Digital Vaccination Records: Exploring Stakeholder Perceptions in Gauteng, South Africa

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Abstract
Electronic health (eHealth) is one of the focus areas of the South African Department of Health (DoH), with the ultimate goal being the development of an electronic health record (EHR) for every citizen. A commonly used subset of eHealth data, vaccination records, is still not yet fully digitised in South Africa. This study aimed to determine the perceptions of key stakeholders (doctors, nurses, parents, and school administrators) about a digital system for vaccination records for minors in South Africa's Gauteng Province. Using a prototype online, cloud-based vaccine records management system created during the research, called e-Vaccination, quantitative and qualitative interaction-related data from 118 participants were collected using a five-point Likert-scale questionnaire. The questionnaire was based on Lund's (2001) USE user perception framework, which considers usefulness, satisfaction, ease of use, and ease of learning. This study found that the participants supported the use of the digital vaccine records management system, with an emphasis on five identified factors: user friendliness, graphical design, practicality, user experience, and usability. Accordingly, this article recommends that policymakers and system designers carefully consider these factors in the design and development of South Africa's digital vaccination records management system.

Keywords
vaccination records, eHealth, digitisation, health information systems, user perception, USE framework, Gauteng, South Africa

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1. Introduction

The recent fire at one of South Africa's largest academic hospitals, Charlotte Maxeke Johannesburg Academic Hospital (Motara, Moeng, Mohamed, & Punwasi, 2021), as well as the riots in the KwaZulu-Natal and Gauteng Provinces—in which organisations, including pharmacies and healthcare facilities, were looted and vandalised (South African Government, 2021b)—highlight the need to secure vital medical information such as patient records. Information that is exclusively stored on local servers, on hard drives, and in paper-based files is at risk of total loss during such events and other disasters.

An increasingly critical subset of patient information, vaccination records, has shown a hastened conversion to a digital form as a result of the COVID-19 pandemic (GAVI, 2020). There are several "patient-facing" health information systems in South Africa, including MomConnect and B-wise (DoH, 2020b; Health Enabled, 2021). A new addition to these disparate systems is the Electronic Vaccination Data System (EVDS), which was created as a self-registration portal that allows South Africans to register to receive their vaccination against COVID-19 (South African Government, 2021a).

The hybrid EVDS, with a digital back-end but a physical vaccination card handed to a patient once the vaccination has been administered, allows the government to track and monitor the COVID-19 vaccination rollout. This hybrid approach, however, does not give the patient easy access to a digital version of their vaccination record as it requires the proof of vaccination code, which can easily be misplaced. Decades since the first physical vaccination cards were handed to patients, South Africans must continue to store their physical vaccination cards safely, even with expensive technology having been created to register the patient. Such systems lack patient-centeredness, which is the key to eHealth (Nyatuka & De la Harpe, 2022).

Immunisations are one of the greatest success stories of modern medicine (WHO, 2019). The study considered the grassroots level of vaccines and focused on the digitisation of vaccination records for some of the most vulnerable in our society: minors (from new-born to 12 years of age). The research therefore focused on South Africa's expanded programme on immunisation (EPI) schedule (DoH, 2018). (The research did not focus on the COVID-19 vaccinations because adult vaccination records storage is at the infancy stage in South Africa.)

This study commenced by determining the main challenges associated with the paper-based vaccination card in Gauteng. This was followed by an assessment of how vaccination records are stored by government and non-government entities globally. The eHealth aims of the DoH were then investigated. Based on information collected, a prototype online digital vaccine records management system, named e-Vaccination, was developed and tested with key stakeholders to determine their perceptions of the system. This was achieved by a questionnaire comprising of three sections. Section A was used to collect demographic information, section B collected perceptions of vaccinations in Gauteng, South Africa, and Section C collected user perception (usefulness, satisfaction, ease of use, and ease of learning) information based on the USE tool (Lund, 2001. In addition to these four categories, one more user perception category (design and visual aids) was added due to the graphical nature of e-Vaccination's user interface. The questionnaire was guided by the study's core research question: What are the perceptions of the key stakeholders about replacing the paper-based vaccination card with a digital vaccination record system?

2. Challenges with paper-based vaccination cards

Paper-based records are prone to damage or total destruction by disasters such as fires and flooding. In addition to this, South Africa experienced civil unrest during 2021, in which some healthcare facilities were looted and vandalised. In certain cases, patient records were stolen or damaged. These events fall under the vulnerability challenge. Another challenge, accessibility, has also been noted. In some instances, the vaccination card, which has been the primary storage mechanism for over three decades, has to be presented to a healthcare worker for medical purposes or to school administrators for admission to a school. If the card is not available, the vaccination records cannot be accessed easily. Another challenge related to the use of paper-based vaccination records is the reliability of the data. Handwritten paper-based records are prone to human error and have the added disadvantage of being illegible. This can also cause downstream digital records captured from this medium to be incorrect. Processes that load vaccination records as daily, weekly, or monthly batches cannot provide real-time information. These scenarios result in information that is not always reliable. These three main challenges are further explained in Table 1.

Table 1: Challenges with paper-based vaccination cards

Challenge	Category	Details
Vulnerability	Fires	Fire hazards pose a threat to physical documents such as vaccination cards. Fire hazards include fires at dwellings as well as healthcare facilities. During such events, paper-based documents, as well as physical hardware containing patient records such as vaccination records, can be damaged.
	Floods	Flooding, especially in informal settlements, poses a threat to homes and with it, paper-based records such as vaccination cards.
	Civil unrest	During civil unrest such as the recent riots in Gauteng and KwaZulu-Natal, healthcare facilities can be looted and damaged. Paper-based documents, as well as physical hardware containing patient records such as vaccination records, can be damaged or stolen.
Accessibility	Medical care	In cases where patients need medical care requiring previous vaccination records, doctors have to rely on the presence of the physical vaccination card or the parental recall of the child's vaccination history.
	Admission at schools	In some cases, a child cannot be admitted into a school if the vaccination records are not produced. If the vaccination card is not available, this can cause delays in admission.
Reliability	General statistics	Vaccination statistics that are compiled by hand are prone to errors. Real-time vaccination statistics cannot be measured if physical records have to be manually captured at various levels.
	Reporting of herd immunity	The concept of herd immunity is receiving much attention due to the current COVID-19 pandemic. Herd immunity, however, has always been valid in terms of vaccine-preventable diseases affecting minors. Without accurate and up-to-date data, policymakers will not be fully equipped to make critical decisions regarding vaccination campaigns and other programmes.

Source: Authors

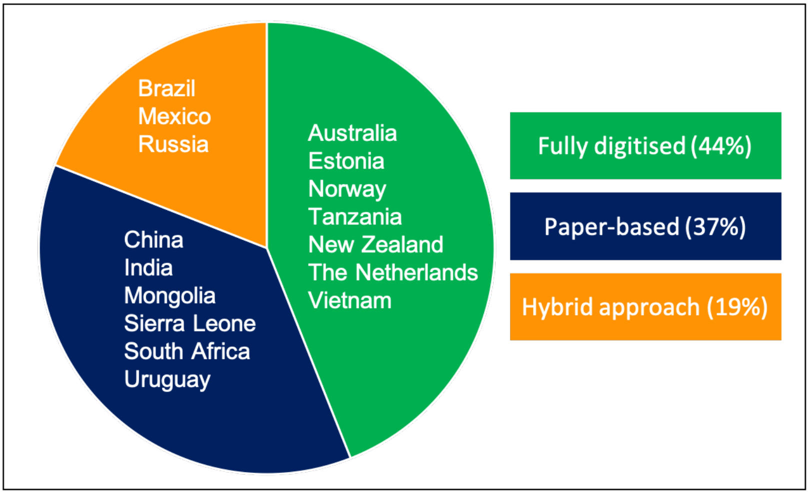
3. Management of vaccination records

An investigation of 16 countries (developed, developing, and countries in transition) was carried out to determine how they managed their vaccination records. The findings were categorised as follows:

- **Fully digitised** – A child's entire vaccination record can be accessed with or without the presence of the vaccination card. The card merely serves as proof for the parent or guardian.
- **Paper-based** – The primary storage mechanism is a paper-based vaccination card or other paper-based documents.
- **Hybrid approach** – A digital system that stores the vaccination records does exist, but it is not updated in real-time and, healthcare practitioners, as well as parents, cannot access these records. The primary storage mechanism remains the vaccination card.

The investigation revealed that 44% of the investigated countries had a fully digitised storage mechanism whilst 37% were paper-based and 19% used a hybrid approach. This is illustrated in Figure 1.

Figure 1: Vaccination record storage mechanisms across 16 investigated countries



Source: Authors

In addition to determining how other countries managed their vaccination records, non-government-related initiatives, such as mobile applications (apps) that can be downloaded from the Apple iStore or Google Play store, were also investigated. The capabilities of the mobile applications that were assessed are listed in Table 2.

Table 2: Main features of investigated mobile applications

Mobile app name	Register child	Add vaccination records	View vaccination records	Share vaccination records	Vacci-nation reminders	Schedule-based vaccination records	Pass-code protec-tion
Vaccine Reminder	✓	✓	✓	×	✓	✓	×
Vaccines Log – Vaccination Reminder & Tracker	✓	✓	✓	✓	✓	✓	✓
Child Immunisation Tracker – Baby Immunisation	✓	✓	✓	×	×	×	×
My Kids Vac-cine Tracking	✓	✓	✓	×	×	✓	×
My Immunizations	✓	✓	✓	✓	✓	×	×

Source: Authors

The five investigated mobile applications listed in Table 2 had features that were common. These features were the registration of a child, adding a vaccination record, and viewing a vaccination record. These features do represent the core functionality of a vaccination records management system. Similar datasets were noted amongst these mobile applications. It should be noted that none of them shared data with any government entity. The applications were meant to be used as stand-alone systems to assist parents and guardians with keeping track of their children's vaccines.

This led to the understanding that there were no freely available mechanisms for parents to store and retrieve official (verified) vaccination records that share data with government entities in South Africa. An investigation of South Africa's DoH's aims for eHealth was then conducted.

4. Department of Health's aims for eHealth

The 2019–2023 National Digital Health Strategy prioritises EHRs, digital processes, linkage of patient data across various systems, mHealth (mobile health), and knowledge in a digital form (DoH, 2020a). Some of these priorities relate to the previous National eHealth Strategy 2012–2016, which indicates that the measure of success of a country's eHealth maturity is made up of five stages (DoH, 2012). These stages are summarised in Table 3.

Table 3: Five stages of eHealth maturity

Stage	Description
Stage 1	District health indicators are collected using 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

Source: Adapted from DoH (2012)

The DoH's eHealth maturity model is a framework that guides the development of electronic health records using the flows and sources of health information (DoH, 2020a). Overall, South Africa is at Stage 3 of eHealth maturity. Some provinces, however, are at Stage 4 in certain areas and other provinces are at Stages 1, 2, or 3. The DoH has outlined the following steps for South Africa to reach Stages 4 and 5 of eHealth maturity:

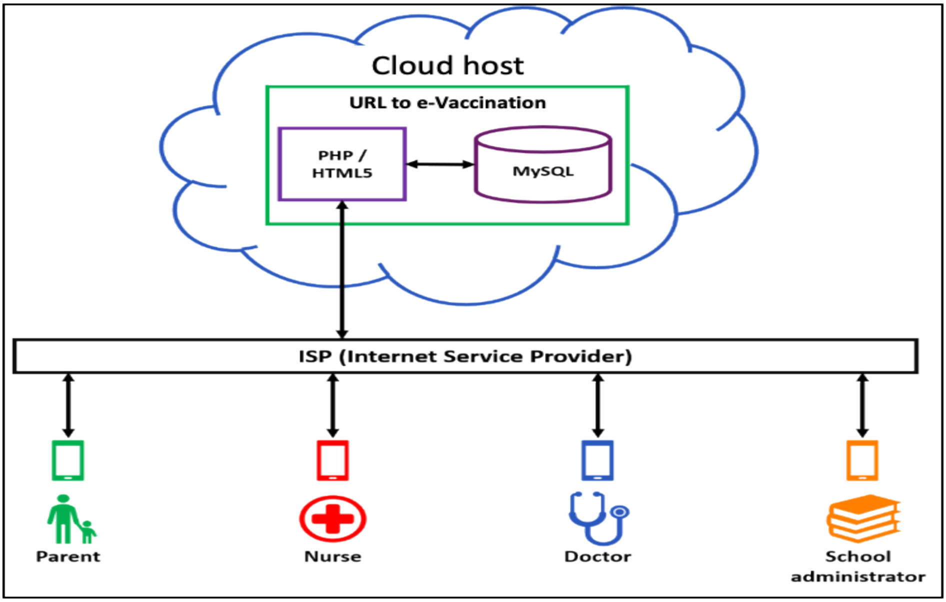
- patient-based health information systems need to be implemented at the point where health care is delivered;
- these systems need to be linked to a national health record system;
- all information should be captured into the electronic system at the point of patient care;
- every South African should have a unique identifier on the Health Information System;
- births and deaths need to be effectively registered; and
- all facilities must be able to access information from other facilities (DoH, 2012).

These steps essentially describe a system that stores the digital records centrally, and which can be accessed and updated from any healthcare facility. This would remove the need to recapture information from the individual healthcare facilities to the district, provincial, and national levels. Equipped with the aims of the DoH, together with generally used datasets and key functions of vaccination record systems, a prototype centrally based digital vaccination records management system called e-Vaccination was developed.

5. e-Vaccination prototype

e-Vaccination was created with four different profiles, one for each of the four key stakeholder types (doctors, nurses, parents, and school administrators). This allowed each stakeholder to engage with e-Vaccination from their particular perspective. With reference to the eHealth aims of the DoH, e-Vaccination was designed as a centralised system that allowed the stakeholders to access it via their internet-enabled devices. This centralised architecture is illustrated in Figure 2.

Figure 2: Architecture of e-Vaccination prototype



As illustrated in Figure 2, the key stakeholders could use their internet-enabled device (smartphone, tablet, laptop) to access e-Vaccination via their web browser. e-Vaccination was hosted on a remote server (the cloud) and was accessible via a URL (www.e-vaccination.co.za).

The features that were built into e-Vaccination took into consideration those features that were included in the investigated mobile applications. Since prototypes are normally built with limited purposes (Houde & Hill, 1997), only selected features were included in the design of e-Vaccination. The included features were viewing, requesting, and adding vaccination records. Vaccination statistics, in the form of reports at national, provincial, and district levels, were also included. The features linked to the different stakeholder views are described in Table 4.

Table 4: Features included in e-Vaccination, per stakeholder type

Feature	Doctor	Nurse	Parent	School administrator
View a child's vaccination records	✓	✓	✓	×
Request a child's vaccination record	×	×	×	✓
Add a vaccination record	×	×	✓	×
View national reports	✓	✓	✓	✓
View provincial reports	✓	✓	✓	✓
View local government (district level) reports	✓	✓	✓	✓

e-Vaccination had six features built into it, as listed in Table 4. The viewing of reports was common amongst all the stakeholder types. The rest of the features were selectively added to the relevant stakeholder type. Based on the features and profiles built into e-Vaccination, 18 process flows (some process flows were common amongst the stakeholder types) were designed. These are illustrated in Figures 3 to 6.

Figure 3: Process flows for parents

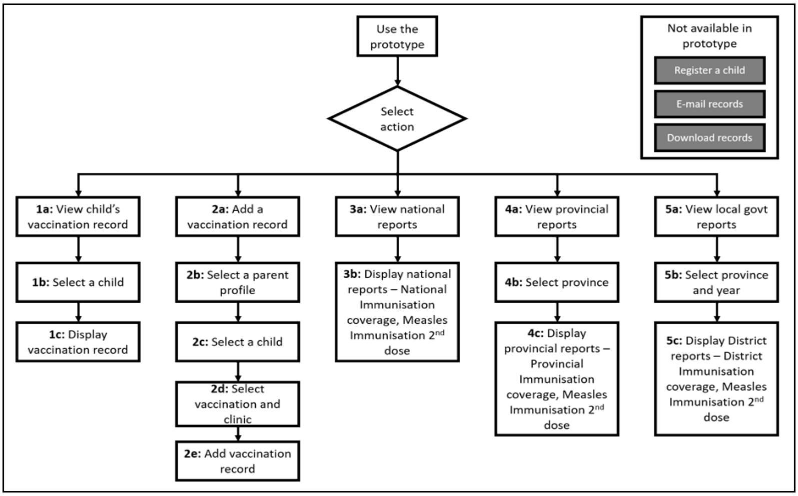
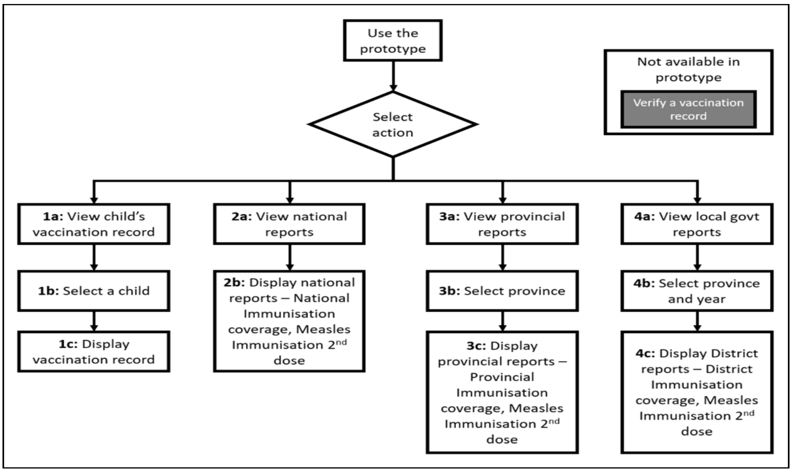


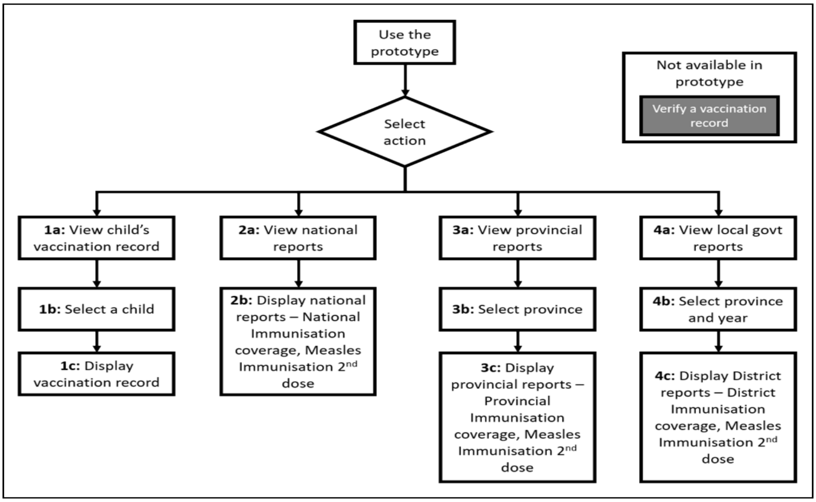
Figure 3 is an illustration of the process flows that were built into e-Vaccination for the parent stakeholder type. Once a parent logged into e-Vaccination, they could select from a list of five processes. To avoid complexity due to e-Vaccination being a prototype and not a live system, some of the processes that were identified early on in the design were not built. These are the "register a child", "e-mail records" and "download records" processes.

Figure 4: Process flows for nurses



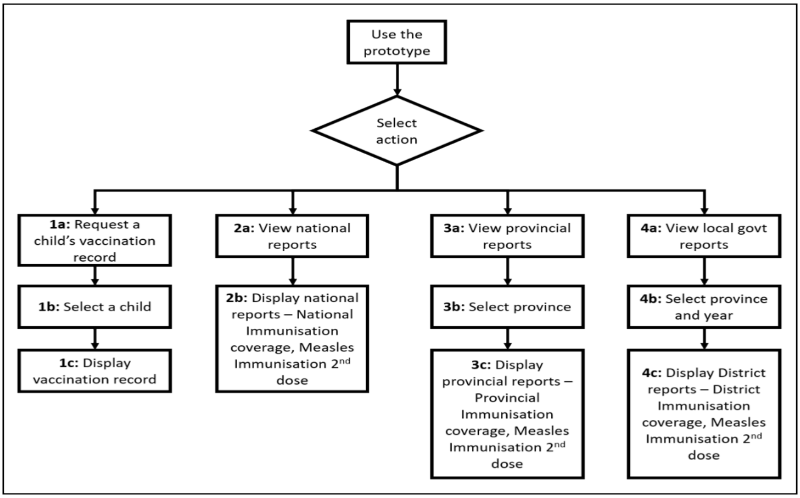
The overall process flows for the nurse stakeholder type are illustrated in Figure 4. Nurses could select from four main processes. These processes are to view a child's vaccination record and to view national, provincial, and local government (district level) vaccination reports. The "verify a vaccination record" process was not built into the prototype.

Figure 5: Process flows for doctors



The process flows illustrated in Figure 5 are for the doctor stakeholder type. The process flows for doctors are the same as the process flows for nurses. The "verify a vaccination record" process was not built into the prototype.

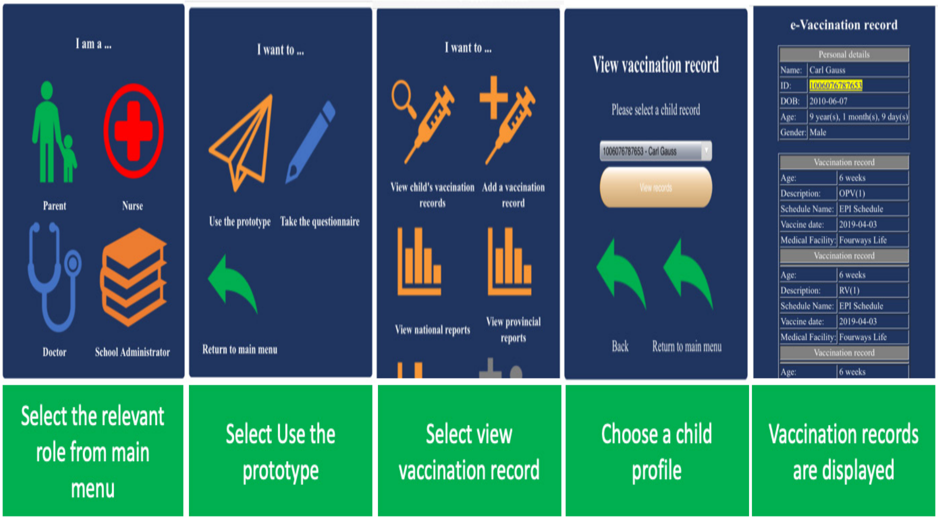
Figure 6: Process flows for school administrators



The process flows for the school administrator stakeholder type are illustrated in Figure 6. School administrators could select from four possible processes. Apart from viewing the national, provincial, and local government vaccination reports as the other stakeholder types could, school administrators could also request a child's vaccination record.

e-Vaccination was designed to be more graphical, allowing the user to type as little as possible with most of the options provided by large icons and dropdown lists. Figure 7 shows the actual user interface of e-Vaccination.

Figure 7: e-Vaccination's user interface



6. Assessment of e-Vaccination prototype

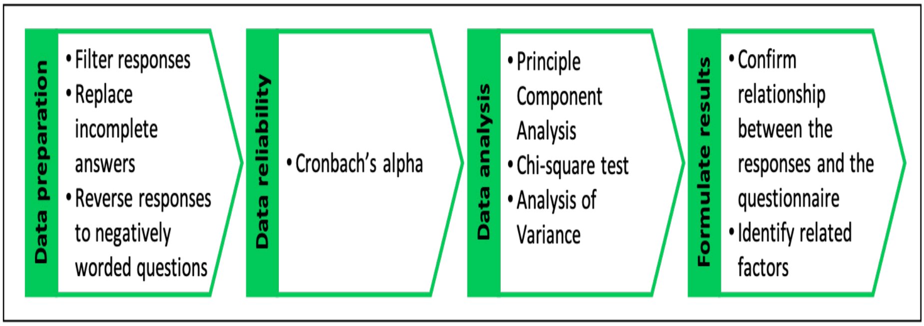
To assess the effectiveness of e-Vaccination, a questionnaire was designed to collect feedback from the relevant stakeholders. e-Vaccination was initially piloted by 10 users, who provided their feedback regarding the system. e-Vaccination was thereafter refined and prepared for distribution to the potential participants.

A quantitative research analysis was conducted on the data collected from the questionnaire, which was based on the stakeholder's engagement with e-Vaccination. A questionnaire with three sections was designed to collect demographic information (Section A), perceptions about vaccinations in Gauteng (Section B), and user perception (usefulness, satisfaction, ease of use and ease of learning, design and visual aids) information (Section C). (See Appendix 1 for the questionnaire.)

The participants who completed the questionnaire were anonymous. They were selected by word-of-mouth as well as via contact information that was available in the public domain. A link to e-Vaccination and the questionnaire was distributed to the prospective participants via e-mail, phone call, SMS, or visit. The prospective participants were asked to use e-Vaccination and to select the user profile based on their stakeholder type. Once they had used e-Vaccination, the participants answered the questionnaire and submitted their responses.

Following the data collection process, the data were statistically tested for reliability using a Cronbach's alpha test. The Cronbach's alpha scores were verified against the rating table by Gliem and Gliem (2003). To confirm that the data collected were not a randomised occurrence, a chi-square goodness of fit test followed as a subsequent step. The ANOVA test was used to determine if there were significant differences between different experimental conditions (Rutherford, 2000). This statistical method was used to analyse Likert-type scales in a similar study by Holtz and Krein (2011). 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) test was conducted. A PCA is a data reduction method (UCLA IDRE, 2020) that can be used to investigate a relationship between dependent variables (Syms, 2019). The PCA was used to determine whether the responses to the questionnaire were related to the overall research question as well as to uncover any underlying factors that influenced the responses. The data analysis steps are summarised in Figure 8.

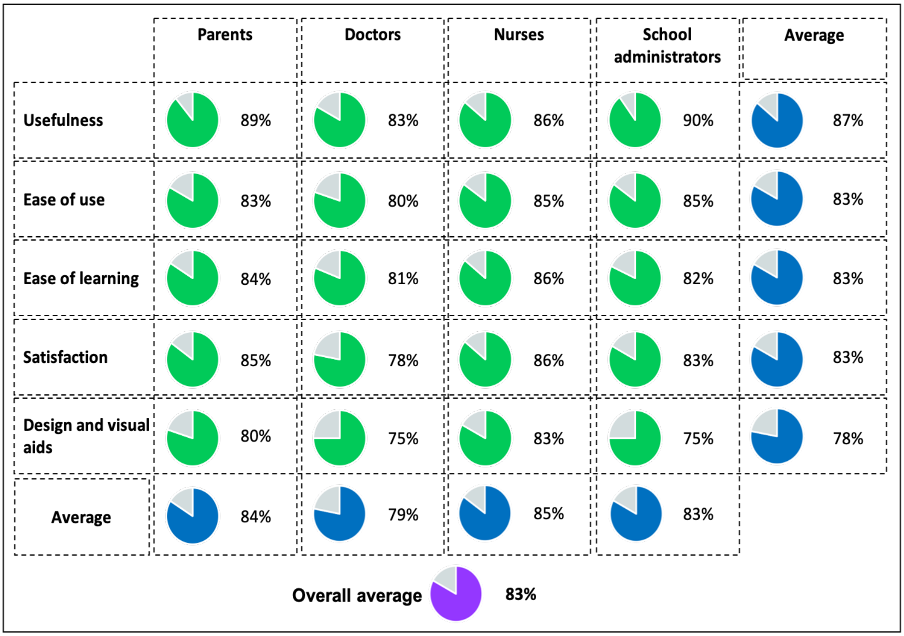
Figure 8: Data analysis steps



7. Results

There were 118 respondents to the questionnaire (doctors: 16; nurses: 16; parents: 74; school administrators: 12). Of the 118 respondents, 95% had access to a smartphone and at least 96% had access to the internet and email. The paper-based vaccination card was the primary storage mechanism according to 91% of the respondents, while 5% felt that a digital system was the primary mechanism. Approximately 4% were uncertain. Most of the respondents, 94%, had at least one experience with a lost vaccination card. The results of the Cronbach's alpha test showed that the data collected were reliable. The chi-square test showed that the data collected were not a random occurrence and were due to an underlying factor. There was no significant difference in the data collected between the four stakeholder groups according to the results of the ANOVA test. The weighted scores for the questionnaire per user perception category and stakeholder type are depicted in Figure 9.

Figure 9: Weighted scores per user perception category and stakeholder type



The weighted scores as illustrated in Figure 9 show that the overall perceptions about the digitisation of vaccination records scored an 83%. The usefulness of e-Vaccination had the highest weighted score, 87%.

The PCA test was conducted on all 33 questions of section C of the questionnaire for all 118 participants (the full dataset). This test was used to determine the underlying factors relating to the five categories of the questionnaire as well as the perceptions of the stakeholders about the digital vaccination record. Eigenvalues were calculated and thereafter used to determine the main factors for each of the 33 questions. The factors with eigenvalues greater than 1 should be retained (UCLA IDRE, 2020). These factors are the significant factors that make up the principal components of the dataset. The factors with eigenvalues greater than 1 are displayed in Table 5.

Table 5: Factors with eigenvalues greater than 1

Factor	Eigenvalue
1	16.93
2	2.05
3	1.78
4	1.38
5	1.22
6	1.05

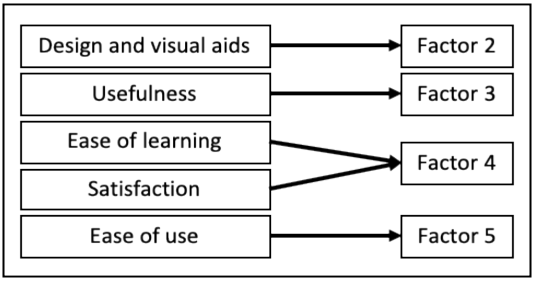
Factor 1, with an eigenvalue of 16.93, generated the steepest gradient on a scree plot (see Appendix 2). This main factor was identified as the one concerning the overall research question on the digitisation of the vaccination record. The remaining factors were renamed Factors 1 to 5. The contributions of the factors towards each of the user perception categories are detailed in Table 6 below.

Table 6: Percentage contributions of five factors to user perception categories

User perception 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

For each user perception category, the factor that the category contributed most towards was determined. The factors were then labelled based on the underlying reason for why they contributed towards that category. The relationship between the factors and the categories, based on the highest contributions, is illustrated in Figure 10.

Figure 10: Main factor contributions of each user perception category



None of the user perception categories made its highest contribution to factor 1. The "ease of use" category which revealed the "user friendliness" factor during the PCA, however, made the highest contribution towards this factor. The contributions, labels, and descriptions are listed in Table 7.

Table 7: Five underlying factors uncovered by PCA test

Factor	Contribution (%)	Label	Description
Factor 1	23.421	User friendliness	The system has to be appealing to the stakeholders and should not intimidate those who are new to such platforms.
Factor 2	74.208	Graphical design	The use of graphics adds to the intuitiveness of the system and guides the user on accessing the features they want to access with minimal effort.
Factor 3	60.125	Practicality	The system must provide the users' anticipated features.
Factor 4	52.903	User experience	The user experience must be engaging; users must not feel the need to use help files to access the features they want to use.
Factor 5	63.911	Usability	The features of the system must match the users' expectations. The features must also work in the way that the user anticipates.

The result of the statistical analysis demonstrated that e-Vaccination is user-friendly, practical, usable, provides a good user experience, and has a graphical design that aids in the use of the system. The results of each statistical test are summarised in Table 8.

Table 8: Summary of data analysis

Statistic	Usefulness	Ease of use	Ease of learning	Satisfaction	Design and visual aids
Data Reliability					
Cronbach's 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					

Statistic	Usefulness	Ease of use	Ease of learning	Satisfaction	Design and visual aids
Contribution to Factor 1 (User friendliness)	18.6	23.4	21.3	21.6	15.1
Contribution to Factor 2 (Graphical design)	17.5	0.0	0.2	8.1	74.2
Contribution to Factor 3 (Practicality)	60.1	9.3	18.0	4.7	7.9
Contribution to Factor 4 (User experience)	3.2	3.4	52.9	39.9	0.7
Contribution to Factor 5 (Usability)	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

The data analysis alone cannot tell us the full story as it is important to consider the current context. Whilst conducting this research, the COVID-19 pandemic reached South Africa, necessitating the implementation of the EVDS. Though the EVDS was not examined in detail, it can be noted that some of the features, such as creating and viewing vaccination records, are common in both systems.

8. Response to new challenges

The current COVID-19 pandemic has introduced a new paradigm, namely vaccination records for adults. Whilst the EVDS has been created primarily as a vaccination registration tool for COVID-19 vaccinations, it also serves a secondary purpose, which is to store the vaccination records of the patients (adults). It is not unreasonable to assume that we will possibly move to adult immunisation schedules on a seasonal basis. The vaccination card, SMS notifications and QR codes provided to the patients after their vaccination still represent one-way information flow from the healthcare facility to the patient. Whilst the EVDS seems to satisfy some of the eHealth aims mentioned earlier, such as the centralisation of data (which facilitates the sharing of data between healthcare facilities), the patient is not yet fully able to access his or her vaccination records through an available portal independently. It must be noted that the sharing of medical information, even with the patient, must take into account the Protection of Personal Information Act (POPIA) (RSA, 2013).

The COVID-19 pandemic has also raised another consideration. This is vaccination coverage, which can contribute towards herd immunity reporting. If the information is appropriately utilised, herd immunity reporting can be done at a national level. Further research needs to be conducted regarding the reporting of herd immunity for other vaccine-preventable diseases based on the EPI schedule and at a more granular level, such as district level or lower.

Though the EVDS does indeed represent a leap towards an EHR for South Africa, it has now contributed to a patchwork of systems created to address an immediate need. It contributes towards an EHR for every citizen, but we should be wary of it becoming the foundation for EHRs. Information Systems principles tell us that a solid foundation must first be laid. This includes getting the interconnectedness between the various systems done (whilst considering aspects such as POPIA) and then getting the related (medical) records appropriately positioned. In the past, other developing countries such as Tanzania have made massive investments in Health Information Systems, but issues relating to the adoption of integration resulted in resources being wasted (Smith et al., 2008). Considering that South Africa has a history of failed e-Government projects (Singh & Travica, 2018), the coupling of the current eHealth foundations and the EVDS needs to be analysed for current and future-readiness. In its haste, the DoH may have failed to adequately assess a key factor, which is the usability of the EVDS. The downstream applications of the EVDS as well as an assessment of whether it fully meets the DoH's eHealth aims are other areas that need further research.

9. Conclusions

The results of the study show that the key stakeholders supported the development of a digital system for the safe and secure storage of vaccination records for minors in Gauteng. The successful design of such a system is influenced by several factors. These factors (user friendliness, graphical design, practicality, user experience, and usability) were identified during this research and should drive the design and development of a digital vaccination records management system.

The DoH's response to the COVID-19 pandemic has accelerated the strides that South Africa is taking towards an EHR for all citizens. Vaccination records for minors (based on the EPI schedule), however, have still not made the same advances.

The reason could be that the move towards stages 4 and 5 of the eHealth model might require a more gradual approach as historic information needs to be considered.

Facets of prototypes such as e-Vaccination, working eHealth systems like the EVDS, and existing healthcare infrastructure should converge when considering the factors uncovered during this study as well as future research. If the usability of the system satisfies the key stakeholders, the chances of the system being used and the overall vision of the DoH being met will increase. To avoid wasteful expenditure, eHealth designers and policymakers should carefully consider the usability of applications that are being proposed for all key stakeholders.

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Appendix 1: Questionnaire

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		Govern-ment	

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					

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
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					

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
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					

Appendix 2: Scree plot of eigenvalues