF RESULTS

The responses to the demographic questions were displayed in the form of pie charts and bar charts where applicable. **Table 5.23** is a summary of the responses.

***Table 5.23:*** *Summary of the demographic results*

| | |
|---|---|
| Stakeholder type | Parents: 74 (62,7%)<br>Doctors: 16 (13,6%)<br>Nurses: 16 (13,6%)<br>School administration staff: 12 (10,2%) |
| Access to a smartphone | Yes: 112 (95%)<br>No: 6 (5%) |
| Access to the Internet | Yes: 113 (96%)<br>No: 3 (2%)<br>Not applicable: 2 (2%) |
| Access to an E-mail address | Yes: 113 (96%)<br>No: 5 (4%) |
| Perceptions towards vaccination storage in Gauteng | Paper-based vaccination card: 108 (91%)<br>Electronic systems: 5 (5%)<br>No records are kept: 1 (1%)<br>Not sure: 4 (3%) |
| Experience with lost / damaged vaccination card | Yes: 56 (47%)<br>No: 62 (53%) |
| Perceptions towards vaccination rates in Gauteng (vaccines are administered on time) | Strongly agree: 16 (14%) |

| | |
|---|---|
| | Agree: 49 (41%)<br>Neither agree nor disagree: 30 (25%)<br>Disagree: 20 (17%)<br>Strongly disagree: 3 (3%) |
| Perceptions towards the reliability of vaccination cards (vaccination cards are reliable) | Strongly agree: 10 (8%)<br>Agree: 25 (21%)<br>Neither agree nor disagree: 14 (12%)<br>Disagree: 41 (35%)<br>Strongly disagree: 28 (24%) |

The responses to the USE tool section of the questionnaire were grouped by category based on the five sections (usability, ease of use, ease of learning, satisfaction and design and visual aids) and were analysed as composite values. The data were checked for reliability using the Cronbach alpha. A PCA was then done to confirm that the principle factor matched the research question. The data were then analysed using a Chi-Square test, Analysis of Variance test and a Principle Component Analysis. **Table 5.24** is a summary of the results of the statistical analysis

***Table 5.24:*** *Summary of the statistical analysis*

| Statistics | Usefulness | Ease of Use | Ease of Learning | Satisfaction | Design and Visual Aids |
|---|---|---|---|---|---|
| **Data Reliability** | | | | | |
| Cronbach alpha | 0,91 | 0,92 | 0,9 | 0,9 | 0,67 |
| **Chi-Square test** | | | | | |
| Chi-Square value † | 151,41 | 165,47 | 154,97 | 128,36 | 169,20 |
| *df* | 4 | 4 | 4 | 4 | 4 |
| Critical Chi-Square value ‡ | 9,49 | 9,49 | 9,49 | 9,49 | 9,49 |
| Approximate *p value* | <0,001 | <0,001 | <0,001 | <0,001 | <0,001 |
| Alpha value | 0,05 | 0,05 | 0,05 | 0,05 | 0,05 |
| Outcome of calculation | 151,41† > 9,49‡ | 165,47† > 9,49‡ | 154,97† > 9,49‡ | 128,36† > 9,49‡ | 169,20† > 9,49‡ |
| Result | $H_{0\text{- usefulness Chi-Square}}$ Rejected | $H_{0\text{- easy to use Chi-Square}}$ Rejected | $H_{0\text{- easy to learn Chi-Square}}$ Rejected | $H_{0\text{- satisfaction Chi-Square}}$ Rejected | $H_{0\text{- design and visual aids Chi-Square}}$ Rejected |
| **ANOVA test** | | | | | |
| Alpha value § | 0,05 | 0,05 | 0,05 | 0,05 | 0,05 |
| *df* between groups | 3 | 3 | 3 | 3 | 3 |
| *df* within groups | 114 | 114 | 114 | 114 | 114 |
| *F value* | 1,48 | 0,54 | 0,55 | 1,54 | 1,45 |
| *p value* ¦ | 0,23 | 0,66 | 0,65 | 0,21 | 0,23 |
| *f crit* | 2,68 | 2,68 | 2,68 | 2,68 | 2,68 |
| Outcome of calculation | 0,23¦ > 0,05§ | 0,66¦ > 0,05§ | 0,65¦ > 0,05§ | 0,21¦ > 0,05§ | 0,23¦ > 0,05 § |
| Result | $H_{0\text{- usefulness ANOVA}}$ Accepted | $H_{0\text{- easy to use ANOVA}}$ Accepted | $H_{0\text{- easy to learn ANOVA}}$ Accepted | $H_{0\text{- satisfaction ANOVA}}$ Accepted | $H_{0\text{- design and visual aids ANOVA}}$ Accepted |
| **Principle Component Analysis** | | | | | |
| Contribution to Factor 1 | 18,6 | 23,4 | 21,3 | 21,6 | 15,1 |

| | | | | | |
|---|---|---|---|---|---|
| Contribution to Factor 2 | 17,5 | 0,0 | 0,2 | 8,1 | 74,2 |
| Contribution to Factor 3 | 60,1 | 9,3 | 18,0 | 4,7 | 7,9 |
| Contribution to Factor 4 | 3,2 | 3,4 | 52,9 | 39,9 | 0,7 |
| Contribution to Factor 5 | 0,6 | 63,9 | 7,5 | 25,8 | 2,2 |
| **Overall** | | | | | |
| Result | $H_{0\text{- usefulness}}$ Accepted | $H_{0\text{- easy to use}}$ Accepted | $H_{0\text{- easy to learn}}$ Accepted | $H_{0\text{- satisfaction}}$ Accepted | $H_{0\text{- design and visual aids}}$ Accepted |

*† Chi-Square value*
*‡ Critical Chi-Square value*
*§ Alpha value*
*¦ p value*

In this chapter, the responses to the questionnaire were analysed and presented. In the following chapter (Discussion of results), the results will be interpreted. These interpretations will lead up to the conclusion.

# CHAPTER 6: DISCUSSION OF RESULTS

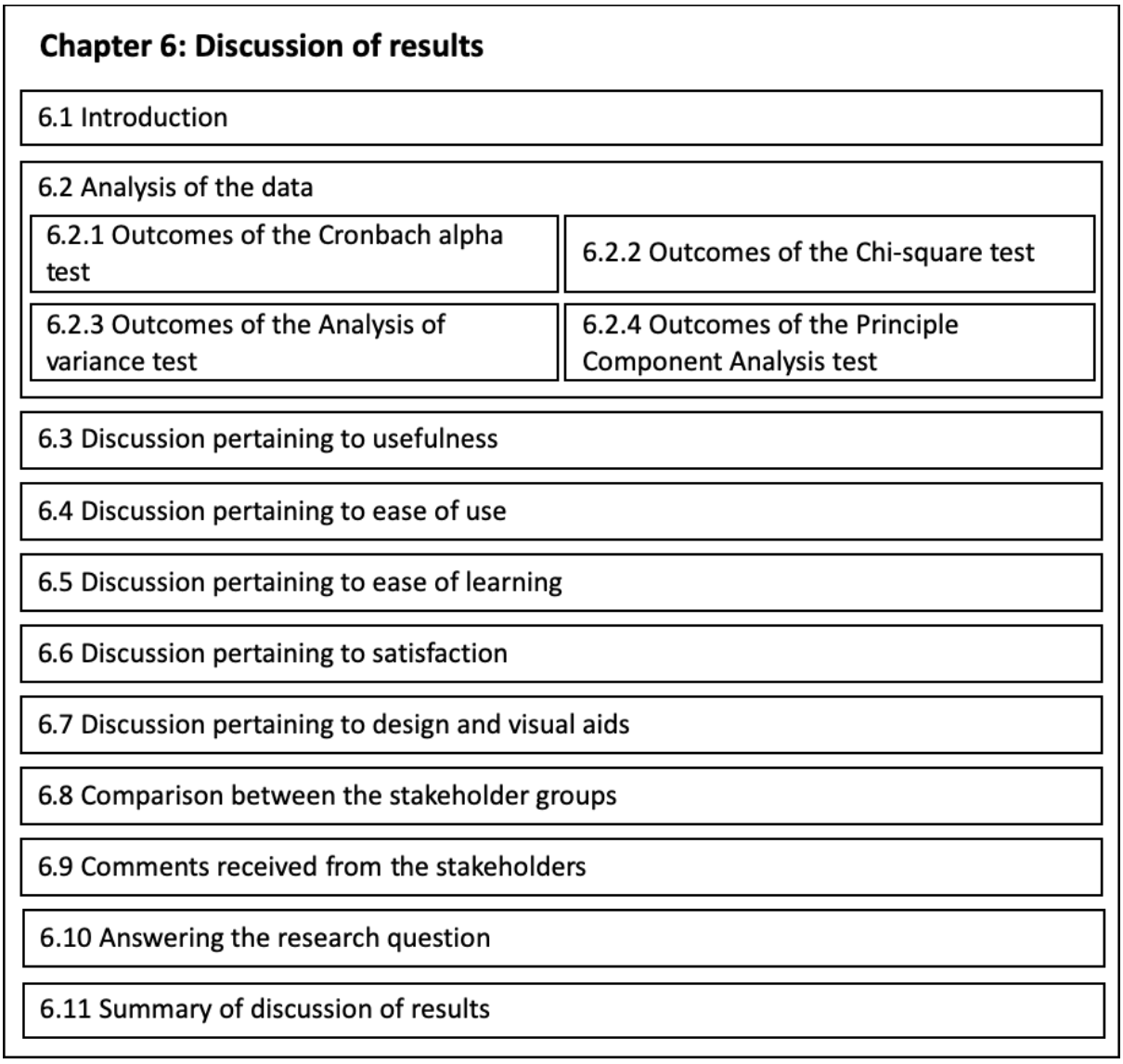



***Figure 6.1:*** *Structure of Chapter 6*

## 6.1 INTRODUCTION

The results obtained from the previous chapter (the Cronbach Alpha, Chi-Square test, ANOVA test and the Principle Component Analysis test) are summarised in **Figure 6.2** and will be interpreted in this chapter. In the next section, the results of the data analysis are summarised.

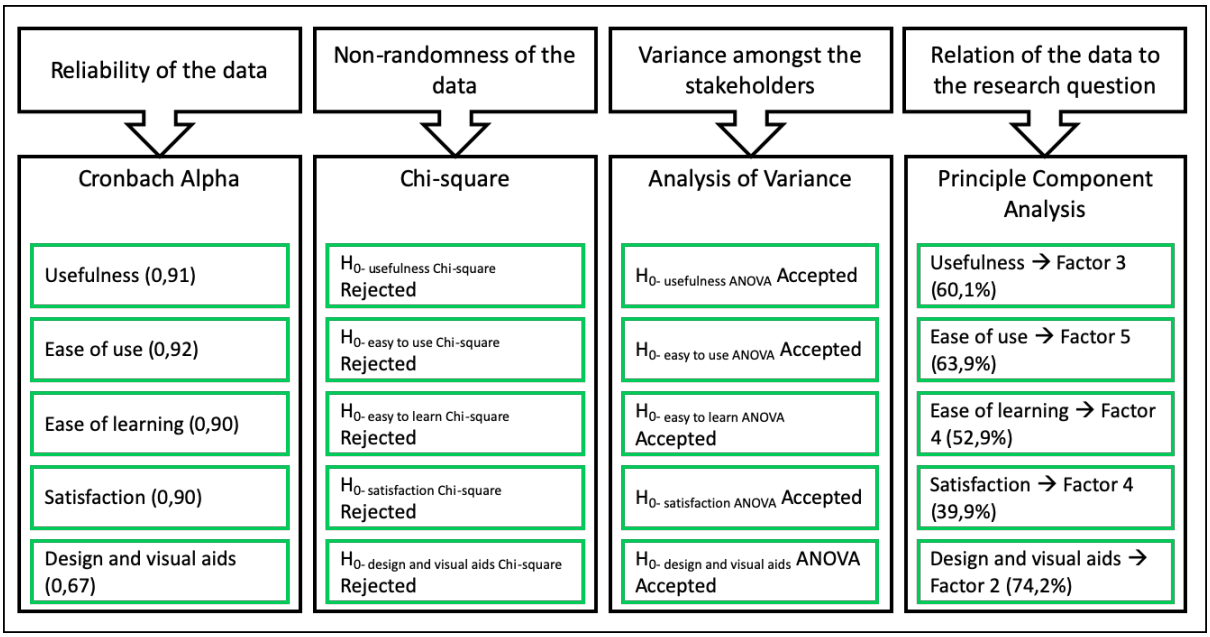



***Figure 6.2:*** *Summary of the data analysis results for each step as per Chapter 5*

## 6.2 ANALYSIS OF THE DATA

The outcomes of the Cronbach alpha, Chi-Square, ANOVA and PCA tests will be discussed in the sections that follow.

### 6.2.1 OUTCOMES OF THE CRONBACH ALPHA TEST

The Cronbach alpha is used to determine the reliability of a set of questions (Goforth, 2015). Cronbach alpha scores are expressed as a decimal value from 0 to 1 (Goforth, 2015). The scores are interpreted according to the Cronbach alpha scores and ratings that were provided in **Table 3.5**.

The Cronbach Alpha test was run on the composite scores of the five categories yielding the following results (rounded off to 2 decimal places):

***Table 6.1:*** *Summary of the Cronbach Alpha scores per category*

| Category | Score | Comment |
|---|---|---|
| Usefulness | 0,91 | Excellent as per Table 3.5 |
| Ease of Use | 0,92 | Excellent as per Table 3.5 |
| Ease of Learning | 0,90 | Excellent as per Table 3.5 |
| Satisfaction | 0,90 | Excellent as per Table 3.5 |
| Design and Visual Aids | 0,67 | Questionable according to Table 3.5 but still above the recommended minimum of 0,65 |

The results of the Cronbach alpha showed that data that was collected from the questionnaire was reliable and could then be analysed further.

### 6.2.2 OUTCOMES OF THE CHI-SQUARE TEST

The Chi-Square test is used to determine the likelihood that an observed distribution of categorical data is due to chance (University of Pennsylvania School of Arts and Sciences, 2008). To ensure that that the data collected from the questionnaire was not due to a random occurrence and was instead related to a variable, a Chi-Square test was performed. This test was run on the composite scores of the five categories yielding the following results in **Table 6.2**.

***Table 6.2:*** *Summary of the Chi-Square test outcome per category*

| Category | Outcome | Comment |
|---|---|---|
| Usefulness | $H_{0\text{- usefulness Chi-Square}}$ rejected | Data was not random |
| Ease of Use | $H_{0\text{- easy to use Chi-Square}}$ rejected | Data was not random |
| Ease of Learning | $H_{0\text{- easy to learn Chi-Square}}$ rejected | Data was not random |
| Satisfaction | $H_{0\text{- satisfaction Chi-Square}}$ rejected | Data was not random |
| Design and Visual Aids | $H_{0\text{- design and visual aids Chi-Square}}$ rejected | Data was not random |

The results of the Chi-Square test showed that the data that was collected from the questionnaire was not random.

### 6.2.3 OUTCOMES OF THE ANALYSIS OF VARIANCE TEST

Once it was established that the data was reliable and not random, the ANOVA test was run. The analysis of variance test was used as data was collected from more than two stakeholder types. The ANOVA test is used to determine if there are significant differences between different experimental conditions (Rutherford, 2000). This test compared the mean scores across the four stakeholder groups for each category to determine if the null hypothesis for each sub-category was accepted. The results of the ANOVA test are summarised in **Table 6.3**.

***Table 6.3:*** *Summary of the ANOVA test outcome per category*

| Stakeholder group | Outcome | Comment |
|---|---|---|
| Usefulness | $H_{0\text{- usefulness ANOVA}}$ accepted | No statistical difference between the mean scores of the 4 stakeholder groups |
| Ease of Use | $H_{0\text{- easy to use ANOVA}}$ accepted | No statistical difference between the mean scores of the 4 stakeholder groups |
| Ease of Learning | $H_{0\text{- easy to learn ANOVA}}$ accepted | No statistical difference between the mean scores of the 4 stakeholder groups |
| Satisfaction | $H_{0\text{- satisfaction ANOVA}}$ accepted | No statistical difference between the mean scores of the 4 stakeholder groups |

| Stakeholder group | Outcome | Comment |
|---|---|---|
| Design and Visual Aids | $H_{0\text{- design and visual aids ANOVA}}$ accepted | No statistical difference between the mean scores of the 4 stakeholder groups |

At this point it was determined that, in addition to the data being reliable and not random, the mean scores between the stakeholder groups for each category were not statistically different indicating that they had the same perceptions.

### 6.2.4 OUTCOMES OF THE PRINCIPLE COMPONENT ANALYSIS TEST

The questionnaire was created based on an adaptation of the USE tool as mentioned in Chapter 3. The four categories of the USE tool, that is, *usefulness*, *ease of use*, *ease of learning* and *satisfaction* were included. A fourth category called design and visual aids was added to the questionnaire. This category was added due to a new dimension of applications such as e-Vaccination as well as the other applications mentioned in Chapter 2. These applications have a graphically focussed user interface that helps to drive the functions of the application. The five categories were then manually added to the questionnaire under their respective headings.

The PCA was conducted on the entire dataset of all 118 participants to the 33 questions contained in Section C of the questionnaire. A PCA which is a data reduction method (UCLA Institute for Digital Research & Education, 2020) can be used to investigate the relationship between dependent variables (Syms, 2019). The PCA was used to determine whether the stakeholders' responses were related to the overall research question relating to the digitisation of the vaccination card. The PCA was also used to determine the factors relating to the 5 sub-categories of the questionnaire viz. usefulness, ease of use, ease of learning, satisfaction and design and visual aids. The PCA calculations were done using XLSTAT version 2020.3.1.15.

Prior to conducting the PCA, the Kaiser-Meyer-Olkin (KMO) value was calculated to determine whether the data was suitable for a PCA, since the KMO value is a measure of sampling adequacy (UCLA Institute for Digital Research & Education, 2020). The KMO value should be greater than 0,5 (David & Jacobs, 2014). The KMO value was calculated as 0,91 which is above the minimum recommended value. The data was therefore suitable for a PCA.

Eigenvalues were used to determine the main factors of the 33 questions. Generally, the factors with Eigenvalues greater than 1 should be kept (UCLA Institute for Digital Research & Education, 2020). These factors are considered significant and form the principle components of the dataset. The factors with Eigenvalues greater than 1 and can be referred to in **Table 5.21** with an accompanying scree plot in **Figure 5.17**. The results reflected that the responses of the stakeholders were related to the research question relating to the digitisation of the vaccination card.

The remaining factors 2 to 6, though with gentler gradients, had Eigenvalues that were greater than 1. To determine which categories contributed to factors 2 to 6, a PCA was then run on the composite values of the 5 categories. From this, 5 factors were identified. The percentage contributions of the categories to these factors helped to determine what these 5 underlying factors related to. **Figure 6.3** is a graphical summary of the percentage contributions of each of the five categories as determined by a PCA, across five factors (as previously captured in **Table 5.22)**, as well as the main contributors to those factors.

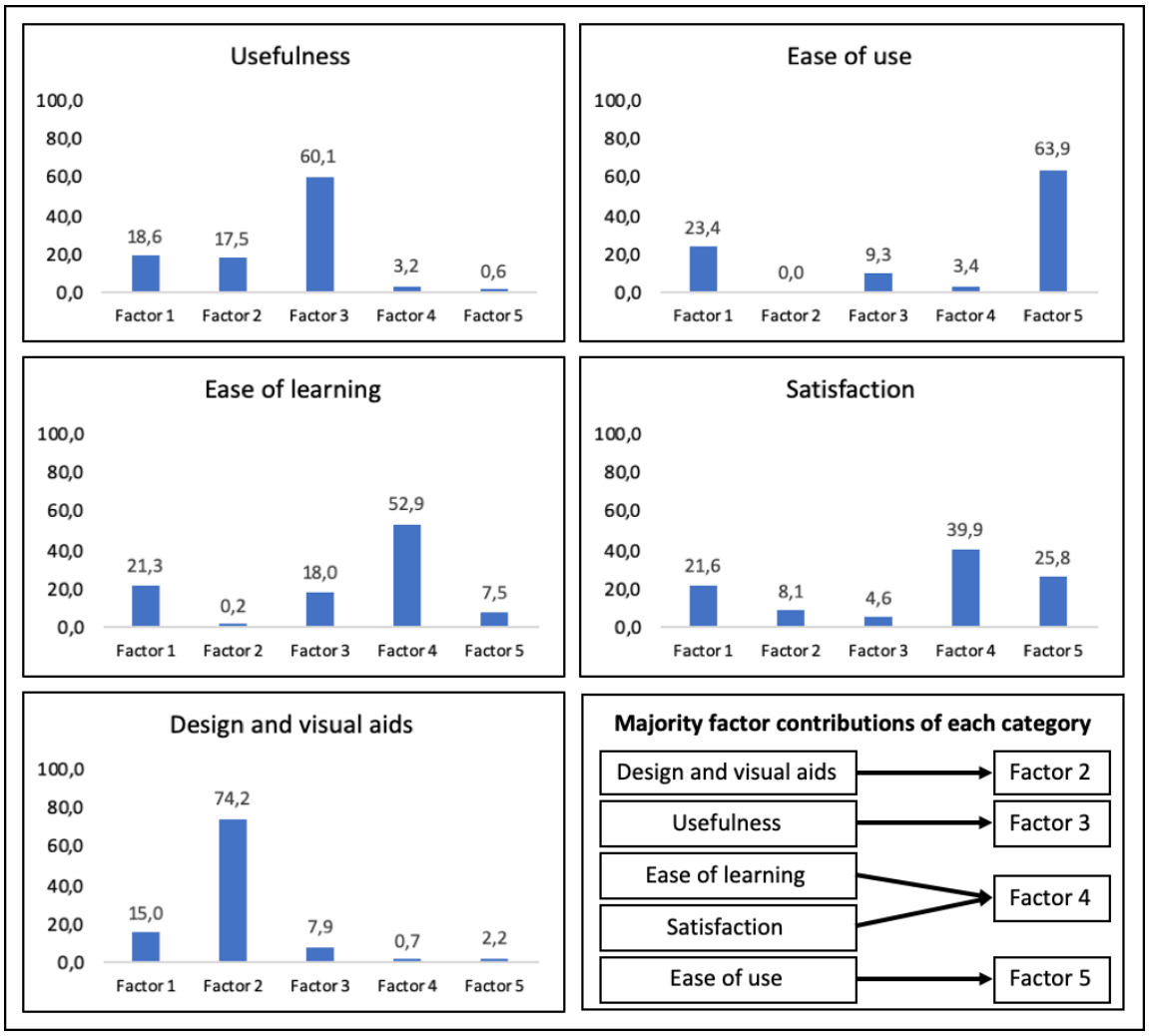



***Figure 6.3:*** *The percentage contributions of the categories towards the five factors identified by the PCA and the majority factor contributions of each category*

The percentage contributions towards the factors then led to the naming of the factors as listed below;

- Factor 1 → User friendliness
- Factor 2 → Graphical design
- Factor 3 → Practicality
- Factor 4 → User experience
- Factor 5 → Usability

The interpretations relating to each of the five categories are discussed below.

## 6.3 DISCUSSION PERTAINING TO USEFULNESS

The nine questions from the "Usefulness" category were combined to form composite values (calculated as the mean score) to aid in understanding the overall perception of this category.

A score of 0,91, according to the Cronbach Alpha scores in **Table 6.1** has a rating of "excellent". This score showed that data that was collected from the questionnaire was reliable and could be further analysed.

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable. The related null hypothesis and alternate hypothesis are presented below

***Table 6.4:*** *The null and alternate hypotheses for the Chi-Square test for the usefulness category*

| Null Hypothesis | Null hypothesis description | Alternate Hypothesis | Alternate Hypothesis description |
|---|---|---|---|
| $H_{0\text{- usefulness Chi-Square}}$ | The proportions of scores for the usefulness category are the same between the observed and the expected responses | $H_{1\text{- usefulness Chi-Square}}$ | At least 2 proportions of scores for the usefulness category are different between the observed and the expected responses |

The results of the Chi-Square test were provided in **Table 5.2**, reproduced below.

***Table 5.2:*** *Chi-Square results table for the usefulness category data*

| | |
|---|---|
| Chi-Square value† | 151,41 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 151,41† > 9,49‡ |
| Result | $H_{0\text{- usefulness Chi-Square}}$ rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The results of the Chi-Square test showed that the data that was collected from the questionnaire for the usefulness category was not random.

Once it was determined that the data collected for this category was reliable and not random, the ANOVA test was run. The ANOVA test was used to determine if the variances in the responses between the 4 stakeholder groups was statistically significant for the usefulness category. The related null hypothesis and alternate hypothesis are presented below.

***Table 6.5:*** *The null and alternate hypotheses for the ANOVA test for the usefulness category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- usefulness ANOVA}}$ | The mean scores for the usefulness category across the 4 stakeholder groups are the same | $H_{1\text{- usefulness ANOVA}}$ | At least 2 mean scores for the usefulness category across the 4 stakeholder groups are different |

**Table 5.4** which has been reproduced below is a summary of the ANOVA calculations for the usefulness category.

***Table 5.4:*** *Results of the ANOVA calculation for the usefulness category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,91 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,48 |
| *p value* ¦ | 0,23 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,23¦ > 0,05§ |
| Result | $H_{0\text{- usefulness ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

Subsequent ANOVA tests showed that the mean scores between the stakeholder groups for the usefulness category were not statistically different. This meant that the four stakeholder groups shared common perceptions towards the usefulness of e-Vaccination.

The PCA was then run on the composite values of the usefulness category. From this, five factors were identified. The percentage contributions of the usefulness category towards the five factors as identified by the PCA are depicted in **Figure 6.4**.

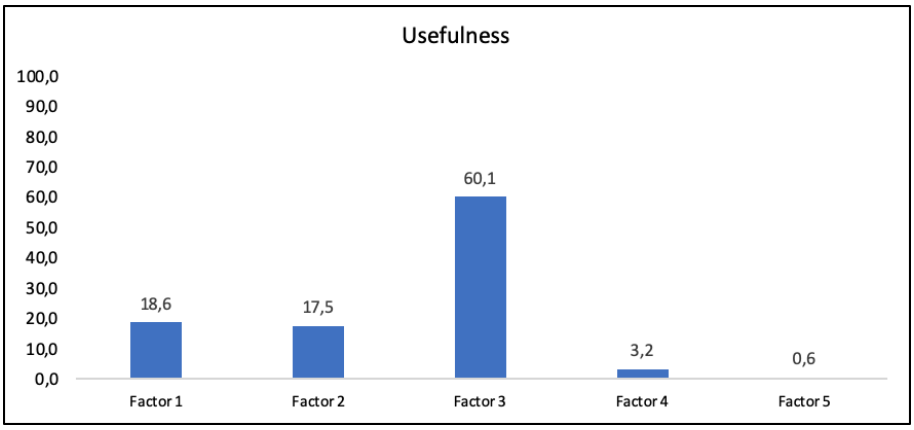



***Figure 6.4:*** *The percentage contributions of the usefulness category towards the five factors identified by the PCA*

The PCA demonstrated that there was a 60,1% contribution of the usefulness category towards Factor 3, this was previously labelled in Section 6.2.4 as "*Practicality*". In other words, for e-Vaccination to be adopted by key stakeholders, the system would need to be practical. The system would need to provide all of the current functionality of the paper-based vaccination card at the minimum and provide additional benefits where possible. During a clinic visit, the nurses were impressed by the vision of the system as well as its practicality. It was noted however that e-Vaccination did not contain all the data fields that are required for the creation of a vaccination record. These fields were the "batch number" and "expiry date" of the vaccine being administered. This is not a major concern as these two data fields can be easily added later on. Many of the nurses could see how a system of this nature would be useful to them. Many asked, "When will the system be ready for us to use?"

From the parents' perspective, it was discussed in Chapter 2 that the loss of a paper-based vaccination card is a threat to these records. e-Vaccination being a digital platform, can give parents access to these records without having to locate the physical card. A new dimension can be considered for doctors as well as school administrators who may want access to these records. Based on the design, school administrators could request the records from the parents and doctors could access the records themselves. In Chapter 2, the Measles outbreak in Gauteng during 2017 was mentioned. Another potential use of e-Vaccination is related to the mining of digital data. Having real-time information on vaccination coverage at an individual child level could give key decision makers enough information to form an effective strategy during times of such pandemics. These features, some of which are not possible with

the paper-based vaccination card contribute to the usefulness and practicality of e-Vaccination.

**Figure 6.5** is a radar chart that shows the mean weighted scores (expressed as a percentage) of the responses for all the stakeholder types related to the usefulness category.

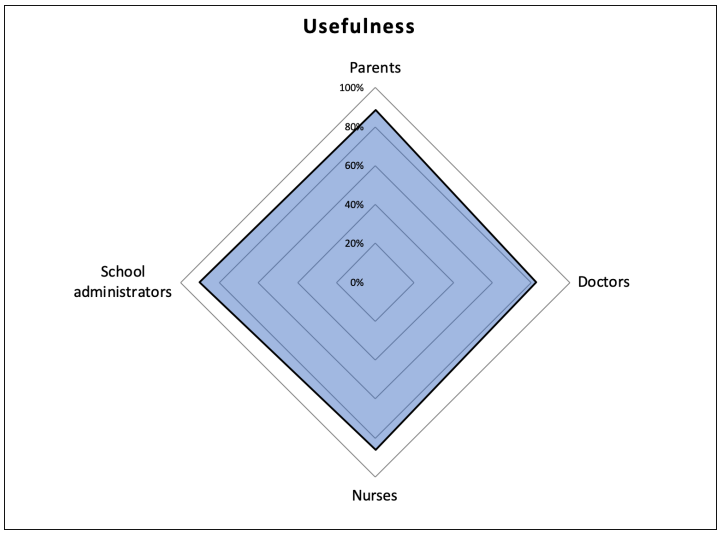



***Figure 6.5:*** *Mean weighted scores (expressed as a percentage) amongst the four stakeholder groups for the usefulness category*

**Figure 6.5** above graphically represents the responses related to the usefulness category. The weighted percentage scores per stakeholder group and the average weighted percentage score are detailed in **Table 6.6**.

***Table 6.6:*** *Mean weighted scores per stakeholder group for the usefulness category (expressed as a percentage)*

| Parents | Doctors | Nurses | School admin | Average weighted percentage |
|---|---|---|---|---|
| 89% | 83% | 86% | 90% | 87% |

The average weighted percentage score for this category was 87%. The average weighted percentage score was converted from a weighted average score of 4,38 out of 5,00 on the 5-point Likert scale that was used in the questionnaire. This score falls within the “Agree” range of the Likert scale. According to these results, the statistical analysis and interpretations, it is clear that e-Vaccination was found to be useful.

## 6.4 DISCUSSION PERTAINING TO EASE OF USE

The nine questions from the "Ease of use" category were combined to form composite values (calculated as the mean score) to aid in understanding the overall perception of this category.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,92 was obtained and based on Cronbach alpha scores and ratings listed previously in **Table 3.5**, this score has a rating of "excellent" (>0.9). This score showed that the data that was collected from the questionnaire was reliable and could be further analysed.

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the "*participants' perceptions of the ease of use of e-Vaccination*". The related null hypothesis and alternate hypothesis are presented below:

***Table 6.7:*** *The null and alternate hypotheses for the Chi-Square test for the ease of use category*

| Null Hypothesis | Null hypothesis description | Alternate Hypothesis | Alternate Hypothesis description |
|---|---|---|---|
| $H_{0\text{- easy to use Chi-square}}$ | The proportions of scores for the ease of use category are the same between the observed and the expected responses | $H_{1\text{- easy to use Chi-square}}$ | At least 2 proportions of scores for the ease of use category are different between the observed and the expected responses |

The results of the Chi-square test have been summarised in **Table 5.6** which has been reproduced below.

***Table 5.6:*** *Chi-square results table for the ease of use category data*

| | |
|---|---|
| Chi-Square value† | 165,47 |
| df | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate p value based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 165,47† > 9,49‡ |
| Result | $H_{0\text{- easy to use Chi-Square}}$ Rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The results of the Chi-Square test showed that the data that was collected from the questionnaire for the ease of use category was not random.

Once it was determined that the data collected for this category was reliable and not random, the ANOVA test was run. The ANOVA test was used to determine if the variances in the responses between the 4 stakeholder groups was statistically significant for the ease of use category. The related null hypothesis and alternate hypothesis are presented below.

***Table 6.8:*** *The null and alternate hypotheses for the ANOVA test for the ease of use category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- easy to use ANOVA}}$ | The mean scores for the ease of use category across the 4 stakeholder groups are the same | $H_{1\text{- easy to use ANOVA}}$ | At least 2 mean scores for the ease of use category across the 4 stakeholder groups are different |

**Table 5.8** reproduced below is a summary of the ANOVA calculations for the ease of use category.

***Table 5.8:*** *Results of the ANOVA calculation for the ease of use category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,92 |
| Level of significance (Alpha value) § | 0,05 |
| df between groups † | 3 |
| df freedom within groups ‡ | 114 |
| F value | 0,54 |
| p value ¦ | 0,66 |
| f crit | 2,68 |
| Outcome of calculation | 0,66¦ > 0,05§ |
| Result | $H_{0\text{- easy to use ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

The result of the ANOVA test shows that the mean scores between the stakeholder groups for the “Ease of Use” category were not statistically different. This meant that the four stakeholder groups shared common perceptions towards the ease of use of e-Vaccination.

The PCA was then run on the composite values of the “Ease of Use” category. From this, five factors were identified. The percentage contributions of the “Ease of Use” category towards the five factors identified by the PCA are depicted in **Figure 6.6**.

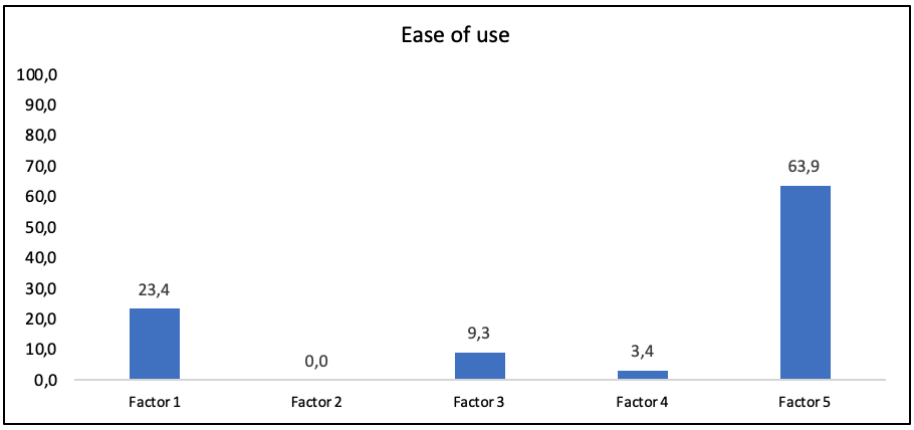



***Figure 6.6:*** *The percentage contributions of the ease of use category towards the five factors identified by the PCA*

The PCA showed that the "Ease of Use" category contributed 63,9% towards Factor five, this was labelled in Section 6.2.4 as "Usability". For a system of this nature with user groups who could vary in their experience with digital technologies, the system needs to be easy to use. The users would need to instinctively know where to go to complete their specific task. There were no incidents where the stakeholders requested assistance to fulfil a task.

**Figure 6.7** is a graphical representation of the mean weighted scores (expressed as a percentage) for the "Ease of Use" category for the four stakeholder groups. The weighted percentage scores per stakeholder group and the average weighted percentage score are further detailed in **Table 6.9**.

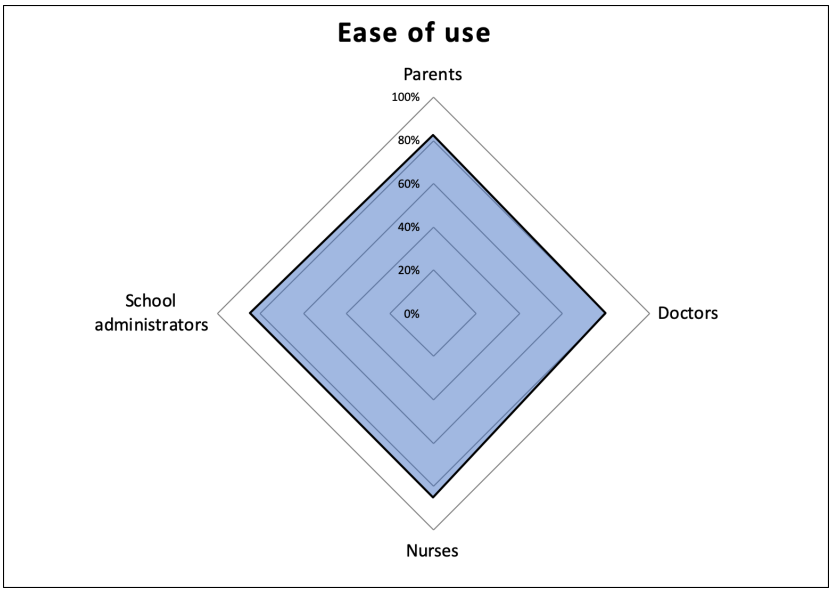



***Figure 6.7:*** *Mean weighted scores (expressed as a percentage) amongst the four stakeholder groups for the ease of use category*

***Table 6.9:*** *Mean weighted scores per stakeholder group for the ease of use category (expressed as a percentage)*

| Parents | Doctors | Nurses | School admin | Average weighted percentage |
|---|---|---|---|---|
| 83% | 80% | 85% | 85% | 83% |

The average weighted percentage score for this category was 83%. The average weighted percentage score was converted from a weighted average score of 4,14 out of 5,00 on the 5-point Likert scale that was used in the questionnaire. This score falls within the "Agree" range of the Likert scale. The outcome of the statistical analysis and the fact that no assistance was required by the stakeholders in using the application, show that e-Vaccination was easy to use.

## 6.5 DISCUSSION PERTAINING TO EASE OF LEARNING

The five questions from the "Ease of Learning" category were combined to form composite values (calculated as the mean score) to aid in understanding the overall perception of this category.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,90 was obtained and based on the Cronbach alpha scores and ratings previously listed in **Table 3.5**, this score has a rating of "good" (>0,8 alpha <=0,9). This score shows that the data that was collected from the questionnaire was reliable and could be further analysed.

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the participants' perceptions of the ease of learning of e-Vaccination. The related null hypothesis and alternate hypothesis are presented below:

***Table 6.10:*** *The null and alternate hypotheses for the Chi-Square test for the ease of learning category*

| Null Hypothesis | Null hypothesis description | Alternate Hypothesis | Alternate Hypothesis description |
|---|---|---|---|
| $H_{0\text{- easy to learn Chi-Square}}$ | The proportions of scores for the ease of learning category are the same between the observed and the expected responses | $H_{1\text{- easy to learn Chi-Square}}$ | At least 2 proportions of scores for the ease of learning category are different between the observed and the expected responses |

The results of the Chi-Square test have been summarised in **Table 5.10** which has been reproduced below.

***Table 5.10:*** *Chi-Square results table for the ease of learning category data*

| | |
|---|---|
| Chi-Square value† | 154,97 |
| df | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate p value based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 154,97 > 9,49‡ |
| Result | $H_{0\text{- easy to learn Chi-Square}}$ Rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The results of the Chi-Square test showed that the data that was collected from the questionnaire for the ease of learning category was not random.

Once it was determined that the data collected for this category was reliable and not random, an ANOVA test was run.

The ANOVA test was used to determine if the variances in the responses between the 4 stakeholder groups was statistically significant for the ease of learning category. The related null hypothesis and alternate hypothesis are presented below.

***Table 6.11:*** *The null and alternate hypotheses for the ANOVA test for the ease of learning category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- easy to learn ANOVA}}$ | The mean scores for the ease of learning category across the 4 stakeholder groups are the same | $H_{1\text{- easy to learn ANOVA}}$ | At least 2 mean scores for the ease of learning category across the 4 stakeholder groups are different |

**Table 5.12** reproduced below is a summary of the ANOVA calculations for the ease of learning category.

***Table 5.12:*** *Results of the ANOVA calculation for the ease of learning category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,90 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 0,55 |
| *p value* ¡ | 0,65 |
| *f crit* | 2,68 |
| Outcome of calculation | $0{,}65^{¡} > 0{,}05^{§}$ |
| Result | $H_{0\text{- easy to learn ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

The related null hypothesis and alternate hypothesis for the ANOVA test were provided in **Table 3.7** and the results of the ANOVA test showed that the mean scores between the stakeholder groups for the "Ease of Learning" category were not statistically different. This meant that the four stakeholder groups shared common perceptions towards the "Ease of Learning" of e-Vaccination.

A PCA was then run on the composite values of the "Ease of Learning" category. From this, five factors were identified. The percentage contributions of the "Ease of Learning" category towards the five factors identified by the PCA are depicted in **Figure 6.8**.

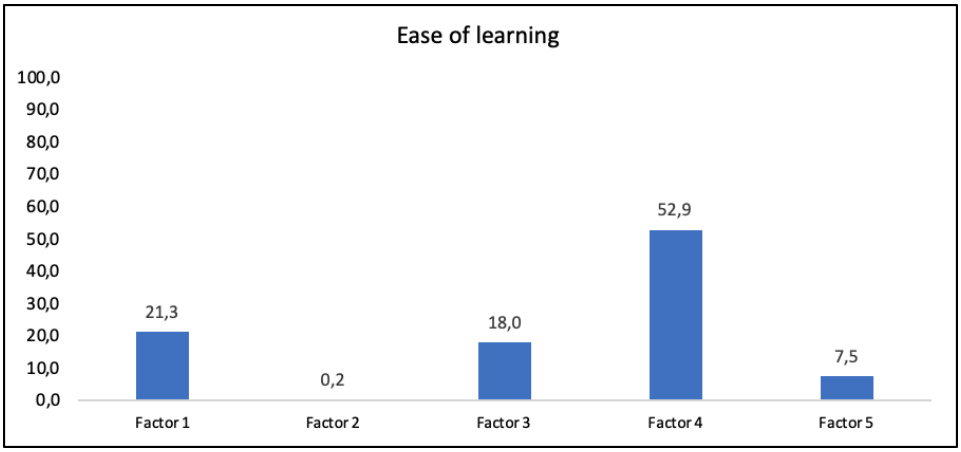



***Figure 6.8:*** *The percentage contributions of the ease of learning category towards the five factors identified by the PCA*

The PCA test showed that this category contributed 52,9% towards Factor 4, this factor was labelled in Section 6.2.4 as "User experience". Due to the nature of vaccination records, medical staff such as doctors and nurses would need to create and access vaccination records more frequently than parents and school administrators would. The latter groups generally access these records only at certain times of the year or during a child's development. The vision of the system is that it should be possible for stakeholders to use the system without any formal training. The system therefore needs to be easy to learn. Once logged into e-Vaccination, each stakeholder group was directed to the area of the system relevant for them. A "conversational style" navigation was used, putting the stakeholder at the centre of the required function. A parent would, as an example, select "I am a Parent" and "I want

to view a vaccination record". This style of navigation required no formal training for the stakeholders. There were also no "helpful hints" provided, meaning that the navigation text and graphics served as the only help offered.

**Figure 6.9** is a graphical representation of the overall mean weighted scores (expressed as a percentage) for the "Ease of Learning" category.

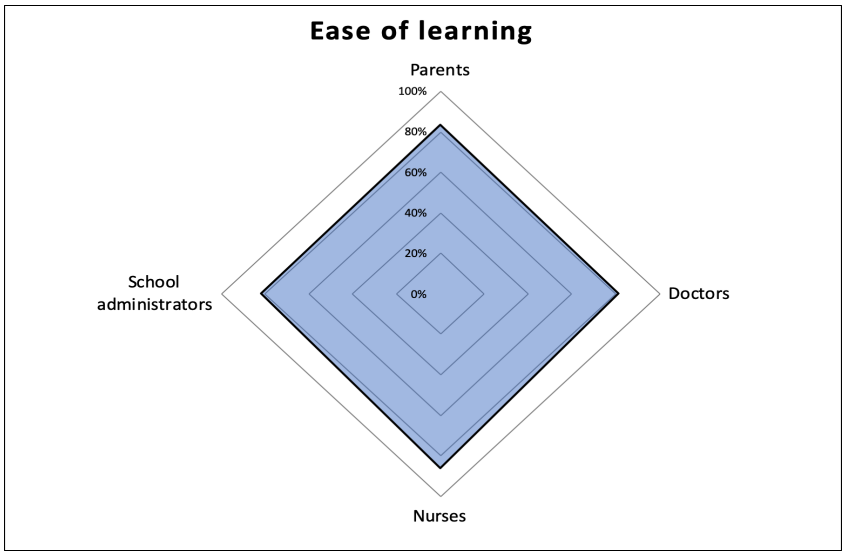



***Figure 6.9:*** *Mean weighted scores (expressed as percentage) amongst the 4 stakeholder groups for the ease of learning category*

The weighted percentage scores per stakeholder group and the average weighted percentage score are detailed in **Table 6.12**.

***Table 6.12:*** *Mean weighted scores per stakeholder group for the ease of learning category (expressed as a percentage)*

| Parents | Doctors | Nurses | School admin | Average weighted percentage |
|---|---|---|---|---|
| 84% | 81% | 86% | 82% | 83% |

The average weighted percentage score for this category was 83%. The average weighted percentage score was converted from a weighted average score of 4,17 out of 5,00 on the 5-point Likert scale that was used in the questionnaire. This score falls within the "Agree" range of the Likert scale. The statistical analysis shows that the stakeholders agreed that e-Vaccination was easy to learn and offered a good user experience.

## 6.6 DISCUSSION PERTAINING TO SATISFACTION

The five questions from the "Satisfaction" category were combined to form composite values (calculated as the mean score) to aid in understanding the overall perception of this category.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,90 was obtained and based on the Cronbach alpha scores and ratings in **Table 3.5**, this score has a rating of "good" (>0,8 alpha <=0,9). This score shows that the data that was collected from the questionnaire was reliable and could then be analysed.

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the participants' level of satisfaction with e-Vaccination. The related null hypothesis and alternate hypothesis are presented below:

***Table 6.13:*** *The null and alternate hypotheses for the Chi-Square test for the satisfaction category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- satisfaction Chi-Square}}$ | The proportions of scores for the satisfaction category are the same between the observed and the expected responses | $H_{1\text{- satisfaction Chi-Square}}$ | At least 2 proportions of scores for the satisfaction category are different between the observed and the expected responses |

The results of the Chi-Square test have been summarised in **Table 5.14** which has been reproduced below.

***Table 5.14:*** *Chi-Square results table for the satisfaction category data*

| | |
|---|---|
| Chi-Square value† | 128,36 |
| *df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 128,36† > 9,49‡ |
| Result | $H_{0\text{- satisfaction Chi-Square}}$ Rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The results showed that data that was collected from the questionnaire for the "Satisfaction" category was not random.

Once it was determined that the data collected for this category was reliable and not random, the ANOVA test was run. The ANOVA test was used to determine if the variances in the responses between the 4 stakeholder groups was statistically significant for the satisfaction category. The related null hypothesis and alternate hypothesis are presented below.

***Table 6.14:*** *The null and alternate hypotheses for the ANOVA test for the satisfaction category*

| Null Hypothesis | Null hypothesis description | Alternate Hypothesis | Alternate Hypothesis description |
|---|---|---|---|
| $H_{0\text{- satisfaction ANOVA}}$ | The mean scores for the satisfaction category across the 4 stakeholder groups are the same | $H_{1\text{- satisfaction ANOVA}}$ | At least 2 mean scores for the satisfaction category across the 4 stakeholder groups are different |

**Table 5.16** reproduced below is a summary of the ANOVA calculations for the satisfaction category.

***Table 5.16:*** *Results of the ANOVA calculation for the satisfaction category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,90 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,54 |
| *p value* ¦ | 0,21 |
| *f crit* | 2,68 |
| Outcome of calculation | $0{,}21^{¦} > 0{,}05^{§}$ |
| Result | $H_{0\text{- satisfaction ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

The result of the ANOVA test showed that the mean scores between the stakeholder groups for the “Satisfaction” category were not statistically different. This meant that the four stakeholder groups were satisfied with e-Vaccination.

A PCA was then run on the composite values of the “Satisfaction” category. From this, five factors were identified. The percentage contributions of the “Satisfaction” category towards the five factors identified by the PCA are depicted in **Figure 6.10**.

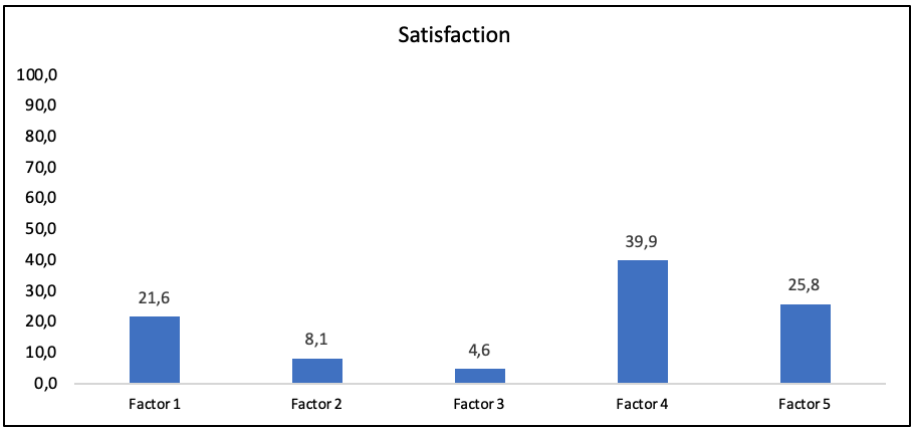



***Figure 6.10:*** *The percentage contributions of the satisfaction category towards the five factors identified by the PCA*

The PCA test showed that this category contributed 39,9% towards Factor 4, this factor was labelled in Section 6.2.4 as "User experience". The "Ease of Learning" category also had a major proportion of its contribution towards Factor 4. It can therefore be deduced that the ability of the stakeholder in learning how to use e-Vaccination is related to their satisfaction with e-Vaccination. It was mentioned under the "Ease of Use" discussion that none of the stakeholders requested assistance with completion of any task. If the stakeholder wanted to complete a task such as to view a vaccination record, they probably easily navigated to that function and viewed the results that they intended to see. This may have given the stakeholder a sense of satisfaction for completing the task they had set out to do.

**Figure 6.11** is a radar chart that shows the mean weighted scores (expressed as a percentage) per stakeholder group.

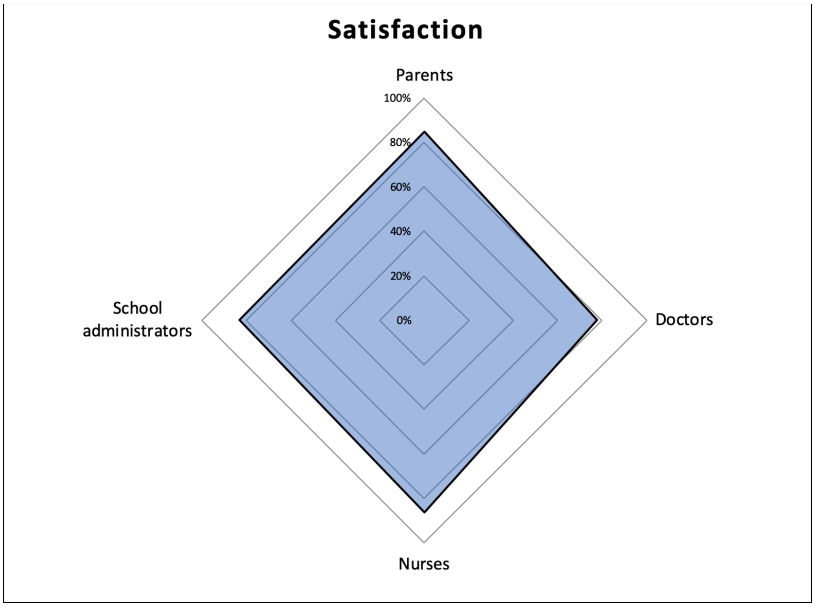


***Figure 6.11:*** *Mean weighted scores (expressed as a percentage) amongst the four stakeholder groups for the satisfaction category*

**Figure 6.11** graphically represents the responses related to the "Satisfaction" category. The weighted percentage scores per stakeholder group and the average weighted percentage score are detailed in **Table 6.15**.

***Table 6.15:*** *Mean weighted scores per stakeholder group for the satisfaction category (expressed as a percentage)*

| Parents | Doctors | Nurses | School admin | Average weighted percentage |
|---|---|---|---|---|
| 85% | 78% | 86% | 83% | 83% |

The average weighted percentage score for this category was 83%. The average weighted percentage score was converted from a weighted average score of 4,20 out of 5,00 on the 5-point Likert scale that was used in the questionnaire. This score falls within the "Agree" range of the Likert scale. Taking into consideration that the "Satisfaction" and "Ease of Learning" categories both had a major proportion of their contributions towards Factor 4 (User experience), it is clear that e-Vaccination offered an overall good user experience and that stakeholders were satisfied with the system.

## 6.7 DISCUSSION PERTAINING TO DESIGN AND VISUAL AIDS

The five questions from the "Design and Visual Aids" category were combined to form composite values (calculated as the mean score) to aid in understanding the overall perception of this category.

A Cronbach alpha was used to determine the reliability of the data collected for this category. A score of 0,67 was obtained and based on the Cronbach alpha scores and ratings presented in **Table 3.5**, this score has a rating of "questionable" (>0,6 alpha <=0,7). It is nonetheless still above the recommended minimum of 0,65. This score showed that data that was collected from the questionnaire was reliable and could further be analysed.

A Chi-Square test was used to determine if the responses provided by the participants were random or were related to a variable, being the participants' perceptions of the design and visual aids in e-Vaccination. The related null hypothesis and alternate hypothesis are presented below:

***Table 6.16:*** *The null and alternate hypotheses for the Chi-Square test for the design and visual aids category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- design and visual aids Chi-Square}}$ | The proportions of scores for the design and visual aids category are the same between the observed and the expected responses | $H_{1\text{- design and visual aids Chi-Square}}$ | At least 2 proportions of scores for the design and visual aids category are different between the observed and the expected responses |

The results of the Chi-Square test have been summarised in **Table 5.18** which has been reproduced below.

***Table 5.18:*** *Chi-Square results table for the design and visual aids category data*

| | |
|---|---|
| Chi-Square value† | 169,20 |
| *Df* | 4 |
| Critical Chi-Square value based on the Chi-Square f table‡ | 9,49 |
| Approximate *p value* based on the Chi-Square f table | <0,001 |
| Level of significance (Alpha level) | 0,05 |
| Outcome of Chi-Square calculation | 169,20† > 9,49‡ |
| Result | $H_{0\text{- design and visual aids Chi-Square}}$ Rejected |

*† Chi-Square value*
*‡ Critical Chi-Square value based on the Chi-Square f table*

The results of the Chi-Square test showed that data that was collected from the questionnaire for the “Design and Visual Aids” category was not random.

Once it was determined that the data collected for this category was reliable and not random, the ANOVA test was run. The subsequent ANOVA test results was used to determine if the variances in the responses between the 4 stakeholder groups was statistically significant for the design and visual aids category. The related null hypothesis and alternate hypothesis are presented below.

***Table 6.17:*** *The null and alternate hypotheses for the ANOVA test for the design and visual aids category*

| **Null Hypothesis** | **Null hypothesis description** | **Alternate Hypothesis** | **Alternate Hypothesis description** |
|---|---|---|---|
| $H_{0\text{- design and visual aids ANOVA}}$ | The mean scores for the design and visual aids category across the 4 stakeholder groups are the same | $H_{1\text{- design and visual aids ANOVA}}$ | At least 2 mean scores for the design and visual aids category across the 4 stakeholder groups are different |

**Table 5.20** reproduced below is a summary of the ANOVA calculations for the design and visual aids category.

***Table 5.20:*** *Results of the ANOVA calculation for the design and visual aids category*

| | |
|---|---|
| Sample size | 118 |
| Cronbach alpha | 0,67 |
| Level of significance (Alpha value) § | 0,05 |
| *df* between groups † | 3 |
| *df* within groups ‡ | 114 |
| *F value* | 1,45 |
| *p value* ¦ | 0,23 |
| *f crit* | 2,68 |
| Outcome of calculation | 0,23¦ > 0,05 § |
| Result | $H_{0\text{- design and visual aids ANOVA}}$ Accepted |

*§ Level of significance (Alpha value)*
*† df between groups*
*‡ df within groups*
*¦ p value*

The result of the ANOVA test shows that the mean scores between the stakeholder groups for the design and visual aids category were not statistically different. This meant that the four stakeholder groups shared common perceptions towards the design and visual aids of e-Vaccination.

A PCA was then run on the composite values of the "Design and Visual Aids" category. From this, five factors were identified. The percentage contributions of the "Design and Visual Aids" category towards the five factors identified by the PCA are depicted in **Figure 6.12**.

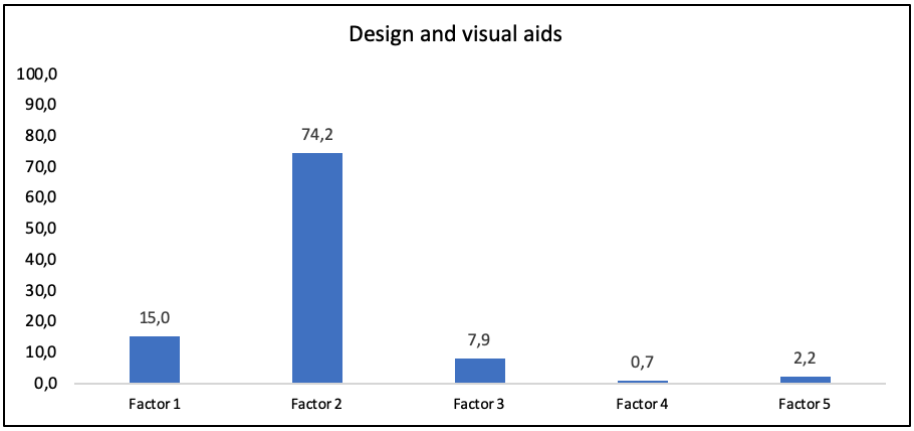



***Figure 6.12:*** *The percentage contributions of the design and visual aids category towards the five factors identified by the PCA*

The PCA test showed that this category contributed 74,2% to Factor 2 that was labelled in Section 6.2.4 as "Graphical design". It was noted in Chapter 5 that a question from this category was worded in a negative way. This could have resulted in some of the respondents being unsure of which option to select with regards to their

perceptions towards the use of graphical images in the menu versus written instructions. Based on the results of the ANOVA test and the overall weighted percentage score of 78% for this category it is inferred that the stakeholders were in favour of the use of images or icons as a primary means to navigate through the system and that text was a secondary means. The use of a graphical interface could have saved the stakeholders' time while navigating to the required function without having to read the text below it. The large icons could have also made clicking or tapping on the required feature easier when using a desktop or smartphone.

**Figure 6.13** is a graphical representation of the overall mean weighted scores (expressed as a percentage) for this category.

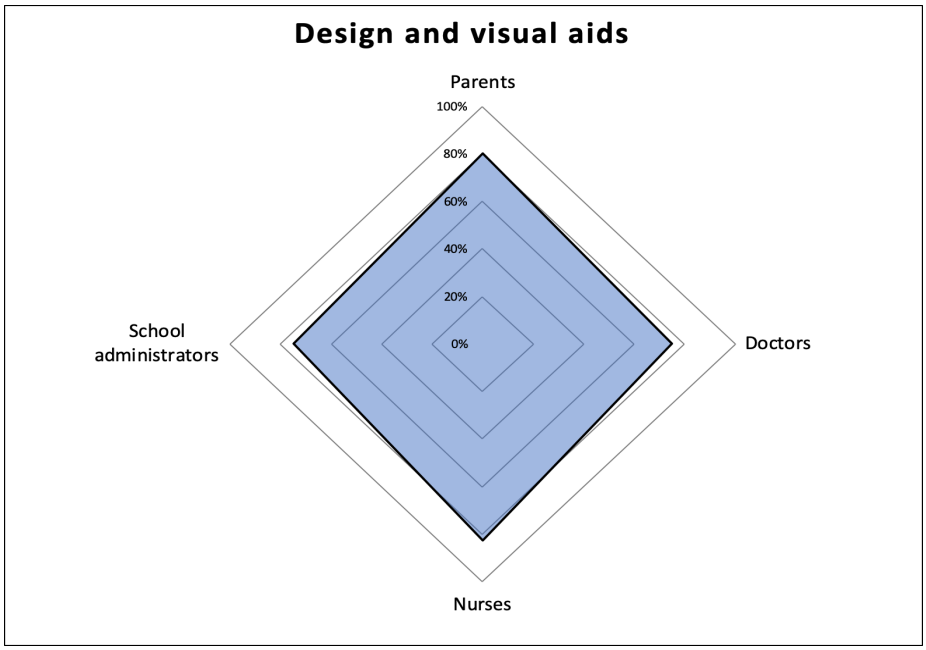



***Figure 6.13:*** *Mean weighted scores (expressed as a percentage) amongst the four stakeholder groups for the design and visual aids category*

**Figure 6.13** graphically represents the responses related to the "Design and Visual Aids" category. The weighted percentage scores per stakeholder group and the average weighted percentage score are detailed in **Table 6.18**.

***Table 6.18:*** *Mean weighted scores per stakeholder group for the design and visual aids category (expressed as a percentage)*

| Parents | Doctors | Nurses | School admin | Average weighted percentage |
|---|---|---|---|---|
| 80% | 75% | 83% | 75% | 78% |

The average weighted percentage score for this category was 78%. The average weighted percentage score was converted from a weighted average score of 3,96 out of 5,00 on the 5-point Likert scale that was used in the questionnaire. This score falls within the “Agree” range of the Likert scale. Based on the statistical analysis and mean scores per stakeholder group as well as the overall scores, it is evident that the stakeholders are in favour of this type of graphical user interface (utilising large icons) for this type of application. The stakeholders were therefore in favour of the design and visual aids of e-Vaccination.

## 6.8 COMPARISON BETWEEN THE STAKEHOLDER GROUPS

The average weighted scores (expressed as a percentage) for the different stakeholders across the five categories was above 83%. **Figure 6.14** is an illustration of the average weighted scores (expressed as a percentage) for the four stakeholder groups for all five categories.

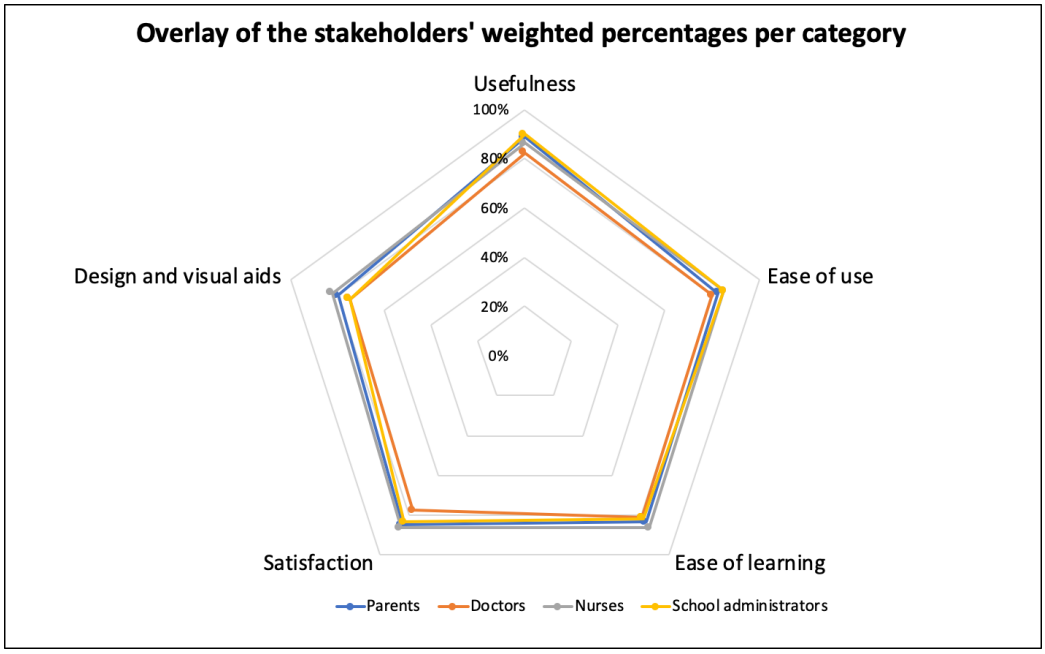



***Figure 6.14:*** *An overlay of the average weighted scores (expressed as a percentage) for the four stakeholder groups for all five categories*

**Figure 6.15** is a bar chart that shows the comparison of the average weighted scores (expressed as a percentage) for all the categories across all the stakeholders.

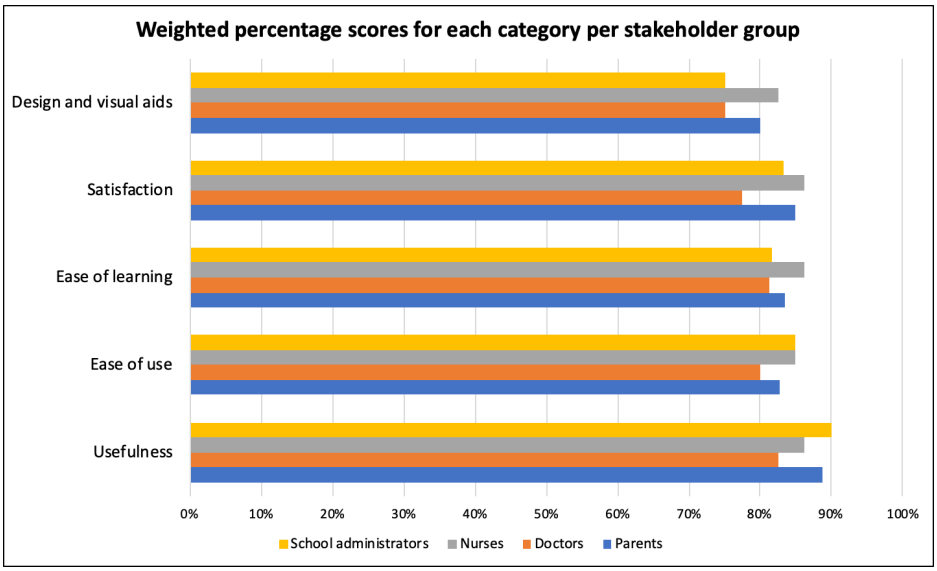



***Figure 6.15:*** *Combined bar chart of the stakeholders' average weighted scores (expressed as a percentage) per category*

**Figure 6.15** shows that the "Design and Visual Aids" category had a lower score amongst the stakeholders. As mentioned earlier, this could be due to a question being negatively worded. The "Usefulness" category showed the highest score at 90% whilst the lowest score of 75% was observed for the "Design and Visual Aids".

**Figure 6.16** contains a detailed breakdown of the average weighted scores (expressed as a percentage) for all five categories.

| | Parents | Doctors | Nurses | School administrators | Average |
|---|---|---|---|---|---|
| Usefulness | 89% | 83% | 86% | 90% | 87% |
| Ease of use | 83% | 80% | 85% | 85% | 83% |
| Ease of learning | 84% | 81% | 86% | 82% | 83% |
| Satisfaction | 85% | 78% | 86% | 83% | 83% |
| Design and visual aids | 80% | 75% | 83% | 75% | 78% |
| Average | 84% | 79% | 85% | 83% | |

Overall average 83%

***Figure 6.16:*** *Average weighted scores (expressed as a percentage) of the stakeholders per category*

Based on the **Figures 6.14 – 6.16**, the stakeholders' scores are ranked as follows:

1. Nurses (85%);

2. Parents (84%);
3. School administrators (83%); and
4. Doctors (79%).

As mentioned in Section 3.3, another study showed that doctors showed the least support for an information system that shared patient information with other hospitals. This study shows doctors (ranked 4th) also had the lowest scores.

## 6.9 COMMENTS RECEIVED FROM THE STAKEHOLDERS

During some engagement with the stakeholders, many positive comments were received regarding e-Vaccination. Many of the stakeholders seemed pleased with the idea of a digital record for vaccination storage. The stakeholders also enjoyed using e-Vaccination and did not seem to require assistance with it. The comments received from the stakeholders are captured at the end of Chapter 7 (**Figure 7.2**).

## 6.10 ANSWERING THE RESEARCH QUESTION

The research question, "*What are the perceptions of the key stakeholders towards replacing the paper-based vaccination card with an electronic vaccination record system?*" can now be answered.

Based on the results of the statistical analysis, it is evident that the four key stakeholder groups share a common perception towards the use of a digital storage mechanism for vaccination records. The high weighted scores of approximately four out of five for all five categories matches the "Agree" option in the Likert-scale. The stakeholders therefore agree that e-Vaccination is useful, easy to use, easy to learn, satisfying to use and contains good design and visual aids. The four stakeholder groups are therefore in favour of replacing the current paper-based vaccination card with an electronic vaccination record system.

## 6.11 SUMMARY OF DISCUSSION OF RESULTS

The eHealth maturity model for developing countries and the steps identified by the Department of Health to move South Africa into Stages 4 and 5 of the model were discussed in-depth in Chapters 2 and 4. To recap, The Department of Health has identified the steps as summarised in **Figure 2.24**, which has been reproduced below.

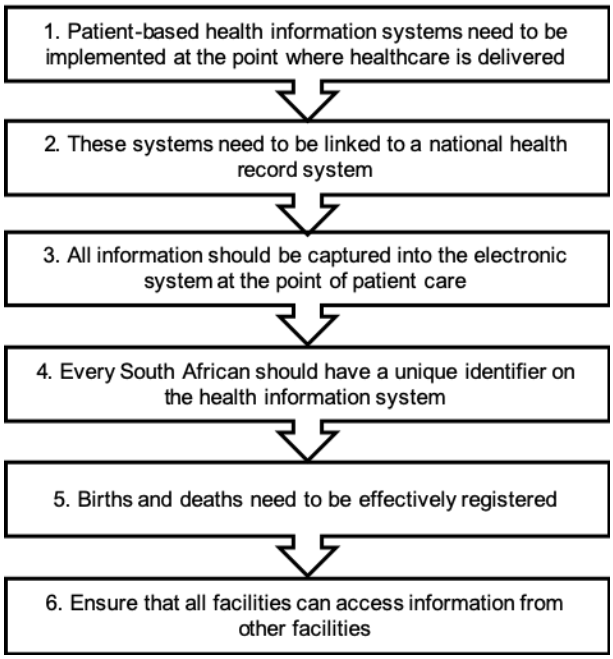



***Figure 2.24:*** *The 6 steps identified by the Department of Health to take South Africa into stages 4 and 5 in terms of eHealth* (Department of Telecommunications and Postal Services, 2017)

Steps 1, 2, 3, 4 and 6 of those steps can be associated with the practicality of a health information system.

It is noted that the PCA revealed five underlying factors, one of which was practicality. In addition, the average weighted percentage score for the "Usefulness" category (practicality) was 87% which, together with the $H_{0\text{- usefulness ANOVA}}$ being accepted, highlights that stakeholders supported a digital vaccination records management system that is practical. We can therefore deduce that a digital vaccination records management system must be designed with these practical features in mind, in order to support both the Department of Health's steps to move South Africa into Stages 4 and 5 of the eHealth maturity model as well as stakeholder acceptance of such a system. Being able to move South Africa into the higher stages of eHealth maturity can benefit the overall healthcare system.

The PCA revealed five underlying factors relating to the digitisation of vaccination records. These were user friendliness, graphical design, practicality, user experience and usability. These five important factors will have an influence on the successful implementation of a digital vaccination records management system. The designers and implementers of such a system would need to pay special attention to the graphical design of the system, as this has an impact on how stakeholders interact with the system. In addition, there needs to be adequate and relevant functionality

within the system to ensure that the system is of practical use to stakeholders. Incorporation of these factors would therefore promote a positive user experience, contributing to the usability of the system.

While the above provided useful information for any future development of digital vaccination records management systems, it was not sufficient to answer the research question. To answer the research question, a statistical analysis needed to be performed.

An analysis of the weighted scores shows an average score of 4 out of 5 for all five categories contained in the questionnaire, which were *usefulness*, *ease of use*, *ease of learning*, *satisfaction* and *design and visual aids*. This translated to the "Agree" option from the Likert scale. The stakeholders therefore agreed that e-Vaccination was useful, easy to use and easy to learn. The stakeholders are also satisfied with e-Vaccination and found the design and visual aids useful. This result is further supported by the outcome of the ANOVA test, which showed that the four stakeholder groups shared common perceptions for all five categories.

The next chapter (Conclusions and recommendations), will present the conclusions of this research together with future recommendations. The research process will also be reflected upon.

# CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

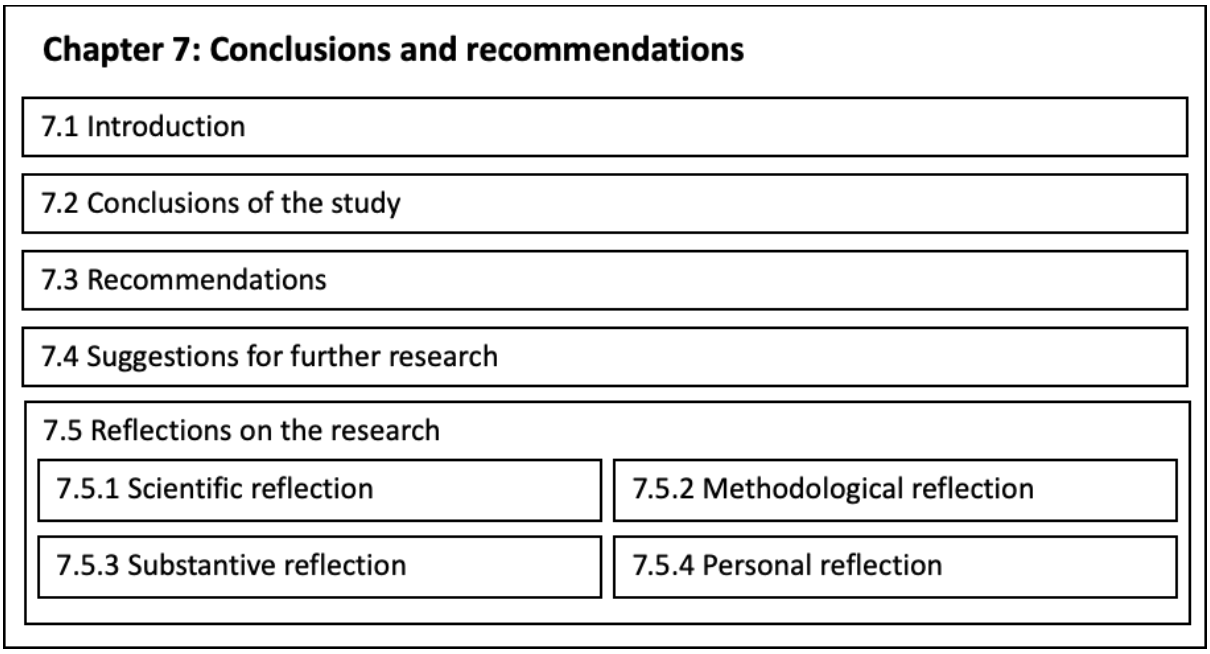



***Figure 7.1:*** *Structure of Chapter 7*

## 7.1 INTRODUCTION

In the previous chapter, the results of the statistical analysis were discussed. The research question was answered in relation to the five hypotheses created from the research instrument as well as the stakeholders' perceptions towards vaccination storage in Gauteng. In this chapter, the conclusions of the study will be discussed together with the recommendations and suggestions for further research.

## 7.2 CONCLUSIONS OF THE STUDY

The results of this study show that the key stakeholders support the development of a digital system for the safe and secure storage of vaccination records in Gauteng. Countries are moving towards EHR for citizens (Kleynhans, 2011). An electronic vaccination record system in Gauteng would support this trend. A digital system of this nature also supports the Department of Health's aims to move South Africa from Stage 3 to Stage 4 & 5 of the eHealth maturity model for developing countries (Department of Telecommunications and Postal Services, 2017). Having access to real-time information as discussed in Chapter 6 could also bring in new dimensions to what is possible during outbreaks.

These conclusions are based on the data that was received and analysed in a quantitative manner. In addition to this, there was information of a qualitative nature collected indirectly. These were comments from the stakeholders. There were nurses who asked, “When will the system be ready to use?” Some parents commented, “I thought this was already done.” There were doctors who said, “There are cases when I need vaccination records, but we don’t have access to them. This will help.”

The commencement of this research in 2017 coincided with a Measles outbreak in Gauteng and other parts of the World (WHO, 2018). Towards the tail end of this research in 2020, the Coronavirus disease (COVID-19) pandemic swept across the globe (WHO, 2020). Pandemics such as this can and have occurred without warning. Knowing whether patients are immunised against these diseases can help determine how at risk patients are to the disease. Reliable, accessible, accurate and real-time vaccination records can play a crucial role. Having more data points such as vaccination information at the fingertips of policy makers could reduce mortality rates.

## 7.3 RECOMMENDATIONS

Vaccination records for minors form one subset of information needed for an EHR for every citizen. The foundations of an EHR should be laid first, followed by data subsets such as vaccination records. In 2011, the South African environment was not ready for a national electronic health record (Kleynhans, 2011). A re-evaluation of the South African environment could be conducted to determine if now, in 2020, the South African environment can support an electronic health record. Once this has been established, data subsets such as vaccination records can be included in the overall design of the electronic health record for all South Africans.

## 7.4 SUGGESTIONS FOR FURTHER RESEARCH

This study focuses on the mandatory and optional vaccinations required by the South African Department of Health for minors. Future research could include one or more of the following aspects:

- Travel vaccinations – When visiting certain countries, individuals might be required to have vaccines to limit their risk to vaccine preventable disease which might exist in that area (Netcare, 2016),

- Cross-border access to vaccination information – Allowing different countries to access South Africa's vaccination records when gaining entrance into their country in the event of the physical vaccination card not being present,
- A more in-depth analysis could be performed on other underlying factors not highlighted in this research which could affect the implementation of a digital vaccination records management system,
- The effect of a digitised system on the supplying and distribution of vaccines to clinics based on the demand and availability of vaccines,
- This research could be extended to include vaccinations for adults with an emphasis on vaccinations relating to pandemics.

This research was conducted for Gauteng (provincial level). Research could be conducted at a national level to determine the perceptions of the key stakeholders across all the provinces in South Africa.

## 7.5 REFLECTIONS ON THE RESEARCH

In this section I discuss my reflections on this research. The scientific reflection describes how I grew as a researcher from a scientific perspective. This includes how I looked at and analysed the relevant data. The methodological reflection highlights some of the challenges that I experienced and what I would have done differently. My substantive reflection emphasises my thoughts on the importance of electronic medical records. In the personal reflection, I discuss how the idea of this research originated as well as some of the highlights that I experienced during this research.

### 7.5.1 SCIENTIFIC REFLECTION

During the course of this research, I expanded my scientific knowledge immensely. I gained an understanding of how to conduct a literature review, utilising a systematic approach, how to filter the research that I had collected and analyse it in accordance with the aims of my research. I became proficient in the various ways that data could be collected, how to determine which collection approach should be used based on the type of research, the requirements that I would need to comply with in order to gather information from the general public, and how to perform a statistical analysis of the data once collected. Crafting this research and evaluating the results of the

different aspects has led me to think and analyse in new and different ways, which I am profoundly grateful for.

### 7.5.2 METHODOLOGICAL REFLECTION

A project of this nature, which took over 3 years to complete, had challenges as well. The university's ethical clearance process took longer than expected due to the perception that patient's medical records were being accessed and shared by the stakeholders. This however was untrue, as the vaccination records on the system were randomly created. Looking back at the clearance process, I would have made the patient data aspect clearer. I would have shared examples of the random data that was created, proving that no real information was being shared. During the second leg of the ethical clearance process, there were also delays from the Gauteng Department of Health. These delays resulted in the research taking almost a year longer than it should have.

The first round of statistical analysis showed a summary of the outcomes but did not emphasize the details of each technique. The statistical analysis was then reformatted to include more details of the analysis. Careful consideration was made to avoid "*p* hacking" which includes changing the data analysis techniques in a way that makes the data show that the claims are supported (Cumming, 2016). This concept was based on the research by Ioannidis (2005).

### 7.5.3 SUBSTANTIVE REFLECTION

The literature review shows that countries are moving towards the use of electronic medical records for their citizens. Perhaps not every sub-set of medical records needs to be available to the government and all health practitioners. In the case of vaccination records however, the need for efficient access to this type of information is vital especially during epidemics and pandemics such as the Coronavirus disease (COVID-19).

This research has shown that electronic health records are in use in globally. Even though some health practitioners have shown lower support for such systems (Wang et al., 2015), once digital records are securely stored, they can be accessed easier than paper-based records in cases where time is limited. When national decisions

need to be made, having access to accurate and up to date information will make a difference.

### 7.5.4 PERSONAL REFLECTION

As I reflected on the research, I thought back to how the seed for this topic was planted. In 2014, I became a father and witnessed the first vaccinations being administered to my daughter. Once the nurse was done, the vaccination card was updated and handed to me. I was told to keep the card very safe. Being an Information Systems professional holding an Honours degree in Computer Science, I decided to embark on a mission to determine how to digitise the vaccination card.

When I approached UNISA in 2016, Professor Singh who was familiar with the electronic government systems as well as electronic medical systems was open to the idea. In 2017 my research proposal was accepted and in 2018, I started this dissertation.

During the course of this research I had the opportunity to speak to some of the key stakeholders in person. This gave me a feel for their perceptions towards e-Vaccination. Many of the stakeholders were visibly excited about the research and praised the idea. They hoped to see a digital vaccination record management system implemented not only for Gauteng but for the whole of South Africa. Some of the comments I received are displayed in **Figure 7.2**.


***Figure 7.2:*** *Comments received from some of the stakeholders with respect to e-Vaccination and this research*

Receiving these positive comments made me feel like this research could have a major impact on the identified stakeholders as well as the eHealth aims of South Africa. These comments also lifted my spirits during those moments when the research challenged me.

The opportunity to publish a conference proceeding article and to present my research at conferences such as the IEEE and the Ekurhuleni Annual Health Research Conference (where I received the award for the best research poster) are cherished experiences. I met other researchers who had similar interests, with a drive to improve eHealth in South Africa and the rest of Africa. I still correspond with these researchers and hope that in the future we may collaborate on projects or research that will take us further in our aims.

It is my sincere hope that this research makes material impact on those policy makers who have the ability to implement such a system, so that we can see e-Vaccination, and the consequential benefits thereof, come to fruition in the near future.

**Figure 7.3** is a summary of this research from idea to conclusion.

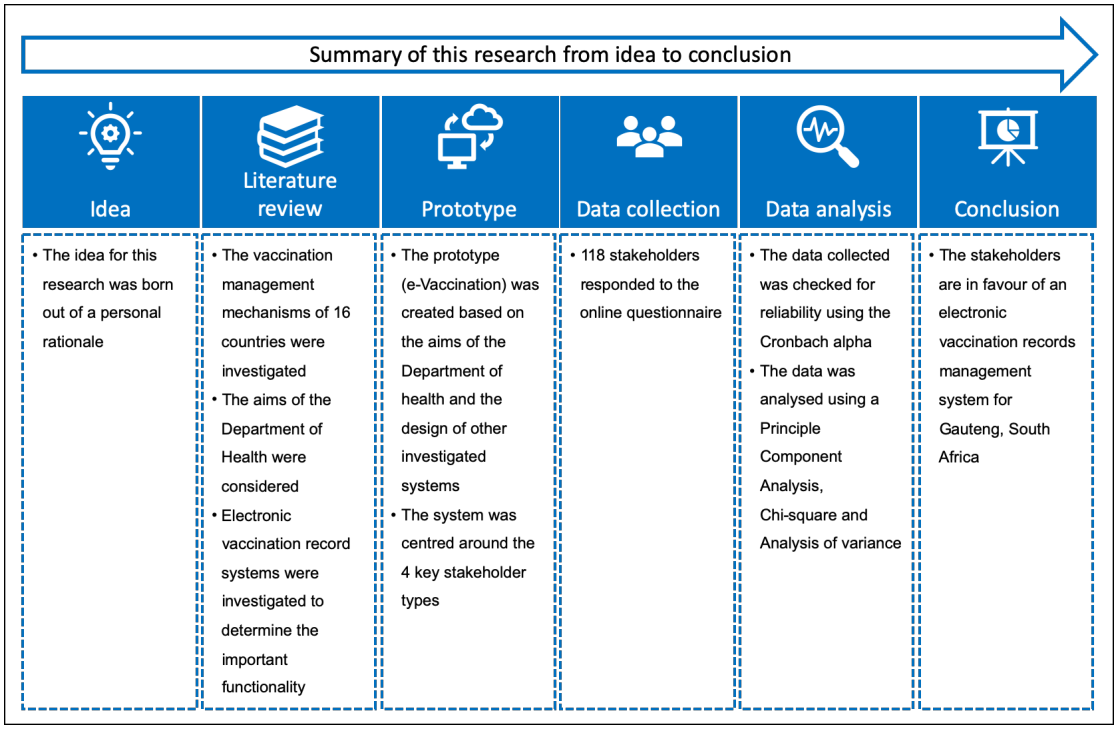



***Figure 7.3:*** *A summary of this research from idea to conclusion*

This research study may be understood as a platform for ongoing research. The findings from this research offer opportunities for others to follow on and further improve on these understandings. In the words of Checkland (1999), writing about systems thinking and practice:

> "Obviously the work is not finished, and can never be finished. There are no absolute positions to be reached in the attempt by men to understand the world in which they find themselves: new experience may in the future refute present conjectures. So the work itself must be regarded as an on-going system of a particular kind: A learning system which will continue to develop ideas, to test them out in practice, and to learn from the experience gained."

# 8. REFERENCES


About BRICS. (2017). What is BRICS. Retrieved March 24, 2018, from https://www.brics2017.org/English/AboutBRICS/BRICS/

Anda, B., Dreiem, H., Sjøberg, D. I. K., & Jørgensen, M. (2001). Estimating Software Development Effort Based on Use Cases — Experiences from Industry. In *≪UML≫ 2001 — The Unified Modeling Language. Modeling Languages, Concepts, and Tools* (pp. 487–502). https://doi.org/10.1007/3-540-45441-1_35

Andres, M. J. T., & Borabo, M. L. (2015). Development of Prototype Outcomes-Based Training Modules for Aesthetic Dentistry. *European Journal of Contemporary Education*, *12*(2), 129–136. https://doi.org/10.13187/ejced.2015.12.129

Apple. (2018a). Child Immunisation Tracker - Baby Immunisation. Retrieved April 1, 2018, from https://itunes.apple.com/us/app/child-immunisation-tracker-baby-immunisation/id1046207931?mt=8

Apple. (2018b). My Immunizations. Retrieved April 2, 2018, from https://itunes.apple.com/us/app/my-immunizations/id914709957?mt=8

Apple. (2018c). My Kids Vaccine Tracking. Retrieved April 2, 2018, from https://itunes.apple.com/us/app/my-kids-vaccine-tracking/id1024829386?mt=8

Apple. (2018d). Vaccines Log - Vaccination Reminder & Tracker. Retrieved April 1, 2018, from https://itunes.apple.com/us/app/vaccines-log-vaccination-reminder-tracker/id1185156196?mt=8

Apple Inc. (2018a). App Store Preview. Retrieved July 26, 2018, from https://itunes.apple.com/au/app/vaccidate/id891579530?mt=8

Apple Inc. (2018b). Vaccine Reminder - Pediatrics. Retrieved July 26, 2018, from https://itunes.apple.com/nz/app/vaccine-reminder-pediatric/id599232445?mt=8).

Apple Inc. (2018c). VaxOnTime – Immunisation reminders for Victorians. Retrieved July 26, 2018, from https://itunes.apple.com/au/app/vaxontime-immunisation-reminders-for-victorians/id1063193669?mt=8

Battaglia, M. (2008). Convenience Sampling. In *Encyclopedia of Survey Research Methods*. 2455 Teller Road, Thousand Oaks California 91320 United States of

America: Sage Publications, Inc. https://doi.org/10.4135/9781412963947.n105

Botha, M. (2015). *Prioritising data quality challenges in electronic healthcare systems in South Africa*. Retrieved from http://hdl.handle.net/10500/20100

Brand South Africa. (2015). A parent's guide to schooling. Retrieved October 30, 2017, from https://www.brandsouthafrica.com/governance/services/education-services/a-parents-guide-to-schooling

Chachou, M. J., Mukinda, F. K., Motaze, V., & Wiysonge, C. S. (2015). Electronic and postal reminders for improving immunisation coverage in children: protocol for a systematic review and meta-analysis. *BMJ Open*, *5*(10), e008310. https://doi.org/10.1136/bmjopen-2015-008310

Chan, J., Mungun, T., Dorj, N., Volody, B., Chuluundorj, U., Munkhbat, E., … Russell, F. (2017). High agreement between the new Mongolian electronic immunization register and written immunization records: a health centre based audit. *Western Pacific Surveillance and Response Journal*, *8*(3), 5–10. https://doi.org/10.5365/wpsar.2016.7.4.006

Checkland, P. (1999). *Systems Thinking, Systems Practice.* John Wiley, Chichester, UK, 1981.

Child Healthcare. (2018). What should be done if the Road-to-Health Card is lost? Retrieved February 15, 2018, from https://childhealthcare.co.za/immunisation/introduction/what-should-be-done-if-the-road-to-health-card-is-lost/

Cilliers, J. (2017). How technology is helping India move toward smart service delivery. Retrieved March 23, 2018, from http://www.undp.org/content/undp/en/home/blog/2017/8/2/Opinion-How-technology-is-helping-India-move-toward-smart-service-delivery.html

City of Johannesburg. (2018). Primary Health Care Facility List (public sector clinics) [as on 16 April 2013]. Retrieved February 15, 2018, from https://joburg.org.za/images/stories/2013/April/copy of health facility list with services provided as in april 2013 _city of johannesburg.pdf

Cumming, G. (2016). One reason so many scientific studies may be wrong. Retrieved

August 17, 2020, from https://theconversation.com/one-reason-so-many-scientific-studies-may-be-wrong-66384

David, C. C., & Jacobs, D. J. (2014). Principal Component Analysis: A Method for Determining the Essential Dynamics of Proteins (pp. 193–226). https://doi.org/10.1007/978-1-62703-658-0_11

Department of Health. (2012). eHealth Strategy South Africa. Retrieved April 10, 2018, from https://www.health-e.org.za/wp-content/uploads/2014/08/South-Africa-eHealth-Strategy-2012-2017.pdf

Department of Health. (2018). Road to Health. Retrieved March 22, 2020, from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwi_7suU363oAhXJAmMBHQlxD4IQFjAAegQIBRAB&url=http%3A%2F%2Fwww.health.gov.za%2Findex.php%2Fshortcodes%2F2015-03-29-10-42-47%2F2015-04-30-08-29-27%2F2015-04-30-08-33-30%2Fcategory%2F54

Department of Health. (2019a). Immunization. Retrieved May 29, 2019, from http://www.health.gov.za/index.php/shortcodes/2015-03-29-10-42-47/2015-04-30-08-29-27/immunization

Department of Health. (2019b). Immunization Documents. Retrieved February 15, 2018, from http://www.health.gov.za/index.php/component/phocadownload/category/165

Department of Health. (2020). What is MomConnect? Retrieved February 24, 2018, from http://www.health.gov.za/index.php/mom-connect#momconnect

Department of Human Services. (2018). AIR - Immunisation History Statement. Retrieved March 21, 2018, from https://www.humanservices.gov.au/individuals/enablers/immunisation-history-statement

Department of Telecommunications and Postal Services. (2017). *NATIONAL e-Government STRATEGY AND ROADMAP*. Retrieved from http://www.ddyn.com/downloads/docsofinterest/ECT_GG40772_R.341_of_2017.pdf

Downey, R. G., & King, C. V. (1998). Missing Data in Likert Ratings: A Comparison of

Replacement Methods. *The Journal of General Psychology*, *125*(2), 175–191. https://doi.org/10.1080/00221309809595542

Dyosop, N. (2012). Flawed data undermines SA claims on vaccination coverage. Retrieved from https://africacheck.org/reports/flawed-data-undermines-sa-claims-on-vaccination-coverage/

e-Estonia. (2016). healthcare. Retrieved March 7, 2018, from https://e-estonia.com/solutions/healthcare/e-health-record/

e-Estonia. (2018). FACTSHEET e-Health. Retrieved March 7, 2018, from https://e-estonia.com/wp-content/uploads/facts-a4-v02-e-health.pdf

eHealth Africa. (2018). VaxTrac. Retrieved March 21, 2018, from https://www.ehealthafrica.org/vaxtrac-1/

Fedhealth. (2019). The South African Vaccination Schedule. Retrieved May 28, 2019, from https://www.fedhealth.co.za/?s=vaccination+schedule

Fire Protection Association. (2018). Fire Protection Association. Retrieved July 26, 2018, from http://www.fpasa.co.za/

Fontanesi, J. M., Flesher, D. S., De Guire, M., Lieberthal, A., & Holcomb, K. (2002). The cost of doing business: Cost structure of electronic immunization registries. *Health Services Research*, *37*(5), 1291–1307. https://doi.org/10.1111/1475-6773.10772

Fundacion Carlos Slim. (2016). The Electronic Immunization Record Is Ready. Retrieved June 26, 2020, from https://www.salud.carlosslim.org/english2/the-electronic-immunization-record-is-ready/

Gauteng: Informal Settlements Status. (2012). Retrieved from http://thehda.co.za/pdf/uploads/multimedia/HDA_Informal_settlements_status_Gauteng.pdf

Gliem, J. A., & Gliem, R. R. (2003). Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales. In *2003 Midwest Research to Practice Conference in Adult, Continuing, and Community Education* (pp. 82–88). Retrieved from https://scholarworks.iupui.edu/bitstream/handle/1805/344/Gliem+&+Gliem.pdf?s

equence=1

Goforth, C. (2015). Using and Interpreting Cronbach's Alpha. Retrieved October 6, 2019, from https://data.library.virginia.edu/using-and-interpreting-cronbachs-alpha/

Google Play. (2018). VaxOnTime. Retrieved July 26, 2018, from https://play.google.com/store/apps/details?id=au.gov.vic.dhhs.vaxontime&hl=en

Health Information Translations. (2016). Vaccines for your children. Retrieved March 28, 2018, from https://www.healthinfotranslations.org/pdfDocs/VaccinesChildren_RU.pdf

Health Systems Trust. (2017). *District Health Barometer*. Retrieved from http://www.hst.org.za/publications/District Health Barometers/District Health Barometer 2016-2017.pdf

Health24. (2018). Childhood Diseases. Retrieved May 14, 2018, from https://www.health24.com/Medical/Childhood-diseases/Measles/Measles-20120721

Heidebrecht, C. L., Kwong, J. C., Finkelstein, M., Quan, S. D., Pereira, J. A., Quach, S., & Deeks, S. L. (2014). Electronic immunization data collection systems: application of an evaluation framework. *BMC Medical Informatics and Decision Making*, *14*(1), 5. https://doi.org/10.1186/1472-6947-14-5

Holtz, B., & Krein, S. (2011). Understanding Nurse Perceptions of a Newly Implemented Electronic Medical Record System. *Journal of Technology in Human Services*, *29*(4), 247–262. https://doi.org/10.1080/15228835.2011.639931

Hospital CMQ. (2020). The First Vaccines For Your Baby. Retrieved June 26, 2020, from https://hospitalcmq.com/blog/first-vaccines-for-your-baby/

Houde, S., & Hill, C. (1997). What do Prototypes Prototype? In *Handbook of Human-Computer Interaction* (pp. 367–381). Elsevier. https://doi.org/10.1016/B978-044481862-1.50082-0

IBM. (2012). Hospitals in Russia's Regions Turn to IBM to Transform Healthcare. Retrieved March 24, 2018, from https://www-

03.ibm.com/press/us/en/pressrelease/37661.wss

Immunize India. (2016). The world's largest vaccination reminder service. Retrieved March 23, 2018, from http://www.immunizeindia.org/

Impressol. (2018). Impressol. Retrieved July 26, 2018, from http://www.impressolservices.com/

Ingram, J., & Gaskell, P. (2018). Reflections on co-constructing a digital adviser with stakeholders in agriculture and forestry. *13th European IFSA Symposium*. Retrieved from http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2018/Theme4_Ingram.pdf

Intrahealth. (2015). Creativity: The Key to Developing Tanzania's Electronic Immunization System. Retrieved July 26, 2018, from https://www.intrahealth.org/vital/creativity-key-developing-tanzania's-electronic-immunization-system

Ioannidis, J. P. A. (2005). Why Most Published Research Findings Are False. *PLoS Medicine*, *2*(8), e124. https://doi.org/10.1371/journal.pmed.0020124

Jozsa, K., & Morgan, G. (2017). Reversed items in Likert scales: Filtering out invalid responders. *Journal of Psychological and Educational Research*, (25 (1)), 7–25. Retrieved from https://fac.ksu.edu.sa/sites/default/files/likert2_0.pdf

Kleynhans, A. (2011). *Is South Africa ready for a national Electronic Health Record ( EHR )?* Retrieved from http://hdl.handle.net/10500/6128

Klopper, R., & Lubbe, S. (2011). Using Matrix Analysis to Achieve Traction, Coherence, Progression and Closure in Problem-Solution Oriented Research. *Alternation Special Edition*, 403–419. Retrieved from https://www.researchgate.net/publication/265408466_Using_Matrix_Analysis_to_Achieve_Traction_Coherence_Progression_and_Closure_in_Problem-Solution_Oriented_Research

Kombian, H. (2017). Electronic Immunization Registry and Tracking System in Sierra Leone. Retrieved March 21, 2018, from https://www.ehealthafrica.org/blog/2017/07/14/2017712electronic-immunization-registry-and-tracking-system-in-sierra-leone

Lam, M. (2017). Digital Health in the Context of China's Healthcare System. Retrieved March 28, 2018, from https://yaleglobalhealthreview.com/2017/05/14/digital-health-in-the-context-of-chinas-healthcare-system/

LeardMann, C. a, Smith, B., Smith, T. C., Wells, T. S., & Ryan, M. A. K. (2007). Smallpox Vaccination: Comparison of Self-Reported and Electronic Vaccine Records in the Millennium Cohort Study. *Human Vaccines*, *3*(6), 245–251. https://doi.org/10.4161/hv.4589

LINKLINKS. (2018). LINKLINKS. Retrieved April 1, 2018, from http://www.thelinklinks.com/index.html

Liu, G., Liao, Z., Xu, X., Liang, Y., Xiong, Y., & Ni, J. (2017). Accuracy of parent-reported measles-containing vaccination status of children with measles. *Public Health*, *144*(1), 92–95. https://doi.org/10.1016/j.puhe.2016.12.013

Lund, A. M. (2001). Measuring usability with the USE questionnaire. *Usability Interface*, *8*(2), 3–6. Retrieved from https://www.researchgate.net/publication/230786746_Measuring_Usability_with_the_USE_Questionnaire

Mapchart.net. (2019). Mapchart.net. Retrieved May 20, 2019, from https://mapchart.net/

McConachie, S. M., Giuliano, C. A., Mohammad, I., & Kale-Pradhan, P. B. (2020). Adverse drug reactions in drug information databases: does presentation affect interpretation? *Journal of the Medical Library Association*, *108*(1), 76–83. https://doi.org/10.5195/jmla.2020.748

Mdhluli, N. (2017). Measles outbreak hits Gauteng. Retrieved from http://www.sabc.co.za/news/a/619a5200410f54d2a9ccfd8dcf0b605f/Measles-outbreak-hits-Gauteng-20170805

Michalopoulos, S. (2017). Commission backs electronic immunisation record to manage vaccination. Retrieved February 26, 2018, from https://www.euractiv.com/section/health-consumers/news/commission-backs-electronic-immunisation-record-to-manage-vaccination/

Ministry of Health. (2015). National Immunisation Register. Retrieved March 21, 2018,

from https://www.health.govt.nz/our-work/preventative-health-wellness/immunisation/national-immunisation-register

Ministry of Health. (2016). District health board websites. Retrieved March 21, 2018, from https://www.health.govt.nz/new-zealand-health-system/key-health-sector-organisations-and-people/district-health-boards/district-health-board-websites

Minitab Express. (2019). Interpret the key results for One-Way ANOVA. Retrieved July 24, 2020, from https://support.minitab.com/en-us/minitab-express/1/help-and-how-to/modeling-statistics/anova/how-to/one-way-anova/interpret-the-results/key-results/

N. Alberts, H.G.A.M. van der Avoort, W.A.M. Bakker, G.A.M. Berbers, R.S. van Binnendijk, J.A. Bogaards, P. Bruijning-Verhagen, A. Buisman, J. Cremer, R. Donken, G.A. Donker, E. Duizer, R. Eilers, K.E.M. Elberse, C.A.C.M. van Els, A. van der Ende, I.H.M. F, H. J. V. (2013). *The National Immunisation Programme in the Netherlands*. Retrieved from https://www.rivm.nl/bibliotheek/rapporten/150202002.pdf

Naidoo, H., Avenant, T., & Goga, A. (2018). Completeness of the Road-to-Health Booklet and Road-to-Health Card: Results of cross-sectional surveillance at a provincial tertiary hospital. *Southern African Journal of HIV Medicine*, *19*(1). https://doi.org/10.4102/sajhivmed.v19i1.765

National Institute for Communicable Diseases. (2017). Measles Mass Campaign: Frequently Asked Questions. Retrieved October 30, 2017, from http://www.nicd.ac.za/index.php/measles-mass-campaign-frequently-asked-questions/

National Portal of India. (2018). India at a glance. Retrieved March 24, 2018, from https://www.india.gov.in/india-glance

Ndirangu, J., Bärnighausen, T., Tanser, F., Tint, K., & Newell, M. (2009). Levels of childhood vaccination coverage and the impact of maternal HIV status on child vaccination status in rural KwaZulu-Natal, South Africa*. *Tropical Medicine & International Health*, *14*(11), 1383–1393. https://doi.org/10.1111/j.1365-3156.2009.02382.x

Netcare. (2016). Netcare travel clinics. Retrieved July 8, 2019, from http://www.netcare.co.za/Divisions/Complementary-business-operations/Netcare-travel-clinics

Nicholson, L. (2012). Challenges & Prospects for Electronic Health Records. In *Health Information Managers' Association of Nigeria National Meeting*. Lagos. Retrieved from http://docshare01.docshare.tips/files/26396/263969574.pdf

Nolen, S. L., Giblin-Scanlon, L. J., Boyd, L. D., & Rainchuso, L. (2018). Development and Testing of a Smartphone Application Prototype for Oral Health Promotion. *Journal of Dental Hygiene*, *92*(2), 6–14. Retrieved from http://0-search.ebscohost.com.oasis.unisa.ac.za/login.aspx?direct=true&db=rzh&AN=129885911&site=eds-live&scope=site

Office of the Registrar General & Census Commissioner India. (2001). Area and Populatio. Retrieved March 24, 2018, from http://censusindia.gov.in/Census_And_You/area_and_population.aspx

Orenius, T., LicPsych, Säilä, H., Mikola, K., & Ristolainen, L. (2018). Fear of Injections and Needle Phobia Among Children and Adolescents: An Overview of Psychological, Behavioral, and Contextual Factors. *SAGE Open Nursing*, *4*, 237796081875944. https://doi.org/10.1177/2377960818759442

PATH. (2017). From paper to e-records: Vietnam's digital immunization registry. Retrieved March 22, 2018, from http://www.path.org/publications/files/ID_vietnam_immreg_fs_2017.pdf

Pediatric Oncall. (2019). Vaccination Center. Retrieved October 5, 2019, from https://www.pediatriconcall.com/vaccine-reminder

Queensland Government. (2018). Vaccination matters. Retrieved April 1, 2018, from https://vaccinate.initiatives.qld.gov.au/vaccidate/

Remenyi, D. (2017). Dictionary of research concepts and issues. *UK: Academic Conferences and Journals International Limited*.

Roland, L. K. (2016). eHealth in Norway. Retrieved March 10, 2018, from http://www.uio.no/studier/emner/matnat/ifi/INF5761/v16/timeplan/ehealth-in-norway.pdf

Rutherford, A. (2000). *Introducing ANOVA and ANCOVA: A GLM Approach (Introducing statistical methods)*. Sage publications. Retrieved from https://0-ebookcentral-proquest-com.oasis.unisa.ac.za/lib/unisa1-ebooks/reader.action?docID=254651

Sanftenberg, L., Schrörs, H.-J., & Schelling, J. (2016). Influences on immunization rates: Vaccination coverage of mumps, measles, rubella and varicella before and after the STIKO intervention 2011 – A retrospective study. *Vaccine*, *34*(34), 3938–3941. https://doi.org/10.1016/j.vaccine.2016.06.027

Shobert, B. (2017). Digital Healthcare in China: Hope or Hype? Retrieved March 26, 2018, from https://www.futurehealthindex.com/2017/05/26/digital-healthcare-china-hope-hype/

South African Government. (2018). South Africa at a glance. Retrieved March 30, 2018, from https://www.gov.za/about-sa/south-africa-glance

Statista - The Statistics Portal. (2018). Brazil - Statistics & Facts. Retrieved March 24, 2018, from https://www.statista.com/topics/1537/brazil/

StatisticsSolutions. (2020). Using Chi-Square Statistic in Research. Retrieved July 24, 2020, from https://www.statisticssolutions.com/using-chi-square-statistic-in-research/

Stats SA. (2016). *Provincial profile: Gauteng - Community Survey 2016*. Gauteng. Retrieved from http://cs2016.statssa.gov.za/wp-content/uploads/2018/07/Gauteng.pdf

Stats SA. (2018a). *Mid-year population estimates*. Retrieved from http://www.statssa.gov.za/publications/P0302/P03022018.pdf

Stats SA. (2018b). *Migrants flock to Gauteng*. Retrieved from http://www.statssa.gov.za/?p=11331

Syms, C. (2019). Principal Components Analysis. In *Encyclopedia of Ecology* (pp. 566–573). Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.11152-2

The State Council of the People's Republic of China. (2005). Geography. Retrieved March 26, 2018, from http://english.gov.cn/archive/china_abc/2014/09/02/content_281474985266381.

htm

The University of Sydney. (2019). Systematic Reviews: Steps to Conduct a Systematic Review. Retrieved June 29, 2019, from https://libguides.library.usyd.edu.au/c.php?g=516278&p=4639255

The University of Texas at Austin. (2004). Table of Chi-square statistics. Retrieved July 3, 2020, from https://web.ma.utexas.edu/users/davis/375/popecol/tables/chisq.html

Tozzi, A. E., Gesualdo, F., D'Ambrosio, A., Pandolfi, E., Agricola, E., & Lopalco, P. (2016). Can Digital Tools Be Used for Improving Immunization Programs? *Frontiers in Public Health*, *4*. https://doi.org/10.3389/fpubh.2016.00036

Twizeyimana, E. F. (2016). *ASSESSING VALUE OF ELECTRONIC MEDICAL RECORDS SYSTEMS AT CARAES NDERA REFERRAL HOSPITAL IN RWANDA*. University of Rwanda. Retrieved from http://dr.ur.ac.rw/bitstream/handle/123456789/241/TWIZEYIMANA Dissertation.pdf?sequence=1&isAllowed=y

UCLA Institute for Digital Research & Education. (2020). PRINCIPAL COMPONENTS ANALYSIS | SPSS ANNOTATED OUTPUT. Retrieved July 14, 2020, from https://stats.idre.ucla.edu/spss/output/principal_components/

United Nations. (2014). Country classification. Retrieved July 8, 2019, from https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

University of Pennsylvania School of Arts and Sciences. (2008). Tutorial: Pearson's Chi-square Test for Independence. Retrieved November 14, 2019, from https://www.ling.upenn.edu/~clight/chisquared.htm

van den Heever, J. (2012). What is the South African Immunisation coverage?, (October). Retrieved from https://africacheck.org/wp-content/uploads/2012/11/S-Africans-Immunization-Coverage-ppt-EPI-Manager3.pdf

Victoria State Government. (2015). VaxOnTime Victoria app promotional card. Retrieved April 2, 2018, from https://www2.health.vic.gov.au/about/publications/formsandtemplates/VaxOnTi

me-Victoria-app-promotional-card

w3schools. (2019). Entity Relationship(ER) Model. Retrieved October 5, 2019, from https://www.w3schools.in/dbms/er-model/

Wang, J.-Y., Ho, H.-Y., Chen, J.-D., Chai, S., Tai, C.-J., & Chen, Y.-F. (2015). Attitudes toward inter-hospital electronic patient record exchange: discrepancies among physicians, medical record staff, and patients. *BMC Health Services Research*, *15*(1), 1–15. Retrieved from http://10.0.4.162/s12913-015-0896-y

Westley, E., Greene, S., Tarr, G., & Hawes, S. (2014). URUGUAY'S NATIONAL IMMUNIZATION PROGRAM REGISTER. *Paper Health Registers Project*. Retrieved from http://uwstartcenter.org/wp-content/uploads/2015/12/START_43_HealthRegisters_UruguayCaseStudy_FINAL_2014-07-31.pdf

WHO. (2017). From warehouse to remote indigenous communities: The journey of vaccines in Brazil. Retrieved March 22, 2018, from http://www.who.int/features/2017/vaccines-brazil-communities/en/

WHO. (2018). Measles cases spike globally due to gaps in vaccination coverage. Retrieved April 21, 2020, from https://www.who.int/news-room/detail/29-11-2018-measles-cases-spike-globally-due-to-gaps-in-vaccination-coverage

WHO. (2019a). Immunization. Retrieved May 28, 2019, from https://www.who.int/topics/immunization/en/

WHO. (2019b). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=EST

WHO. (2019c). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=NOR

WHO. (2019d). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from

http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=NLD

WHO. (2019e). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=AUS

WHO. (2019f). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=NZL

WHO. (2019g). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=MNG

WHO. (2019h). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=VNM

WHO. (2019i). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=MEX

WHO. (2019j). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=URY

WHO. (2019k). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=SLE

WHO. (2019l). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from https://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=TZA

WHO. (2019m). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=BRA

WHO. (2019n). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=RUS

WHO. (2019o). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from https://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=IND

WHO. (2019p). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=CHN

WHO. (2019q). *WHO vaccine-preventable diseases: monitoring system. 2019 global summary*. Retrieved from http://apps.who.int/immunization_monitoring/globalsummary/countries?countrycriteria%5Bcountry%5D%5B%5D=ZAF

WHO. (2020). Coronavirus disease (COVID-19) Pandemic. Retrieved April 21, 2020, from https://www.who.int/emergencies/diseases/novel-coronavirus-2019

WHO and UNICEF. (2010). *Who Recommends Recall and Destruction of All Lots of Shan5 Vaccine*. Retrieved from http://www.who.int/immunization_standards/vaccine_quality/who_unicef_joint_statement_Shan5_26apr10.pdf

Worldatlas. (2018). The Largest Countries in the World. Retrieved March 26, 2018, from https://www.worldatlas.com/articles/the-largest-countries-in-the-world-the-biggest-nations-as-determined-by-total-land-area.html

# APPENDIX

## 1. TURNITIN REPORT

29 October 2020 PDF

ORIGINALITY REPORT

| 3% | 0% | 3% | 0% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Wesley Moonsamy, Shawren Singh. "An investigation into electronic vaccination cards for minors in Gauteng, South Africa", 2019 International Multidisciplinary Information Technology and Engineering Conference (IMITEC), 2019<br>Publication | 3% |

| | | | |
|---|---|---|---|
| Exclude quotes | On | Exclude matches | < 1% |
| Exclude bibliography | On | | |

## 2. VUT / IEEE CERTIFICATION OF PARTICIPATION

VUT
Vaal University of Technology

IEEE INTERNATIONAL MULTIDISCIPLINARY INFORMATION TECHNOLOGY AND ENGINEERING CONFERENCE (IMITEC) 2019

Certificate of Participation

awarded to

Wesley Moonsamy

21 -22 November 2019

Signature
Executive Dean: FACS

IEEE
South Africa Section
Computer Society Chapter

Your world to a better future

## 3. EKURHULENI ANNUAL HEALTH RESEARCH CONFERENCE CERTIFICATE

## 4. UNISA CAES ETHICAL CLEARANCE

UNISA university of south africa

**CAES HEALTH RESEARCH ETHICS COMMITTEE**

Date: 03/12/2018

NHREC Registration # : REC-170616-051
REC Reference # : 2018/CAES/153
Name : Mr W Moonsamy
Student #: 41179609

Dear Mr Moonsamy

**Decision: Ethics Approval from 01/12/2018 to 30/11/2019**

**Researcher(s):** Mr W Moonsamy
41179609@mylife.unisa.ac.za

**Supervisor (s):** Dr S Singh
singhs@unisa.ac.za; 011-471-2721

**Working title of research:**

An investigation into electronic vaccination cards for minors in Gauteng South Africa

**Qualification:** MSc Computing

Thank you for the application for research ethics clearance by the CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

**Due date for progress report: 30 November 2019**

*The **low risk application** was **reviewed** by the CAES Health Research Ethics Committee on 29 November 2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

## 5. EKURHULENI HEALTH DISTRICT RESEARCH PERMISSION

City of Ekurhuleni

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

# EKURHULENI HEALTH DISTRICT RESEARCH PERMISSION

**Research Project Title**: An investigation into electronic vaccination cards for minors in Gauteng South Africa.

**NHRD No:** GP_201812_018

**Research Project Number:** 14/02/2019-02

**Name of Researcher(s):** Mr Wesley Moonsamy

**Division/Institution/Company:** University of South Africa

**Date of review by the EHDRC:** 14 February 2019

**DECISION TAKEN BY THE EKURHULENI HEALTH DISTRICT RESEARCH COMMITTEE (EHDRC)**

- This document certifies that the above research project has been reviewed by the EHDRC and permission is granted for the researcher(s) to commence with the intended research project.
- Facilities approved for the research: All Ekurhuleni clinics and Germiston Hospital
- study period and when disseminating the findings.
- No resources (financial, material and human resources) from the health facilities will be used for the study. Neither the district nor the health facilities will incur any additional cost for the study.
- The study will comply with Publicly Financed Research and Development Act 2008 (Act 51 of 2008) and its related regulations.

Title: An investigation into electronic vaccination cards for minors in Gauteng South Africa

- The EHDRC must be informed in writing before publication or presentation of research findings and a copy of the report/publications/presentation must be submitted to the EHDRC
- The district must be acknowledged in all the reports/publications generated from the research.
- The researcher will be expected to provide the EHDRC with
  - Six monthly progress updates including any adverse events
  - The final study report in electronic format
  - Present the final research findings at the annual Ekurhuleni research conference if possible.
- The EDHRC reserves the right to withdraw the approval, if any of the conditions mentioned above have being breached
- The research committee wishes the researcher(s) the best of success.

DR. J. SEPUYA

**DEPUTY CHAIRPERSON: CITY OF EKURHULENI**

Dated: 14/02/2019

Dr. R. Mellerman

**CHAIRPERSON: GAUTENG DEPARTMENT OF HEALTH (EKURHULENI HEALTH DISTRICT)**

Dated: 14/02/2019

## 6. TSHWANE RESEARCH COMMITTEE CLEARANCE CERTIFICATE

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

**Enquiries:** Mpho Moshime-Shabagu
Tel: +27 12 451 9036
**E-mail:** Mpho.Moshime@gauteng.gov.za

**TSHWANE RESEARCH COMMITTEE: CLEARANCE CERTIFICATE**

**DATE ISSUED: 07/02/2019**
**PROJECT NUMBER: 06/2019**
**NHRD REFERENCE NUMBER: GP_201812_018**

**TOPIC: An investigation into electronic vaccination cards for minors in Gauteng South Africa**

| | |
|---|---|
| **Name of the Researcher:** | Mr. Wesley Moonsamy |
| **Name of the supervisor:** | Dr. S Singh |
| **Facility:** | Tshwane District Health Facilities |
| **Name of the Department:** | UNISA |

***NB: THIS OFFICE REQUEST A FULL REPORT ON THE OUTCOME OF THE RESEARCH DONE AND***

***NOTE THAT RESUBMISSION OF THE PROTOCOL BY RESEARCHER(S) IS REQUIRED IF THERE IS DEPARTURE FROM THE PROTOCOL PROCEDURES AS APPROVED BY THE COMMITTEE.***

**DECISION OF THE COMMITTEE: APPROVED**

.....
**Mr. Peter Silwimba**
**Deputy Chairperson: Tshwane Research Committee**
**Date**.....7/02/19.....

.....
**Mr. Mothomone Pitsi**
**Chief Director: Tshwane District Health**
**Date:** 2019.02.07

## 7. GAUTENG SCHOOLS VACCINATION RECORD REQUIREMENTS (RANDOM SAMPLE OF 24)

| Name of School | Details | Link | Date accessed | Required |
|---|---|---|---|---|
| Beaulieu College | Vaccination card not mentioned on application form | http://www.kyalamischools.org/images/KyalamiSchoolsApplicationForm2018.pdf | 12/02/2018 | No |
| Brescia House School | Vaccination card required upon application | http://www.brescia.co.za/index.php/admissions-to-brescia-house | 12/02/2018 | Yes |
| British International College | Copy of vaccination card required for registration | http://www.britishinternationalcollege.co.za/Preparatory-School/Admissions/ | 12/02/2018 | Yes |
| Bryandale Primary School | Scanned copy of Vaccination card requested on application | http://www.bryandale.co.za/?page_id=4191 | 12/02/2018 | Yes |
| Bryanston Primary School | Certified copy of vaccination card upon application for admission | http://bryanstonprimary.co.za/wp-content/uploads/2017/05/APPLICATION-FORM-2018.pdf | 11/02/2018 | Yes |
| Cedarwood School | Vaccination card not mentioned on application form | http://www.cedarwoodschool.co.za/wp-content/uploads/2016/11/Policy-Document-Application-for-Enrolment-2.pdf | 12/02/2018 | No |
| Dainfern College | Vaccination card not mentioned on application form | http://www.dainferncollege.co.za/images/pdf_files/Admissions/Application-Form---2018.pdf | 12/02/2018 | No |
| Dynamo Kidz | Vaccination card not mentioned on admissions page | http://www.dynamokidz.co.za/Enrolment_Form%20Florida%20North.pdf | 14/02/2018 | No |
| Grayston Preparatory School | Vaccination card not mentioned on application form | http://graystonprep.co.za/wp-content/uploads/2017/09/GPS-Application-Form-03-17.docx-1.pdf | 12/02/2018 | No |
| King Edward VII School | Vaccination card requested upon admission | http://www.kes.co.za/School/School%20Enrolment | 14/02/2018 | Yes |

| | | | | |
|---|---|---|---|---|
| Kyalami Preparatory School | Vaccination card not mentioned on application form | http://www.kyalamischools.org/images/documents/KyalamiSchoolsApplicationForm.pdf | 12/02/2018 | No |
| Nature & Nurture Montessori Pre-school | Copy of vaccination record if available | http://nurtureandnature.co.za/resources/Application4.7.pdf | 12/02/2018 | Required if available |
| Parktown High School for Girls | Vaccination card not mentioned on registration page | http://www.parktowngirls.co.za/admissions#admissions_accordion-block-1 | 14/02/2018 | No |
| Pine Forest Pre-Primary School | Vaccination card requested on application card | http://pfpp.co.za/wp-content/uploads/2018/01/Enrolment-Form-2018.pdf | 12/02/2018 | Yes |
| Pretoria Boys High School | Vaccination card not mentioned on admissions page | http://boyshigh.com/admissions/ | 14/02/2018 | No |
| Rivonia Primary School | Vaccination card requested upon admission | https://www.rivoniaprimary.info/ | 12/02/2018 | Yes |
| St Peter's Prep School | Vaccination card not mentioned on application form | https://www.stpeters.co.za/uploads/files/ST_PETER%E2%80%99S_PREP_SCHOOL_APPLICATION_FORM_.pdf | 12/02/2018 | No |
| St Stithians College | Vaccination card not mentioned on online application form | http://apply.stithian.com/Register | 12/02/2018 | No |
| St Teresa's School | Vaccination card not mentioned on application form | http://www.stteresas.co.za/administration/admission-documents/application-form.html | 12/02/2018 | No |
| The Kings College | Vaccination card not mentioned on application form | http://www.thekingscollege.co.za/wp-content/uploads/2012/05/Application-Forms-2017-Master-Document.pdf | 12/02/2018 | No |
| The Kings School Linbro Park | Vaccination card not mentioned on application form | http://www.kslp.org.za/images/documents/Pre-School%20Application%20Form%20for%202017.pdf | 12/02/2018 | No |

| | | | | |
|---|---|---|---|---|
| Vuleka School | Vaccination card requested upon admission | https://www.vulekaschool.co.za/admissions/ | 12/02/2018 | Yes |
| Wendywood High School | Copy of vaccination card required for registration | http://www.wendywoodhigh.co.za/documents/Applic%20form%20WWHS%202018.pdf | 12/02/2018 | Yes |
| Willowridge High School | Vaccination card requested upon admission | http://www.willowridge.co.za/?page_id=40 | 14/02/2018 | Yes |

## 8. IMAGE OF MEASLES RASH IN A CHILD

The skin reaction that results from contracting the Measles virus, (Health24, 2018).

## 9. MEASLES 2ND DOSAGE COVERAGE IN GAUTENG FROM 2015 TO 2017

| Province | District | 2015 / 2016 | 2016 / 2017 |
|---|---|---|---|
| | | Coverage % | Coverage % |
| Gauteng | Ekurhuleni | 95,8 | 124,8 |
| Gauteng | Johannesburg | 91,5 | 102,7 |
| Gauteng | Sedibeng | 104,9 | 129,2 |
| Gauteng | Tshwane | 83,4 | 84,1 |
| Gauteng | West Rand | 101,8 | 114,4 |

Measles (2nd dosage) in South Africa by district from 2015 / 2016 to 2016 / 2017, (Health Systems Trust, 2017)

## 10. RESEARCH INSTRUMENT

## QUESTIONNAIRE

### INTRODUCTION

My name is Wesley Moonsamy. I am a MSc. student at the University of South Africa (UNISA). My research topic is: An investigation into electronic vaccination cards for minors in Gauteng. This questionnaire will assist me in gaining more insight regarding the current paper-based vaccination record and the proposed electronic vaccination card.

You have been identified as a key stakeholder in determining whether an electronic-based vaccination storage system is preferred to the current paper-based vaccination card.

Please take note of the following:

- The completion of this questionnaire is voluntary and is entirely up to you. You may stop filling in this questionnaire at any time.
- All responses to this questionnaire will be treated in a confidential manner.
- Your responses will remain anonymous. Please do not insert any information on this questionnaire which could lead to you being personally identified.
- There are no compensations or incentives offered for the completion of this questionnaire.

Contact details:

Wesley Moonsamy (Researcher) – 41179609@mylife.unisa.ac.za

Dr Shawren Singh (Supervisor) – singhs@unisa.ac.za

The questionnaire should take approximately 20 minutes to complete.

Please indicate all answers with a tick ("✓") in the appropriate box.

Please select only 1 answer per question.

### SECTION A: Respondent information (Demographics)

1. Regarding this questionnaire, please select your primary role:

| | | | |
|---|---|---|---|
| Medical Doctor | | Parent | |
| Nurse | | School Administration Staff | |

| For the following questions, please tick the appropriate box | Yes | No |
|---|---|---|
| 2. Do you work in Gauteng, South Africa? | | |
| 3. Do you have access to a smartphone? | | |
| 4. Do you have access to the Internet? | | |
| 5. Do you have an e-mail address? | | |

## SECTION B: Vaccination records in Gauteng, South Africa

1. In your experience with vaccinations, how is a child's vaccination records primarily stored?

| | | | |
|---|---|---|---|
| Paper-based vaccination card | | No records are kept | |
| Electronic systems | | Not sure | |

2. Paper-based vaccination cards can be susceptible to loss or damage. Are you aware of a vaccination card that has been lost?

| | | | |
|---|---|---|---|
| Yes | | No | |

3. If your answer to the question above was "Yes", please select the measures taken to recover the lost vaccination records. If your answer was "No", please select "Not applicable".

| | |
|---|---|
| Successfully obtained vaccination records from the vaccination clinic | |
| Performed a blood analysis on the child to determine the vaccines that were administered | |
| Other (if Other, please describe the measures taken below): | |
| Not applicable | |

4. In your opinion, who should be responsible for ensuring that a child's vaccination records are safely stored?

| | | | |
|---|---|---|---|
| Parents / Guardians | | Government | |

Please indicate the extent to which you agree or disagree with the statements below.

| | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| 5. Children living in Gauteng receive their vaccinations on time | | | | | |
| 6. Paper-based vaccination cards are a reliable way to store a child's vaccination records | | | | | |

**SECTION C: A centralised electronic vaccination record system in Gauteng, South Africa managed by the Government**

Based on the prototype system (E-vaccination application) that you have used, please indicate the extent to which you agree or disagree with the following statements:

| | Strongly agree | Agree | Neither agree nor disagree | Disagree | Strongly disagree |
|---|---|---|---|---|---|
| **Usefulness** | | | | | |
| 1. The E-vaccination application can help me to be more effective when handling vaccination records | | | | | |
| 2. The E-vaccination application can help me to be more productive when using the vaccination functions | | | | | |
| 3. The E-vaccination application is useful for managing vaccination records | | | | | |
| 4. The E-vaccination application will save me time when storing vaccination records | | | | | |
| 5. The E-vaccination application will save me time when accessing vaccination records | | | | | |
| 6. The E-vaccination application meets my needs in terms of storing vaccination records | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 7. The E-vaccination application meets my needs in terms of retrieving vaccination records | | | | | |
| 8. The E-vaccination application saves my inputs as required | | | | | |
| 9. The E-vaccination application displays vaccination records in a way that I can understand | | | | | |
| **Ease of use** | | | | | |
| 10. The E-vaccination application is easy to use | | | | | |
| 11. The E-vaccination application is not a complicated system to use | | | | | |
| 12. The E-vaccination application is user friendly as it minimises the amount of input I need to enter | | | | | |
| 13. Any action on the E-vaccination application is completed with the minimum number of possible steps | | | | | |
| 14. Using the E-vaccination application is effortless | | | | | |
| 15. I can use the E-vaccination application without written instructions | | | | | |
| 16. There are no inconsistencies within the E-vaccination application | | | | | |
| 17. I can recover from mistakes easily when using the E-vaccination application | | | | | |
| 18. I can use the E-vaccination application successfully every time | | | | | |
| **Ease of Learning** | | | | | |
| 19. I quickly understood how to use the E-vaccination application | | | | | |
| 20. I easily remember how to use the E-vaccination application | | | | | |
| 21. I quickly became skilful with the E-vaccination application | | | | | |
| 22. I quickly learned how to navigate through the E-vaccination application | | | | | |
| 23. I quickly learned what the colour coding of the visual aids (icons) meant | | | | | |
| **Satisfaction** | | | | | |
| 24. I am satisfied with the E-vaccination application | | | | | |
| 25. I would recommend the E-vaccination application to a friend | | | | | |
| 26. The E-vaccination application works the way I want it to work | | | | | |
| 27. I am satisfied with the overall appearance of the E-vaccination application | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 28. I am satisfied with how the navigation of the E-vaccination application works | | | | | |
| **Design and Visual Aids** | | | | | |
| 29. The use of visual aids (icons) are helpful when using the E-vaccination application | | | | | |
| 30. I would prefer written instructions on the E-vaccination application instead of visual aids (icons) | | | | | |
| 31. The visual aids (icons) help me navigate the E-vaccination application easily | | | | | |
| 32. The colour coding of the visual aids (icons) helps me to determine what the link means | | | | | |
| 33. The vaccination statistics provided are useful | | | | | |

## 11. KMO VALUES

| Question number | KMO value |
|---|---|
| 1 | 0,88 |
| 2 | 0,92 |
| 3 | 0,93 |
| 4 | 0,85 |
| 5 | 0,84 |
| 6 | 0,89 |
| 7 | 0,87 |
| 8 | 0,91 |
| 9 | 0,96 |
| 10 | 0,91 |
| 11 | 0,91 |
| 12 | 0,96 |
| 13 | 0,95 |
| 14 | 0,94 |
| 15 | 0,92 |
| 16 | 0,92 |
| 17 | 0,89 |
| 18 | 0,89 |
| 19 | 0,91 |
| 20 | 0,90 |
| 21 | 0,91 |
| 22 | 0,95 |
| 23 | 0,92 |
| 24 | 0,96 |
| 25 | 0,91 |
| 26 | 0,93 |
| 27 | 0,92 |
| 28 | 0,93 |
| 29 | 0,93 |
| 30 | 0,48 |
| 31 | 0,88 |
| 32 | 0,86 |
| 33 | 0,91 |
| **KMO (Overall)** | **0,91** |

## 12. EIGENVALUES FOR THE 33 QUESTIONS

| Component | Eigenvalue | Variability (%) | Cumulative % |
|---|---|---|---|
| 1 | 16,93 | 51,30 | 51,30 |
| 2 | 2,05 | 6,22 | 57,52 |
| 3 | 1,78 | 5,38 | 62,91 |
| 4 | 1,38 | 4,19 | 67,10 |
| 5 | 1,22 | 3,69 | 70,79 |
| 6 | 1,05 | 3,19 | 73,98 |
| 7 | 0,85 | 2,57 | 76,55 |
| 8 | 0,76 | 2,29 | 78,84 |
| 9 | 0,71 | 2,16 | 80,99 |
| 10 | 0,64 | 1,94 | 82,93 |
| 11 | 0,60 | 1,81 | 84,75 |
| 12 | 0,55 | 1,65 | 86,40 |
| 13 | 0,49 | 1,47 | 87,87 |
| 14 | 0,43 | 1,30 | 89,18 |
| 15 | 0,40 | 1,21 | 90,39 |
| 16 | 0,37 | 1,11 | 91,50 |
| 17 | 0,34 | 1,04 | 92,54 |
| 18 | 0,31 | 0,95 | 93,49 |
| 19 | 0,28 | 0,84 | 94,33 |
| 20 | 0,25 | 0,77 | 95,10 |
| 21 | 0,22 | 0,67 | 95,78 |
| 22 | 0,21 | 0,63 | 96,40 |
| 23 | 0,18 | 0,56 | 96,96 |
| 24 | 0,16 | 0,48 | 97,45 |
| 25 | 0,14 | 0,43 | 97,87 |
| 26 | 0,13 | 0,39 | 98,26 |
| 27 | 0,12 | 0,35 | 98,61 |
| 28 | 0,11 | 0,34 | 98,95 |
| 29 | 0,10 | 0,29 | 99,25 |
| 30 | 0,08 | 0,25 | 99,50 |
| 31 | 0,07 | 0,20 | 99,70 |
| 32 | 0,05 | 0,17 | 99,87 |
| 33 | 0,04 | 0,13 | 100,00 |

## 13. FACTOR LOADINGS FOR THE 33 QUESTIONS

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 | F21 | F22 | F23 | F24 | F25 | F26 | F27 | F28 | F29 | F30 | F31 | F32 | F33 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| c1 | 0,635 | 0,383 | 0,105 | 0,011 | 0,280 | 0,241 | 0,071 | 0,030 | 0,390 | 0,057 | -0,028 | 0,115 | -0,050 | 0,108 | -0,202 | -0,126 | -0,054 | 0,086 | 0,091 | -0,069 | -0,063 | -0,018 | 0,051 | -0,023 | -0,101 | 0,016 | 0,102 | 0,017 | -0,020 | 0,006 | 0,041 | -0,034 | 0,024 |
| c2 | 0,739 | 0,380 | 0,069 | 0,272 | 0,131 | 0,079 | -0,008 | -0,009 | 0,078 | -0,004 | 0,162 | 0,166 | -0,002 | 0,007 | -0,178 | 0,015 | 0,005 | 0,037 | -0,101 | 0,251 | 0,055 | -0,031 | -0,006 | 0,035 | 0,085 | 0,035 | -0,138 | -0,008 | -0,074 | -0,009 | -0,005 | 0,010 | -0,040 |
| c3 | 0,528 | 0,331 | 0,253 | -0,125 | -0,068 | -0,380 | 0,156 | 0,192 | 0,014 | 0,069 | 0,448 | 0,190 | -0,091 | 0,002 | 0,166 | -0,100 | 0,058 | -0,102 | 0,116 | -0,048 | 0,013 | 0,013 | -0,018 | -0,026 | 0,020 | 0,022 | 0,010 | 0,014 | 0,042 | 0,022 | -0,006 | 0,005 | -0,001 |
| c4 | 0,585 | 0,429 | -0,222 | -0,009 | -0,187 | 0,255 | 0,074 | -0,036 | -0,035 | -0,235 | -0,069 | 0,307 | 0,331 | -0,110 | 0,080 | -0,007 | 0,001 | -0,061 | -0,010 | -0,107 | 0,031 | 0,085 | 0,011 | 0,017 | -0,029 | -0,061 | 0,017 | 0,012 | -0,020 | -0,037 | -0,051 | 0,037 | -0,012 |
| c5 | 0,632 | 0,556 | 0,105 | 0,185 | 0,055 | 0,068 | 0,089 | -0,036 | 0,002 | 0,020 | -0,071 | -0,271 | 0,152 | -0,079 | 0,170 | 0,020 | 0,218 | -0,013 | -0,023 | 0,139 | 0,055 | -0,061 | -0,001 | -0,017 | -0,038 | -0,022 | 0,014 | -0,032 | 0,080 | 0,000 | 0,020 | -0,064 | 0,058 |
| c6 | 0,630 | 0,333 | -0,409 | -0,238 | -0,169 | -0,062 | 0,062 | 0,109 | -0,090 | 0,210 | -0,102 | -0,008 | -0,179 | 0,208 | 0,030 | 0,005 | -0,152 | -0,034 | -0,045 | 0,055 | 0,024 | 0,121 | -0,001 | 0,087 | -0,055 | -0,120 | -0,037 | -0,074 | 0,004 | -0,009 | -0,014 | -0,059 | -0,007 |
| c7 | 0,775 | 0,434 | 0,045 | -0,005 | -0,101 | -0,113 | -0,006 | 0,027 | 0,040 | 0,137 | -0,137 | -0,282 | 0,012 | 0,058 | -0,030 | -0,038 | 0,046 | 0,080 | -0,035 | -0,112 | 0,058 | 0,031 | -0,054 | 0,022 | -0,035 | 0,059 | -0,013 | 0,061 | 0,028 | 0,020 | 0,017 | 0,114 | -0,090 |
| c8 | 0,734 | 0,315 | 0,050 | 0,096 | -0,358 | -0,071 | -0,132 | 0,117 | -0,207 | -0,072 | -0,137 | 0,012 | -0,058 | 0,130 | -0,002 | -0,055 | -0,102 | -0,014 | -0,117 | -0,036 | -0,004 | -0,090 | 0,098 | -0,128 | 0,148 | 0,042 | 0,074 | 0,021 | -0,054 | 0,006 | 0,036 | 0,003 | 0,051 |
| c9 | 0,751 | 0,018 | -0,302 | -0,146 | -0,177 | -0,041 | 0,155 | 0,036 | -0,274 | -0,091 | -0,110 | -0,006 | 0,033 | -0,003 | -0,147 | -0,020 | 0,045 | 0,073 | 0,298 | 0,070 | -0,105 | -0,039 | -0,090 | -0,084 | -0,047 | 0,078 | -0,085 | 0,015 | -0,013 | 0,003 | 0,000 | -0,013 | 0,014 |
| c10 | 0,839 | -0,011 | 0,261 | 0,091 | -0,159 | -0,143 | -0,110 | -0,118 | 0,037 | -0,056 | 0,013 | -0,093 | -0,006 | -0,110 | 0,030 | 0,021 | -0,039 | 0,027 | 0,080 | 0,075 | -0,216 | -0,042 | 0,179 | -0,032 | -0,016 | -0,126 | 0,023 | -0,011 | -0,002 | 0,005 | -0,037 | -0,016 | -0,090 |
| c11 | 0,835 | 0,051 | 0,343 | -0,010 | -0,031 | -0,153 | -0,147 | -0,029 | -0,018 | -0,090 | 0,057 | -0,144 | 0,003 | -0,088 | -0,072 | 0,046 | -0,068 | 0,016 | 0,114 | -0,062 | 0,008 | 0,040 | 0,044 | 0,187 | -0,010 | -0,037 | -0,046 | -0,054 | -0,070 | -0,035 | 0,026 | 0,063 | 0,101 |
| c12 | 0,780 | -0,107 | 0,244 | -0,090 | 0,245 | -0,137 | -0,027 | -0,012 | -0,200 | -0,138 | -0,020 | -0,001 | 0,031 | -0,011 | -0,091 | 0,124 | -0,181 | -0,096 | 0,069 | 0,122 | 0,248 | -0,009 | -0,013 | -0,047 | -0,086 | -0,015 | 0,116 | 0,035 | 0,006 | 0,007 | 0,003 | -0,005 | -0,032 |
| c13 | 0,813 | -0,053 | 0,167 | -0,064 | 0,375 | -0,040 | 0,009 | 0,035 | -0,042 | -0,092 | -0,099 | 0,056 | 0,130 | 0,050 | 0,003 | -0,042 | -0,185 | 0,109 | 0,003 | -0,075 | -0,042 | 0,008 | -0,006 | 0,013 | 0,135 | 0,015 | -0,067 | -0,061 | 0,186 | -0,022 | 0,006 | -0,016 | -0,007 |
| c14 | 0,757 | -0,014 | -0,053 | -0,245 | 0,366 | -0,072 | 0,016 | 0,164 | -0,033 | -0,203 | -0,065 | -0,006 | 0,044 | 0,116 | 0,222 | 0,067 | 0,010 | -0,011 | -0,099 | 0,006 | -0,134 | -0,117 | -0,041 | 0,115 | -0,043 | 0,083 | 0,023 | -0,003 | -0,098 | 0,072 | -0,027 | -0,010 | -0,015 |
| c15 | 0,652 | -0,099 | 0,191 | -0,333 | -0,205 | 0,079 | -0,214 | 0,117 | 0,164 | -0,331 | -0,015 | 0,066 | -0,152 | 0,112 | -0,104 | 0,182 | 0,267 | 0,007 | -0,040 | -0,017 | 0,019 | 0,065 | -0,049 | -0,038 | 0,012 | -0,039 | -0,006 | -0,049 | 0,047 | 0,001 | 0,039 | -0,010 | -0,016 |
| c16 | 0,570 | -0,354 | -0,253 | 0,128 | -0,334 | -0,014 | -0,125 | 0,101 | 0,305 | -0,006 | 0,180 | -0,135 | 0,282 | 0,236 | -0,041 | 0,023 | -0,098 | -0,138 | 0,023 | -0,001 | 0,039 | -0,120 | 0,018 | 0,008 | -0,043 | 0,028 | -0,044 | 0,007 | 0,039 | -0,006 | -0,023 | -0,010 | 0,007 |
| c17 | 0,743 | -0,291 | -0,207 | 0,311 | 0,000 | -0,126 | -0,097 | 0,233 | 0,079 | -0,109 | -0,001 | -0,009 | 0,029 | -0,104 | 0,101 | -0,147 | -0,052 | 0,042 | -0,042 | 0,091 | -0,068 | 0,113 | -0,142 | 0,008 | -0,005 | -0,070 | 0,030 | 0,097 | -0,015 | -0,043 | 0,113 | -0,010 | -0,003 |
| c18 | 0,715 | -0,244 | -0,063 | -0,024 | 0,240 | -0,022 | -0,082 | 0,414 | 0,006 | 0,049 | -0,141 | -0,077 | -0,046 | -0,170 | -0,101 | -0,230 | 0,136 | -0,115 | -0,017 | -0,068 | 0,087 | -0,022 | 0,073 | -0,044 | 0,003 | -0,021 | -0,042 | -0,043 | -0,036 | -0,038 | -0,083 | -0,012 | -0,007 |
| c19 | 0,768 | -0,101 | 0,177 | -0,183 | -0,083 | 0,390 | -0,058 | -0,092 | 0,149 | 0,003 | -0,017 | -0,047 | -0,121 | -0,113 | 0,137 | -0,106 | -0,160 | -0,058 | 0,001 | 0,060 | 0,013 | 0,007 | -0,093 | -0,104 | -0,004 | -0,041 | -0,066 | -0,013 | 0,003 | 0,139 | -0,027 | 0,050 | 0,033 |
| c20 | 0,752 | -0,146 | 0,152 | -0,250 | -0,169 | 0,384 | -0,125 | -0,121 | -0,021 | 0,136 | 0,050 | -0,036 | -0,017 | -0,040 | 0,166 | -0,091 | -0,011 | -0,019 | 0,092 | 0,018 | 0,046 | -0,001 | -0,018 | 0,057 | 0,054 | 0,124 | 0,048 | -0,066 | -0,044 | -0,116 | 0,040 | -0,041 | -0,054 |
| c21 | 0,719 | -0,311 | 0,007 | -0,250 | -0,010 | 0,128 | -0,105 | -0,003 | -0,305 | 0,215 | 0,129 | 0,166 | 0,128 | 0,014 | -0,053 | -0,098 | 0,106 | 0,079 | -0,141 | 0,048 | -0,022 | -0,041 | 0,124 | 0,021 | -0,120 | -0,014 | -0,014 | 0,010 | 0,053 | 0,040 | 0,073 | 0,040 | 0,016 |
| c22 | 0,875 | -0,154 | 0,120 | -0,184 | -0,040 | 0,077 | -0,013 | -0,124 | -0,046 | 0,073 | 0,078 | -0,061 | 0,030 | 0,085 | -0,051 | -0,046 | 0,087 | 0,162 | 0,000 | -0,019 | 0,045 | 0,019 | -0,048 | 0,074 | 0,100 | -0,068 | 0,033 | 0,186 | -0,011 | 0,012 | -0,102 | -0,056 | 0,024 |
| c23 | 0,719 | -0,185 | -0,076 | 0,340 | 0,035 | 0,178 | 0,179 | 0,102 | -0,089 | -0,101 | 0,243 | -0,097 | -0,116 | 0,057 | 0,125 | 0,112 | -0,044 | 0,277 | -0,052 | -0,086 | 0,054 | 0,037 | 0,036 | -0,106 | -0,081 | 0,009 | -0,013 | -0,053 | -0,027 | -0,051 | -0,044 | 0,011 | 0,008 |
| c24 | 0,851 | 0,008 | -0,222 | -0,069 | -0,069 | -0,099 | -0,017 | -0,091 | 0,081 | -0,039 | 0,042 | -0,055 | -0,074 | -0,214 | -0,073 | 0,090 | -0,058 | -0,079 | -0,127 | 0,013 | -0,061 | 0,192 | 0,099 | 0,005 | -0,035 | 0,185 | 0,001 | 0,059 | 0,050 | 0,017 | -0,030 | -0,041 | 0,023 |
| c25 | 0,700 | 0,087 | -0,325 | -0,378 | 0,197 | 0,049 | 0,165 | -0,044 | 0,078 | 0,124 | 0,100 | -0,063 | -0,065 | -0,153 | -0,030 | 0,210 | -0,041 | -0,091 | -0,066 | -0,063 | -0,050 | -0,157 | -0,026 | -0,069 | 0,045 | -0,078 | -0,023 | 0,064 | -0,005 | -0,100 | 0,042 | 0,029 | 0,011 |
| c26 | 0,765 | -0,186 | -0,455 | 0,060 | -0,097 | -0,080 | 0,177 | -0,061 | 0,070 | 0,017 | 0,053 | 0,012 | -0,031 | -0,082 | -0,110 | -0,039 | 0,059 | 0,061 | -0,010 | 0,096 | -0,008 | -0,045 | -0,056 | 0,069 | 0,086 | -0,002 | 0,175 | -0,128 | 0,039 | 0,038 | -0,037 | 0,064 | 0,008 |
| c27 | 0,707 | -0,137 | -0,149 | 0,137 | -0,155 | -0,268 | 0,087 | -0,342 | 0,105 | -0,148 | -0,146 | 0,163 | -0,196 | -0,077 | 0,072 | -0,119 | 0,019 | 0,050 | -0,034 | -0,103 | 0,138 | -0,164 | 0,016 | 0,058 | -0,058 | 0,003 | -0,067 | 0,012 | 0,013 | 0,007 | 0,029 | -0,041 | -0,009 |
| c28 | 0,711 | -0,273 | -0,227 | -0,070 | 0,273 | -0,173 | 0,128 | -0,209 | 0,157 | 0,076 | -0,106 | 0,012 | 0,103 | 0,170 | 0,143 | 0,024 | 0,117 | -0,022 | 0,106 | 0,037 | 0,065 | 0,149 | 0,140 | -0,088 | 0,085 | -0,009 | -0,027 | -0,004 | -0,070 | 0,023 | 0,041 | 0,033 | 0,009 |
| c29 | 0,810 | -0,087 | 0,231 | 0,124 | 0,006 | -0,150 | 0,071 | -0,197 | -0,099 | 0,146 | 0,082 | -0,044 | 0,184 | -0,029 | -0,150 | 0,018 | 0,017 | -0,070 | -0,110 | -0,174 | -0,046 | 0,053 | -0,148 | -0,069 | 0,001 | -0,023 | -0,003 | -0,098 | -0,082 | 0,054 | 0,025 | -0,070 | -0,018 |
| c30 | 0,003 | -0,304 | 0,532 | -0,119 | -0,337 | -0,028 | 0,569 | 0,247 | 0,149 | 0,098 | -0,210 | 0,066 | 0,082 | -0,060 | -0,004 | 0,083 | -0,040 | 0,048 | -0,059 | 0,062 | 0,011 | 0,000 | 0,027 | 0,032 | 0,003 | 0,015 | -0,010 | 0,011 | -0,015 | -0,008 | 0,012 | -0,003 | 0,002 |
| c31 | 0,735 | -0,170 | 0,306 | 0,286 | 0,077 | 0,035 | 0,115 | -0,204 | -0,093 | 0,012 | -0,106 | 0,068 | -0,140 | 0,215 | 0,001 | -0,060 | 0,066 | -0,215 | -0,060 | 0,047 | -0,121 | 0,021 | -0,068 | -0,012 | -0,059 | 0,011 | 0,010 | 0,021 | 0,041 | -0,104 | -0,055 | 0,055 | 0,026 |
| c32 | 0,647 | -0,115 | -0,095 | 0,471 | 0,035 | 0,380 | 0,141 | 0,137 | -0,162 | 0,042 | 0,005 | 0,006 | -0,127 | -0,002 | -0,017 | 0,145 | 0,048 | -0,161 | 0,115 | -0,108 | 0,005 | -0,007 | 0,060 | 0,109 | 0,064 | -0,015 | -0,003 | 0,045 | 0,030 | 0,089 | 0,049 | -0,016 | -0,025 |
| c33 | 0,652 | -0,025 | 0,038 | 0,227 | -0,017 | -0,134 | -0,375 | 0,104 | 0,094 | 0,372 | -0,190 | 0,268 | 0,008 | -0,075 | 0,103 | 0,241 | 0,019 | 0,086 | 0,069 | -0,008 | -0,001 | -0,032 | -0,066 | -0,025 | -0,021 | 0,027 | 0,012 | -0,004 | 0,009 | 0,000 | -0,041 | 0,005 | 0,020 |

## 14. FACTOR LOADINGS FOR THE 5 COMPOSITE CATEGORIES

| Category | F1 | F2 | F3 | F4 | F5 |
|---|---|---|---|---|---|
| Usefulness | 0,806 | -0,320 | -0,486 | 0,101 | 0,035 |
| Ease of Use | 0,905 | 0,001 | 0,191 | -0,103 | 0,367 |
| Ease of Learning | 0,864 | -0,037 | 0,266 | 0,408 | -0,126 |
| Satisfaction | 0,868 | -0,218 | 0,135 | -0,354 | -0,233 |
| Design and Visual Aids | 0,725 | 0,661 | -0,176 | -0,045 | -0,067 |