COST-BENEFIT ANALYSIS OF AN ELECTRONIC MEDICAL RECORD SYSTEM IN AN EMERGENCY UNIT BASED PRIVATE PRACTICE IN SOUTH AFRICA

Natasha Banda

Student Number: 451468

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree:

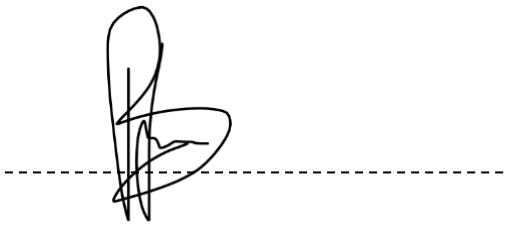
Master of Public Health (Health Economics)

Johannesburg, September 2025

Supervisor: Dr Evelyn Thsehla

DECLARATION

I, Natasha Banda, declare that this research report is my original work submitted for the Degree Master of Public Health (Focus of Study: Health Economics) at the University of the Witwatersrand, Johannesburg. There has not been any prior submission of this report to any other University for any other degrees.



(Signature of Candidate)

8th day of September 2025 in Johannesburg

To myself,

who was willing to step out of my comfort zone and pursue my passion.

ABSTRACT

Background

In South Africa, various electronic medical records systems (EMRS) have been implemented in both the private and public healthcare sectors. Currently, there is lack of evidence on the economic consequences of adopting EMRS in the South African context. The aim of this study is to estimate the cost-benefit of adopting EMRS in an emergency hospital setting in South Africa.

Methods

A retrospective cost benefit analysis was conducted to ascertain the economic consequences of EMRS use compared to a Paper-based Medical Records System (PMRS) in a private practice which runs 25 emergency units in South Africa. The EMRS was implemented in these emergency units from 2019. Out of the 25 emergency units currently being managed by the practice, 18 were identified to meet the study criteria and were thus selected as part of the sample. Cost data was collected from existing records and from interviews with experts where data was not available. Costs for the EMRS included development costs, hardware costs, installation costs, training costs, software costs, personnel costs, and printing costs. Costs for the PMRS included costs for stationery, storage space, transportation and personnel. The measured amounts were discounted by the expected interest rate and inflationary adjustments made using the consumer price index (CPI). The outcomes of interest were the net present value (NPV), benefit-cost ratio (BCR), and discounted payback period (DPP). The benefits included cost reductions after EMRS adoption. A time horizon from 2017 to 2024 was adopted for the analysis.

Results

Over the period 2018 to 2024, PMRS costs decreased by 85% from R2,868,554.60 (US$153,948.35) in 2018 to an estimated cost of R423,186.45 (US$22,711.39) in 2024. The total cost for the EMRS implementation and maintenance was estimated at R11,396,872.79 (US$611,642.45). From the start of implementation in 2019 till 2024, the total estimated cost savings for the study sample were R6,668,580.76 (US$357,886.51). A NPV of -R4,728,292.02 (-US$253,755.94) and a BCR of 0.59 were estimated. The DPP was approximately 6.97 years.

Conclusion

Even though the adoption of the EMRS resulted in reduction of PMRS costs, there was no positive cost-benefit with the EMRS intervention shown over the study period. Post-implementation, it is expected to take almost 7 years for the practice to breakeven with the EMRS intervention. Reducing EMRS costs and further reducing concurrent PMRS usage may potentially result in the intervention having positive economic returns and may shorten the time taken to breakeven.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr Evelyn Thsehla, for her guidance and support throughout this journey.

Thank you to my family; my father, Ernest, and my siblings, Natalie and Bradley. Most of all, I am so grateful to my mother, Grace. Thank you mom for being my biggest fan and pillar of strength.

I would also like to thank my closest and dearest friends; Denel, Amisha and Beuna. Thank you for always cheering me on.

Thank you to the team at the study site that assisted me with data retrieval. I am so grateful for your willingness to assist with the retrieval of data and answering any questions that I had.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

BCR	Benefit-Cost Ratio
CBA	Cost-Benefit Analysis
DPP	Discounted Pay-back Period
EHR	Electronic Health Records
EMR	Electronic Medical Records
EMRS	Electronic Medical Record System
HCP	Healthcare Provider
ICT	Information Communication and Technology
LMIC	Low and middle income countries
NDHS	National Digital Health Strategy
NHI	National Health Insurance
NPV	Net Present Value
PMR	Paper Medical Records
PMRS	Paper Medical Record System
ROI	Return on Investment
SARB	South African Reserve Bank
SARS	South Africa Revenue Service
Stats SA	Statistics South Africa
UPS	Uninterruptible Power Supplies

LIST OF FIGURES

CHAPTER THREE:

LIST OF TABLES

CHAPTER TWO:

CHAPTER THREE:

CHAPTER ONE - INTRODUCTION

1.1 Background

There has been a move towards the implementation of electronic medical record systems (EMRS) globally (1), with the World Health Organization endorsing the use of such health information systems, with the aim of improving health system efficiency and quality of patient care (2). EMRS have not only been implemented in high income countries but also in a number of low to middle income countries (LMICs) such as Malawi (3), Kenya (4) and Nepal (5), especially in HIV and TB care units ((6–8).

Traditionally, record-keeping in both the private and public health sectors has been paper-based. Many issues are associated with this paper-based record system, such as the need for storage facilities, susceptibility to damage and loss, illegibility, and difficulty sharing health information with relevant parties. Paper medical records (PMRs) do have their advantages, such as ease of use which makes them easy to implement and adopt. PMRs are also associated with low costs. PMRs are also not susceptible to system down times as with EMRS (9–12).

1.1.1 Electronic medical records

An electronic medical record (EMR) is a digital record of the patient's encounters with a healthcare facility. This record contains the patient's demographics, healthcare workers' clinical notes, diagnosis and treatment plan. EMRs facilitates the sharing of information among authorised healthcare providers in different locations (2,9,13). Although, often used interchangeably, an EMR differs from an electronic health record (EHR) in that an EMR is limited to a particular practice or healthcare facility unlike an EHR which is interoperable across various practices and healthcare facilities. EHRs allow for integration with multiple levels of care including laboratory, pharmacy and radiology. EHRs also allow patients access

to their health record and for greater patient engagement with their health. EMRs can be seen as a precursor to EHR (2,13).

1.1.2 The benefits of EMR

With EMRs, many of the issues related to PMRs, such as loss of records and illegibility, may be negated (9,12). A multitude of other benefits have been described in the literature. Menachemi and Collum (12) divide these benefits of EMRs into three categories; clinical, organisational and societal.

Clinical benefits relate to the effect of EMRs on quality of service and patient outcomes. Through using EMRs, medical records can be easily retrieved and also accessed remotely by healthcare providers. This can facilitate the sharing of medical information among healthcare providers resulting in improved service quality and continuity of care (14). With the addition of applications such as Clinical Decision Support systems, EMRs can result in improved quality of care through reduction of medical errors (12,15,16).

Organisational benefits relate to operational and financial outcomes such as cost reductions or savings and increased revenue. This can be through the elimination of costs related to the paper medical record system (PMRS) and by decreasing the number of redundant investigations, reducing hospital length of stay and reducing the number of adverse drug events (3,16–19). An example of improved operational efficiency was shown in a study conducted at a Kenyan teaching hospital. In the study, it was found that EMR implementation was associated with improved productivity due to ease of access to patient records with less time spent retrieving files (4,20). EMR may also put healthcare providers at a less vulnerable position when faced with medicolegal claims (12).

At a societal level, EMRS increase the ease of data collection with clinical data being more readily available and complete. This is beneficial from a monitoring and evaluation perspective (4,20), as this can help improve public health surveillance and assist with future healthcare planning. Additionally, EMRs can act as a repository of data that can facilitate research (12).

Although EMRs may seem to be superior to PMRs, EMRs are not free of drawbacks.

1.1.3 The drawbacks of EMR

The high cost of EMR implementation, which includes hardware, software, training, project management, and high maintenance costs, is one of the biggest drawbacks of EMRS (2,12,16). With time, hardware will need to be replaced and software upgraded which further adds to these costs. These high costs have a negative impact on adoption and successful implementation of EMRS (12). Greater investment may be required in LMICs where there is a lack of infrastructure, and information communication and technology (ICT) expertise. Another factor to consider is that in LMICs, there is often an issue of no persistent and reliable electricity provision, and energy alternatives may need to be invested in with the implementation of EMRS which can be costly (2).

Other negative consequences of EMRS that have been described in some studies include reduction in productivity, especially during the early stages of implementation as staff are trying to navigate through the new system and going through training (21,22). To mitigate the increase in time spent on data entry by healthcare providers post EMR implementation, medical transcriptionists have been employed to assist with inputting medical notes onto the EMRS in some instances (23). This however, results in additional costs incurred for the EMRS implementation.

Loss of productivity can be further exacerbated in instances whereby the EMRS is developed without extensive consultation with the future users of the EMRS. This can lead to the users struggling to the navigate the system and may lead to data entry consuming too much of the healthcare providers' (HCPs) time thus taking away from the doctor-patient interaction (24). In some instances, poorly designed interfaces may result in medical errors (12).

Findings from a systematic review looking at the impact of EMR implementation on documentation times, support that there is an increase in documentation time by clinicians associated with EMR implementation. The review found the increase is more so when there is a mix of the PMRS and EMRS being used. However, when EMRS is fully utilised and not mixed with PMRS use, it was found that the documentation time did not significantly increase (22).

Other EMRS issues relate to concerns over security of patient data which may be compromised through data breaches. Stringent regulations regarding security and access controls are required to mitigate this (12).

1.1.4 EMR in South Africa

There has been a move towards the establishment of EMRS at a national policy level in South Africa, with the National Digital Health Strategy (NDHS) promoting the establishment of an interoperable EMRS in the South African public healthcare sector (25). PMRS, however, still dominate in the public sector. Studies have shown that the current use of the PMRS in South Africa has negative consequences such as the lack of adequate storage space, misfiling, missing files and time lost to retrieving files (11,26). Missing files result in investigations being repeated unnecessarily and negatively affects patient follow up care, resulting in treatment delays and in additional costs incurred by the healthcare system. This ultimately impacts negatively on productivity, efficiency and quality of patient care (11,26).

Various EMRS from a variety of vendors have been implemented in both the private and public health care sectors in South Africa. In the Western Cape province, interoperable EMRS have been implemented in the public sector at both the primary level and hospital level. However, PMRS are still used concurrently with EMRS (27). This is due to multiple factors such as low rates of computer literacy, and limited network capacity and stability (28).

Nationally, EMRs are being phased in at primary level for HIV and TB management through the Three Interlinked Electronic Registers (TIER.Net) Project. It is a phased approach for moving from a PMRS to a EMRS in public healthcare facilities with the main focus currently being HIV and TB care. The goal is to expand this system to include other chronic disease management and antenatal care (8).

Most recently, representatives from the largest hospital in South Africa, have announced that they plan to move from PMRS to EMRS (29). In the private sector, many practices are moving towards EMRs with one of the largest private hospital groups in the country having fully implemented an EMRS (30). With the plan to implement a National Health Insurance (NHI) system in South Africa, having an interoperable EMRS in place would support the function of the NHI system by ensuring continuity of care, improving the ease of data collection, improving billing and provider claims processes (25,31). In addition, long term, the use of EMR can potentially lead to cost savings for the NHI fund (12).

However, like in other LMICs, South Africa faces issues of frequent power cuts and lack of infrastructure especially in rural settings (8,32). The NDHS acknowledges the need for investment in infrastructure, and in building ICT capacity and expertise in the country for such digital health projects such as EMRs to succeed (25,32). Investment in EMRS may be a very costly endeavour for the country.

1.2 Literature Review

Despite cost being a significant barrier to EMRS implementation (33,34), long-term return on investment (ROI) has been demonstrated in settings like China and Malawi (3,17). Globally, there are few economic evaluations of EMRS, with the majority based in the United States. A 2012 scoping review found only seven economic evaluations of EMRS, only one of which was a cost-benefit analysis (CBA) (35). While a handful of subsequent studies have emerged from other regions, including South Korea, China and Malawi (3,17,23), a significant evidence gap persists, particularly in LMIC contexts. The literature is dominated by model-based analyses from high-income countries (17,31,37) which limits generalisability. While one cannot deny the value of these studies, their models often rely on secondary data and assumptions that may not hold in a different healthcare ecosystem. The reliance on single-site studies, often conducted within a single hospital (3,17,23), also limits the generalisability of the findings and may introduce site-specific biases into the results.

1.2.1 Approach

Previous CBA studies have mostly taken the perspective of the provider with the study settings ranging from primary care (31,33) to hospital settings (17,23). This choice of using a provider perspective in these CBAs creates a limitation as benefits incurred by other relevant parties, such as the patient or third party payers, are often excluded from the analysis (12). In most of the CBA studies, a model-based approach was used (17,31,33,34). Wang et al (31) and Li et al (17) have used a mix of primary data, secondary data and expert opinion for their models, whilst Kumar and Bauer (34) have used secondary data. In contrast, Choi et al (23) conducted a retrospective primary study at a tertiary hospital in South Korea in order to assess the real-life economic consequences of EMR implementation. CBA's done retrospectively, that is after

the EMR intervention has already been decided upon and implemented, are valuable in that they can inform policy makers and healthcare providers on the expected costs and benefits of EMR thus helping in future decision-making. The information gained from these retrospective CBAs can also help inform future prospective CBAs (35).

1.2.2 Costs

In their scoping review, Bassi and Lau (36) outline the input cost items for EMRS. These range from hardware and software to personnel and IT support. Previous CBA studies have put costs into two categories; direct costs of the EMRS, and induced costs (17,23,31,34). The direct EMRS costs can be further subdivided into one time or implementation costs, and ongoing or maintenance costs (17,23,36). Implementation costs include the purchase of hardware, software development costs, purchase of software licences, training and the installation costs. Maintenance costs include subscriptions costs, ongoing training, IT support and salaries (7,17,23,36). Induced costs refer to costs that were incurred as a result of the EMRS being in place, such as the scanning of paper records onto the EMRS and the hiring of transcribers (23). Some induced costs, such as the ongoing scanning of paper records noted by Choi et al. (23), are frequently underreported in literature.

In their study based at a South Korean tertiary care hospital, Choi et al (23), found personnel costs associated with the EMRS implementation made up majority of the costs at 53.6% followed by EMR applications and system infrastructure costs. The high personnel costs were similar to a Ugandan cost analysis that found that personnel costs were the greatest cost drivers for EMRS implementation at an urban clinic, making up about 70% of costs in the study (7). This finding may not translate to other contexts that rely more on outsourced services or different staffing models.

1.2.3 Benefits

As with the costs, benefits have been traditionally split into two categories; increased revenue and averted costs, with non-monetisable outcomes, such as improved care coordination, communication, and patient satisfaction, often excluded from the analyses (17,23,31,34). Increased revenue is described to be due to improved billing processes and/or productivity due to EMRS (31,34). Wang et al (31) describe a potential decrease in billing errors by 78%. In their study , Choi et al (23), found the sources of increased revenue where from the remodelling of former PMR storage spaces to clinical rooms that could be used to see additional patients. The use of medical transcribers although costly, helped increase revenue by increasing the number of patients seen per doctor (23).

Averted costs are described to be due to reduction in investigations, and the reduction of the costs associated with the PMRS such as storage space, paper charts and stationery (17,23,31). Wang et al (31) found that averted costs where from reduction of time spent on file retrieval, transcription and refiling. Other financial benefits were from a reduction in utilisation from a decrease in laboratory and radiology tests, and a decrease in adverse drug events (31).

In keeping with the Wang et al (31), in their CBA Li et al (17) found cost savings were also from a reduction in adverse drug events and reduction in billing errors. Another area of cost saving mentioned in their study was the reduction in the number of full-time equivalent employees which was a similar finding in Choi et al's study (23). An area of cost savings common to all studies was the cost reduction from the operational costs from the old paper-chart system. This included a decrease in paper chart pulls, stationery supplies and storage facility requirements (12,23,31). In a fee-for-service system, some of the benefits such as a reduction in investigations performed or reduction in hospital stay may actually translate to

cost savings for third-party payers and patients rather than the provider who has invested in the EMRS (12).

1.2.4 Time horizon

The time horizon used in CBA studies varies. Kumar and Bauer (34) used a five-year time horizon based on the useful life of hardware. The 8-year time horizon employed by Choi et al. (23) was chosen to encompass both the 3-year phased implementation of the EMR system and a subsequent 5-year period for a comprehensive assessment of its full economic impact post-implementation.(23)(23)

1.2.5 Outcomes of interest

Net present value (NPV) is one the outcomes of interest in previous CBA studies (3,23,34). NPV is a way to assess the profitability of the intervention. This is done by assessing the total present values of the net income over a certain time period compared to the value of the initial investment. A positive NPV indicates that the intervention is profitable. A negative NPV indicates that the intervention's costs outweigh the cash inflows hence not profitable (37). Choi et al (23), as well as Kumar and Bauer (34), all report positive net present values in their analyses.

Net benefit is another outcome of interest in EMR CBA studies (3,17,31). Net benefit assesses the difference between the total benefits and total costs. Similar to net present value, a positive net benefit indicates that the benefits outweigh the costs and suggests that the intervention is worth implementing. A negative net benefit indicates the costs outweigh the benefits and the intervention should not be implemented (35). Li et al (17) report a positive net benefit of US$559 025 for the EMRS at a general hospital in China over a 6 year period. Wang et al (31) and Driessen et al (3) also estimated a positive net benefit in their analyses.

Benefit-cost ratio (BCR) is used in some of the studies as an outcome of interest. A BCR greater than 1 suggests that the intervention is cost effective and the BCR less than one indicates that the intervention is not cost effective (35). Choi et al (23) found the BCR to be 1.23 in their CBA.

Discounted pay-back period (DPP) is another outcome of interest in CBA studies. DPP is the time that it takes for the cumulative cash flows in the form of net present values, to equal the initial investment value. A short DPP indicates that the initial investment cost can be recovered much sooner that when there is a long DPP (37). In their study, Choi et al (23), found the DPP to be 6.18 years. Some studies have used time to ROI in place of DPP (17). Although, DPP and time to ROI are similar, the later does not usually account for the time value of cash flows. Li et al (17) found the time to ROI was 3 years, with 5.38 years being the most pessimistic value from their model.

1.2.6 Economic evaluation of EMRS in the African context

Only a ROI modelling study (3) and a cost analysis study (7) were identified to have been done in the African context, with no economic evaluations of EMRS done in South Africa found.

A cost analysis of EMRs conducted at a Ugandan HIV Clinic using mostly primary data from the clinic looked at the costs of the implemented EMRS, the costs of the PMRS and the costs of an open-source EMRS as an alternative. Over the period from 2009 to 2016, the direct costs of the EMRS amounted to US$1 066 965 and the costs of the PMRS were estimated to be about half that of the EMRS. The study did show that over time, the EMRS costs followed a downward trend (7). The only economic evaluation found from an African context by Driessen et al (3), showed that EMRS resulted in significant cost savings with the break-even point being reached in the third year of use. The authors used a model with a 5-year time horizon for their

analysis and a combination of primary data from a hospital in Malawi and secondary data from other studies from various contexts, was used (3).

Most of the previous CBA studies have been conducted in high-income settings. The contextual differences between high-income countries and LMICs need to be taken into account in the decision-making process. Low computer literacy rates, inconsistent electricity supply and lack of infrastructure may render EMRS not cost effective in such contexts (2,3).

1.3 Problem Statement

In South Africa there are various EMRS that have been implemented in both the private and public healthcare sectors (27,38). However, there is a lack in studies assessing the economic consequences EMRS use. There is little evidence to show that EMRS are economically beneficial in the South African context.

1.4 Justification

There is a dearth of EMRS costing studies and economic evaluations in the South African context. With a move towards expanding EMRS across the healthcare sector at a national policy level (25), there is a need for economic evaluations of EMRS, particularly in the South African context, to further guide policymakers.

This study aims to inform policymakers on the costs associated with EMRS and how these costs may potentially be offset by the associated benefits. The aim is to answer the question of whether EMRS are an economically viable option in South Africa. The data from this study can also assist in providing data for future EMR CBA or cost-effectiveness studies.

1.5 Research question, study aim and objectives

1.5.1 Research Question

What are the economic effects of an EMRS in a private emergency unit setting in South Africa?

1.5.2 Aim

To estimate the economic effects of an EMRS, using a CBA, in a private emergency unit setting in South Africa?

1.5.3 Objectives

1. To estimate the direct and indirect costs of the paper-based records system in a private emergency unit setting.

2. To estimate the direct and indirect costs of the implementation and maintenance of EMRS in a private emergency unit setting.

3. To estimate the benefits, in monetary terms, of the implementation and maintenance of EMRS in a private emergency unit setting.

4. To evaluate the economic effects of the implementation and maintenance EMRS compared to PMRS in a private emergency unit setting.

CHAPTER TWO – METHODS

2.1 Introduction

This chapter describes the steps undertaken to estimate the economic effects of an EMR implementation and maintenance in a private medical practice. The approach taken to explore the economic effects was a retrospective cost benefit analysis. Primary data collection was performed at the study site and where data was not available, data was obtained from grey literature and expert opinion. A mixed methodology approach was used for the cost analysis. This included both top-down and a bottom-up microcosting depending on the quality of data available (39,40). This chapter will provide a description of the study setting, sampling methods used, data collection processes, analysis techniques and the rationale behind the steps undertaken.

2.2 Study design

A private medical practice which currently runs 25 emergency units in private hospitals across South Africa was the site of this study. The head office of the practice is based in Johannesburg. Over 400 HCPs including doctors and clinical associates, are employed by the practice on a permanent and locum basis. The HCPs provide care to patients consulting at emergency units based at various private hospitals. On average, the practice as a whole was reported to consult approximately 40000 patients per month. Similar to Choi et al's (23) study setting, the practice implemented an EMRS in phases over a period of time. Two units were used as pilot sites in 2018. Full EMRS implementation then began in April 2019 and by September 2021 all units were using the EMRS. The study site was selected because it is a medical practice of considerable size with units at multiple locations across the country and the EMRS has been fully implemented across all units under the practice for a fairly considerable amount of time. Using such a study site to explore the economic consequences of EMR, may offer insights on the effects of EMR use at scale.

A retrospective CBA was conducted to ascertain the economic consequences of EMR use compared to PMR use in the above mentioned medical practice. Similar to prior studies (17,23,31), the study took the perspective of the provider, which was the fee-for service emergency unit based private practice in this case. A purposive sampling technique was used whereby, of the 25 units run by the practice, only the units that have been consistently run by the practice from January 2018 to July 2024 were included in the sample. This was to capture units that have been part of the EMR implementation and maintenance process (from 2019 till 2024) and to use the year prior to implementation (2018) as a base case. The rationale behind this was to eliminate potential confounding factors and to be able to make a more accurate comparison between the pre-EMR implementation phase and the post implementation phase. The two units that were used as pilot sites, were not included in the sample, as they did not fulfil the criteria above. Out of the total 25 units, 18 units were selected as part of the sample for the study. The target population was all patients, employees and managers of the practice who were affected by this intervention (25).

The EMRS used by the HCPs and administrators employed by the practice was the intervention of interest. The EMRS is a recordkeeping system that allows for HCPs to make clinical notes and other medical documentation such as prescriptions, sick notes and referral letters, on the electronic system. The EMRS also has some clinical decision support functionality. The notes made on the EMRS are stored on a cloud-based system. This means the records are accessible at different locations and by different practitioners. This allows for the HCP to easily access the patient's medical history when a patient comes back to one of the emergency units or goes to a different unit that is managed by the same medical practice. The HCPs print out the necessary medical documents to give to the patient at the end of the consultation process. This

is however has been changing, with some units now emailing the medical documents to the patient instead of printing.

Prior to the start of EMR implementation, the practice administrators already used an electronic system for billing and claims processes. In 2017, the practice began a collaborative process with the vendor providing the electronic billing system already in use at the practice. This was done with aim of creating an EMRS that would integrate the processes of recordkeeping by the HCPs with the billing and claims system that was already used by the administrators. Due to recurrent power outages, uninterruptible power supplies (UPS) were installed at each unit and at the head office in 2022 to provide back-up power.

The PMRS which was mainly used before the implementation of the EMRS was the comparator in the study. The PMRS made use of preprinted stationery which was ordered and purchased centrally at the head office. The preprinted stationery consisted of sick note pads, prescription note pads and books that the HCPs would make their notes in. The books allowed notes to be made in triplicates. The one copy was taken out of the book and given to the patient. The second copy was taken out and given to the unit administrator for billing. The third, which was the original, was kept in the book. The used books were sent back to the head office based in Johannesburg for storage.

The preprinted stationery was mainly transported to the different units via traditional courier companies. However, alternative transportation such as ride-hailing companies such as Uber have been occasionally used for transport to units within Johannesburg as the costs are not weight based as with traditional courier companies. Another alternative mode of transportation was having staff members who are travelling between the head office and the units to also

transport the stationery in the process. The medical records contained in the books were eventually scanned and stored on a cloud-based storage (SharePoint®). Thereafter, the PMRs were then shredded and sent for recycling. Post EMRS implementation, the PMRS was used concurrently with the EMRS at the practice. Even at the time of the study, the PMRS was still used although to a much lesser extent.

The time horizon used for the CBA was from 2017 to 2024. This was to capture all the associated costs and benefits of the EMRS (38). Three phases were identified in relation to the EMRS cycle; the development phase of the EMRS (2017 to 2018), the implementation phase (2019 to 2021), and the maintenance phase (2022 to 2024).

2.3 Data collection methods

Retrospective quantitative primary data was collected from the records of the practice. Data from 2017 to mid 2024 was collected. For instances where the data was not available, secondary data was used and/or obtained through a consultative process with various staff members.

The process of data collection included first identification of cost centres followed by identification of the resources that fall under each cost centre. After identifying the type and quantity of resources required, the cost data was collected and assigned to each resource. Cost and benefit data was collected using a data collection tool created by the researcher based on literature which has identified the relevant cost and benefit categories. The data collection tool is attached under Appendix 2.

2.3.1 Costs for PMRS

The first step undertaken was to gain an understanding of the PMRS that was previously predominantly used in the practice. This was done through a consultative process with staff members from various departments. These staff members included doctors, administrators, managers and executives. Through this process the PMRS related cost centres were identified. The resources that fall under each cost centre were then identified. Costs for the different cost centres were then collected.

Preprinted Stationery costs

Previous order requests and invoices were provided by the logistics department. These were used to acquire data on quantities that have been ordered by the practice and to also obtain the unit prices of the items. Data was also extracted from the financial accounts. To understand the number of preprinted stationery that was used, data on number of used books returned to the head office for storage was also acquired from the logistics department.

Transport costs

The logistics manager provided insight on which transport methods were used by the practice. Old courier invoices obtained from the logistics department were used to ascertain the costs of transporting preprinted stationery to and from the units.

Document management costs

The number of medical records scanned per year were acquired by looking at the scanned uploads on the computer and correlating to the date of upload. Consultation with the employee responsible for the management of the PMRs at the head office was done to estimate total time spent on document management. An estimate of the employee cost to company was provided by the operations executive.

Storage space costs

To ascertain the amount of storage space used for the storage of PMR over the period of interest, the researcher consulted the document manager who oversees the storage space. The dimensions of the storage rooms were measured by the researcher. As the storage rooms are included as part of the general office space rental fee, online sources were then used to estimate the storage costs per square metre in the area.

2.3.2 Cost for EMRS

Various staff members who were involved in the EMR project at the practice were consulted to gain insight on the EMRS and identify cost centres. This included the IT manager, implementation manager and operations executive. After identification of the relevant resources, cost data for the resources was collected.

Implementation costs

Development costs

The former EMR implementation manager provided insight on the EMRS development process. Together with the operations executive, they provided the estimate costs for the EMR development.

Hardware costs

The types and number of hardware at each unit were identified using two asset lists obtained from the IT department,. Where there were discrepancies between the two lists, the IT manager's opinion was used. The final asset list generated was used to extract the cost of the

hardware from the financial accounts. The useful life years of the hardware was obtained from a combination of WHO-CHOICE data (39–41), the manufacturer and expert opinion.

Installation costs

Cost estimates for the installation of hardware, software and internet connectivity were determined through a consultative process with the operations executive.

Training costs

The former EMR implementation manager provided insight to how the initial EMR training was done and how it has changed over time. The operations executive provided estimates on the travel costs associated with the training process as well as the direct training costs.

Maintenance costs

Software costs

The various types of software in use were identified through consultation with the IT manager and reviewing the invoices from the supplier. The costs for the software programmes were extracted from invoices.

Personnel costs

The operations executive provided information regarding which staff members were hired for the EMR development, implementation and maintenance. They also provided estimates of the cost to company for the employees hired.

Printing costs

The data on printing costs were obtained from invoices from the vendor and through consultation with the IT manager.

Developer maintenance costs

For the continued use of the EMRS, the practice paid a monthly fee to the developer of the EMRS platform. The cost estimate for the developer maintenance cost was provided by the operations executive.

2.3.3 Benefits for EMRS

Through discussions with the management team and reviewing the cost trends from the PMRS data collected above, areas of cost saving were identified.

2.3.4 Other data

Patient volume data for each unit was obtained from previous utilisation reports from the operations division. The inflation rate was obtained from Statistics South Africa (Stats SA) (42). The discount rate was based on the current repo rate which was obtained from the South African Reserve Bank (SARB) (43). Currency conversions from South African Rands to US Dollars were done using an annual average that was calculated based on the average monthly 2024 exchange rates sourced from the South African Revenue Service (SARS) (44).

The table below shows the input variables for each objective and the source of data collected for the variable.

Table 2.1 Input variables and their sources

Variable	Costing Method	Average Unit Cost (Range)*		Data Source
Objective 1		*Intervention case*	*Base case***	
PMRS Costs:				
Preprinted stationery	Top-down	R1.58 per patient (R0.35-R3.39)	R2.58 per patient	Old quotations from Logistics, Financial accounts
Storage	Bottom-up	R1,093.33 per square metre	R1,093.33 per square metre	Expert opinion, Online quotations
Transportation	Top-down	R2.18 per patient (R0.24 – R4.49)	R5.03 per patient	Old invoices from Logistics department
Document management:	Bottom-up			
Document manager rate		R128.21 per hour	R128.21 per hour	Expert opinion
Time per scan		0.02 hours	0.02 hours	Expert opinion, Observation

Objective 2			
EMR Direct Costs:			
Development	Top-down	R3,135,823.80 per practice	Expert opinion, Financial reports
Hardware	Bottom-up		IT asset list, Financial accounts, Expert opinion
Computer		R 13,179.86 (R9,236.63 - R17,014.66)	
Laptop		R5,330.63 (R5,550.81 - R6,119.77)	
Switch		R 2,168.36 (R863.84 - R3,472.88)	
Router		R3,341.43	
Software	Top-down	R 59,933.90 per year for each EU	Invoices, Expert opinion
Personnel:			
Implementation manager	Bottom-up	R45,000 per month	Expert opinion
Training:			
Staff training	Top-down	R158,258.91	Expert opinion
Travel & accommodation	Top-down	R31,428.57 per EU	Expert opinion

Developer maintenance	Top-down	R 4,800.00 per EU per year	Expert opinion
Installation	Top-down	R8,064.52 per unit	Expert opinion
EMR Induced Costs:			
UPS	Bottom-up	R 1,383.64	IT asset list, Financial accounts
Printing	Bottom-up	R 494.80 per month for each EU (R202.50 – 1,012.80)	IT records, Financial accounts

Objective 3			
Benefits:	Difference between PMRS annual costs in intervention arm and base case.		
Averted costs			
Preprinted stationery			Old quotations from Logistics, Financial accounts
Storage space			Expert opinion, Online quotations
Transportation			Old invoices from Logistics department
Document management			Scanning upload record on PC, Expert opinion

Discount rate (2024)	8%	South African Reserve Bank
Inflation rate (2024)	5%	Statistics South Africa
Exchange rate (2024)	R18.63 to 1US Dollar	South African Revenue Services

*Cost range dependent on the year of purchase, vendor used, service level agreement and brand of product. **Base case costs based on 2018 (pre-EMR intervention) costs.
EU – Emergency unit

2.4 Data Management

Data was collected and input directly onto a Microsoft Excel (Office 365) spreadsheet on the researcher's personal laptop that is password protected. The researcher ensured that all relevant data is depersonalized. Analyses and modelling was done in Microsoft Excel (Office 365). The data was shared with only the supervisor during the research process. The data will be stored for 3 years after completion of research and thereafter will be deleted from storage.

2.5 Ethical Considerations

The private practice's executive board granted permission for the researcher to collect and use the practice's data for this study. The ethics clearance was granted by the University of the Witwatersrand Human Research Ethics Committee; reference number W-MvN-240214-01 (Appendix 5).

2.6 Data Analysis

All analyses were done in Microsoft Excel. A mixed methodology approach was used for the cost analysis (40). The costing method used for a particular variable was dependent on the data available. In general a micro-costing approach was used as this a more precise method for estimating costs. Furthermore, depending on the type of data available, either a bottom up or a top down approach was used. When only aggregated costs, were available, a top-down approach was used whereby the aggregated costs are converted to cost per patient based on utilisation data collected. When unit costs and utilisation data were available, a bottom up approach was used (39,40).

The analysis excluded costs for resources shared by both the PMRS and EMRS to focus solely on the incremental costs of implementation. Excluded common costs encompassed:

- Administrative staff whose roles encompassed both systems (e.g., practice managers, general IT support not dedicated to the EMRS).

- Pre-existing infrastructure (internet, foundational billing hardware).
- The document scanner, as it was required for the persistent paper system and was not a new cost of the EMRS.

This method aligns with incremental cost analysis, which aims to identify the additional costs and savings directly attributable to the new intervention.

Costs are reported in 2024 South African Rands and US Dollars. Currency conversions of South African Rands to US Dollars were done using the average annual 2024 exchange rate of R18.63 per US dollar obtained using date from SARS (44). Inflationary adjustments were made for costs obtained from previous years using the 2024 mid-year Consumer Price Index of 5% obtained from Statistics South Africa (42). It was assumed that all costs are incurred at the end of the year.

To adjust for inflation for costs incurred in previous years, the following formula was used:

$$Present\ value\ in\ 2024 = Cost\ in\ year\ n \times (1 + inflation\ rate)^{2024-n} \quad (35,37)$$

To convert costs that occur after 2024 to the present value, the following equation was used:

$$Present\ value = Costs\ in\ year\ n \div (1 + discount\ rate)^{n-2024} \quad (35,37)$$

Where *n* denotes the year of interest.

Capital costs of resources with a useful life of more than one year were annualised using the equations below. The annuity factor was calculated based on the discount rate of 8% obtained from the SARB (43).

- Annuity factor = $\frac{1-(1+\text{discount rate})^{-x}}{\text{discount rate}}$ (35,37,40)

  Where x is the useful life of the asset.

- Annualized capital cost = Capital cost ÷ Annuity factor *(37)*

For EMRS maintenance costs, pro-rata costs were calculated for the first year of EMR use based on when each unit commenced using the EMRS.

2.6.1 Estimating PMRS Costs:

Preprinted Stationery costs

A top down approach was undertaken to estimate to costs for preprinted stationery as the most complete costs which were obtained from the financial accounts were aggregated costs. The yearly preprinted stationery costs per patient were calculated using the following equation:

Cost per patient = Total preprinted stationery cost ÷ Total patient count for practice

To get the preprinted stationery cost per unit, the cost per patient was multiplied by the patient count for the unit. The sum for the units in the sample was calculated to get to total annual cost of preprinted stationery (40).

Transport costs

Due to inadequate and missing data, a simple linear regression model was used to estimate annual transport costs using the invoices acquired from the logistics department. Although multiple regression models with multivariate predictors were tested, the highest coefficient for the variable of interest was observed in a simple linear regression model. The independent variable used for the model was the number of used books returned to head office per year. This independent variable was chosen as it was thought to give a more accurate picture of preprinted stationery utilization and had the greatest the correlation coefficient. The equation for the line of best fit from the regression model is as follows:

$$y = 0.2667x - 1168.1$$

Where y is the courier costs to transport preprinted stationery to the units i.e. transfer out costs and x is the number of used books returned to the head office from the units. The output results of the regression model are found in Appendix 3. For the estimation courier costs for the return of PMRs to the head office, the ratio of the return costs to the transfer out costs was calculated using the invoices available. Return costs were estimated to be 76.57% of transfer out. Total estimated transport costs were the sum of the return costs and transfer out costs. For the model, it was assumed that the only mode of transportation used was the courier method.

Document management costs

The employee that was responsible for document management had more than one job title and had other responsibilities beyond document management. Therefore, the number of scan uploads per year was used to estimate the amount of time spent of document management. Based on the number of total patients seen in the practice and the total number of scans

performed per year for the entire practice, the researcher estimated the number of scans per patient for each year. The number of scan per year was multiplied by the total number of patients seen for the sample units to ascertain the total number of scans for the sample. Using the estimated time taken per book for extraction, scanning and disposal, the time spent per page was calculated. It was assumed that each book had the complete set of 40 pages scanned. The following equations were used to estimate to document management related personnel costs:

Total time spent on document management = Number of scans per year x Time spent per page

Annual personnel cost = Total time spent on document management per year x Hourly wage rate

The cost of the scanner was not included as due to the continued use of PMRs, the cost of the scanner was common to both pre and post EMR implementation.

Storage costs

Online quotations for storage spaces in the area were used to estimate the cost per square metre. Using the average unit cost estimates and the estimates on the amount of the storage space in square metres dedicated to PMR from 2018 to 2024, the annual valuation of the storage space was calculated.

Total storage cost per year = Cost per square metre x Average square metres used for PMR per year

2.6.2 Estimating EMRS Costs:

Development costs

Total aggregated development costs were used in the analysis. This is because these costs were incurred at the practice level, not at the unit level and thus were not dependent on the number of units.

Hardware costs

Bottom-up costing was done to estimate the cost of hardware. Items and their quantities which fall under the hardware category were first identified. Thereafter, the unit cost data was collected. From this data, the value of the hardware was calculated. The capital costs were then annualized. As per WHO-CHOICE recommendations, a maintenance cost of 5% of the annual hardware costs was included in the total hardware costs (40,41).

The standard IT equipment required for any unit is as follows:

- 2 x Personal Computers (one for Administrator and one for the HCP)
- 2 x Printer (one for Administrator and one for HCP)
- 1 x Fibre Router with dual functionality (fibre + 3G/5G)
- 1 x Switch
- 1 x Router Cabinet
- 2 x UPS (one for Administrator and one for HCP)

This is the minimal requirement but the amount required can differ depending on the size of the unit, number of HCPs working at the unit and the patient count. For this analysis, only additional hardware that was purchased for the use of EMR by the HCPs were considered. It was confirmed by an expert in the IT department that hardware used by the administrators was already in use before EMR implementation.

Installation costs

Using the aggregated installation cost and the total number of units under the practice that have required installation, the average installation cost per unit was calculated. This cost per unit was used to calculate the cost of installation for the sample.

Training costs

For the training related travel and accommodation costs, the average costs per unit were calculated based on the aggregated cost and number of units were training occurred. This was used to calculate the related costs for the units which are part of the sample. For staff training direct costs, cost per unit was not used due to the shared HCP pool that allows for HCPs to work across the various units. Instead, the aggregated cost was used in the analysis.

Software costs

Due to the presence of existing software prior to EMR implementation, incremental costs were used to ascertain the cost of EMR related software. Incremental costs were first calculated by using 2024 costs, when all units are using EMR and 2018 costs when all units are using PMR. Inflationary adjustments were made for the 2018 costs. It was assumed the cost difference was due to EMR. This assumption was supported by an expert from the operations department. Top-down costing was used whereby the total shared software costs are divided by total number of units to estimate cost per unit.

Personnel Costs

As with the development costs, the personnel costs were incurred at a practice level and not dependent on number of units. Therefore, the aggregated personnel costs were used in the analysis.

Developer maintenance costs

These costs constitute the use of the EMRS, system updates and support. Using the 2024 monthly fee paid by the practice to the developer and the total number of units, the annual cost per unit was derived. This was then used to estimate to annual developer costs for the sample. It was confirmed by the IT manager that besides the annual inflationary increases, these costs had not increased significantly in the last five years. The maintenance costs are charged depending on the number of units.

Other

Electricity costs were mostly incurred by the private hospitals were the emergency units were situated rather than the practice itself hence were not included in this analysis.

2.6.3 Estimating Benefits:

Non-financial outcomes such as clinical outcomes were not considered in the analysis. The benefits included in the analysis are the costs averted from the reduction in the operation costs of the PMRS. Hence, the benefits were only accrued from 2019 when EMR implementation began. The 2018 cost per patient for the PMRS was calculated and treated as the baseline measure of the paper-based system's underlying performance. Subsequently, for each year from 2019 to 2024, the 'no-EMR' base case cost was recalculated by applying this 2018 per-patient cost to the actual patient volumes in those years, as described by the formula:

$$\text{Base Case Cost}_t = (\text{PMRS Cost}_{2018} / \text{Patient Volume}_{2018}) \times \text{Patient Volume}_t$$

This approach ensured that the baseline costs accurately reflected what the PMRS expenses would have been each year based on patient volumes, had the EMRS not been introduced. The

resulting cost savings were then estimated as the difference between this volume-adjusted baseline and the observed costs in the intervention arm. Thus, this method isolates the improvements attributable specifically to the EMRS by controlling for variation in patient volume and other external factors, ensuring that the measured benefits represent true gains in system performance.

Due to a lack of practice-specific data on claim rejection rates, the impact of the EMRS on billing efficiency could not be quantified. Insights from a billing department supervisor indicated minimal perceived improvement, attributed primarily to user errors in data entry. Consequently, this potential benefit category was excluded from the analysis, a decision consistent with other retrospective studies such as Choi et al. Furthermore, benefits related to clinical quality, which primarily accrue to patients and funders rather than the provider, were also outside the scope of this provider-perspective analysis.

2.6.4 Estimation of 2024 data

Patient utilisation data and cost data for the first few months of 2024 was collected and used in the analysis. This data was used to extrapolate the 2024 annual data by using the monthly averages.

2.6.5 Cost Benefit Analysis

A cost benefit analysis was conducted using the outputs from objective 1, 2 and 3. The outcomes of interest in this analysis were Net Present Value (NPV), Benefit-cost Ratio (BCR) and Discounted Pay-Back Period (DPP).

$$NPV = \sum (Present\ value\ of\ benefits\ in\ year\ n - Present\ value\ of\ costs\ in\ year\ n \quad (46,47)$$

$$BCR = \frac{\Sigma\ Present\ Value\ of\ Benefits}{\Sigma\ Present\ Value\ of\ Costs} \quad (35)$$

$$DPP = Last\ year\ with\ negative\ cumulative\ net\ cash\ flows + \frac{Absolute\ value\ of\ CNCF\ in\ that\ year}{Total\ cash\ flow\ in\ the\ following\ year}$$

(37,48)

To estimate future costs and benefits in order to calculate the DPP, it was assumed that the EMRS costs had reached a plateau based on the historical data from 2022 to 2024. For the benefits data, the average percentage increase in cost savings was calculated based in the percentage change for the maintenance years (2022, 2023 and 2024). This was then used to estimate the annual increase in cost savings beyond 2024. The assumption that benefits will continue to grow at the stated historical average rate is grounded in expectations of further system optimisation and increased EMRS uptake, leading to additional reductions in residual PMRS costs. This projected trajectory was validated through consultation with the practice's Operations Executive, who at the time, did not anticipate significant new cost drivers but expected continued efficiency gains.

2.6.6 Sensitivity Analysis:

Due to the use of cost estimates, sensitivity analysis was performed to assess parametric uncertainty. Univariate and bivariate deterministic analysis was performed which involved varying input parameters to ascertain their effect on the outputs of interest (17,31). The results for the univariate sensitivity analysis are presented in the form of a tornado diagram.

The parameter ranges for the one-way sensitivity analysis were informed by established practices in the health economic literature; for instance, Li *et al*. (17) employed comparable ranges for savings variables, derived from expert panel discussions. The selected range for the discount rate was determined by analysing historical fluctuations in the South African Reserve Bank's repo rate over the preceding five-year period, with a similar rationale applied to the inflation rate (42,43).

2.6.7 Scenario Analysis:

As there is still concurrent use of the old PMRS within the practice, scenario analyses were done to assess the impact of different degrees of PMRS use on the outcomes (NPV, BCR and DPP). PMRS costs were varied to 50%, 75% and 100% reduction compared to the current case in the maintenance years (2022 and beyond). It was assumed that reduction in the main variable (preprinted stationery costs), would result in a proportional reduction in the associated variables (i.e. transport, scanning and storage costs). Hence for the scenario analyses, all components of the PMRS were varied depending on the reduction factor.

According to an EMR expert, there are now various ready-made EMRS packages offered by various vendors in the South African market. This would mean minimal to no costs for EMRS development for medical institutions. A scenario whereby the practice does not need to pay for the development of the EMRS but instead uses an EMRS that is available on the market was also assessed.

In conclusion, this chapter outlined the study design as well as the techniques used for data collection and for the economic evaluation. The following chapter will present the results of the analysis.

CHAPTER THREE - RESULTS

3.1 Introduction

The primary objectives of this study were to estimate the costs and benefits associated with an EMRS as well as assess the cost-benefit of such an intervention compared to the traditional PMRS.

The first section of this chapter provides context through description of the distribution of the sample units as well as the number of patients seen among the study sample. This is then followed by a description of EMR utilisation among the study sample over time. As a contrast, the PMRS utilisation over time is also described using proxy indicators.

The sections that follow then provide the results in relation to the four primary objectives; costs of PMRS, costs of EMRS, benefits of EMRS and CBA. The chapter concludes with the results of the sensitivity analysis and scenario analysis.

Results

Out of the 25 emergency units currently being managed by the practice, 18 were identified to have been under the practice's management from January 2018 till June 2024. These 18 units were selected for the study's sample. Most of the units (44%) were located in Gauteng province with the Eastern Cape having the second most number of units (28%). The least number of units (6%) were in the North West province. Table 3.1 below shows the number of units in the various provinces.

Table 3.1 Distribution of sample units

Province	Number of Units	Percentage
Gauteng	8	44%
KwaZulu-Natal	2	11%
Eastern Cape	5	28%
Mpumalanga	2	11%
North West	1	6%
Total	18	100%

3.2 Patient counts

The number of patients seen per province followed the above trend with Gauteng province having the most patients seen consistently over the study period followed by Eastern Cape. The most amount of patients seen were in 2019. Thereafter, there was significant decline in 2020 followed by a gradual increase in 2021 and 2022. From 2022 to 2023, the patient count remained steady and the trend was predicted to continue in 2024. Table 3.2 shows the patient counts for the sample units for the years 2018 to 2024. Figure 3.1 shows the total number of patients seen for the whole sample over the same time frame.

Table 3.2 Number of patient seen per unit from 2018 to 2024

	2018	*2019*	*2020*	*2021*	*2022*	*2023*	*2024*
Gauteng:							
Unit 1	21513	20288	15440	14449	17146	16830	17260
Unit 2	14768	15255	10356	9998	12511	12633	13094
Unit 3	19793	18259	13100	15878	14461	14897	14100
Unit 4	25653	25163	16308	15198	18965	19580	18956
Unit 5	17034	16865	11215	11780	13897	12900	12772
Unit 6	17743	18525	11416	12603	14759	13651	14948
Unit 7	18931	18265	12892	11360	12169	11830	13464
Unit 8	15633	15252	12350	12782	13416	12954	13038
Total:	*151068* *(47.0%)*	*147872* *(45.6%)*	*103077* *(43.1%)*	*104048* *(42.5%)*	*117324* *(42.0%)*	*115275* *(41.7%)*	*117632* *(41.7%)*
KwaZulu-Natal:							
Unit 9	12565	13880	11502	10639	13837	15107	16298
Unit 10	18352	19101	12661	12059	12754	11553	16784
Total:	*30917* *(9.6%)*	*32981* *(10.2%)*	*24163* *(10.1%)*	*22698* *(9.3%)*	*26591* *(9.5%)*	*26660* *(9.6%)*	*33082* *(11.7%)*

Eastern Cape:							
Unit 11	11715	13607	11026	11300	13300	12554	11440
Unit 12	12349	12601	9227	8197	10043	9337	9344
Unit 13	24212	23127	15433	15187	18979	17967	17642
Unit 14	20356	20495	14933	13774	15377	16091	18899
Unit 15	19732	20807	14483	14657	17984	14956	19002
Total:	*88364* *(27.5%)*	*90637* *(28.0%)*	*65102* *(27.2%)*	*63115* *(25.8%)*	*75683* *(27.1%)*	74848 *(27.1%)*	*72384* *(25.7%)*
Mpumalanga:							
Unit 16	17160	17146	13962	16204	17197	15735	17084
Unit 17	18458	19446	18849	23097	25668	25641	22950
Total:	*35618* *(11.1%)*	*36592* *(11.3%)*	*32811* (13.7%)	*39301* *(16.1%)*	*42865* *(15.3%)*	*41376* *(15.0%)*	*40034* *(14.2%)*
North West:							
Unit 18	15322	16144	13918	15533	16948	18364	18672
Total:	*15322* *(4.8%)*	*16144* *(5.0%)*	*13918* *(5.8%)*	*15533* *(6.3%)*	*16948* *(6.1%)*	*18364* *(6.6%)*	*18672* *(6.6%)*
Nationwide:	*321289*	*324226*	*239071*	*244695*	*279411*	*276523*	*281804*

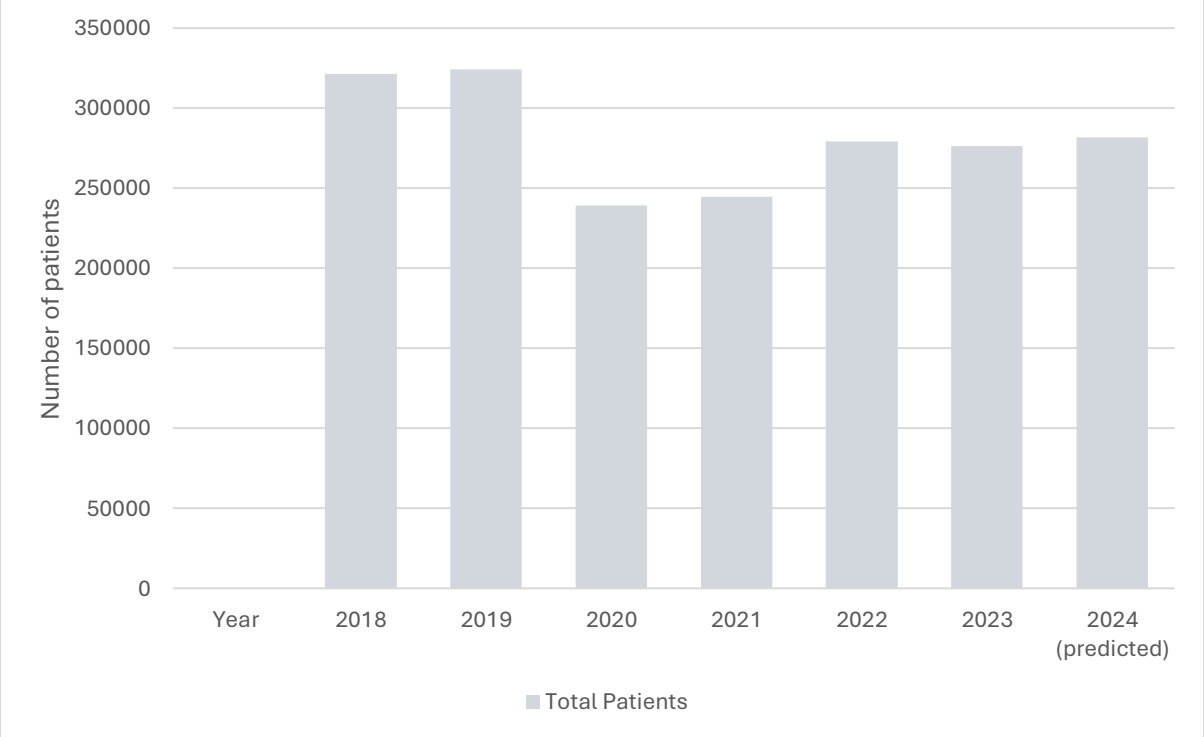


Figure 3.1 Total number of patients seen at sample units

3.3 EMR implementation and usage

For the sample group, the first EMRS implementation was from April 2019. By the end of 2019, a total of three units which were all located in Gauteng had implemented EMRS. The next phase of implementation in 2020, resulted in a further 8 units implementing EMRS. The 8 units included three units in Gauteng, two in Mpumalanga, two in KwaZulu-Natal and one in North West. The remaining seven units, with the bulk being in the Eastern Cape, had EMRS implemented in 2021. By mid-September 2021, the EMRS was live in all units. For this study, the years 2019 to 2021 were considered part of the implementation phase and 2022 onwards was considered the maintenance phase.

The practice only started collecting data on EMR usage across the units from 2021. Figure 3.2 shows the average annual EMR usage per unit from 2021 to 2024. Over that time frame, there was an increase in EMR usage across all units with each of the units having an average EMR usage above 90% by 2024. Figure 3.3 depicts the overall average EMR usage for the whole practice and shows same trend of increasing EMR usage.

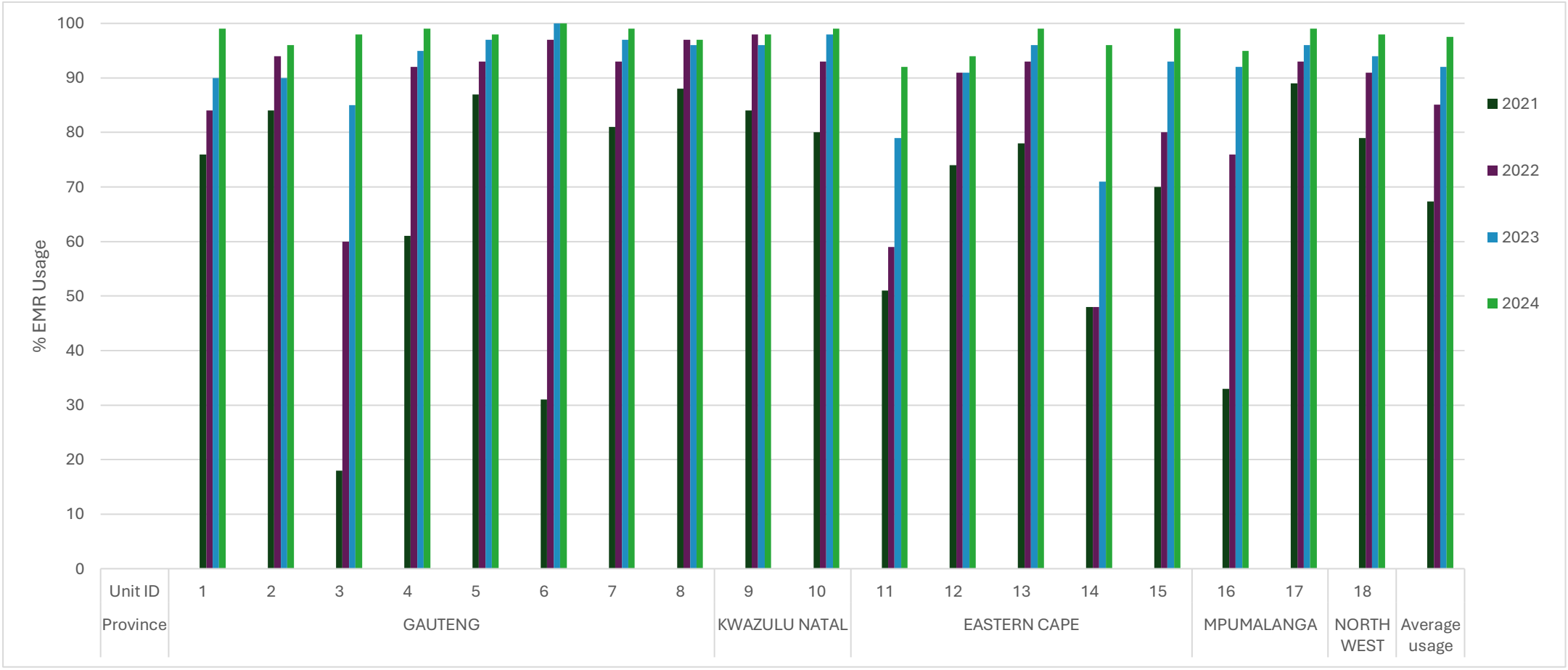


Figure 3.2 Average EMR usage per unit from 2021 to 2024

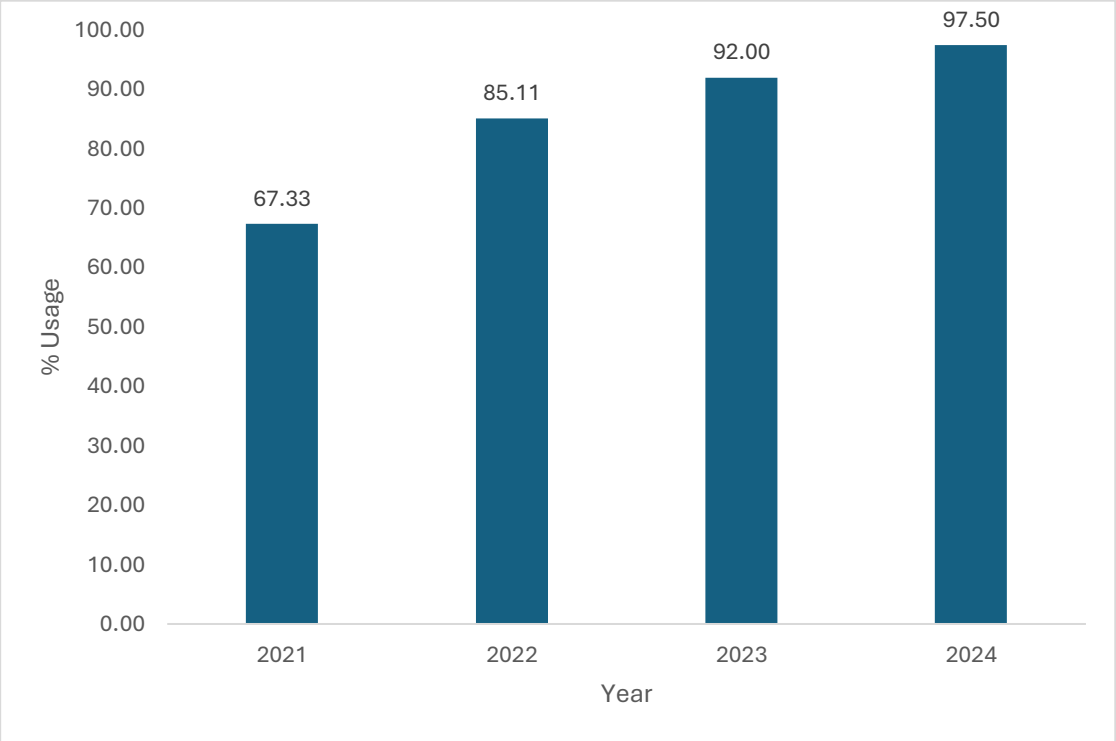


Figure 3.3 Average EMR usage across all sample units

3.4 PMRS utilisation

To ascertain the degree of PMRS utilisation within the practice, data on the number of used books received at the head office from the sample units and the number of scan uploads were used as proxies. Table 3.3 and Figure 3.4 show a general downward trend for both parameters. The number of used books received decreased by 94.4% when comparing 2018 and 2024. Whilst there was a consistent decline in number of used books, the number of scans were not consistent. In 2020 and 2022, the number of scans increased significantly but that was followed by a steep decline in the subsequent years. This shows an overall reduction in PMRS usage in the practice.

Table 3.3 Number of used books received and scan uploads per year

Year	Number of Used books Received	Number of Scans Uploads
2018	290261	177229
2019	261965	129870
2020	214064	242068
2021	86561	143207
2022	42451	214872
2023	39902	61381
2024	16260	33682

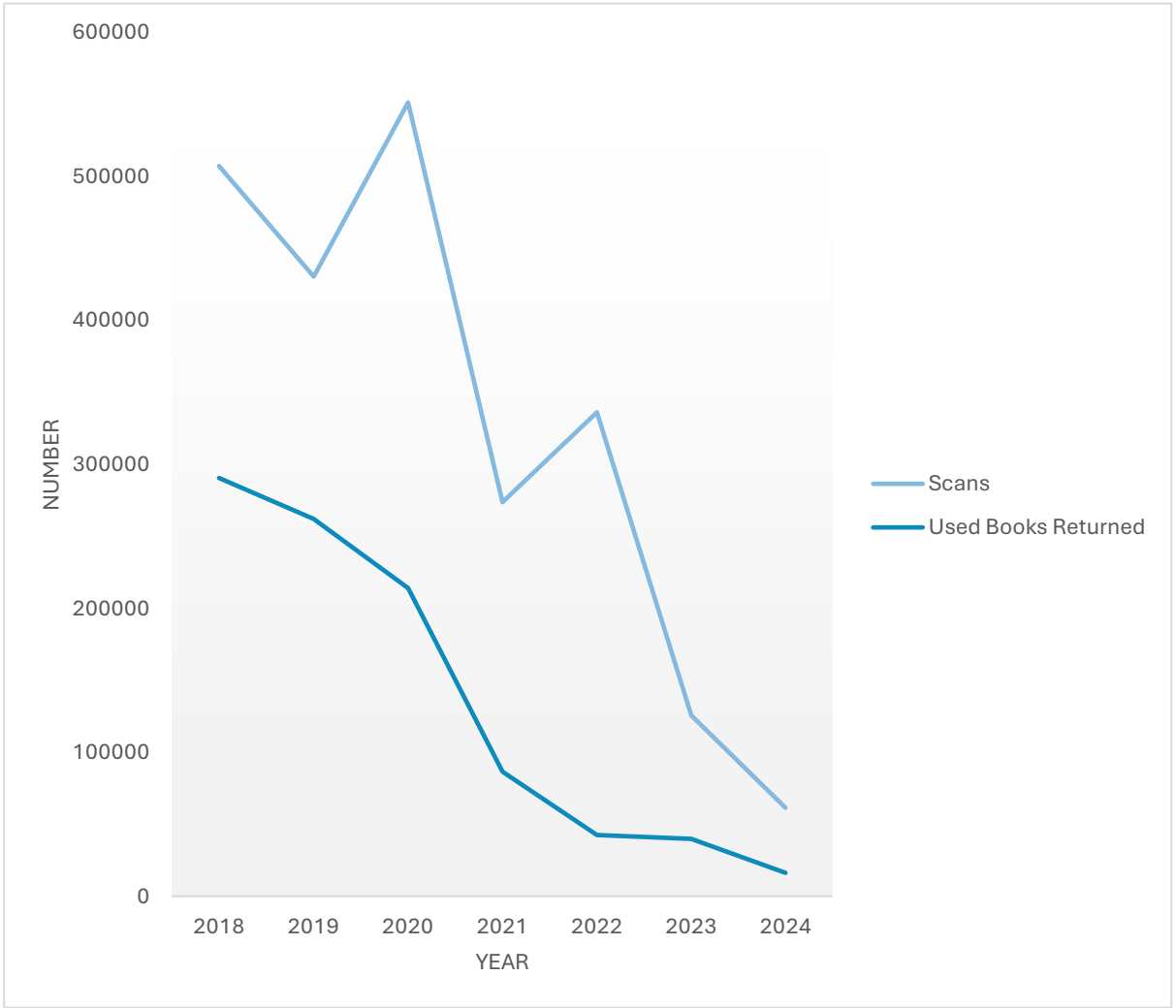


Figure 3.4 Graph showing number of used books received and scan uploads per year

3.5 PMRS Costs

The cost inputs identified for the PMRS were preprinted stationery, transport, storage and document management related personnel costs. As Table 3.4 and figure 3.5 show, there was a general downward trend for total PMRS costs from 2019 onwards. Over the time period 2018 to 2024, PMRS costs decreased by 85% from R2,868,554.60 (US$153,948.35) in 2018 to a predicted cost of R423,186.45 (US$22,711.39) in 2024.

Table 3.4 PMRS associated costs from 2018 to 2024

	2018	2019	2020	2021	2022	2023	2024
Preprinted Stationery	R828,198.45	R906,100.71	R810,947.85	R277,503.09	R98,454.46	R228,759.82	R281,804.00
Transport	R1,615,937.50	R1,455,484.59	R1,184,819.47	R464,363.13	R215,118.88	R200,716.58	R67,126.67
Storage	R45,723.20	R34,292.40	R34,292.40	R22,861.60	R11,430.80	R5,175.40	R2,286.16
Document management	R378,695.45	R277,500.98	R517,239.08	R305,998.70	R459,128.42	R131,156.96	R71,969.62
Total	*R2,868,554.60*	*R2,673,378.68*	*R2,547,298.81*	*R1,070,726.52*	*R784,132.56*	*R566,384.76*	*R423,186.45*

In 2018, before EMR implementation, transport costs constituted greatest proportion of costs making up 56% of the PMRS costs. This was followed by preprinted stationery costs which made up 29% of the costs with storage and document management costs making up the remaining costs. In 2024, however, preprinted stationery made up the greatest proportion of costs at 67%, followed by transport costs (16%) and document management personnel costs (17%).

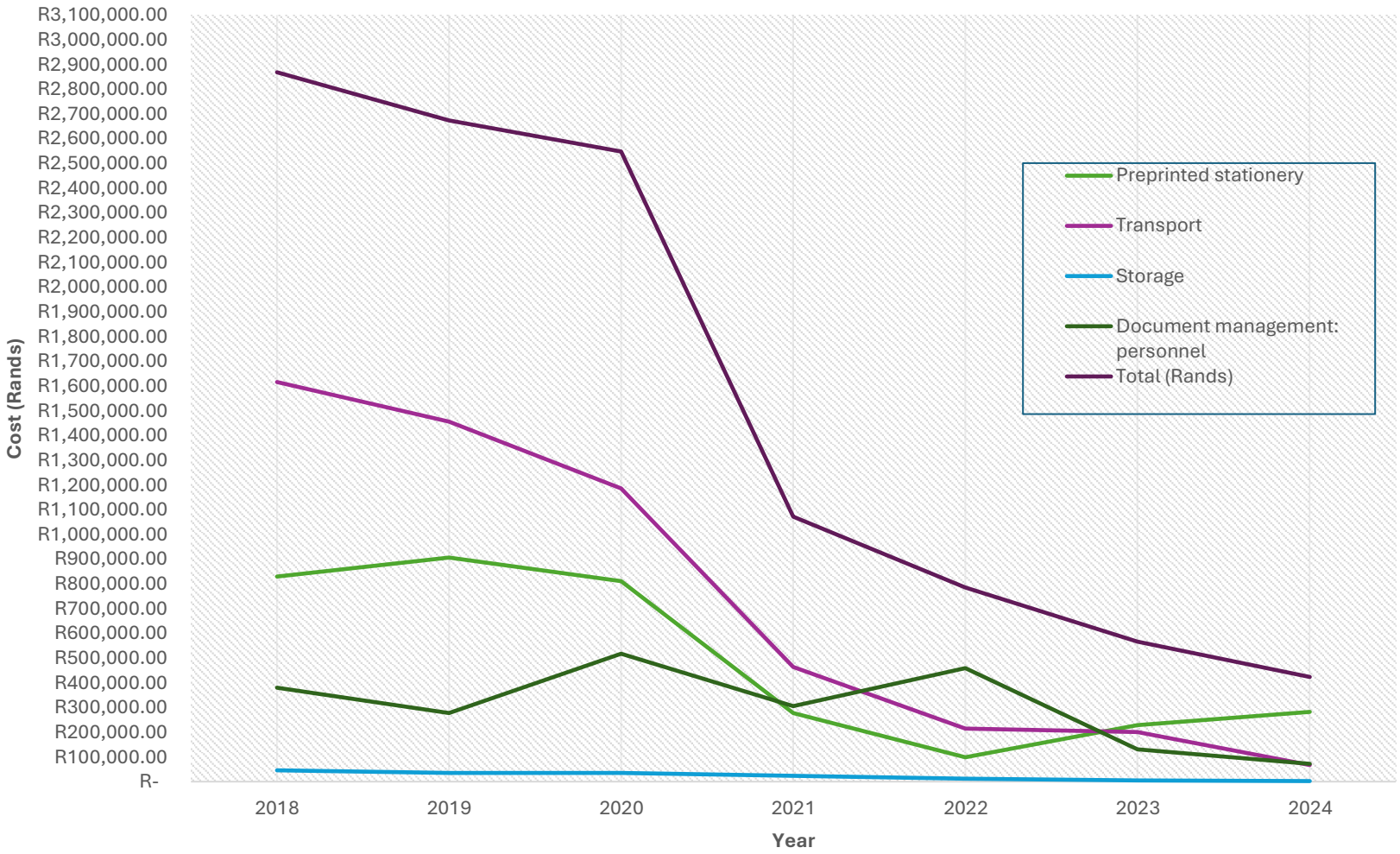


Figure 3.5 PMRS cost inputs from 2018 to 2024

3.6 EMRS Costs

Table 3.5 describes the cost inputs and time frames for each of the phases. The EMRS implementation or one-time costs were categorised into installation, hardware, and training costs. The development costs were also included under the implementation costs in the analysis.

The total estimated implementation costs were R4,114,874.93 (US$ 220,835.37) with development costs making up the bulk of the costs. The maintenance or ongoing costs were categorised into software, printing, and developer maintenance costs. It can be seen from Table 3.5 that after reaching the maintenance phase, the EMRS costs reach a plateau of R1,407,122.15 (US$75,516.82) per year. From the point of conception in 2017 till 2024, the total estimated EMRS costs incurred for the study sample were R11,396,872.79 (US$611,642.45).

Table 3.5 EMRS Associated costs from development to maintenance phase (2017-2024)

	Development phase		Implementation phase			Maintenance phase			
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Implementation:									
Development		R3,135,823.80							R3,135,823.80
Hardware			R13,868.46	R44,932.26	R122,213.54	R135,034.87	R135,034.87	R135,034.87	R 586,118.88
Installation			R30,877.78	R78,419.76	R 65,349.80				R174,647.34
Training			R218,285.71						R218,285.71
Maintenance:									
Software			R119,867.79	R349,354.40	R 973,255.31	R1,078,810.12	R1,078,810.12	R1,078,810.12	R4,678,907.87
Developer maintenance			R9,600.00	R 27,979.18	R77,946.30	R 86,400.00	R 86,400.00	R 86,400.00	R374,725.48
Printing			R 15,728.40	R 39,935.97	R 97,067.86	R 106,877.16	R106,877.16	R 106,877.16	R473,363.71
Personnel	R 540,000.00	R 540,000.00	R540,000.00	R 135,000.00					R1,755,000.00
Total	*R 540,000.00*	*R3,675,823.80*	*R 948,228.15*	*R 675,621.56*	*R 1,335,832.82*	*R1,407,122.15*	*R1,407,122.15*	*R1,407,122.15*	*R11,396,872.79*

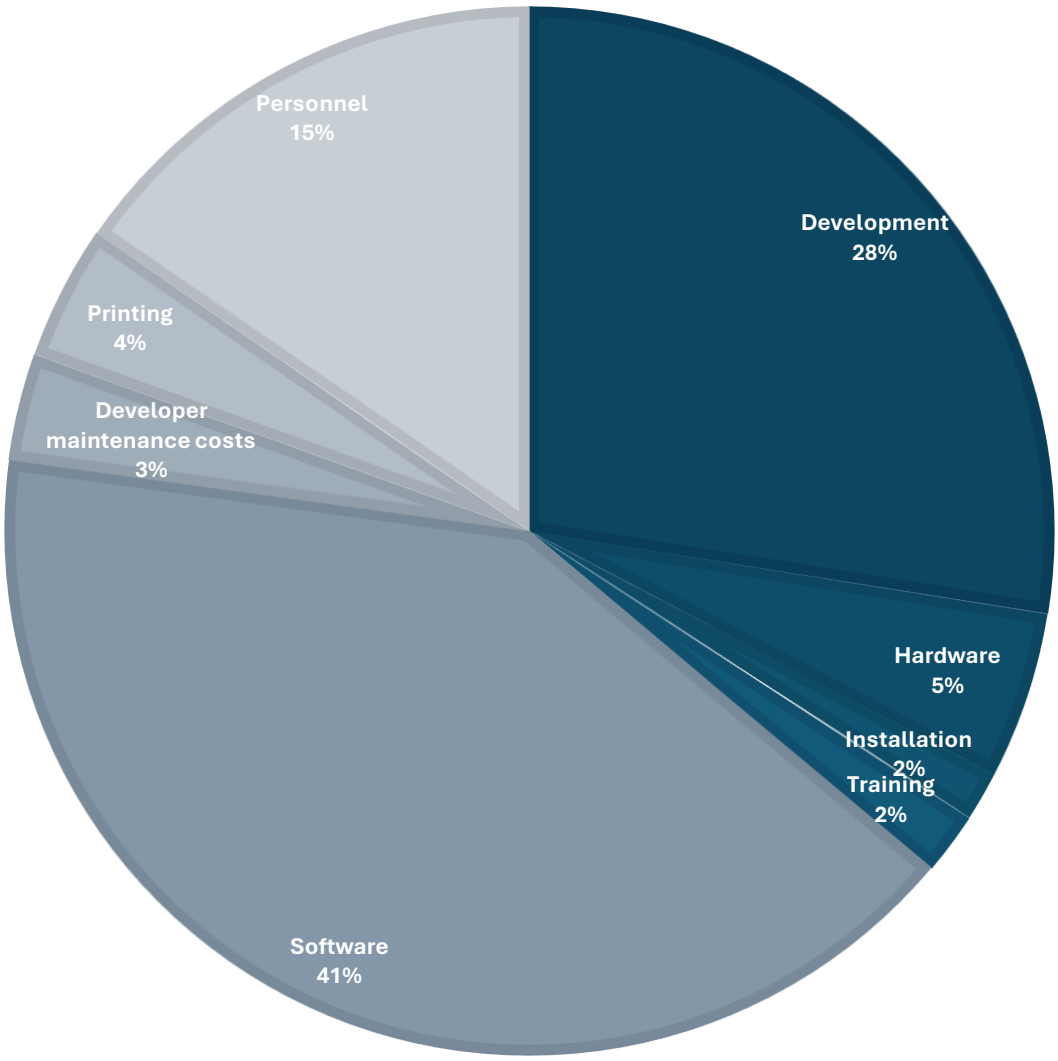


Figure 3.6 Proportions of EMRS costs

As shown above in Figure 3.6, software costs made up the greatest proportion of costs followed by development costs and personnel costs, constituting 41%, 28% and 15% of EMRS costs respectively.

3.7 EMRS Benefits

The benefits identified and measured for this study were related to cost savings acquired by reduced PMR use in the practice. Table 3.6 shows the PMRS costs for the base case scenario.

The cost estimates in the current scenario where EMRS was implemented (Table 3.4), were compared to the base case costs to estimate the savings.

Table 3.6 Base case PMRS costs (without EMR intervention)

	2019	2020	2021	2022	2023	2024	Total
Preprinted Stationery	R835,769.27	R616,262.10	R630,759.29	R720,248.00	R712,803.49	R726,416.52	R4,242,258.66
Transport	R1,630,709.27	R1,202,418.37	R1,230,704.53	R1,405,310.21	R1,390,784.89	R1,417,345.91	R8,277,273.18
Storage	R45,723.20	R45,723.20	R45,723.20	R45,723.20	R45,723.20	R45,723.20	R274,339.20
Document management	R382,157.22	R281,787.11	R288,415.98	R329,334.88	R325,930.86	R332,155.45	R1,939,781.50
Total	*R2,894,358.96*	*R2,146,190.77*	*R2,195,603.00*	*R2,500,616.29*	*R2,475,242.44*	*R2,521,641.08*	*R14,733,652.53*

Table 3.7 shows the estimated cost savings from 2019 to 2024. The table shows a general increase in cost savings over time, with the exception being 2020 when there were negative cost savings accrued. Even throughout the maintenance phase, a continued increase in annual cost savings was observed. From the start of implementation in 2019 till 2024, the total estimated cost savings for the study sample were R6,668,580.76 (US$357,886.51).

Table 3.7 Cost Savings with EMR intervention

	2019	2020	2021	2022	2023	2024	Total
Preprinted Stationery	R(70,331.44)	R(194,686.75)	R353,256.20	R621,793.53	R484,043.67	R444,612.52	R1,638,688.72
Transport	R175,224.69	R17,598.89	R766,341.40	R1,190,191.33	R1,190,068.31	R1,350,219.25	R4,489,643.86
Storage	R11,430.80	R11,430.80	R22,861.60	R34,292.40	R40,007.80	R43,437.04	R163,460.44
Document management	R104,656.24	R(235,451.97)	R(17,582.72)	R(129,793.54)	R194,773.90	R260,185.83	R176,787.74
Total	*R220,980.28*	*R(401,108.03)*	*R1,124,876.48*	*R1,716,483.72*	*R1,908,893.68*	*R2,098,454.63*	*R6,668,580.76*

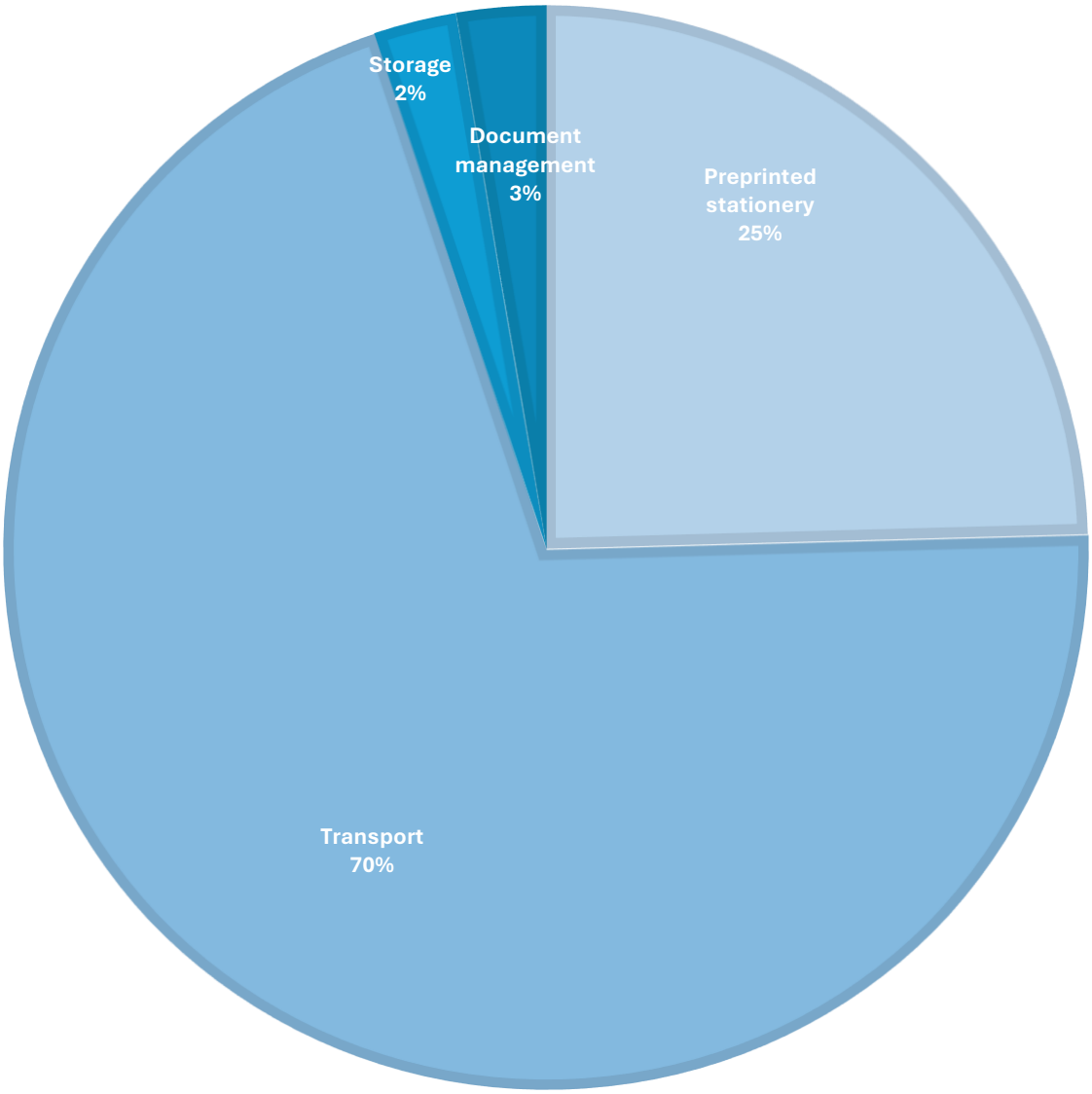


Figure 3.7 Proportions of cost savings with EMR intervention

As depicted in Figure 3.7, the greatest cost savings are due to the reduction in transport costs, with the transport cost savings making up 70% of the total cost savings. This is followed by preprinted stationery cost savings which made up 25% of total cost savings. Figure 3.8 shows the trend of transport costs in the base case and the intervention case.

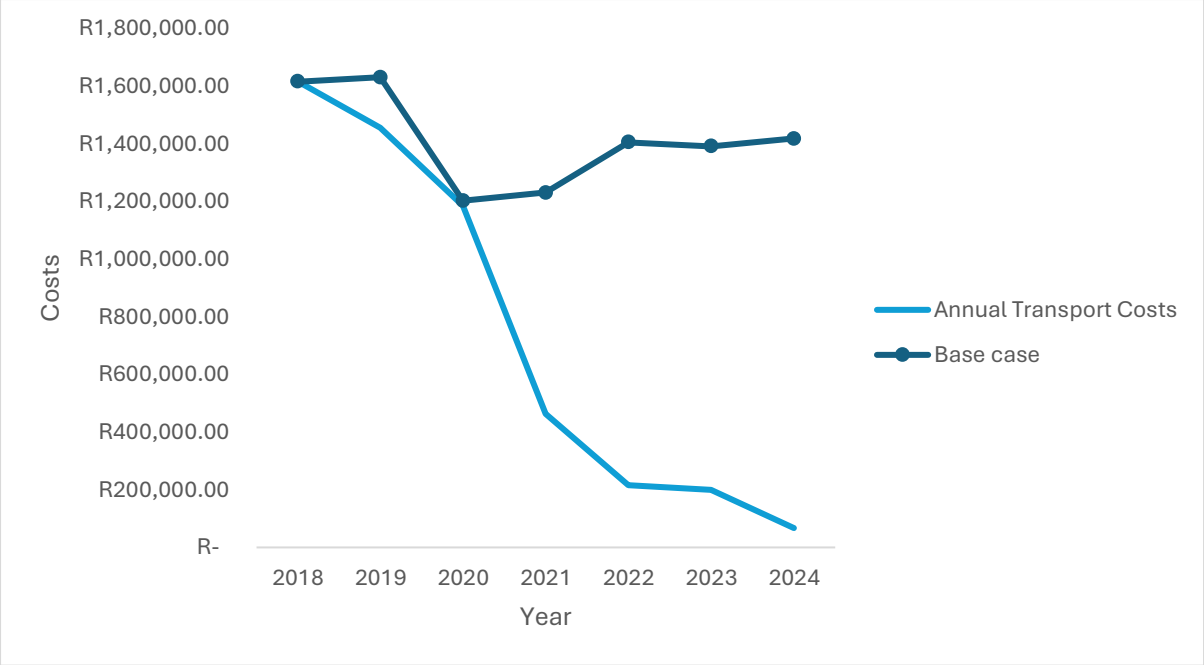


Figure 3.8 Annual transport costs with EMR intervention compared to without EMR intervention

In the base case scenario, transport costs slightly increase from 2018 to 2019 then subsequently decrease in 2020. From 2021 to 2022, there was an increase in costs followed by a plateau from 2022 to 2024. The intervention case scenario showed a general decrease in transport cost over the same time period (2019 to 2024).

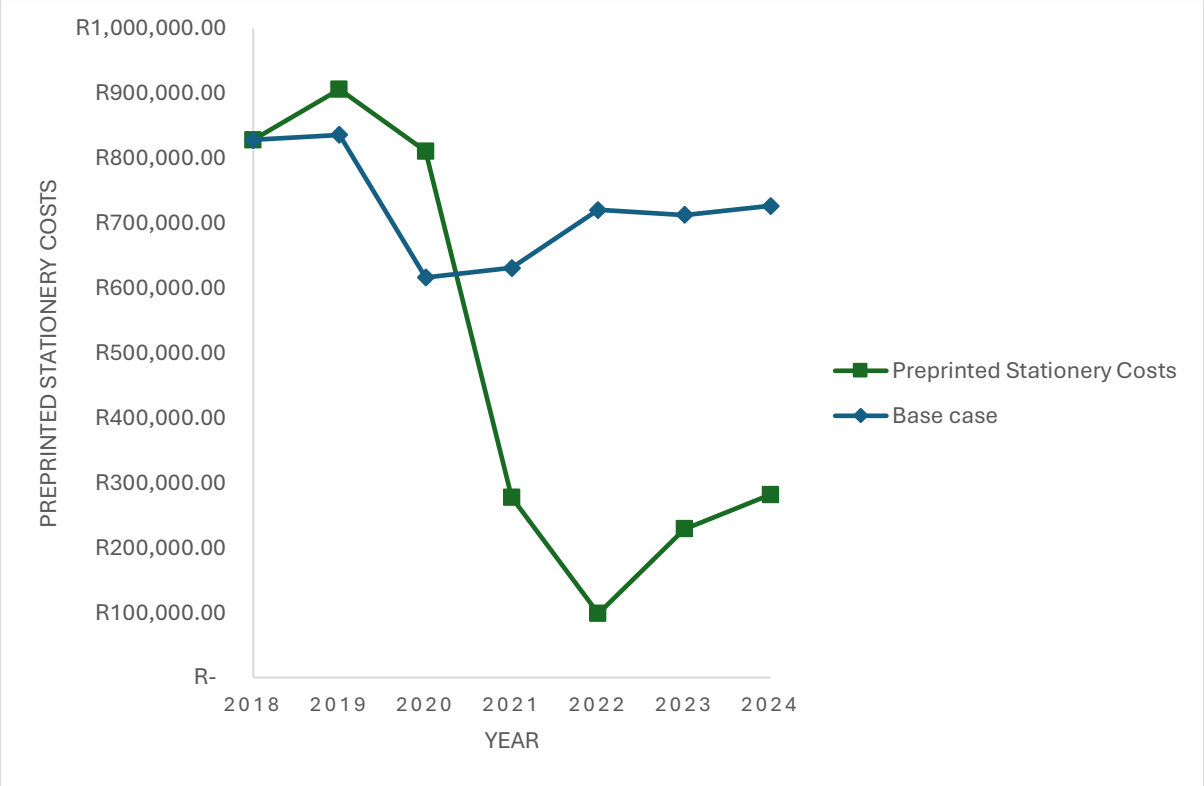


Figure 3.9 Annual preprinted stationery costs with EMR intervention compared to without EMR intervention

Figure 3.9 shows the trend of preprinted stationery costs in the base case and the intervention case. The base case scenario costs for preprinted stationery followed a similar trend as that of the transport costs. For the intervention case, initially, the preprinted stationery costs were high but a steep decline in costs was noted after 2019. From 2021, the EMRS intervention costs were less than those predicted for the base case and remain persistently lower than the base case.

3.8 CBA

Table 3.8 shows the results of the cost-benefit analysis.

Table 3.8 CBA Model

	2017	2018	2019	2020	2021	2022	2023	2024	Total
Costs									
Implementation:									
Development		R 3,135,823.80	R -	R -	R -	R -	R -	R -	R 3,135,823.80
Hardware		R -	R 13,868.46	R 44,932.26	R 122,213.54	R 135,034.87	R 135,034.87	R 135,034.87	R 586,118.88
Installation		R -	R 30,877.78	R 78,419.76	R 65,349.80	R -	R -	R -	R 174,647.34
Training		R -	R 218,285.71	R -	R -	R -	R -	R -	R 218,285.71
Maintenance:									
Software		R -	R 119,867.79	R 349,354.40	R 973,255.31	R 1,078,810.12	R 1,078,810.12	R 1,078,810.12	R 4,678,907.87
Developer costs			R 9,600.00	R 27,979.18	R 77,946.30	R 86,400.00	R 86,400.00	R 86,400.00	R 374,725.48
Printing		R -	R 15,728.40	R 39,935.97	R 97,067.86	R 106,877.16	R 106,877.16	R 106,877.16	R 473,363.71
Personnel	R 540,000.00	R 540,000.00	R 540,000.00	R 135,000.00	R -	R -	R -	R -	R 1,755,000.00
Total	R 540,000.00	R 3,675,823.80	R 948,228.15	R 675,621.56	R 1,335,832.82	R 1,407,122.15	R 1,407,122.15	R 1,407,122.15	R 11,396,872.79
Benefits: Cost savings									
Preprinted stationery		R -	R (70,331.44)	R (194,685.75)	R 353,256.20	R 621,793.53	R 484,043.67	R 444,612.52	R 1,638,688.72
Transport		R -	R 175,224.69	R 17,598.89	R 766,341.40	R 1,190,191.33	R 1,190,068.31	R 1,350,219.25	R 4,689,643.86
Storage			R 11,430.80	R 11,430.80	R 22,861.60	R 34,292.40	R 40,007.80	R 43,437.04	R 163,460.44
Document management: personnel			R 104,656.24	R (235,451.97)	R (17,582.72)	R (129,793.54)	R 194,773.90	R 260,185.83	R 176,787.74
Total		R -	R 220,980.28	R (401,108.03)	R 1,124,876.48	R 1,716,483.72	R 1,908,893.68	R 2,098,454.63	R 6,668,580.76

From the analysis, in the current scenario the net present value (NPV) of -R4,728,292.02 (-US$253,755.94) was obtained for the study sample showing that the practice did not breakeven within the time horizon of the study. The benefit-cost ratio (BCR) was below one at 0.59 showing that for the stated time horizon, the EMR intervention's costs, outweighed the benefits.

As the practice did not break-even within the study time horizon, forecasting was done based on the historical data to estimate when the break-even point would be. It was assumed that the annual EMRS costs would remain constant and the benefits would increase annually based on the average percentage increase noted in the maintenance phase. For this study, it was assumed that all costs and benefits were incurred at the end of the year. It can be seen from Figure 3.10 that the break-even point; when cumulative present costs equal cumulative present benefits, is between the end of 2027 and end of 2028. Final estimates showed that the practice would breakeven at 6.97 years from the end of the implementation phase or 10.96 years from the start of implementation.

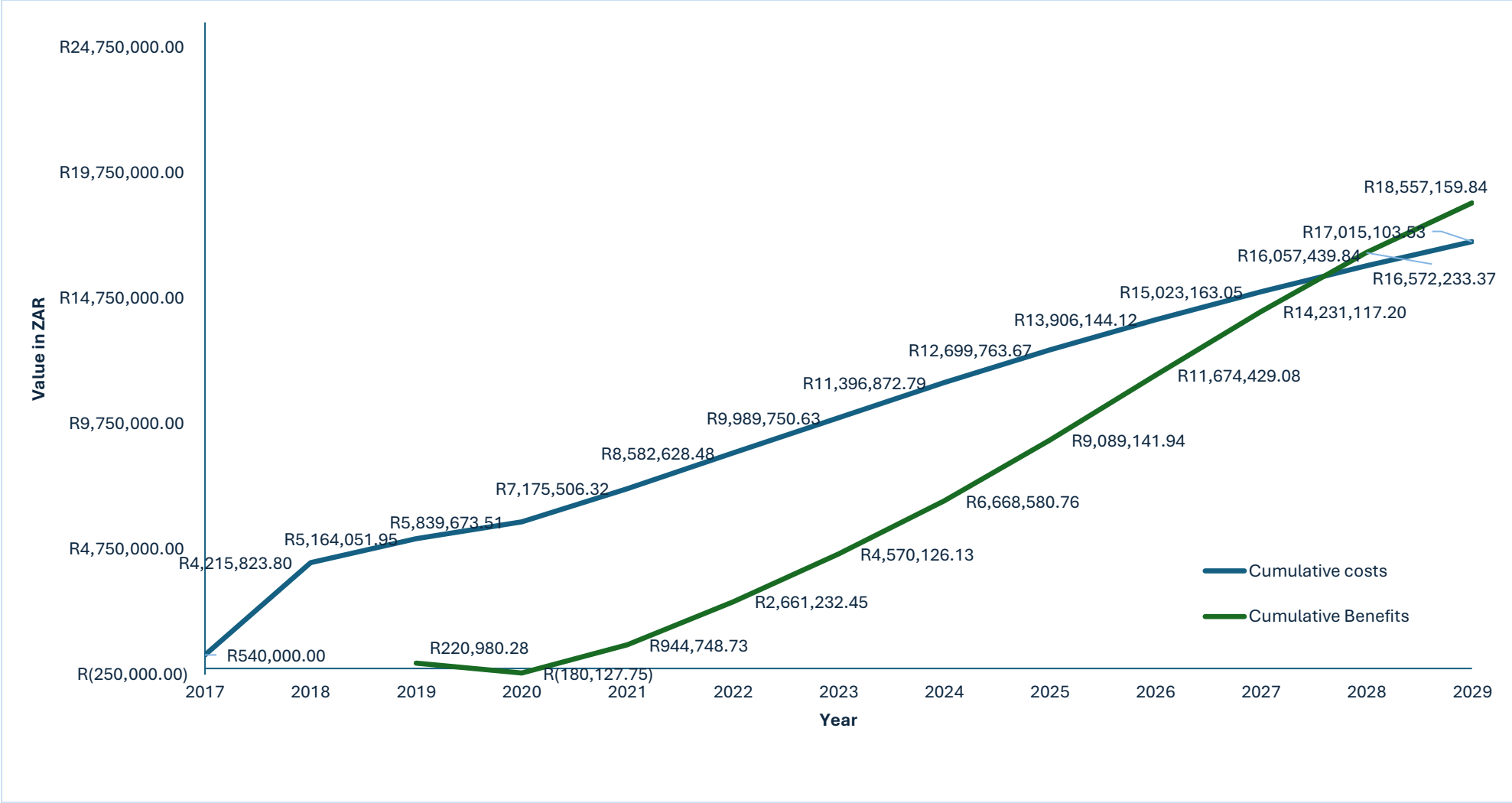


Figure 3.10 EMR Cumulative Present Costs and Benefits over time

3.9 Sensitivity Analysis

Both univariate and bivariate sensitivity analyses were performed. For the univariate sensitivity analysis, one input variable was varied and the effect on NPV and BCR was assessed. The results of the sensitivity analysis are shown in the form of a Tornado diagram (Figure 3.11).

Table 3.9 Univariate sensitivity analysis ranges

Variable	Low value	High value
Development costs	-40%	+40%
Hardware	-30%	+30%
Software	-30%	+30%
Printing	-20%	+20%
Installation	-40%	+40%
Training	-40%	+40%
Personnel	-40%	+40%
Preprinted Stationery savings	-20%	+20%
Transport savings	-20%	+20%
Document management savings	-20%	+20%
Developer maintenance	-20%	+20%
Storage savings	-20%	+20%
Inflation	-40%	+60%
Discount rate	-50%	+50%

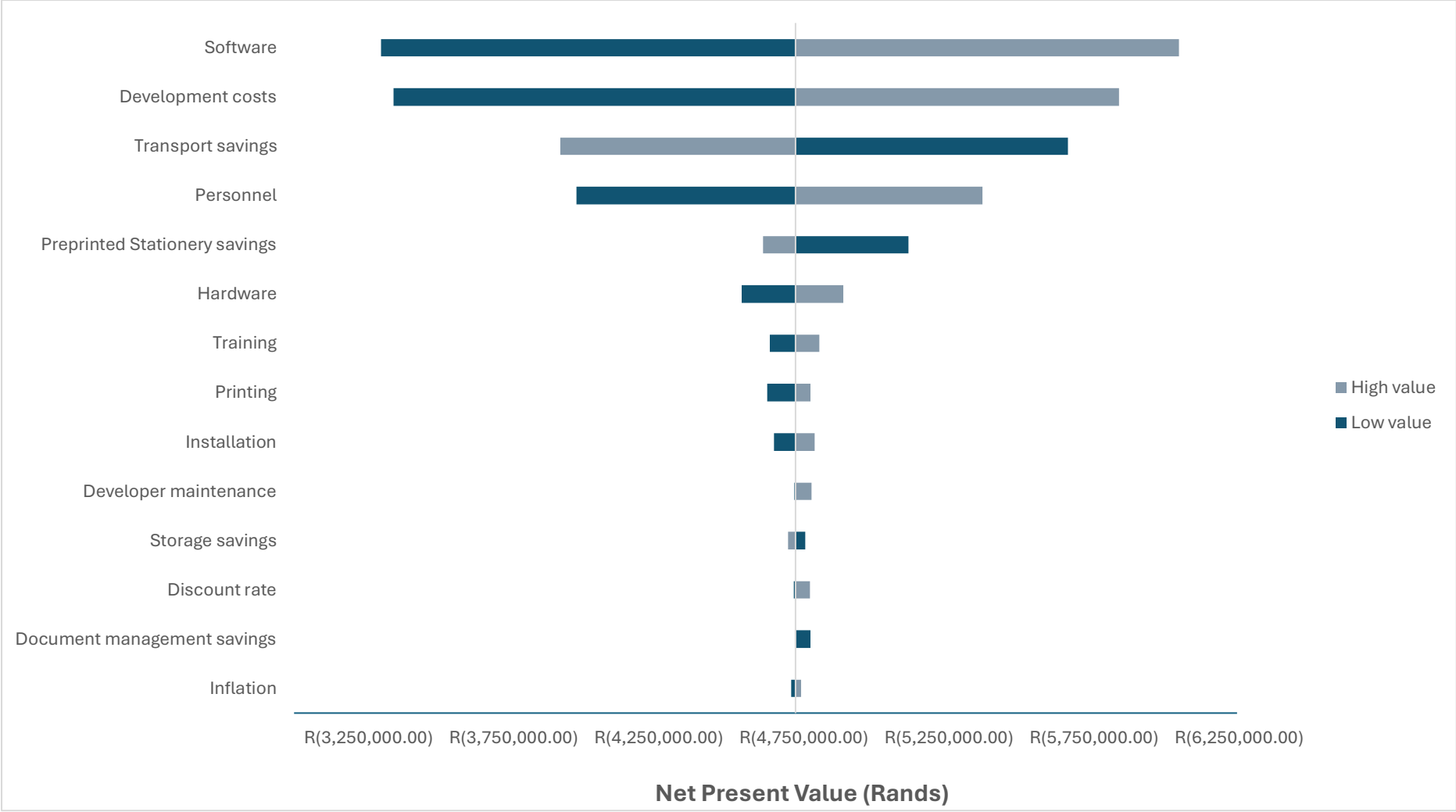


Figure 3.11 Tornado Diagram

The bivariate sensitivity analysis involved varying two input variables at the same time whilst the other input variables were held constant. Outputs are shown in Appendix 4. The variables selected for the bivariate sensitivity were those that made up majority of the EMRS costs and/or costs savings. These inputs were also identified to be variables to which there was the greatest model sensitivity in the univariate analysis.

Preprinted Stationery cost savings and Transport cost savings

Preprinted stationery cost savings were varied from R1,500,000 to R3,500,000 and transport cost savings were varied from R3,500,000 to R6,000,000. The analysis showed that as transport cost savings and preprinted stationery cost savings increase, there was a positive increase in the NPV.

Preprinted Stationery cost savings vs Software costs

Preprinted stationery cost savings were varied from R1,500,000 to R3,500,000 and software costs were varied from R3,500,000 to R6,000,000. The most favourable outcomes were observed when software costs were on the lower end and preprinted stationery cost savings were on the higher end of the range.

Transport cost savings vs Software costs

The transport cost savings were varied from R3,500,000 to R6,000,000 and software costs were varied from R3,500,000 to R6,000,000. Similar to the prior analysis, the most favourable outcomes were seen when the software costs were low and the transport cost savings were high.

Development costs vs Software costs

The development costs were varied over a range between R500,000 and R4,500,000 with software costs varied between R3,500,000 to R6,000,000. Low development costs and low software costs showed the most favourable outcomes. Compared with the other analyses, this scenario had highest NPV.

For all four cases explored in the bivariate analysis and across the selected cost ranges, the NPV was found to be negative.

3.10 Scenario analysis

Four alternative scenarios were explored for this study. The first three scenario looked at the impact of reduction of PMRS related costs and therefore the use of the PMRS throughout the maintenance phase. The specific scenarios assessed were 50%, 75% and 100% reduction in PMRS costs. The fourth scenario was a case whereby the practice did not have to pay development costs but instead used a ready-made EMRS. The outputs of the scenario analysis are shown in Table 3.10.

Table 3.10 Scenario analysis outputs

Scenario:	NPV in ZAR	NPV in US$	*BCR*	*DPP*
Current	R (4,728,292.02)	$ (253,755.94)	0.5851	6.97
1 : 50% reduction PMRS Costs	R (3,841,458.14)	$ (206,161.72)	0.6629	5.89
2 : 75% reduction PMRS Costs	R (3,350,430.48)	$ (179,809.46)	0.7060	4.95
3 : 100% reduction PMRS Costs	R (2,907,013.54)	$ (156,012.35)	0.7449	4.88
4: No Development Costs	R (1,592,468.22)	$ (85,463.90)	0.8072	4.92

From the scenario analysis, it was observed that a greater reduction in PMRS costs resulted in more a positive increase in the NPV and the BCR. The reduction in PMRS costs was associated with a decrease in the discounted payback period (DPP). The difference between the DPP with a 50% versus a 100% reduction in PMRS costs was approximately a year. The difference between the DPP with a 75% versus a 100% reduction in PMRS costs was rather minimal. The fourth scenario whereby there are no development costs incurred, showed the greatest positive increase in the NPV and the BCR when compared to the current scenario. However, the scenario with the shortest DPP was the 100% reduction of PMRS costs although the difference compared to the fourth scenario was very small.

In summary, for the study time horizon, the EMRS has not shown to result in negative economical returns as evidenced by the negative NPV and the BCR that is less than one. Post-implementation, it is expected to take almost 7 years for the practice to breakeven on the EMRS intervention. Reducing PMRS costs may potentially result in practice breaking-even sooner.

CHAPTER FOUR - DISCUSSION

The aim of this study was to estimate the economic effects of an EMRS in the South African context. This was done through a retrospective cost-benefit analysis (CBA). As an increasing number of healthcare institutions in both the private and public sector in South Africa are adopting EMR, it becomes very important to assess the economic consequences of such an intervention and to determine if the benefits outweigh the high costs.

The CBA performed showed that from the point of development in 2017 till the current maintenance phase in 2024, there was a negative net present value (NPV) of -R4,728,292.03 (-US$253,755.94) and a benefit-cost ratio (BCR) of 0.59. The CBA model was most sensitive to changes in software costs, transport cost savings and development costs. The discounted payback period (DPP) was estimated at 6.97 years after the end of implementation or 9.97 years from the start of implementation.

The BCR that is less than one, suggests that over the time horizon of the study, the EMR intervention has resulted in negative economical returns. The negative NPV suggests that over the time horizon of the CBA, the practice failed to breakeven on the EMR intervention; that is, the EMR costs were greater than the benefits. These results are not in-keeping with previous CBA studies which have mostly suggested EMR to be cost-effective over a similar or shorter time horizon and showing positive return on investment quite early on post implementation (3,17,23,31,33,34). Some previous studies have shown a positive NPV as early as the first year post implementation (33,34). Other studies have estimated a break-even period between two and three years post implementation (3,17,31,33,34). However, these CBA studies have mostly been prospective studies making use of secondary data in their models. Choi et al (23), conducted one of the few retrospective CBA studies looking at EMR implementation in the outpatient department at a tertiary hospital in South Korea. They

reported a positive NPV of US$3,617,000 and a BCR of 1.23 over a 8-year time horizon (from 2006 to 2013). Although longer than in previous studies, their DPP of 6.18 years, counting from the start of implementation was shorter than that of this study (23).

Several factors may explain why the EMR intervention did not result in a positive economic return, as well as the prolonged time to reach the breakeven point in our study. Such factors include the type of provider or healthcare institution, the types of benefits included in the analysis, the implementation time frame, concurrent PMR use and the EMR costs.

As with previous studies, the perspective taken in this study, was that of the provider (3,17,23,31,34). This had an effect on which costs and benefits would be included in the analysis. Cost savings from the reduction in PMRS use was a common benefit in previous studies as well as this study. This was in various forms such as reduction in transport costs, reduction in paper chart use, reduction in document management costs and reduction in storage costs ((17,23,31,34). In this study, the provider was a fee-for-service medical practice. Therefore, benefits such as laboratory and radiology utilisation related cost savings, were not included in the analysis as these were paid by either the medical aid or insurer, or directly by the patient. Choi et al (23) also did not include these categories of cost savings in their CBA. The reduced areas of cost savings included in the analyses may be one of the reasons of the longer DPP in this study and in Choi et al's study. Li et al (17), Wang et al (31) Kumar and Bauer (34) and Driessen et al (3) included such benefits in their analyses, which may be one of the reasons for the shorter time to breakeven. This is further supported by Wang et al's (31) study which explored benefits under both capitation and fee-for-service, with cost savings found to be significantly less when there was a higher proportion of fee-for-

service patients in the cohort compared to when there was a higher proportion of capitated patients.

Menachemi and Collum (12) have made the observation that for fee-for service healthcare institutions that implement EMR, although the institutions may incur most of the costs related to EMR implementation, a great proportion of the benefits will be accrued by third party payers and the patients. Hence, institutions such as the current South African public health care system and the proposed national health insurance (NHI), may experience greater cost savings and thus, a greater return on investment when implementing EMRS.

Other studies describe increased revenue generation as a benefit included in their CBA. Choi et al (23) report that the storage space previously used for PMR was converted into consultation rooms and medical transcriptionists were employed, allowing for more patients to be seen per day resulting in increased revenue. Some studies described reduced billing errors (31) and improved charge capture (17,34) as a way to increase revenue. However, there were no clear sources of increased revenue noted during the time of this study. There was insufficient data to assess effect on billing. This lack of revenue generation as a benefit category in our analysis, may have contributed to the negative NPV and longer DPP in this study. During the consultative process, it was noted that the storage space that was freed up after EMR implementation, in the near future, will be used to store medical equipment that will be sold via a new online store. This may be a potential source of increased revenue for the practice to consider for future analysis.

In most CBA models, the implementation time frame is assumed to be one year. In reality this may not be the case as observed in not only this study but also Choi et al's (23) study

whereby, implementation was done over a 3-year time period. This prolonged implementation period results in the benefits not being fully realised sooner due to the concurrent PMR use within the institution. Previous studies have suggested that concurrent PMR and EMR use can result in reduced productivity (22).

Despite full EMRS implementation, significant preprinted stationery use persists, a trend inconsistent with high EMR usage rates. The analysis showed a gradual increase in preprinted stationery costs in 2023 and 2024. While the number of used books) declined overall, scanning activity was more variable, with a significant 2020 spike. This anomaly was attributed by the document manager to a backlog clearance effort following COVID-19 lockdown disruptions. Through the consultative process, it was revealed that although there has been a reduced demand for the books used to write clinical notes, there has been a high demand from the units for the script pads. Some of the reasons for the continued demand for script pads were that some pharmacies would only accept written out scripts as opposed to typed out scripts, especially for certain scheduled medication. In some instances, the script pads were used by some HCPs to make short notes during and after the consultation process as they would make notes on the EMRS much later on, especially in cases where there were high patient volumes. The EMR usage rate measured by the practice, is based on the clinical notes made on the EMRS compared to the number of patients seen. This usage rate does not factor in other aspects such as if prescriptions were made on the EMRS. This gives an impression that the EMR usage is high and yet some functions of the EMRS are not being fully utilised. Overall, this has resulted in the preprinted stationery costs not declining further and even increasing, which reduces the cost savings that can be gained from the EMRS.

In previous studies, medical transcriptionists have been employed to assist with the entry of clinical information on the EMRS at the point of care so as to facilitate EMR use and minimise disruptions to productivity (23). At the time when this study was conducted, the practice was looking into the use of artificial intelligence based transcription applications that can be used to transcribe clinical notes at the point of care, instead of requiring HCPs to type out notes which may be time consuming and may be one of the reasons for continued PMR use. Such applications come at an additional cost. However, previous studies report medical transcriptionist support resulting in significant additional revenue through increased productivity which would off-set the cost (23).

The greatest areas of costs for the EMRS in this study were software, development and personnel costs. Balugaba et al (7) reported personnel and software costs consisting 70% and 20% of EMR costs respectively in their cost analysis. Choi et al (23), found personnel costs associated with the EMRS implementation made up majority of the costs at 53.6% followed by EMR applications and system infrastructure costs. Personnel for the EMRS development and maintenance for the practice in this study, was largely outsourced with the software costs including costs of support services. This may explain why the personnel costs were found to be not as high in this study. Other studies, have also estimated software and support costs making up a significant proportion of the total EMR costs (17,23,31).

A potential area of reduction of costs is the development process. With new EMRS systems on the market, healthcare institutions may not need to incur such high development costs. Balugaba et al (7) estimated a 20% reduction in EMRS costs with the use of an open-source EMRS. If the practice had not incurred EMRS development costs, scenario analysis estimated that over the same time horizon, NPV would be -R1,592,468.22 (-US$85,463.90), BCR 0.81

and the DPP would be reduced by about two years. However, at the time when practice planned to implement EMR, there may not have been many EMRS on the marker that suited the practice's recordkeeping needs. Thus the need to develop an EMRS that was more in line with the practice's requirements. The current EMRS vendor the practice uses, now offers EMRS for use to medical practices of various sizes without the need to pay such high development costs.

Although this study showed a negative NPV and a BCR less than one for the time horizon of interest, some of the reasons for health institutions to still proceed with the EMR intervention are that long-term, the medical practice in this study, is predicted to breakeven. The DPP can be reduced further if the practice takes initiatives to further reduce the current use of the PMRS. The scenario analysis performed, estimated that the DPP can be reduced by about a year and about two years if PMRS use were to be reduced by 50% and 75% respectively. Some of the benefits of EMR use cannot be easily quantified; such as improved doctor-patient communication, ease of access to information and improved quality of care. Hence, this CBA most likely underestimates the potential EMR benefits in this regard.

It has been observed in previous studies, that over time, there is a reduction in annual EMR costs (7,17,23,31). In this study, the annual maintenance costs of the PMRS were found to be greater than the annual maintenance costs of the EMRS, with PMRS annual costs in the base case being over R2,000,000 (US$107,335.14) and EMRS costs in the maintenance phase being R1,407,122.15 (US$75,516.82) per year. A similar observation was made in Balugaba et al (7) and Choi et al (23). Hence, once the start-up costs are overcome, long-term, the EMRS may be less costly to maintain compared to PMRS.

Limitations

A primary limitation of this analysis is its narrow provider perspective, which, while methodologically sound for assessing direct financial return, necessarily excludes the significant benefits of EMRS that accrue to patients and the broader health system. These omitted benefits, particularly those related to clinical outcomes and systemic efficiencies, mean that the reported negative NPV and BCR of 0.59 substantially underestimate the total societal value of the EMRS investment. Our findings should therefore be interpreted not as a final verdict on the value of EMRS, but as a measure of the private, financial return to the practice itself with the societal return likely to be positive.

The existing literature provides strong evidence for the magnitude of these excluded benefits. For instance, a CBA by Li et al. (17) in a Chinese hospital setting estimated a 40% reduction in adverse drug events which constituted a considerable portion of the benefits, contributing to an overall positive net benefit of US$559,025 over a six-year time horizon for a hospital that has 600,000 outpatients and 20,000 inpatients per year (17). Extrapolating these findings to the scale of the present study (18 emergency units seeing over 280,000 patients annually), a conservative estimate of a 10–15% reduction in ADEs could translate to annual cost savings in the millions of Rands for the broader healthcare system. However, as these savings primarily avert costs for medical schemes and patients rather than the provider who incurred the implementation cost, they remain absent from our financial model, creating a fundamental disconnect between investment and return.

Similarly, the reduction in duplicate diagnostic testing is a well-documented benefit of EMRS that was excluded from our analysis. Li et al. (17) in a CBA of a Chinese general hospital, and Wang et al (31) in a CBA in a primary care setting in the USA, identified reduced

utilisation of laboratory and radiology tests, facilitated by easy access to previous results within the EMRS, as a major driver of cost savings and a positive net benefit. In the South African private healthcare context, where medical schemes bear the cost of these tests, this represents a significant financial externality. A conservative scenario where the implemented EMRS reduced duplicate testing by merely 5% would result in considerable annual cost savings for funders, further emphasising that the entity financing the EMRS is not the sole beneficiary of its financial gains.

The omission of time savings for healthcare providers and administrators is significant limitation of this study. The introduction of an EMRS can result in substantial productivity gains through reduced time spent on tasks such as record retrieval, transcription, and filing (4,20). However, quantifying these gains would have required primary data collection methods such as time-and-motion studies or structured interviews with clinical staff. Due to the constraints of the ethics clearance granted for this study, which focused on the analysis of existing retrospective operational and financial data, it was not feasible to conduct such primary data collection involving staff. Consequently, this potentially significant driver of cost savings could not be robustly captured and monetised in the model. This approach, while a limitation, is not without precedent in retrospective CBAs. For instance, Choi *et al*. (23), in their retrospective CBA of EMR in a South Korean tertiary hospital, also did not incorporate time savings for clinicians and administrators for similar methodological reasons, focusing instead on more readily quantifiable financial metrics. The impact of EMRS on productivity is a critical area for future research and a separate, dedicated study is required to accurately explore the extent of these gains or losses, particularly within the LMIC context. Such a study would be invaluable in providing a more holistic understanding of the economic impact of health information technologies in settings like South Africa.

Another limitation is that certain costs and benefits of EMRs, such as improvements in quality of care and accessibility of information, are difficult to express in monetary terms and were therefore excluded from the analysis (23). This omission is consistent with previous CBAs, which have also excluded such outcomes for similar reasons (17,23,31). Some values were based on cost estimates, introducing potential uncertainty; however, this was explored through sensitivity analysis. Transport cost savings were estimated using a simple linear regression model, which has inherent limitations. While the collected data displayed a linear trend, the relationship between transport costs and volume may not remain strictly linear, particularly where economies of scale reduce unit costs with higher volumes. Moreover, linear regression assumes stable relationships between cost drivers and total costs over time, without accounting for technological change or market shifts that may alter these dynamics (50).

The generalisability of these findings is likely limited to private institutions operating on a similar fee-for-service model. Public health institutions, which typically employ alternative payment structures, could potentially derive greater advantages, such as diminished unnecessary investigations. Nonetheless, these benefits may be offset by the substantial infrastructure investments required, potentially increasing overall costs. Additional research is warranted to explore the implications for the public health sector.

Recommendations

EMRs generate benefits that extend beyond providers to healthcare professionals, payers, government, and patients. Accordingly, future CBAs should adopt a societal perspective to capture these wider gains, which may be overlooked in provider-focused evaluations (7).

Such analyses should also account for the extended timeframes often required for successful EMR implementation, as demonstrated both in this study and in Choi et al. (23). For healthcare institutions considering adoption, the use of standardised, market-available EMR systems may help reduce development costs and accelerate returns on investment. In parallel, strategies to minimise continued use of paper medical records (PMRs) are critical, as concurrent systems increase costs and delay breakeven (37). This challenge is particularly relevant in South Africa, where studies show that despite EMR implementation in some public facilities, PMRs remain widely used. In several cases, EMRs are underutilized, serving only to record basic demographic and diagnostic data rather than supporting full clinical workflows (11,27).

Lastly, the quantified operational savings identified in this study likely represent only a fraction of the total economic value created by the EMRS. The incorporation of the broader clinical and systemic benefits from the literature. suggests that the societal BCR could easily exceed 1.0, markedly shifting the cost-benefit balance. This highlights a crucial policy implication; the business case for digital health adoption cannot solely rely on provider-centric financial returns. This justifies policy interventions, such as government co-investment or subsidies for digital health infrastructure, as outlined in South Africa's National Digital Health Strategy (2,12,25). By reducing the initial investment barrier for providers, the government can accelerate the adoption of digital health technologies that unlock broader societal benefits. leading to a more efficient, higher-quality, and sustainable health system which is a core objective of the NHI (2,18,25,45).

CHAPTER FIVE – CONCLUSION

This study provides cost and benefit data that may be of use for future EMR CBAs and assist healthcare institutions in decision making. As this is a retrospective analysis, it offers insights into the real world economic implications of EMR implementation. As far as the researcher is aware, it is the first CBA done looking at the South African context. There has been a move towards the adoption of EMR in South Africa and it is important to first understand the economic consequences of such an endeavour which would assist in decision making and planning.

This study shows that the EMR costs are extremely high and in the short-term, the EMR investment may not be cost effective in LMICs. The study also highlights that full implementation of EMRS in reality may require a number of years. Even with full EMR implementation, there can be residual PMR use which can reduce cost savings to be gained from EMR. Health institutions should keep in mind that the return of investment may take longer than previously estimated in other studies especially for fee-for-service organisations.

REFERENCES

1. Fragidis LL, Chatzoglou PD. Implementation of a nationwide electronic health record (EHR): The international experience in 13 countries. *Int J Health Care Qual Assur*. 2018;31(2):116–30.
2. World Health Organization. Regional Office for the Western Pacific. Electronic health records: a manual for developing countries. World Health Organization Western Pacific Region; 2006. 76 p.
3. Driessen J, Cioffi M, Alide N, Landis-Lewis Z, Gamadzi G, Gadabu OJ, Douglas G. Modelling return on investment for an electronic medical record system in Lilongwe, Malawi. *J Am Med Inform Assoc*. 2013 Jul-Aug;20(4):743-8. doi: 10.1136/amiajnl-2012-001242. Epub 2012 Nov 9. PMID: 23144335; PMCID: PMC3721156.
4. Waithera L, Muhia J, Songole R. Impact of electronic medical records on healthcare delivery in Kisii Teaching and Referral Hospital. *Med Clin Rev*. 2017;3(4):21.
5. Raut A, Yarbrough C, Singh V, Gauchan B, Citrin D, Verma V, Hawley J, Schwarz D, Harsha Bangura A, Shrestha B, Schwarz R, Adhikari M, Maru D. Design and implementation of an affordable, public sector electronic medical record in rural Nepal. *J Innov Health Inform*. 2017 Jun 23;24(2):862. doi: 10.14236/jhi.v24i2.862. PMID: 28749321; PMCID: PMC5874496.
6. Douglas GP, Gadabu OJ, Joukes S, Mumba S, McKay MV, Ben-Smith A, Jahn A, Schouten EJ, Landis Lewis Z, van Oosterhout JJ, Allain TJ, Zachariah R, Berger SD, Harries AD, Chimbwandira F. Using touchscreen electronic medical record systems to support and monitor national scale-up of antiretroviral therapy in Malawi. *PLoS Med*. 2010 Aug 10;7(8):e1000319. doi: 10.1371/journal.pmed.1000319. PMID: 20711476; PMCID: PMC2919419.
7. Balugaba BE, Ruttoh SK, Ekirapa EK, Siika AA, Were MC. Cost Analysis of an Electronic Medical Record System at an Urban Clinic in Kampala, Uganda. *Journal of Health Informatics in Africa*. 2019;6(2):84–9.
8. Osler M, Boulle A. Three interlinked electronic registers (TIER. Net) Project. Working Paper; 2010 Sep. Available from: http://www.who.int/hiv/pub/imai/pmg_form_booklet_090907.pdf [Accessed on 03 April 2023].

9. Bates DW, Ebell M, Gotlieb E, Zapp J, Mullins HC. A proposal for electronic medical records in U.S. primary care. *J Am Med Inform Assoc*. 2003 Jan-Feb;10(1):1-10. doi: 10.1197/jamia.m1097. PMID: 12509352; PMCID: PMC150354.

10. Hossain A, Quaresma R, Rahman H. Investigating factors influencing the physicians' adoption of electronic health record (EHR) in healthcare system of Bangladesh: An empirical study. *Int J Inf Manage*. 2019 Feb 1;44:76–87.

11. Marutha NS, Ngulube P. Electronic records management in the public health sector of the Limpopo province in South Africa. *Journal of the South African Society of Archivists.* 2012;45:39-67.

12. Menachemi N, Collum TH. Benefits and drawbacks of electronic health record systems. *Risk Manag Healthc Policy*. 2011;4:47-55. doi: 10.2147/RMHP.S12985. Epub 2011 May 11. PMID: 22312227; PMCID: PMC3270933.

13. Ambinder EP. Electronic health records. *J Oncol Pract*. 2005 Jul;1(2):57-63. doi: 10.1200/JOP.2005.1.2.57. PMID: 20871681; PMCID: PMC2793588.

14. Setyadi D, Nadjib M. The Effect of Electronic Medical Records on Service Quality and Patient Satisfaction: A Literature Review. *Journal Research of Social Science, Economics, and Management*. 2023 Jul 6;2(12):2780-91.

15. Gilmer TP, O'Connor PJ, Sperl-Hillen JM, Rush WA, Johnson PE, Amundson GH, Asche SE, Ekstrom HL. Cost-effectiveness of an electronic medical record based clinical decision support system. *Health Serv Res*. 2012 Dec;47(6):2137-58. doi: 10.1111/j.1475-6773.2012.01427.x. Epub 2012 May 11. PMID: 22578085; PMCID: PMC3459233.

16. Menachemi N, Brooks RG. Reviewing the benefits and costs of electronic health records and associated patient safety technologies. *J Med Syst*. 2006 Jun;30(3):159- 68. doi: 10.1007/s10916-005-7988-x. PMID: 16848129.

17. Li K, Naganawa S, Wang K, Li P, Kato K, Li X, Zhang J, Yamauchi K. Study of the cost-benefit analysis of electronic medical record systems in general hospital in China. *J Med Syst.* 2012 Oct;36(5):3283-91. doi: 10.1007/s10916-011-9819-6. Epub 2012 Jan 3. PMID: 22212632.

18. Lee CC, Kim Y, Choi JH, Porter E. Does Electronic Health Record Systems Implementation Impact Hospital Efficiency, Profitability, and Quality?. *Journal of Applied Business & Economics*. 2022 Feb 1;24(2).

19. Bar-Dayan Y, Saed H, Boaz M, Misch Y, Shahar T, Husiascky I, Blumenfeld O. Using electronic health records to save money. *J Am Med Inform Assoc*. 2013

Jun;20(e1):e17-20. doi: 10.1136/amiajnl-2012-001504. Epub 2013 Mar 5. PMID: 23462876; PMCID: PMC3715342.

20. Muinga N, Magare S, Monda J, Kamau O, Houston S, Fraser H, Powell J, English M, Paton C. Implementing an open source electronic health record system in Kenyan health care facilities: case study. *JMIR Medical Informatics*. 2018 Apr 18;6(2):e8403.

21. Kruse CS, Stein A, Thomas H, Kaur H. The use of Electronic Health Records to Support Population Health: A Systematic Review of the Literature. *J Med Syst*. 2018 Sep 29;42(11):214. doi: 10.1007/s10916-018-1075-6. PMID: 30269237; PMCID: PMC6182727.

22. Baumann LA, Baker J, Elshaug AG. The impact of electronic health record systems on clinical documentation times: A systematic review. *Health Policy*. 2018 Aug;122(8):827-836. doi: 10.1016/j.healthpol.2018.05.014. Epub 2018 Jun 5. PMID: 29895467.

23. Choi JS, Lee WB, Rhee PL. Cost-benefit analysis of electronic medical record system at a tertiary care hospital. *Healthc Inform Res*. 2013 Sep;19(3):205-14. doi: 10.4258/hir.2013.19.3.205. Epub 2013 Sep 30. PMID: 24175119; PMCID: PMC3810528.

24. Honavar SG. Electronic medical records - The good, the bad and the ugly. *Indian J Ophthalmol*. 2020 Mar;68(3):417-418. doi: 10.4103/ijo.IJO_278_20. PMID: 32056991; PMCID: PMC7043175.

25. National Department of Health. National Digital Strategy for South Africa 2019-2024. Pretoria; 2019.

26. Luthuli LP, Kalusopa T. The management of medical records in the context of service delivery in the public sector in KwaZulu-Natal, South Africa: the case of Ngwelezana hospital. *South African Journal of Libraries and Information Science*. 2017 Dec 1;83(2):1-1.

27. Wright G, O'mahony D, Cilliers L. Electronic health information systems for public health care in South Africa: a review of current operational systems. *J Health Inform Afr.* 2017;4(1):51–7.

28. Ohuabunwa EC, Sun J, Jean Jubanyik K, Wallis LA. Electronic Medical Records in low to middle income countries: The case of Khayelitsha Hospital, South Africa. *Afr J Emerg Med.* 2016 Mar;6(1):38-43. doi: 10.1016/j.afjem.2015.06.003. Epub 2015 Jul 8. PMID: 30456062; PMCID: PMC6233247.

29. Mint Group. Chris Hani Baragwanath Academic Hospital embarks on groundbreaking digital transformation project. [Internet]. Johannesburg: iTWeb; 2024 May 14 [updated 2024 May; cited 2024 Jul 10]. Available from: https://www.itweb.co.za/article/chris-hani-baragwanath-academic-hospital-embarks-on-groundbreaking-digital-transformation-project/DZQ58vV8GONMzXy2 .

30. Netcare. South African healthcare system garners international acclaim. [Internet]. [place unknown]: Netcare; 2024 Jun 26 [updated 2024 Jun 26; cited 2024 Jul 10]. Available from: https://www.netcare.co.za/News-Hub/Articles/south-african-healthcare-system-garners-international-acclaim .

31. Wang SJ, Middleton B, Prosser LA, Bardon CG, Spurr CD, Carchidi PJ, Kittler AF, Goldszer RC, Fairchild DG, Sussman AJ, Kuperman GJ, Bates DW. A cost-benefit analysis of electronic medical records in primary care. *Am J Med*. 2003 Apr 1;114(5):397-403. doi: 10.1016/s0002-9343(03)00057-3. PMID: 12714130.

32. National Department of Health. District Health Management Information System Policy. 2011.

33. Alzghaibi H, Mughal YH, Alkhamees M, Alasqah I, Alhlayl AS, Alwheeb MH, Alrehiely M. The impact financial resources on implementation of large-scale electronic health records in the Saudi Arabia's primary healthcare centers: Mixed methods. *Front Public Health*. 2022 Dec 12;10:1037675. doi: 10.3389/fpubh.2022.1037675. PMID: 36579058; PMCID: PMC9790912.

34. Dayananda M. Factors influencing Adoption of Electronic Medical Records in Government Hospitals of Sri Lanka. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*. 2020 Dec 1;6(6):190–9.

35. Bassi J, Lau F. Measuring value for money: a scoping review on economic evaluation of health information systems. *J Am Med Inform Assoc*. 2013 Jul-Aug;20(4):792-801. doi: 10.1136/amiajnl-2012-001422. Epub 2013 Feb 15. PMID: 23416247; PMCID: PMC3721162.

36. Wiggins RE Jr, Fridl DC. Analysis of the Financial Return of Electronic Health Records. *Ophthalmology*. 2016 Jan;123(1):214-6.e2. doi: 10.1016/j.ophtha.2015.06.036. Epub 2015 Jul 23. PMID: 26212889.

37. Kumar S, Bauer K. The business case for implementing electronic health records in primary care settings in the United States. *Journal of Revenue and Pricing Management*. 2011 Mar 1;10:119-31.

38. Boardman AE, Greenberg DH, Vining AR, Weimer DL. Cost-Benefit Analysis: Concepts and Practice. 5th ed. Cambridge: Cambridge University Press; 2018.

39. Brealey RA, Myers SC, Allen F. Principles of Corporate Finance. 12th ed. New York: McGraw-Hill Education; 2017.

40. Jinabhai CC, Onwubu SC, Sibiya MN, Thakur S. Accelerating implementation of District Health Information Systems: Perspectives from healthcare workers from KwaZulu-Natal, South Africa. *South African Journal of Information Management*. 2021 Dec 10;23(1).

41. Conteh L, Walker D. Cost and unit cost calculations using step-down accounting. Health Policy Plan. 2004 Mar;19(2):127-35. doi: 10.1093/heapol/czh015. PMID: 14982891.

42. Hendriks ME, Kundu P, Boers AC, Bolarinwa OA, Te Pas MJ, Akande TM, Agbede K, Gomez GB, Redekop WK, Schultsz C, Swan Tan S. Step-by-step guideline for disease-specific costing studies in low- and middle-income countries: a mixed methodology. *Glob Health Action*. 2014 Mar 28;7:23573. doi: 10.3402/gha.v7.23573. PMID: 24685170; PMCID: PMC3970035.

43. World Health Organization. Quantities and unit prices (cost inputs) [Internet]. Available from: https://www.who.int/teams/health-systems-governance-and-financing/economic-analysis/costing-and-technical-efficiency/quantities-and-unit-prices-(cost-inputs)/econometric-estimation-of-who-choice-country-specific-costs-for-inpatient-and-outpatient-health-service-delivery [Accessed on 29 Sept 2024].

44. Statistics South Africa. STATISTICAL RELEASE P0141 Consumer Price Index [Internet]. 2024 Sep. Available from: www.statssa.gov.za [Accessed on 01 Oct 2024].

45. South African Reserve Bank. Repo rate. 2024. Available from: https://www.resbank.co.za/en/home/what-we-do/statistics/key-statistics/current-market-rates [Accessed on 29 Sept 2024].

46. South African Revenue Service. TABLE A: Average exchange rates for a year of assessment [Internet]. 2024. Available from: https://www.sars.gov.za/wp-content/uploads/Legal/Rates/Legal-Pub-AER-02-Average-Exchange-Rates-Table-A.pdf [Accessed on 05 Feb 2025].

47. Žižlavský O. Net Present Value Approach: Method for Economic Assessment of Innovation Projects. *Procedia Soc Behav Sci*. 2014 Nov;156:506–12.

48. Gallo A. A Refresher on Net Present Value [Internet]. 2014 Nov. Available from: www.business-literacy.com. [Accessed on 01 April 2023].

49. Avery AE, Flaherty SM V, Rhee MW. Fortifying The PayBack Period Method For Alternative Cash Flow Patterns. *Journal of Financial and Economic Practice*. 2011;11(2).

50. Wooldridge JM. Introductory econometrics: a modern approach. 7th ed. Boston: Cengage; 2019.

Appendix 1: Plagiarism Declaration Report

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Natasha Banda (Student number: 451468) am a student registered for the degree of Master of Public Health in the academic year 2025.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: _____ Date: 25/02/2025

1

Appendix 2: Data collection tool

Shared Costs **Year:____**

Implementation costs

Category	*Item*	*Unit Cost*	*Quantity*	*Total Value*	*Source*	*Description*
Hardware						
Software						
Training						

Running Costs

Category	*Item*	*Unit Cost*	*Quantity*	*Total Value*	*Source*	*Description*
Hardware						
Software						

	Position	*Annual Salary + Benefits*	*Number employed*	*Total*	*Source*	*Description*
Personnel						

	Description	*Size*	*Cost per m2*	*Total*	*Source*	
Storage						

	Cost	Source	Description
Other			

Unit Name_____ No___ **Year:_____**

Province:_____

Average number of patients seen per month:_____

Unit Implementation Costs:

Category	*Item*	*Unit Cost*	*Quantity*	*Total Value*	*Source*	*Description*
Hardware						
	Desktop					
	Laptop					
	Printer					
	Inverter					
Software						
	Network installation					
Internet						
	Installation costs					

Unit Running Costs:

Category	*Item*	*Unit Cost*	*Quantity*	*Total Value*	*Source*	*Description*
Hardware:						
Paper charts:						
Transportation:						
Scanning						
Software						

% EMR usage:___

Appendix 3: Linear Regression Output

Linear regression done using number of used books returned per year as independent variable and Courier costs as dependent variable. This was done to predict courier costs as the specific cost data was not available.

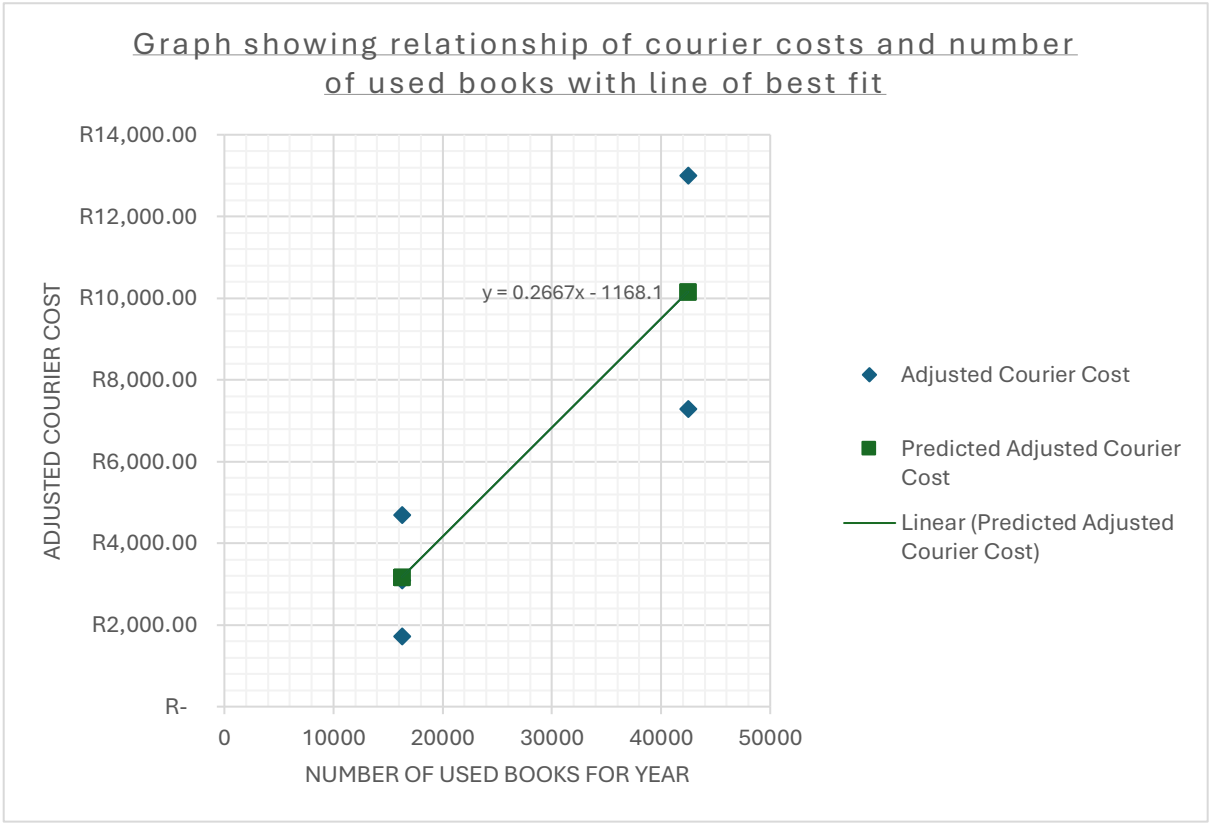
Simple linear regression output summary

Regression Statistics	
Multiple R	0.859326479
R Square	0.738441998
Adjusted R Square	0.651255998
Standard Error	2628.997862
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	58539646.92	58539646.92	8.469731301	0.061982534
Residual	3	20734889.28	6911629.76		
Total	4	79274536.2			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1168.053478	2717.41101	-0.429840563	0.696316218	-9816.068108	7479.961152	-9816.0681	7479.96115
Number of Used Books for year	0.266675636	0.091632286	2.910280279	0.061982534	-0.024939195	0.558290468	-0.0249392	0.55829047



Appendix 4: Bivariate Sensitivity Analysis Output

		Transport savings									
Preprinted stationery savings	R (4,728,292.03)	R 3,500,000.00	R 3,750,000.00	R 4,000,000.00	R 4,250,000.00	R 4,500,000.00	R 4,750,000.00	R 5,000,000.00	R 5,250,000.00	R 5,500,000.00	R 5,750,000.00	R 6,000,000.00
	R 1,500,000.00	R (6,056,624.61)	R (5,806,624.61)	R (5,556,624.61)	R (5,306,624.61)	R (5,056,624.61)	R (4,806,624.61)	R (4,556,624.61)	R (4,306,624.61)	R (4,056,624.61)	R (3,806,624.61)	R (3,556,624.61)
	R 2,000,000.00	R (5,556,624.61)	R (5,306,624.61)	R (5,056,624.61)	R (4,806,624.61)	R (4,556,624.61)	R (4,306,624.61)	R (4,056,624.61)	R (3,806,624.61)	R (3,556,624.61)	R (3,306,624.61)	R (3,056,624.61)
	R 2,500,000.00	R (5,056,624.61)	R (4,806,624.61)	R (4,556,624.61)	R (4,306,624.61)	R (4,056,624.61)	R (3,806,624.61)	R (3,556,624.61)	R (3,306,624.61)	R (3,056,624.61)	R (2,806,624.61)	R (2,556,624.61)
	R 3,000,000.00	R (4,556,624.61)	R (4,306,624.61)	R (4,056,624.61)	R (3,806,624.61)	R (3,556,624.61)	R (3,306,624.61)	R (3,056,624.61)	R (2,806,624.61)	R (2,556,624.61)	R (2,306,624.61)	R (2,056,624.61)
	R 3,500,000.00	R (4,056,624.61)	R (3,806,624.61)	R (3,556,624.61)	R (3,306,624.61)	R (3,056,624.61)	R (2,806,624.61)	R (2,556,624.61)	R (2,306,624.61)	R (2,056,624.61)	R (1,806,624.61)	R (1,556,624.61)

		Software costs									
Preprinted stationery savings	R (4,728,292.03)	R 3,500,000.00	R 3,750,000.00	R 4,000,000.00	R 4,250,000.00	R 4,500,000.00	R 4,750,000.00	R 5,000,000.00	R 5,250,000.00	R 5,500,000.00	R 5,750,000.00	R 6,000,000.00
	R 1,000,000.00	R (4,188,072.88)	R (4,438,072.88)	R (4,688,072.88)	R (4,938,072.88)	R (5,188,072.88)	R (5,438,072.88)	R (5,688,072.88)	R (5,938,072.88)	R (6,188,072.88)	R (6,438,072.88)	R (6,688,072.88)
	R 1,500,000.00	R (3,688,072.88)	R (3,938,072.88)	R (4,188,072.88)	R (4,438,072.88)	R (4,688,072.88)	R (4,938,072.88)	R (5,188,072.88)	R (5,438,072.88)	R (5,688,072.88)	R (5,938,072.88)	R (6,188,072.88)
	R 2,000,000.00	R (3,188,072.88)	R (3,438,072.88)	R (3,688,072.88)	R (3,938,072.88)	R (4,188,072.88)	R (4,438,072.88)	R (4,688,072.88)	R (4,938,072.88)	R (5,188,072.88)	R (5,438,072.88)	R (5,688,072.88)
	R 2,500,000.00	R (2,688,072.88)	R (2,938,072.88)	R (3,188,072.88)	R (3,438,072.88)	R (3,688,072.88)	R (3,938,072.88)	R (4,188,072.88)	R (4,438,072.88)	R (4,688,072.88)	R (4,938,072.88)	R (5,188,072.88)
	R 3,000,000.00	R (2,188,072.88)	R (2,438,072.88)	R (2,688,072.88)	R (2,938,072.88)	R (3,188,072.88)	R (3,438,072.88)	R (3,688,072.88)	R (3,938,072.88)	R (4,188,072.88)	R (4,438,072.88)	R (4,688,072.88)

		Software costs									
Transport savings	R (4,728,292.03)	R 3,500,000.00	R 3,750,000.00	R 4,000,000.00	R 4,250,000.00	R 4,500,000.00	R 4,750,000.00	R 5,000,000.00	R 5,250,000.00	R 5,500,000.00	R 5,750,000.00	R 6,000,000.00
	R 3,500,000.00	R (4,739,028.02)	R (4,989,028.02)	R (5,239,028.02)	R (5,489,028.02)	R (5,739,028.02)	R (5,989,028.02)	R (6,239,028.02)	R (6,489,028.02)	R (6,739,028.02)	R (6,989,028.02)	R (7,239,028.02)
	R 4,500,000.00	R (3,739,028.02)	R (3,989,028.02)	R (4,239,028.02)	R (4,489,028.02)	R (4,739,028.02)	R (4,989,028.02)	R (5,239,028.02)	R (5,489,028.02)	R (5,739,028.02)	R (5,989,028.02)	R (6,239,028.02)
	R 5,000,000.00	R (3,239,028.02)	R (3,489,028.02)	R (3,739,028.02)	R (3,989,028.02)	R (4,239,028.02)	R (4,489,028.02)	R (4,739,028.02)	R (4,989,028.02)	R (5,239,028.02)	R (5,489,028.02)	R (5,739,028.02)
	R 5,500,000.00	R (2,739,028.02)	R (2,989,028.02)	R (3,239,028.02)	R (3,489,028.02)	R (3,739,028.02)	R (3,989,028.02)	R (4,239,028.02)	R (4,489,028.02)	R (4,739,028.02)	R (4,989,028.02)	R (5,239,028.02)
	R 6,000,000.00	R (2,239,028.02)	R (2,489,028.02)	R (2,739,028.02)	R (2,989,028.02)	R (3,239,028.02)	R (3,489,028.02)	R (3,739,028.02)	R (3,989,028.02)	R (4,239,028.02)	R (4,489,028.02)	R (4,739,028.02)

		Software costs									
Development costs	R (4,728,292.03)	R 3,500,000.00	R 3,750,000.00	R 4,000,000.00	R 4,250,000.00	R 4,500,000.00	R 4,750,000.00	R 5,000,000.00	R 5,250,000.00	R 5,500,000.00	R 5,750,000.00	R 6,000,000.00
	R 500,000.00	R (913,560.36)	R (1,163,560.36)	R (1,413,560.36)	R (1,663,560.36)	R (1,913,560.36)	R (2,163,560.36)	R (2,413,560.36)	R (2,663,560.36)	R (2,913,560.36)	R (3,163,560.36)	R (3,413,560.36)
	R 1,500,000.00	R (1,913,560.36)	R (2,163,560.36)	R (2,413,560.36)	R (2,663,560.36)	R (2,913,560.36)	R (3,163,560.36)	R (3,413,560.36)	R (3,663,560.36)	R (3,913,560.36)	R (4,163,560.36)	R (4,413,560.36)
	R 2,500,000.00	R (2,913,560.36)	R (3,163,560.36)	R (3,413,560.36)	R (3,663,560.36)	R (3,913,560.36)	R (4,163,560.36)	R (4,413,560.36)	R (4,663,560.36)	R (4,913,560.36)	R (5,163,560.36)	R (5,413,560.36)
	R 3,500,000.00	R (3,913,560.36)	R (4,163,560.36)	R (4,413,560.36)	R (4,663,560.36)	R (4,913,560.36)	R (5,163,560.36)	R (5,413,560.36)	R (5,663,560.36)	R (5,913,560.36)	R (6,163,560.36)	R (6,413,560.36)
	R 4,500,000.00	R (4,913,560.36)	R (5,163,560.36)	R (5,413,560.36)	R (5,663,560.36)	R (5,913,560.36)	R (6,163,560.36)	R (6,413,560.36)	R (6,663,560.36)	R (6,913,560.36)	R (7,163,560.36)	R (7,413,560.36)

Appendix 5: Ethics Clearance Certificate

p

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Innovation)

14/02/2024

Ref: W-MvN-240214-01

TO WHOM IT MAY CONCERN

Waiver: This certifies that the following research does not require clearance from the Human Research Ethics Committee (Medical)

Investigator: Dr N Banda
Student No. (if appropriate): 451468
Staff No. (if appropriate):

Supervisor: Dr E Thsehla

School: Public Health
Department:
Division: Health Economics
Medical School
University

Project title: *Cost-benefit analysis of an electronic medical record system in an emergency unit-based private practice in South Africa*

Reason: Audit
No human participants will be involved in the study

Ms M van Niekerk
Co-Chairperson: Human Research Ethics Committee (Medical)

Research Office Secretariat:
Third Floor, Phillip Tobias Building, corner of St Andrews and York Roads, Parktown, Johannesburg 2193
Postal address: Private Bag 3, Wits 2050
Tel Nos: +27 (0)11 717 1234/1252/2656/2700
Office E-mail: HREC-Medical.ResearchOffice@wits.ac.za
Website:
https://www.wits.ac.za/research/researcher-support/research-ethics/ethics-committees/

Appendix 6: Turnitin Report

RESEARCH REPORT -3.docx

ORIGINALITY REPORT

11%	7%	4%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to University of Witwatersrand Student Paper	4%
2	Submitted to University of Stellenbosch, South Africa Student Paper	1%
3	wiredspace.wits.ac.za Internet Source	1%
4	repository.up.ac.za Internet Source	<1%
5	Munyewende, Pascalia Ozida. "Analysing the Nature and Dynamics of Nursing Management at Primary Health Care Clinics in Two South African Provinces", University of the Witwatersrand, Johannesburg (South Africa), 2025 Publication	<1%
6	e-sciencecentral.org Internet Source	<1%
7	pure.uva.nl Internet Source	<1%
8	formative.jmir.org Internet Source	<1%
9	Submitted to University of Birmingham Student Paper	<1%
10	"Mental Health Economics", Springer Science and Business Media LLC, 2017 Publication	<1%
11	Submitted to University of Cape Town Student Paper	<1%
12	Piotr Zientara, Joanna Adamska, Monika Bąk. "Social Sustainability and the Employee -	<1%

RESEARCH REPORT -3.docx

by Natasha Banda

Supervisor:
Dr Evelyn Thsehla

Submission date: 25-Feb-2025 03:14PM (UTC+0200)
Submission ID: 2598289069
File name: RESEARCH_REPORT_.docx (2.6M)
Word count: 15972
Character count: 85138