Applying Patient-Admission Predictive Algorithms in the South African Healthcare System

Determining the feasibility and value of applying patient-admission predictive algorithms in the South African healthcare system as an evidence-based preventive care strategy

By

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously, in its totality or in part, submitted the project at any university for any purpose whatsoever.

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Synopsis

Predictive analytics in healthcare has become one of the major focus areas in healthcare delivery worldwide. Due to the massive amount of healthcare data being captured, healthcare providers and health insurers are investing in predictive analytics and its enabling technologies to provide valuable insight into a large variety of healthcare outcomes. One of the latest developments in the field of healthcare predictive modelling (PM) was the launch of the Heritage Health Prize; a competition that challenges individuals from across the world to develop a predictive model that successfully identifies the patients at risk of admission to hospital from a given patient population. The patient-admission predictive algorithm (PAPA) is aimed at reducing the number of unnecessary hospitalisations that needlessly constrain healthcare service delivery worldwide.

The aim of the research presented is to determine the feasibility and value of applying PAPAs in the South African healthcare system as part of a preventive care intervention strategy. A preventive care intervention strategy is a term used to describe an out-patient hospital service, aimed at providing preventive care in an effort to avoid unnecessary hospitalisations from occurring.

The thesis utilises quantitative and qualitative techniques. This included a review of the current and historic PM applications in healthcare to determine the major expected shortfalls and barriers to implementation of PAPAs, as well as the institutional and operational requirements of these predictive algorithms. The literature study is concluded with a review of the current state of affairs in the South African healthcare system to, firstly, articulate the need for PAPAs and, secondly, to determine whether the public and private sectors provide a suitable platform for implementation (evaluated based on the operational and institutional requirements of PAPAs). Furthermore, a methodology to measure and analyse the potential value-add of a **PAPA care intervention strategy** was designed and developed. The methodology required a survey of the industry leaders in the private healthcare sector of South Africa to identify, firstly, the current performance foci and, secondly, the factors that compromise the performance of these organisations to deliver high quality, resource-effective care. A quantitative model was developed and applied to an industry leader in the private healthcare sector of South Africa, in order to gauge the resultant impact of a **PAPA care intervention strategy** on healthcare provider performance. Lastly, in an effort to ensure the seamless implementation and operation of PAPAs, an implementation framework was developed to address the strategic, tactical, and operational challenges of applying predictive analytics and preventive care strategies similar to PAPAs.

The research found that the application of PAPAs in the public healthcare sector of South Africa is infeasible. The private healthcare sector, however, was considered a suitable platform to implement PAPAs, as this sector satisfies the institutional and operational requirements of PAPAs. The value-add model found that a PAPA intervention strategy will add significant value to the performance of healthcare providers in the private healthcare sector of South Africa. Noteworthy improvements are expected in the ability of healthcare provider's to coordinate patient care, patient-practitioner relationships, inventory service levels, and staffing level efficiency and effectiveness. A slight decrease in the financial operating margin, however, was documented. The value-add methodology and implementation support framework provides a suitable platform for future researchers to explore the collaboration of preventive care and PM in an effort to improve healthcare resource management in hospitals.

In conclusion, patient-admission predictive algorithms provide improved evidence-based decision making for preventive care intervention strategies. An efficient and effective preventive care intervention strategy improves healthcare provider performance and, therefore, adds significant value to these organisations. With the proper planning and implementation support, the application of PAPA care intervention strategies will change the way healthcare is delivered worldwide.

Opsomming

Vooruitskattingsanalises in gesondheidsorg het ontwikkel in een van die mees belangrike fokusareas in die lewering van kwaliteit gesondheidsorg in ontwikkelde lande. Gesondheidsorgverskaffers en lewensversekeraars belê in vooruitskattingsanalise en ooreenstemmende tegnologieë om groot hoeveelhede gesondheidsorg pasiënt-data vas te lê, wat waardevolle insigte bied ten opsigte van ʼn groot verskeidenheid van gesondheidsorg-uitkomstes. Een van die nuutste ontwikkelinge in die veld van gesondheidsorg vooruitskattingsanalises, was die bekendstelling van die "Heritage Health Prize", 'n kompetisie wat individue regoor die wêreld uitdaag om 'n vooruitskattingsalgoritme te ontwikkel wat pasiënte identifiseer wat hoogs waarskynlik gehospitaliseer gaan word in die volgende jaar en as bron-intensief beskou word as gevolg van die beraamde tyd wat hierdie individue in die hospitaal sal deurbring. Die pasiënt-toelating vooruitskattingsalgoritme (PTVA) het ten doel om onnodige hospitaliserings te identifiseer en te voorkom tem einde verbeterde hulpbronbestuur in gesondheidsorg wêreldwyd te bewerkstellig.

Die doel van die hierdie projek is om die *uitvoerbaarheid* en *waarde* van die toepassing van PTVAs, as 'n voorkomende sorg intervensiestrategie, in die Suid-Afrikaanse gesondheidsorgstelsel te bepaal. 'n Voorkomende sorg intervensiestrategie poog om onnodige hospitaliserings te verhoed deur die nodige sorgmaatreëls te verskaf aan hoë-riskio pasiënte, sonder om hierdie individue noodwendig te hospitaliseer.

Die tesis maak gebruik van kwantitatiewe en kwalitatiewe tegnieke. Dit sluit in 'n hersiening van die huidige en historiese vooruitskattings modelle in die gesondheidsorgsektor om die verwagte struikelblokke in die implementering van PTVAs te identifiseer, asook die institusionele en operasionele vereistes van hierdie vooruitskattingsalgoritmes te bepaal. Die literatuurstudie word afgesluit met 'n oorsig van die huidige stand van sake in die Suid-Afrikaanse gesondheidsorgstelsel om, eerstens, die behoefte vir PTVAs te identifiseer en, tweedens, om te bepaal of die openbare en private sektore 'n geskikte platform vir implementering bied (gebaseer op die operasionele en institusionele vereistes van PTVAs). Verder word 'n metodologie ontwerp en ontwikkel om die potensiële waarde-toevoeging van 'n PTVA sorg intervensiestrategie te bepaal. Die metode vereis 'n steekproef van die industrieleiers in die private gesondheidsorgsektor van Suid-Afrika om die volgende te identifiseer: die huidige hoë-prioriteit sleutel prestasie aanwysers (SPAs), en die faktore wat die prestasie van hierdie organisasies komprimeer om hoë gehalte, hulpbron-effektiewe sorg te lewer. 'n Kwantitatiewe model is ontwikkel en toegepas op een industrieleier in die private

gesondheidsorgsektor van Suid-Afrika, om die gevolglike impak van 'n PTVA sorg intervensiestrategie op prestasieverbetering te meet. Ten slotte, in 'n poging om te verseker dat die implementering en werking van PTVAs glad verloop, is 'n implementeringsraamwerk ontwikkel om die strategiese, taktiese en operasionele uitdagings aan te spreek in die toepassing van vooruitskattings analises en voorkomende sorg strategieë soortgelyk aan PTVAs.

Die navorsing het bevind dat die toepassing van PTVAS in die openbare gesondheidsorgsektor van Suid-Afrika nie lewensvatbaar is nie. Die private gesondheidsorgsektor word egter beskou as 'n geskikte platform om PTVAs te implementeer, weens die bevrediging van die institusionele en operasionele vereistes van PTVAs. Die waarde-toevoegings model het bevind dat 'n PTVA intervensiestrategie beduidende waarde kan toevoeg tot die prestasieverbetering van gesondheidsorgverskaffers in die private gesondheidsorgsektor van Suid-Afrika. Die grootste verbetering word in die volgende SPAs verwag; sorg koördinasie, dokter-pasiënt verhoudings, voorraad diensvlakke, en personeel doeltreffendheid en effektiwiteit. 'n Effense afname in die finansiële bedryfsmarge word egter gedokumenteer. 'n Implementering-ondersteuningsraamwerk is ontwikkel in 'n poging om die sleutel strategiese, taktiese en operasionele faktore in die implementering en uitvoering van 'n PTVA sorg intervensiestrategie uit te lig. Die waarde-toevoegings metodologie en implementering ondersteuning raamwerk bied 'n geskikte platform vir toekomstige navorsers om die rol van vooruitskattings modelle in voorkomende sorg te ondersoek, in 'n poging om hulpbronbestuur in hospitale te verbeter.

Ten slotte, PTVAs verbeter bewysgebaseerde besluitneming vir voorkomende sorg intervensiestrategieë. 'n Doeltreffende en effektiewe voorkomende sorg intervensiestrategie voeg aansienlike waarde tot die algehele prestasieverbetering van gesondheidsorgverskaffers. Met behoorlike beplanning en ondersteuning met implementering, sal PTVA sorg intervensiestrategieë die manier waarop gesondheidsorg gelewer word, wêreldwyd verander.

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Glossary

Term	*Abbreviation*	*Description*
Heritage health prize	HHP	A competition challenging individuals or groups to develop a predictive algorithm capable of identifying patients at risk of admission to hospital, and estimating the duration of stay in hospital, given these patients' historical claims data.
Heritage Provider Network	HPN	The organisation sponsoring the $3 million Heritage health prize
Patient-admission predictive algorithm	PAPA	The predictive algorithm developed for identifying patients at risk of admission, and their estimated duration of stay in hospital, to ultimately prevent unnecessary hospitalisations from occurring
Preventive care intervention strategy	PCIS	An out-patient care service, provided by hospitals, which supplies preventive care to individuals at high-risk of admission to hospital, to ultimately prevent these individuals from being admitted to hospital unnecessarily
Computationally intensive predictive algorithm	CIPA	Predictive algorithms that utilise big and complex datasets with the use of information technology to generate forecasts
Electronic health records	EHR	Patient health records, stored in a digital format, which contain data such as medical history, demographic data, causes of admission to hospital, laboratory test results *etc.*
Healthcare resource management	HCRM	The discipline of managing employees, inventory, finances, and information to provide a range of healthcare services
Healthcare provider	HCP	Hospital or clinic
Health information management system	HIMS	An extensive aggregation of health statistics from various sources, used to derive information about health status, healthcare provision, utilisation of services, and health impact
Information communication technology	ICT	A collective term for all technologies enabling information distribution and communication
Length of stay	LOS	The duration of a patient's hospital stay, from admission to discharge, measured in days
Length of stay index	LOSI	The index generated by a PAPA for each individual in the patient database, used for identifying possible resource-intensive hospitalisations. Individuals with high LOSIs are more likely to receive preventive care
Preventive care team	PCT	The medical team responsible for interceding with individuals as part of the preventive care intervention strategy

1. Introduction

Chapter one introduces the major research focus of this body of work, by describing the origin of the project, problem statement, research objectives, project scope, project methodology, and plan of development. The *origin of the project* focuses on the manner in which the research proposal and subsequent research objectives were established. Hereafter, the *problem statement* is presented in an effort to identify the major research problems to be addressed in the thesis, followed by a section on the resulting *research objectives*. The *project scope* will provide some perspective on the focus of the thesis and clarifies some ambiguities with regards to the research proposal. The *project methodology* serves as a roadmap of the techniques and methods used to address and achieve the respective research problems and objectives. Finally, the chapter is concluded with a *plan of development* that highlights the major outcomes of each chapter in the thesis.

1.1. Origin of the project

The study was inspired by the Heritage Health Prize (HHP) that launched in April 2011. The objective of the HHP is to develop an algorithm that is able to accurately predict, from a given patient database, which patients will most probably be admitted to hospital in the coming year and, concurrently, specify each patient's estimated length of stay (LOS) (Heritage Provider Network, 2011). The Heritage Provider Network (HPN) believes that a dramatic improvement in healthcare resource management can be expected if these preventable hospitalisations are identified early on and avoided through less resource-intensive care strategies (Heritage Provider Network, 2011).

The HHP inspired thought around the possibility of developing such a tailored South African patient-admission predictive algorithm (PAPA). A collaborative project was launched in conjunction with Mrs Tanya Visser, Ms Ilze van Zyl and Mrs Liezl van Dyk to explore the possibilities of developing and applying PAPAs in the South African healthcare system. It was determined that the feasibility and value proposition of such an algorithm had to be explored first, before the development of the algorithm commences. Hence, the subject of the thesis was determined, which mainly addresses the following elements:

- *defining the enabling factors (requirements) for the successful implementation of PAPAs,*
- *measurement the potential value-add of PAPAs , and*
- *developing an implementation support framework.*

1.2. Problem statement

Healthcare resource management (HCRM) is a global problem (Turner, Mehrotra, & Daskin, 2010). The need for a simple and realistic solution has been articulated by the amount of unnecessary resource expenditures in the healthcare system of the United States of America. In African healthcare systems, HCRM problems are overshadowed by major healthcare pandemics such as HIV/AIDS, Malaria and Tuberculosis (World Health Organisation, 2008).

It is postulated that PAPAs have the potential to aid in the eradication or alleviation of HCRM problems, but the design, development and application of these tools pose various challenges. The feasibility of applying PAPAs in developed countries leaves little doubt. In developed countries with the financial capacity, state-of-the-art technology and competent management, the barriers to implementation can be overcome with proper leadership and commitment. In South Africa, however, various questions are raised with regards to the availability of the essential institutional and operational requirements for the implementation and operation of predictive models in healthcare, especially in the public healthcare sector.

The total value-add of PAPAs and the extent to which these predictive models might improve healthcare provider (HCP) performance, remains essentially unknown. Wharam & Weiner (2012) found that in most cases, healthcare predictive modelling (PM) has uncertain effectiveness. Therefore, it is imperative that the potential ***value-add*** of PAPAs be established prior to the design, development and implementation phases, to ensure that PAPAs have measurable effectiveness when applied in the South African healthcare system.

The lack of proper support and guidance in the implementation of predictive models, in the form of adequate planning and policies, frequently result in failed pilot implementation projects (Wharam & Weiner, 2012). Therefore, the need for a sound implementation support framework for the application of PAPAs, which addresses all of the relevant levels of decision-making in healthcare, exists.

1.3. Research objectives

The preliminary literature study identified the major research question to be addressed in this thesis. The initial **research question** is; will the application of PAPAs add significant value to healthcare providers in South Africa, through the improvement of healthcare provider performance?

Therefore, the primary objective of this thesis is to establish the potential value-add of a preventive care intervention strategy (PCIS), based on the evidence generated with PAPAs, to healthcare providers in the South African healthcare system. In essence, the total value-add of a PCIS will be determined according to the impact of this strategy on healthcare provider (hospital) performance. The impact on hospital performance will be measured from a systems perspective and is not limited to the financial impact of applying the PCIS.

For a PCIS to add value to healthcare providers, it should firstly be determined whether these organisations are fit for applying PAPAs. Therefore, the feasibility of applying a PAPA care intervention strategy in the South African healthcare system should be established, and is considered a secondary research objective of this thesis.

1.4. Project scope

As previously mentioned, patient-admission predictive algorithms aim to predict and identify patients at high-risk of admission to hospital, to ultimately prevent these unnecessary hospitalisations from starving hospital resources.

The application of a PAPA in a healthcare provider setting (hospital or clinic) depends on various key factors. Firstly, healthcare providers (HCPs) need to supply the technological infrastructure and data required by computationally intensive predictive algorithms (CIPAs) similar to PAPAs. The PAPA retrieves the relevant patient data and generates the forecasted results for each individual in the patient population. Finally, the results, which consist of a list of patients at risk of admission to hospital and their associated length of stay indices (LOSIs), are communicated to key decision-makers in the hospital.

The increased use of evidence-based management and care is expected to provide a platform for preventive care intervention strategies and improved HCRM. ***Figure 1*** depicts the use of PAPAs as a driver for healthcare decision-making, given a suitable information technology platform. This relationship between the data and technology, the PAPAs, and the HCPs, aids in the establishment of the project scope.

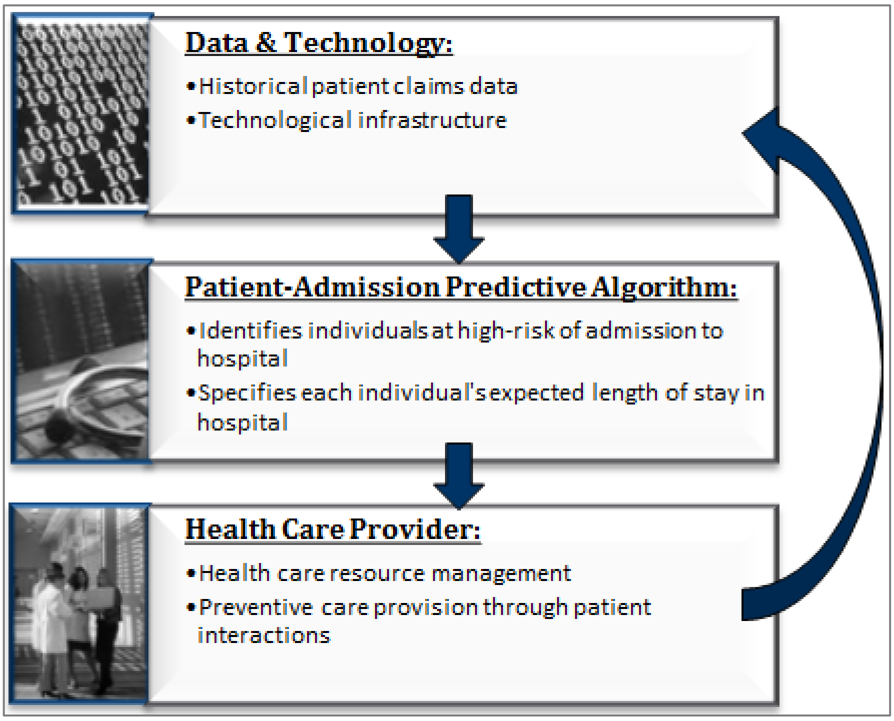


Figure 1 – The patient-admission predictive algorithm as a driver for healthcare decision-making

The project scope of this thesis ***excludes the attempt to design or develop the PAPA***. The thesis focuses on the requirements to successfully apply PAPAs in the South African healthcare system and establishing the potential impact on healthcare provider performance.

1.5. Project methodology

The project methodology serves as a guideline throughout the research process and paves the way for the successful delivery of the research project in the allotted time. From the established research problems and objectives, it can be deduced that a combination of qualitative and quantitative methods will be required to methodically execute the research process.

The project methodology illustrates the methods, techniques and process required for answering the research question. ***Figure 2*** illustrates the essence of the project methodology, with the following project phases; 1) familiarisation of the study domain, 2) design, development and analysis of the value-add methodology and model, and 3) implementation planning.

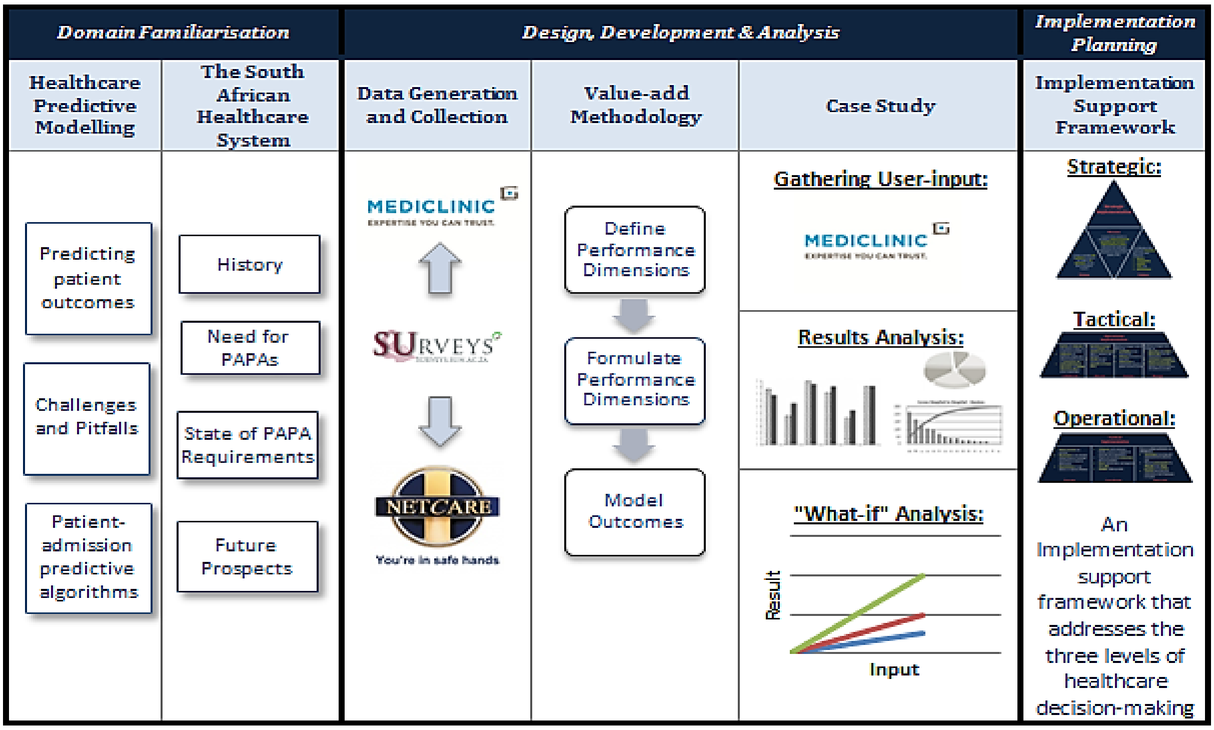


Figure 2 - Project methodology

In the first phase, a familiarisation of the study domain is achieved with a literature review of the predictive modelling applications in healthcare and the current state of affairs in the South African healthcare system. The objectives of the literature study is to 1) identify the major enabling factors (requirements) for applying a PAPA care intervention strategy in the South African healthcare system, and 2) evaluating whether HCPs in South Africa satisfy these requirements. The literature study will identify the possible areas for implementing PAPAs, provided that the public or private healthcare sectors satisfy the requirements for applying PAPAs.

The second phase revolves around the design, development and analysis of the value-add methodology for determining the potential impact of a PAPA preventive care intervention strategy. Due to the massive number of performance indicators in hospitals, surveys will be used to identify the current top-priority key performance indicators (KPIs) from a systems perspective of healthcare provision. The surveys will also be utilised to identify the major factors compromising a hospital's ability to perform with regards to the identified KPIs. These performance compromising factors (PCFs) and KPIs will provide a basis for determining the potential value-add of a PAPA care intervention strategy to hospitals in the South African healthcare system. The value-add model will be applied to a typical hospital group, as a case study of the potential impact on hospital performance. Depending on the nature of the value-add model results, **the research question will answered and the outcome** tested by means of a "what-if" analysis. For example, if the value-add model indicates that the majority of KPIs are positively affected with the implementation of a PAPA care intervention strategy; **the research question will be positively affirmed.** Hereafter, the "what-if" analysis will be used to determine the range of uncertainty in the model output, by comparing the results of a base, best and worst case scenario.

The third and final phase, *implementation planning,* concludes the project methodology. This phase will focus on providing an implementation support framework that draws upon previously developed strategic frameworks in the fields of preventive care services and healthcare predictive modelling.

1.6. Plan of development

The plan of development documents the chapter outline of the study and the expected outcomes associated with the major topics in this thesis.

Chapter 2 studies the field of healthcare predictive modelling in an effort to establish 1) the major comparisons and differences between previously developed predictive algorithms and PAPAs, 2) the common challenges and pitfalls of predictive modelling, and 3) the institutional and operational requirements of applying PAPAs in a healthcare provider setting.

In order to establish the feasibility of applying PAPAs in the South African healthcare system, **Chapter 3** studies 1) whether a definite need for improved healthcare resource management exists, 2) the extent to which the public and private healthcare sectors satisfy the institutional and operational requirements of applying PAPAs, and 3) the future prospects for healthcare in South Africa that might impact the feasibility of applying PAPAs in this country.

Chapter 4 is aimed at determining the potential value-add of PAPAs to HCPs. The major research outputs of this chapter are; 1) a survey of leading HCPs in South Africa to determine the current performance foci of these organisations, and 2) the design and development of value-add methodology and quantitative model to analyse the potential impact of a PAPA care intervention strategy on healthcare provider performance.

Chapter 5 utilises the value-add model in a case study of a leading hospital group in South Africa, to determine the potential impact of a PAPA care intervention strategy on this healthcare provider's performance. The **research question** is reviewed in this chapter and the validity of the results is tested by means of a sensitivity ("what-if") analysis.

Chapter 6 provides the implementation support framework aimed at identifying the key areas of decision-making in the application of PAPAs in the South African healthcare system. **Chapter 7** completes the body of work by articulating the relevance of the study and recommendations for future work.

2. Healthcare predictive modelling

Chapter two initialises the domain familiarisation phase of the project methodology as depicted in ***Figure 3.*** The chapter is introduced with a brief history of healthcare predictive modelling. Furthermore, three major topics are covered in this chapter; a historic review of predictive algorithms aimed at predicting patient outcome trends, common challenges and pitfalls of predictive modelling in healthcare, and the introduction to one of the latest developments in the field of healthcare predictive modelling called patient-admission predictive algorithms (PAPAs).

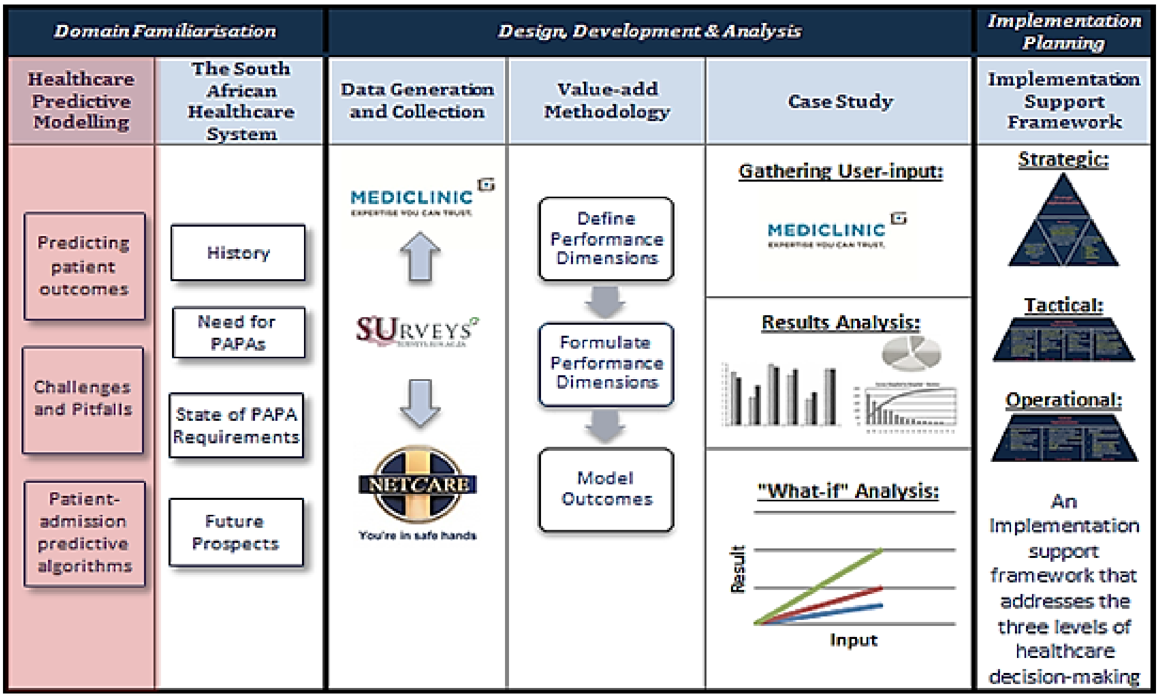


Figure 3 - Reviewing the project methodology: domain familiarisation

2.1. History of healthcare predictive modelling

In the 1800's John Snow used a combination of geographical maps and conventional bar charts (see ***Figure 4***) to identify the source of cholera in 1854 and through this proved that the cholera was being transmitted through the water supply (Tufte, 1997). John Snow used historical data (the number of sick patients per location) to predict an outcome (the cause of the sickness) in an effort to address a persistent and growing problem (an increased number of patients presenting with similar symptoms). Therefore, this example illustrates one the earliest trend-prediction models ever documented (Tufte, 1997).

Figure 4 - Bar charts and geographical maps used to determine the source of cholera in 1854.

Source: (Tufte, 1997)

Since then, a variety of predictive modelling (PM) applications have been applied to a wide range of healthcare problems, ranging from discrete event simulation of emergency room patient flow, the prediction of waiting times and expected resource usage (Brailsford and Schmidt, 2003; Davies, 1997) to the mathematical optimisation of key healthcare processes to improve the cost-effectiveness of selected medical care interventions (Sendi and Al, 2003; Stevens and Normand, 2004).

According to The Microsoft Corporation (2008) "the proliferation of reporting and multidimensional analytics has greatly benefited many organisations of various sizes, the next step in promoting business agility and operational efficiency is to make the leap from retrospective analysis of historical data to proactive actions based on predictive analysis of organisational data, and to embed intelligent, fact-based decision-making into business processes."

The key to accomplishing increased evidence-based decision-making in healthcare is to use accurate *predictive algorithms*. Predictive algorithms should be developed with the sole purpose of analysing patient data sets to enable the identification of previously unknown patient behaviours and underlying patient outcome trends. Furthermore, predictive algorithms can be used to identify classifications and relationships between patients and healthcare processes that deliver accurate predictive insights into the extent to which systems and healthcare processes affect *clinical*, *managerial* and *operational* outcomes in hospitals.

2.2. Overview of healthcare predictive modelling

Data-centric processes and methods allow operations researchers to transform data into predictive models, in an effort to identify underlying trends or patterns and subsequently generate forecasts with well-characterised accuracies about the future (Horvitz, 2010). The role of PM in healthcare is to enable and aid various key decision-making processes in healthcare management (Horvitz, 2010).

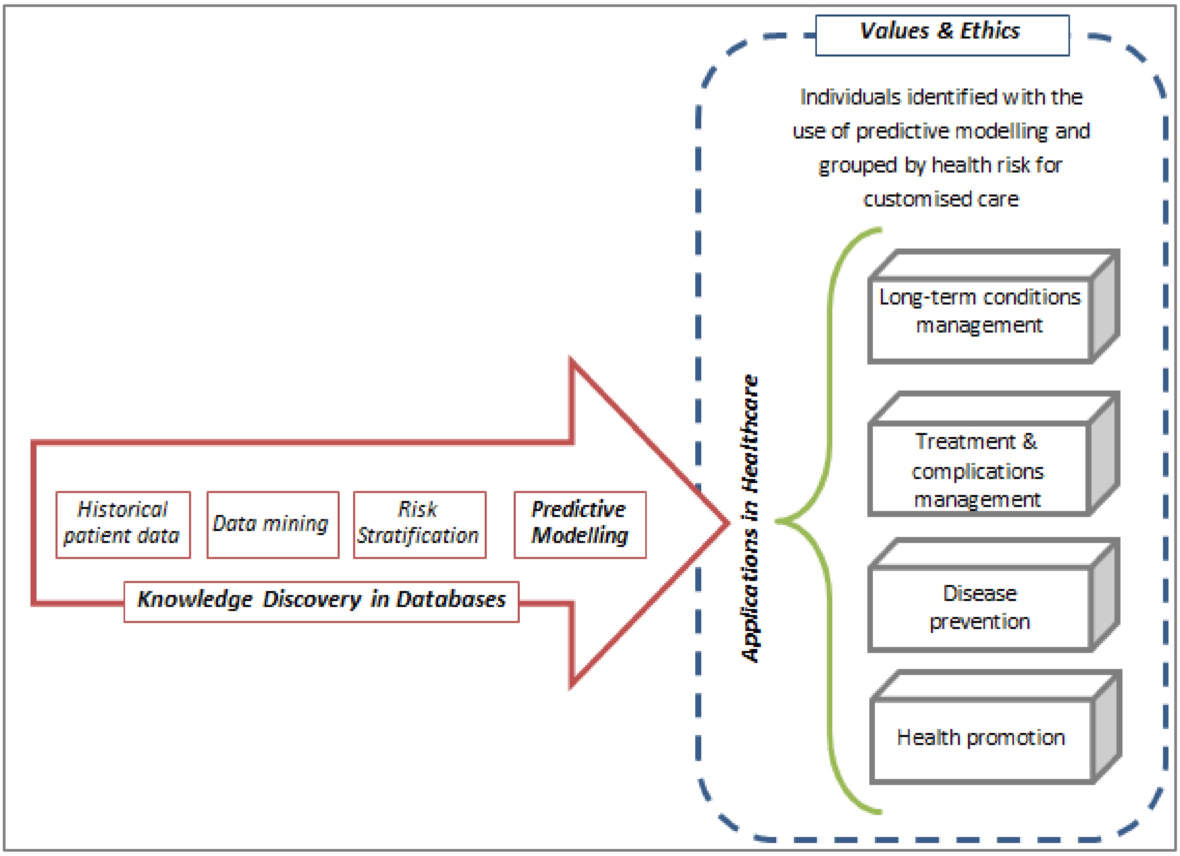


Figure 5 – Overview of healthcare predictive modelling adapted from (De Gruy, 2000).

Figure 5 supplies an overview of the role PM plays in healthcare provision. PM is a product of knowledge discovery in databases, a process in which data is gathered, prepared and mined for the purpose of identifying underlying patterns in the data (De Gruy, 2000). Furthermore, the figure depicts the role of values and ethics in the identification, management, and treatment of patients at risk of admission to hospital. The ethical debate revolves around the provision of customised care to a limited number of individuals, in essence, the patients at high-risk of admission to hospital. Questions regarding the motivation behind healthcare providers' decision to provide customised care plans to a limited number of individuals still remain. ***Figure 5*** illustrates the four major healthcare provider focus areas that have benefitted from improved evidence-based decision making due to the application of predictive modelling (De Gruy, 2000):

- *Long-term condition management of chronic illnesses and non-communicable diseases*
- *Treatment, complications, and acute case management*
- *Disease prevention by identifying patients at risk of admission to hospital*
- *Health promotion with the application of preventive, out-patient, coordinated care*

Health insurance providers are the most well-known users of PM in healthcare. These organisations utilise predictive models to determine insurance premiums and rates, classify scheme coverage, and calculate subsidised payment strategies based on an individual's long-term condition management requirements and the risk of admission to hospital (Lang *et al.,* 2008). Furthermore, health insurance providers utilise predictive models to construct payment structures and models based on the *prospective payment principle*, where historical trends of patient cost data are analysed in order to determine the insurance-coverage payment based on the *anticipated cost* of a patient's care in the near future (Duncan, 2011).

Clinical applications of predictive modelling in healthcare are not especially common, but offer a great deal of potential value to providers and patients (Lang *et al.,* 2008). The problem is the lack of standardised and comprehensive patient information, tracked over an extended period of time (Lang *et al.,* 2008). For this reason, the majority of clinical predictive models in healthcare have been based on claims data, which generally offer limited information about diagnoses and treatments. Subsequently, this information has been used to help insurance providers identify patients who are appropriate for, and would benefit from, participation in disease management programs. However, these predictive models are pseudo-clinical applications of predictive modelling, which are still driven by the *expected cost and revenue impact* on health insurance providers and not the clinical outcomes or the quality of care delivered to the patients(Lang *et al.,* 2008).

Lang *et al.* (2008) believes that patient-risk identification with the use PM can be useful tools in the management of out-patient or preventive care. Care teams will be able to create and direct a patient's plan of care according to the expected disease risks, proactively identify the best clinical protocols for improved timeliness delivery of care, and allocate costly resources to those patients with the greatest need and associated benefits Lang *et al.* (2008).In order to successfully integrate PM in healthcare and standardise the application thereof in clinical practice, Lang *et al.* (2008) advises the following changes to the healthcare delivery model:

- *The systemisation of clinical decision-making and resource utilisation processes*
- *The standardisation of out-patient care delivery processes*
- *The implementation of best practices to improve efficiency and effectiveness of out-patient clinical teams*
- *The standardisation of objective input from predictive models into decision-making processes to focus resources on the patients with the greatest need*
- *The implementation of an enterprise-wide tool to predict patient outcomes can increase understanding, communication, and cooperation in clinical or interdisciplinary teams*

The establishment of these guidelines for the application of clinical predictive models in healthcare has provided a basis for the standardisation and advancement of fact-based decision-making to improve clinical patient outcomes.

The following sections aim to evaluate some of the more recent clinical applications of PM in healthcare and serve as an introduction to one of the latest developments in the field of healthcare predictive modelling.

2.3. Algorithms predicting patient outcomes

The availability of a variety of predictive models in healthcare has provided numerous policy makers with the evidence they need to establish medical insurance rates, manage communicable disease outbreaks, improve hospital utilisations rates, *et cetera*. The following subsections, however, will elaborate on some of the predictive algorithms that aim to predict clinical patient outcomes and behaviours that relate to 1) the identification of individuals at high risk of admission to hospital, 2) the prevention of unnecessary hospitalisations, and 3) estimating a patient's length of stay (LOS) in hospital. These applications are of particular interest due to their affiliation with patient-admission predictive algorithms.

2.3.1. Predicting patients at risk of admission

The discipline of predicting patients at risk of admission to hospital has been widely used to establish, adapt and improve health insurance scheme models (Graf, 2008). The Hospital Admission Risk Profile (HARP) is an example of such a model, similarly used by medical insurance providers to charge higher insurance rates for individuals with high-risk profiles. HARP was developed by conducting a *logistic regression analysis* on various key in-patient data characteristics. Three major patient characteristics were found to be independently predictive of high-risk patients (Graf, 2008):

- *older age,*
- *cognitive ability, and*
- *lower pre-admission instrumental activities of daily living (IADL)*[1] *scores.*

Graf (2008) believed that a patient's risk of admission to hospital is most sensitive to *age-associated physiognomies*. The HARP was later adapted for use in old-age home-based care evaluation systems, as it lacked specificity and accuracy of risk identification in younger individuals.

The risk information system for cost (RISC) tool was developed by United Healthcare with the aim of predicting the patients, in a given patient database, that are most likely to have an unplanned hospital admission in the next twelve months, with the aim of improving the cost-management of these hospital admissions (Martin *et al.*, 2011).

RISC reports provide decision support for policy makers and managed care commissioners to analyse specific pathways and target interventions accordingly. The tool identifies patients who are suitable for disease management or self-care programmes and provides a systematic look at the change in healthcare utilisation patterns for specific managed care cases, aiding in the evaluation of the cost-effectiveness of certain interventions. RISC data sources include (Martin *et al.*, 2011):

- *census data,*
- *registry data,*
- *accident and emergency (A&E) visits,*
- *consultant and general practitioner visits, and*
- *drug history.*

The RISC tool solely focuses on identifying patients at high risk of admission to hospital to improve the cost management of these admissions. However, the scope exists to investigate the non-

[1] Seven IADLs included in the HARP instrument include: managing finances, taking medications, use of the telephone, shopping, transportation, housekeeping, and food preparation.

financial impact of accurately identifying high-risk patients as well. Furthermore, with the increased availability of large and complex sets of patient data, the possibility arises to incorporate additional patient characteristics in the identification of high-risk patient, in an effort to improve the accuracy of these predictive models.

2.3.2. Predicting unnecessary hospitalisations

The term 'unnecessary hospitalisations' is commonly associated with other expressions such as 'avoidable hospital readmissions'. In essence, there is no single definition for the term 'unnecessary hospitalisations' (Maslow and Ouslander, 2012). However, for the purpose of this study, unnecessary hospitalisations are defined as those hospitalisations that could have been prevented, if preventive care measures were properly executed.

Bindman et al. (1995) studied the relationship between and effects of access to healthcare services and the number of preventable hospitalisations. The study applied several stepwise multiple-regression models to predict unnecessary, community-based, hospitalisation rates and used simple insurance claims data to construct a multivariate model from which various relationships could be studied.

The study found Individuals living in areas where residents had difficulty receiving medical care had high rates of unnecessary hospitalisations for chronic medical conditions (Bindman et al., 1995). Furthermore, a strong relationship between access to care and unnecessary hospitalisation rates persisted even after controlling for differences in demographics, income, the propensity to seek care, and physician practice styles (Bindman et al., 1995). Therefore, Bindman's study supports the definition for unnecessary hospitalisations, by suggesting that improved access to medical care, which includes out-patient and home-based care, decreases the rate of unnecessary hospitalisations.

2.3.3. Predicting patient length of stay

Gustafson (1968) documents one of the earliest efforts to predict and explain the effects of patient length of stay (LOS) on hospital performance. The study evaluated the accuracy of five predictive models and concluded that the Bayesian decision theory model offered physicians an additional dimension to consider when deciding whether to operate in high-risk cases or to proceed with nonsurgical treatment, due to the effects on patient LOS.

Since Gustafson's effort in 1968, various efforts have been initiated the model the probability of patient admissions to hospital (Tsui *et al*., 2008; Lewis G, 2006; Satz *et al*., 2003). These applications utilised various methods from artificial neural networks to regression models. However, these models have been found to be limited in their ability to aid in the management of patient length of stay, mainly because the response outputs of these models merely specify a risk index for each patient.

Healthcare providers aim to limit patient LOS to six days, largely due to the decline in profitability after this period and the inconvenience to patients (Srinivasan, 2008). Therefore, if patient X has an 85% risk of admission (ROA) to hospital and an actual LOS of 3 days, and patient Y has a 65% ROA and an actual LOS of 12 days, it may be more beneficial to prevent patient Y from being admitted to hospital, due to the longer LOS. Therefore, future possible work could include the estimation of patient LOS rather than the simple prediction of a binary output such as ROA (Satz et al., 2003).

Wrenn et al. (2005) set out to study the expected LOS of patients at an Emergency Department. The study developed and validated an artificial neural network (ANN) using clinical and operational parameters from more than 16,000 patients. The ANN used patient variables, obtained from a computerised emergency department whiteboard, which included:

- *patient age,*
- *acuity level,*
- *international classification of diseases or ICD-9 chief complaints,*
- *consult service orders,*
- *laboratory examinations, and*
- *radiology examinations.*

The simulation ran on operational parameters such as average waiting time for patients in the waiting room, number of patients with health risk indicators and number of pending departures. Wrenn *et al.* (2005) concluded that the “acuity level” and “chief ICD-9 complaint” indicators were the main patient characteristics that determined the outcome of patient waiting times and the subsequent variations in patient LOS.

Kudyba and Gregorio (2010) focused on the impact of varying patient LOS metrics on hospital performance and stated that patient LOS proves to be a critical performance measurement for healthcare organisations. However, the complexity of fully identifying all the factors that impact patient LOS still remains. Kudyba and Gregorio (2010) advised future researchers to apply concepts established in supply chain optimisation and operations research to provide the fundamental base for addressing this issue.

It is safe to conclude from the extensive amount of research on PM in healthcare, that the potential benefits of identifying previously unknown trends and patterns in patient-outcome evaluation, is substantial. However, apart from the individual model limitations, these predictive analytic efforts are not without their challenges and pitfalls. The following section focuses on the barriers to implementation that healthcare data analysts are currently faced with.

2.4. Challenges and pitfalls of healthcare predictive modelling

With the development of various accurate and complex predictive models aimed at identifying patterns in patient-outcomes, various pitfalls and challenges still remain.

2.4.1. Short-term focus

Due to the rapid turnover of insurance coverage and the current regulations in countries such as the United States of America, where high risk patients may be denied insurance coverage, the majority of predictive models focus on short-term, high-cost outcomes (Wharam & Weiner, 2012). However, predictive models can, and should, also be utilised to identify patients that require longer-term benefits (Wharam & Weiner, 2012).

Furthermore, a short-term focus constrains the ability of healthcare providers to plan with great effectiveness, especially in a less agile care provider environment with a centralised resource management function (Wharam & Weiner, 2012).

2.4.2. Patient information security

There are numerous risks associated with the security of the storage, utilisation and distribution of patient information by means of electronic resources. Patient information security has been on the forefront of inhibiting the implementation of healthcare technologies such as electronic health records, public health networks, and biometric and computerised physician order entry systems (Wharam & Weiner, 2012).

The widespread concern regarding patient information security threatens the application of predictive algorithms that functionally utilise these datasets to produce accurate forecasts and is considered one of the major challenges to implementation of predictive analytics.

2.4.3. Promoting disease management with limited effectiveness

Predictive algorithms may be able to accurately predict patients at a high risk of admission to hospital, but the incapacity of healthcare providers to supply a range of disease management approaches, constrain the effectiveness of producing better health outcomes. This problem is commonly referred to as the "impactibility" problem (Wharam & Weiner, 2012) in predictive modelling.

In essence, little evidence or research suggests how or whether clinical care demand forecasts improve healthcare value (Goetzel *et al.*, 2005). Therefore, predictive models and the effort required to design, develop and validate these models, run the risk of becoming obsolete due to this "impactibility" problem (Lewis G. H., 2010). For example, healthcare data analysts have access to large and complex sets of patient data and are inclined to mindlessly delve into this data with the sole purpose of identifying previously unknown patterns or trends. However, without any sufficient evidence to suggest that these predictive models may add value to healthcare decision-making, the actual impact of these predictive models are insignificant.

2.4.4. Lack of standardisation and collaboration

One of the major shortfalls in the effort to improve the effectiveness of predictive models in healthcare relates to the competitive nature of the private healthcare sectors worldwide. Due to the fact that private companies develop and sell prediction algorithms, a strong incentive exists to maintain proprietary models (Wharam & Weiner, 2012).

Furthermore, no policies or regulations exist that govern the standards of forecasting in healthcare, which results in a decrease in transparency of practicing preventive care interventions. This in turn, constrains collaborative efforts to improve the effectiveness of predictive modelling in healthcare and results in a duplication of effort in the design and development of predictive algorithms that have striking resemblances and mostly address the same problems, with the use of different techniques (Stehno, 2006).

2.4.5. Contributing to increased disparities in quality healthcare delivery

From a private healthcare provider perspective, it is obvious that these companies or organisations would aim to maintain or increase profits at any given time. Subsequently, some predictive model vendors acknowledge that their predictive algorithms can be used to *avoid* high-risk patients (Lewis G. H., 2010). Therefore these models can also be applied to identify patients that are expected to remain healthy. For example, some health plans explicitly ***exclude*** patients with mental health diagnoses, addictions, and language barriers from disease management or preventive care interventions, because these factors might predict a minimal impact with interventions (Lewis G. H., 2010).

A fundamental mind shift needs to occur that strategically and transparently aims to provide quality preventive care to the individuals that are in the greatest need of it, instead of contributing to increased disparities in equitable healthcare delivery, due to the financial benefit of interceding with a limited number of individuals. The role of predictive modelling in this effort will rely on the ability of industry leaders to collaborate their strategic and operational efforts to develop globally accepted, standardised predictive models, to successfully identify and prevent unnecessary hospitalisations from occurring and promote preventive care services as part of these companies' value offerings, in an effort to provide equitable healthcare to all.

Section 2.4 introduces the concept of patient-admission predictive algorithms (PAPAs). The development of PAPAs drew much attention in the year 2011 and has instilled hope in resource stricken healthcare environments around the world, with its potential to decrease the number of unnecessary hospitalisations in a given patient population.

2.5. Introducing patient-admission predictive algorithms

As previously mentioned, patient-admission predictive algorithms were inspired by the Heritage Health Prize, which requires individuals or groups to develop a predictive algorithm that, based on historical insurance claims data, will help identify those patients most likely to be admitted to hospital in the coming year, and concurrently specify the estimated LOS of each individual in the patient database. The following sub-sections aim to establish the algorithm's objectives, method, requirements definition, and scope for implementation in the South African healthcare system.

2.5.1. Background

2.5.1.1. Hypothetical implementation

PAPAs aim to address the growing concern of ineffective resource utilisation in the healthcare system of the United States of America (Heritage Provider Network, 2011). In 2006, it was estimated that well over $30 billion of unnecessary healthcare resources were spent on preventable hospitalisations in the United States alone, articulating the need for a solution that will prevent, or better manage, these unnecessary hospitalisations (Heritage Provider Network, 2011). In 2009, a study determined the potential benefits of accurately forecasting daily healthcare resource requirements according to given hospital admission policies. The study concluded that these predictions increased resource management efficiencies (Garg *et al.*,2010). Therefore, it would seem that a definite scope for the implementation of these interventions exists.

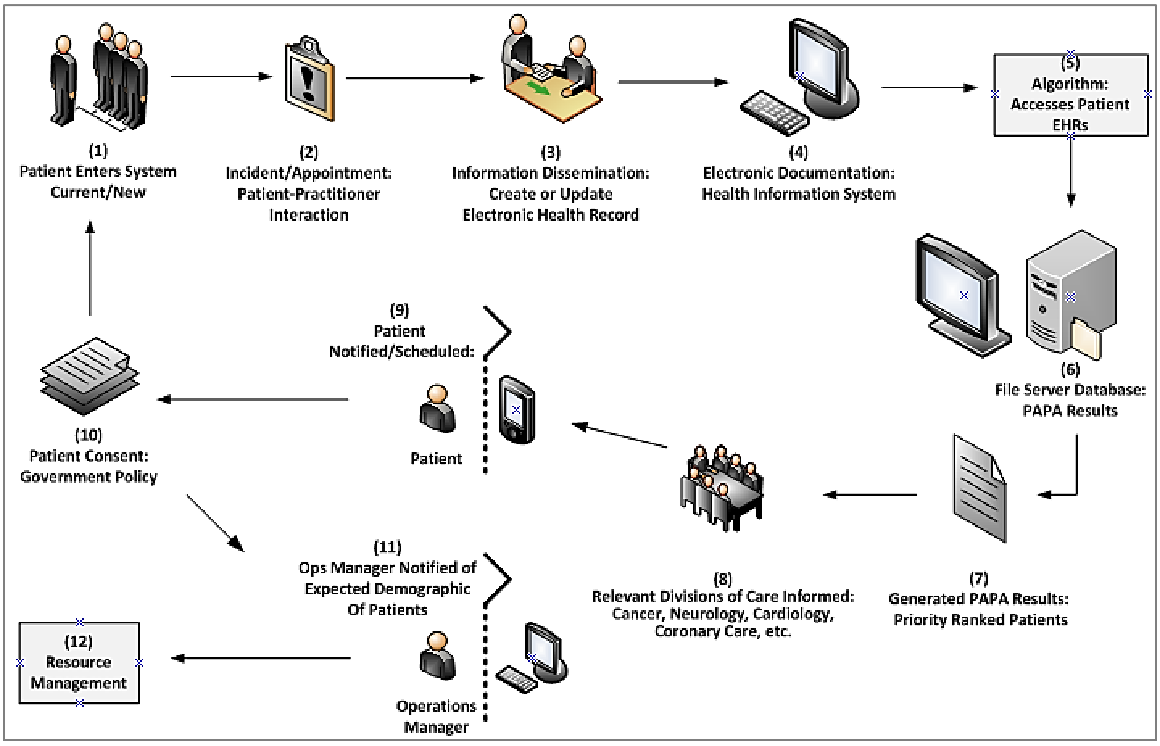


Figure 6 - Hypothetical implementation of a PAPA preventive care intervention strategy

The flowchart in ***Figure 6*** embodies the logical application of a PAPA care intervention strategy in a generic healthcare provider setting. The chart specifies the *key processes* that enables the use of these algorithms, and assists in the identification of the key institutional and operational requirements for the successful implementation of PAPAs. Furthermore, ***Figure 6*** illustrates how these algorithms can be utilised in collaboration with a preventive care intervention strategy (PCIS) to improve healthcare resource management and prevent unnecessary hospitalisations.

The process can be described in the following manner:

1) Patients entering the system can either be a new patient (no health record exists) or a current patient on the hospital's patient database (health record exists).

2) Patient-practitioner interaction occurs due to a scheduled (preventive care intervention) or an unscheduled occurrence (accident and emergency visits).

3) Patient-practitioner interactions result in new patient data that need to be disseminated to the patient's electronic health record.

4) The patient health records are made available on the hospital's health information management system (HIMS), which ensures that the records are easily attainable and in a suitable electronic format as required by the PAPA.

5) PAPA utilises the required patient-data and estimates the risk of admission and associated patient length of stay indices (LOSIs) for each patient in the hospital's database.

6) Generated lists of 'flagged' patients (patients with high LOSIs) are stored locally on the file server database.

7) 'Flagged' patients are prioritised with the help of a tailored decision-support system.

8) On a timely basis, the priority ranked patients are discussed, and the individual divisions of care and policy makers decide whether preventive care measures are required, and consider feasible intervention strategies for each specific case.

9) High priority patients are then notified of their preventive care intervention plan.

10) Provided that the necessary patient consent is obtained to supply preventive care to the identified individuals, the patient is scheduled for his or her preventive care intervention.

11) Once the final list of preventive care patients are identified, the operations manager responsible for managing the hospital's healthcare resources, is notified of the expected demographic of patients the hospital will be able and unable to intercede with in the following year.

12) Improved evidence-based healthcare resource management is effected due to the decrease in clinical care service demand variability.

The cyclic process is constantly updated with new data generated from in-patient care interactions or schedule preventive care interventions, which will require the supply of real-time data to the PAPAs in order to efficiently identify high-risk patients in a timely manner.

2.5.1.2. The role of the preventive care intervention strategy

A preventive care intervention strategy is an out-patient care service provided by healthcare providers in an effort to reduce the burden of unnecessary hospitalisations. Therefore, a PCIS is considered a less resource-intensive way to deliver care. Furthermore, a PCIS is typically associated with home-based care services, where doctors and nurses provide care services tailored to the needs of the individual.

Between 1981 and 1986, a trial was conducted to assess the effectiveness of a health promotion clinic that patients were invited to attend. A control group was identified and each individual received their usual care. A total of 1224 male outpatients were enrolled in the trial. The health promotion clinic model was very effective, *tripling prevention rates* in its first year and sustaining these levels for all 5 years (Belcher, 1990). It is difficult to change the clinical roles of experienced physicians and their long-term patients in a specialized multi-clinic setting however, the need for preventative care evidently exists. Therefore, providing a separate health promotion clinic option is popular with patients, where individuals receive care tailored to their needs, at a reasonable cost, and on a timely basis (Belcher, 1990).

With the aid of increased evidence generated through the application of PAPAs, a PCIS will provide the means to reduce the number of unnecessary hospitalisations through the provision of tailored care services. Integrating a PCIS with the current care services provided by a healthcare provider, however, will be crucial for the success of PAPAs (see ***Chapter 6***).

2.5.2. PAPA development

Section 2.4.2 briefly discusses the technical methods involved with the design and development of the PAPA. The contributions of this section are mainly attributable to the work done by Phil Brierley, David Vogel and Randy Axelrod in their HHP milestone paper on patient-admission predictive algorithms (Brierley *et al.*, 2011).

2.5.2.1. Model building

The PAPA objective function to minimise is the total prediction error represented by ***Equation 1,*** as required by the HHP (Heritage Provider Network, 2011)**.** The algorithm predicts a length of stay index (LOSI) for each individual in the patient population given the individual's historical in-patient hospital data. The total prediction error is a function of the difference between the actual length of stay an individual spent in hospital and the predicted LOSI for that individual.

$$\epsilon = \sqrt{\frac{1}{n} \times \sum_i^n [\log(\rho_i + 1) - \log(a_i + 1)]^2} \quad \textbf{[Eq. 1]}$$

Where,

$i \textit{ is a member in the patient population,}$

n $is\ the\ total\ number\ of\ members\ in\ the\ patient\ population,$

$\rho_i =\ predicted\ number\ of\ days\ spent\ in\ hospital\ for\ member\ i$, and

$a_i = actual\ number\ of\ days\ spent\ in\ hospital\ for\ member\ i$

If the actual number of days spent in hospital is transformed to the log scale, then the function to minimise becomes the *root of the mean squared error*, or RMSE. This is convenient, as there are a number of existing algorithms designed to minimise this function (Brierley *et al.,* 2011).

Four underlying predictive algorithms are used in the PAPA, most of which are freely available in the R language for statistical computing:

1) *Gradient Boosting Machines,*
2) *Neural Networks,*
3) *Bagged Trees - Random Forests, and*
4) *Linear Models*

As described in the following subsection, the method of combining these predictive algorithms, to improve the forecasting accuracy of PAPAs, is termed *"ensembling".*

2.5.2.2. Ensembling

PAPAs were based on a linear combination of the candidate predictive algorithms as mentioned in the previous section. The largest incremental gain was not achieved by fine tuning the training parameters of an individual algorithm, but by combining predictions from multiple algorithms (Brierley *et al.*, 2011).

This result is depicted in ***Figure 7***, which illustrates how the various combinations of three of the candidate predictive algorithms arrive at their solutions through different paths. In ***Figure 7***, these combinations were applied to two separate datasets in an effort to identify the combinations of algorithms that produce the most accurate results. The lower the correlation between the individual algorithms' output, the better the synergy when forming the ensemble model (Brierley *et al.*, 2011).

In essence, it can be said that these algorithms look at the problem from different perspectives. However, when these algorithms form an ensemble, it synergises these individual perspectives to form an increasingly accurate predictive algorithm, more formally referred to as the PAPA.

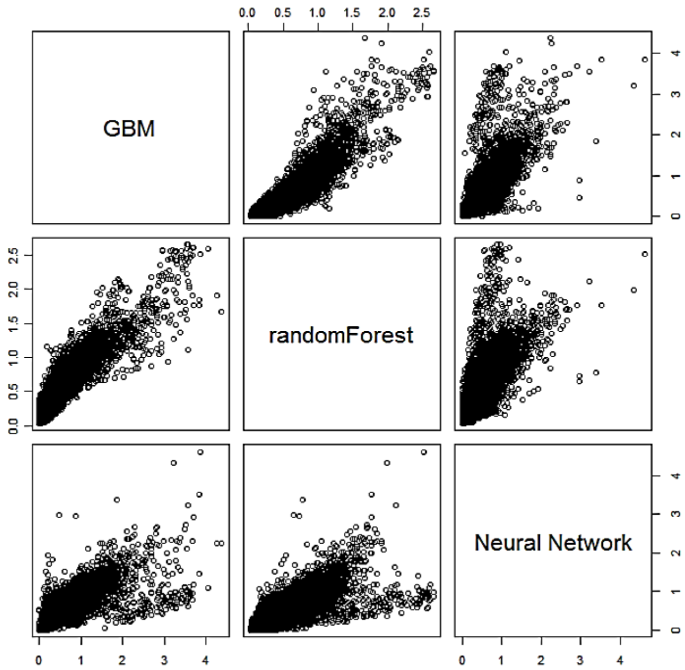


Figure 7 – Correlation diagrams to determine the best-fit ensemble predictive model

2.5.3. Input data

As previously mentioned, the PAPA output, or positive predictive value, is a list of patient length of stay indices (LOSIs) for each individual in the patient population database. The LOSI for each patient is an estimate of the total expected number of days a patient is expected to spend hospitalised in the coming year (Heritage Provider Network, 2011). To accurately produce positive predictive values, PAPAs require extensive amounts of patient data.

The Heritage Provider Network (HPN) released un-identifiable patient databases for the design, development and testing of the PAPA. The datasets had the following notable characteristics:

- *Number of entries per year > 2,000,000*
- *Number of patient attributes > 20 (including member ID, primary condition and procedure groups , length of stay per admission, age, sex, and primary care physician)*
- *Multiple discrepancies (including missing values and non-sensible values)*

The HPN data illustrates the following patient LOS distribution, where the majority of annual admissions have LOSIs less than two days as depicted in ***Figure 8***. As previously mentioned, healthcare providers aim to limit patient LOS to six days, largely due to the decline in profitability after this period (Srinivasan, 2008). Furthermore, researchers found that higher profit margins are placed on the procedures and treatments done in the early stages of a hospitalisation (Srinivasan, 2008). In ***Figure 8,*** 92% of the estimated patient LOSIs is less than six days.

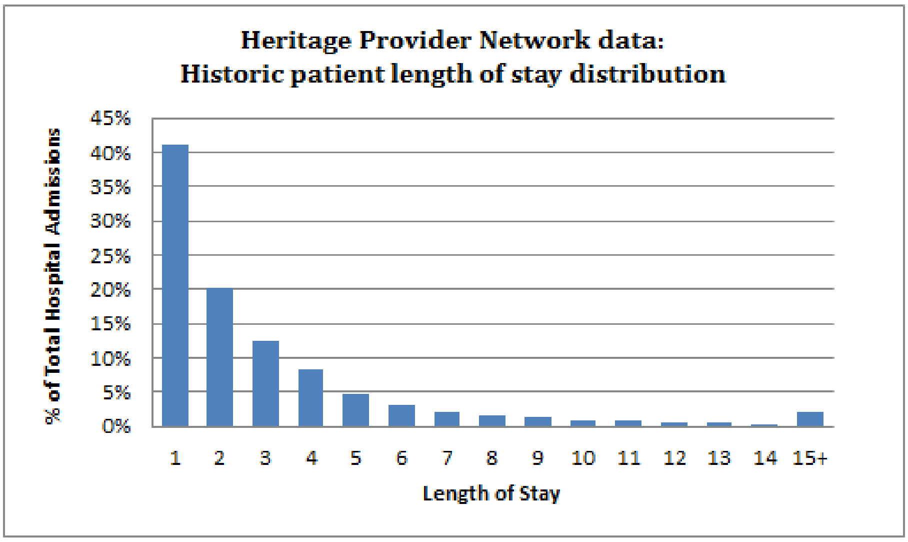


Figure 8 – Patient length of stay distribution

One of the major input-data characteristics, affecting the estimated patient LOS, is that of the specific causes of admission. A Pareto analysis of the annual number of admissions caused by the primary condition groups revealed that 70% of the established effects (hospitalisations) are as a result of 20% of the causes (condition groups or causes of admission) as depicted in ***Figure 9***.

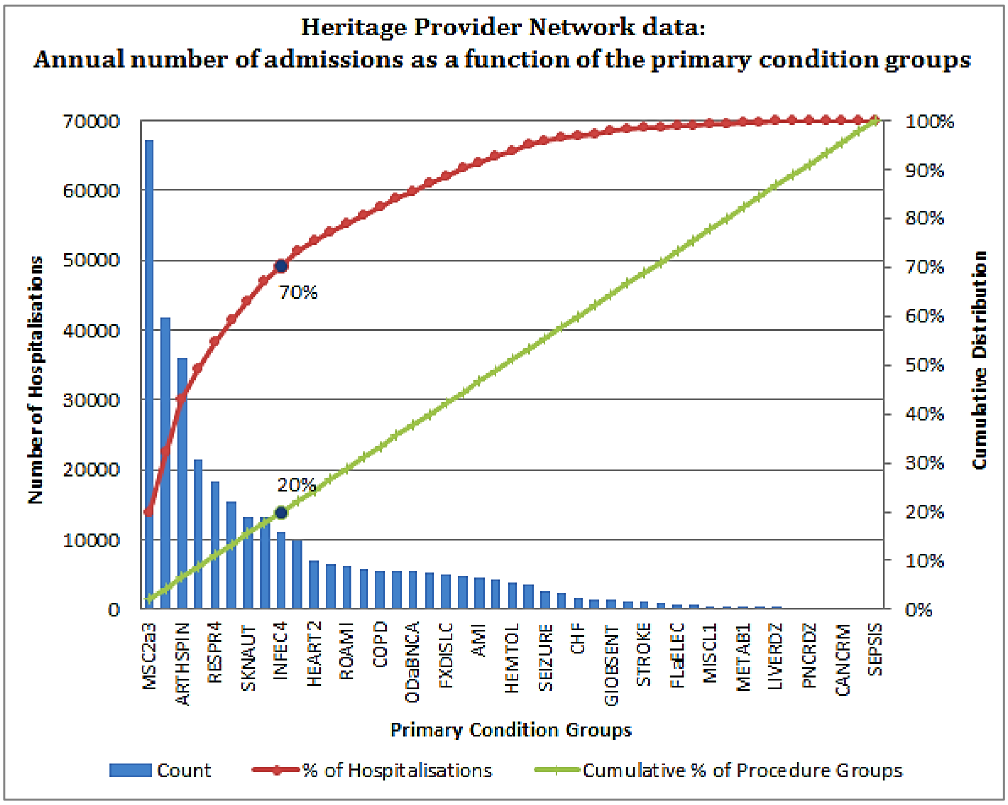


Figure 9 – Annual number of admissions per primary condition group in the Heritage Health Prize dataset

Therefore, the predictive accuracy of PAPAs will largely depend on the ability of these algorithms to accurately predict the diseases that result in the majority of hospitalisations. Refer to ***Appendix A*** for a complete explanation of the primary condition group abbreviations used in the Pareto analysis.

These input-data characteristics are some of the defining factors in the design and development of PAPAs that is expected to aid healthcare providers to improve healthcare resource management. However, various questions regarding the total value-add of PAPAs to healthcare providers still remain, for example:

- *Will the availability of accurate patient LOSIs further improve the discipline of HCRM?*
- *Will PAPA output inspire new preventive care interventions strategies that will improve patient health?*

Before these questions are addressed, it should firstly be established whether the South African healthcare system possesses the baseline requirements to successfully implement PAPAs and whether healthcare providers have the capacity to provide additional preventive care services. Hence, the following subsection defines the *institutional* and *operational* requirements of PAPAs in any healthcare provider setting.

2.5.4. Requirements definition

Identifying the major enabling factors for the implementation of a PAPA care intervention strategy plays a critical part in the establishment of the feasibility of applying these algorithms in the South African healthcare system. The major enabling factors are categorised into two groups:

- *institutional requirements, and*
- *operational requirements*

Figure 10 was adapted from ***Figure 6*** and depicts the various institutional and operational requirements that will enable the implementation and operation of a PAPA care intervention strategy.

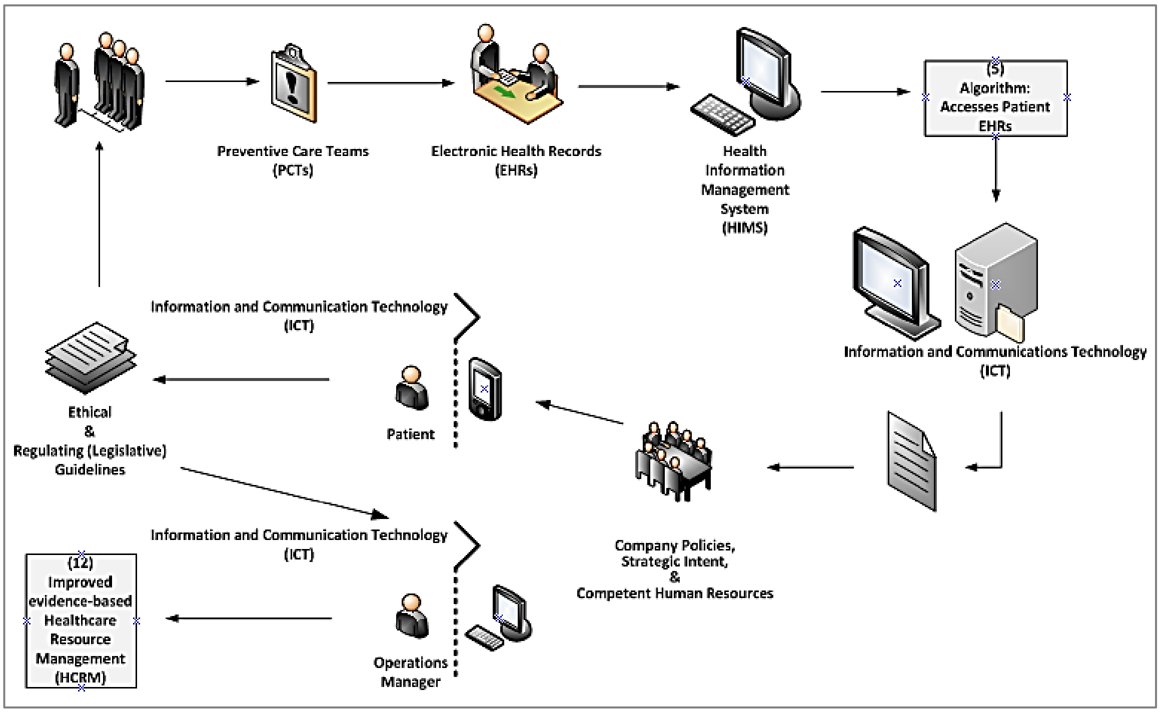


Figure 10 - Establishing the institutional and operational requirements of PAPAs

The *institutional requirements* are considered as the non-physical components in the healthcare sector required to either guide or govern the implementation of a PAPA care intervention strategy. The identified institutional requirements include:

- *organisational strategic intent, and*
- *regulatory legislation.*

The *operational requirements* are considered the physical hospital components required for the successful operation of a PAPA care intervention strategy. The identified operational components include:

- *electronic health records (EHRs),*
- *health information management systems (HIMS),*
- *information and communications technology (ICT),*
- *funds, and*
- *preventive care teams (PCTs) consisting of competent practitioners and nurses.*

With the availability of EHRs, ICT infrastructure, HIMS, competent management structures, and the necessary funds, overcoming the potential barriers to implementation of PAPAs in developed countries, is likely. Therefore, the feasibility of applying PAPA care intervention strategies in these countries is beyond doubt. In the developing world, however, these barriers are more prominent and greatly influence the feasibility of implementing PAPAs, especially in the public sectors of African healthcare systems. Therefore, a study of the extent to which the South African healthcare system satisfies the institutional and operational requirements of PAPAs, is conducted in ***Chapter 3***.

2.5.5. Potential benefits of applying PAPA care intervention strategies

Healthcare systems are complex and depend on various economic, structural, and organisational factors, to function optimally. However, when analysing the efficiency and effectiveness of a healthcare system, two factors are considered as key performance indicators (KPIs); quality of care service delivery and patient waiting time (Aktaş et al., 2007). PAPA intervention strategies narrowly relate to both these measures.

For example, a healthcare provider (HCP) implementing a PAPA preventive care intervention strategy predicts that 150 patients are acute cardiovascular patients, who, if admitted to hospital would have LOSIs of ten days. Therefore, healthcare providers have the option to intercede with these high-risk cardiovascular patients, providing preventive, home-based care services in an effort to prevent these potential hospitalisations from occurring. However, due to capacity constraints of the cardiovascular care division, the HCP is not able to provide the necessary preventive care to each of the high-risk patients. Therefore, healthcare providers will be required to identify a limited number of patients they intent to intercede with. This decision can be based on various ethical motivations to ultimately decide which patients to intercede with first:

- *patients with the highest risk of admission (ROA) to hospital,*
- *patients with the longest estimated length of stay (LOS),*
- *patients with the highest combination of ROA and LOS,*
- *most profitable patient interactions, or*
- *patient-interactions that will most likely result in the prevention of an unnecessary hospitalisation.*

At this moment, the HCP has the ability to intercede with these priority patients, ultimately reducing these patients' risk of admission to hospital and, in addition, effectively schedule cardiovascular medication, treatments, cardiothoracic surgeons, nurses, hospital beds, and laboratory tests in accordance with the expected number of patient interventions. If this is achieved, improvements in quality of service (due to the preventive care intervention strategy) and reductions in service waiting times (due to more efficient levels of healthcare resources) are likely to be achieved with a PAPA preventive care intervention strategy.

The PCIS focuses on establishing better patient-practitioner relationships, through the provision of patient-tailored care plans (higher quality of service). Initially, however, yearly patient interactions might not have this desired effect, but as the system progresses, half-year or even monthly interactions will enable HCPs to foster better patient relationships and prevent these patients from becoming "lost" in the system.

2.6. Summary

The objective of this chapter was to familiarise the author with the field predictive modelling in healthcare and to identify the major enabling factors for applying a PAPA care intervention strategy. A number of challenges and pitfalls were identified and will be considered in the development of the implementation support framework in ***Chapter 6***.

The major institutional and operational requirements for the implementation and operation of PAPA care intervention strategies were identified (***Table 1***) and will subsequently be used to establish the feasibility of applying these interventions in the South African healthcare system (see ***Chapter 3***).

Table 1 - Summary of the enabling factors for the implementation of PAPAs

Enabling factors	*Type*	*Definition*
Electronic health records (EHRs)	Operational	*Longitudinal electronic records of patient health information*
Health information management systems (HIMS)	Operational	*Systems that integrate data collection, processing, reporting, and information generation for healthcare decision-making*
Information and communications technology (ICT)	Operational	*The technologies that facilitate communication and the processing and transmission of information*
Competent human resources	Operational	*Quality trained, developed and managed doctors, nurses, and administrative staff*
Healthcare funding	Operational	*Monetary funds allocated for the delivery of clinical care*
Strategic intent of healthcare providers	Institutional	*Mission, vision and value statement*
Regulatory legislation	Institutional	*Governmentally regulated legislation and policies*

3. Healthcare in South Africa

The following study depicts the extent to which the private and public healthcare sectors in South Africa are able to satisfy the baseline institutional and operational requirements as established in the previous chapter. Firstly, an account is given of the history of the South African healthcare system, which introduces the concept of private and public healthcare, as well as the current challenges faced by both these sectors. Secondly, a need for interventions similar to PAPAs is established. Thirdly, the state of the institutional and operational requirements within each healthcare sector is evaluated. Lastly, the current developments that will have a major impact on the healthcare system of South Africa are discussed, to determine its potential effect on predictive modelling applications similar to PAPAs (see ***Figure 11***).

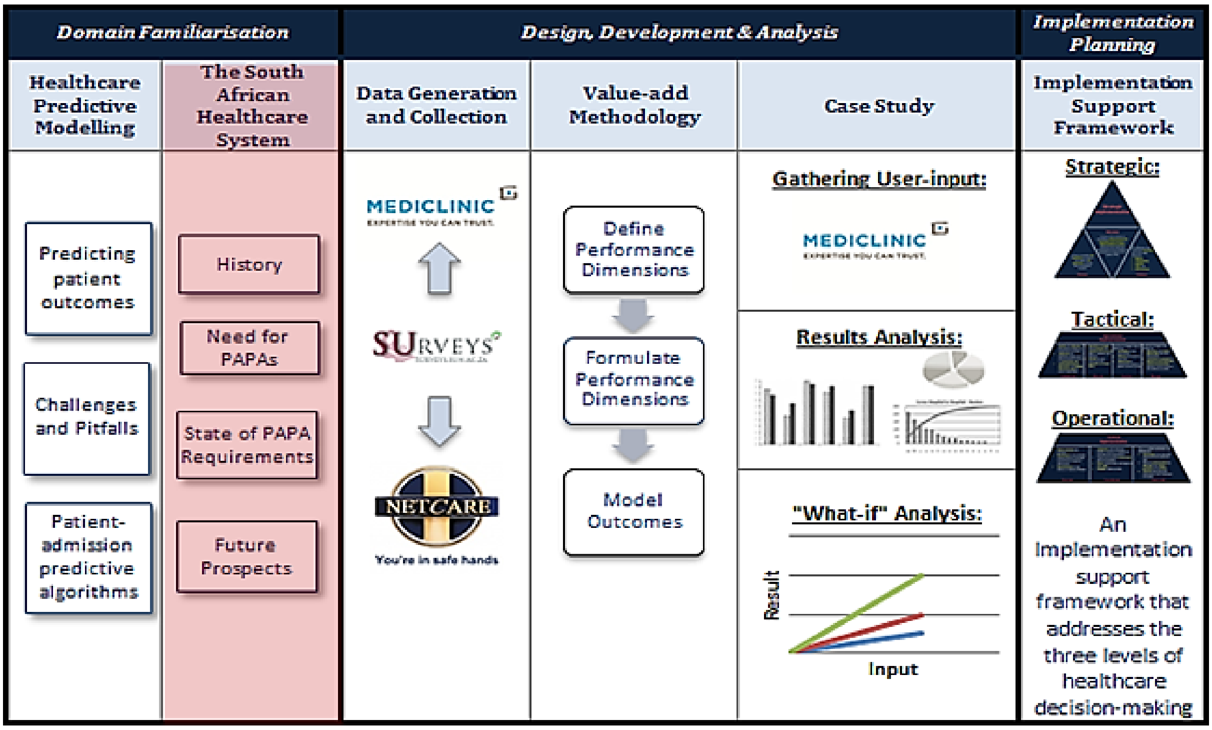


Figure 11 – Reviewing the project methodology: healthcare in South Africa

3.1. History

A healthcare system is the organisation of people, institutions, and resources to deliver healthcare services to meet the health needs of a target population (World Health Organisation, 2004). The South African healthcare system constitutes a private and a public healthcare sector. Since the post-apartheid era the South African healthcare system has seen the introduction of the

National Health Act (NHA) in 2004, which legislates for a national health system that (Coovadia *et al.*, 2009):

- *provides equitable health-care services to all,*
- *provides for the fulfilment of the rights of children with regards to basic services,*
- *entrenches the rights of pregnant women and children to free care throughout the public sector if they are not on a medical scheme, and*
- *establishes a district health system to implement primary healthcare throughout South Africa.*

Even with the introduction of the NHA in 2004, the South African healthcare system has come under immense criticism, mainly attributable to the persistently great divide between public and private healthcare. ***Table 2*** summarises the principal accomplishments and shortcomings of the past 15 years in the South African healthcare system (Harrison, 2010).

Table 2 – Accomplishments and shortcomings of the South African healthcare system from 1994 to 2010

ACCOMPLISHMENTS	SHORTCOMINGS
Legislation and gazetted policy	**Insufficient prevention and control of epidemics**
Free primary healthcare	Limited effort to curtail HIV/AIDS
Essential drugs programme	Emergence of MDR-TB and XDR-TB
Choice on termination of pregnancy	Lack of attention to the epidemic of alcohol abuse
Anti-tobacco legislation	**Persistently skewed allocation of resources between public and private sectors**
Community service for graduating health professionals	Inequitable spending patterns compared to health needs
	Insufficient health professionals in public health sector
Better health systems management	**Weaknesses in health systems management**
Greater parity in district expenditure	Poor quality of care in key programmes
Clinic expansion and improvement	Operational inefficiencies
Hospital revitalisation programme	Insufficient delegation of authority
Improved immunisation programme	Persistently low health worker morale
Improved malaria control	Insufficient leadership and innovation

From the shortcomings column in ***Table 2*** it is evident that the South African healthcare system has been plagued with an increased burden of communicable diseases due to the lack of quality preventive care strategies, as well as poor healthcare resource and systems management. The following subsection addresses these shortcomings in greater detail and articulates the need for intervention.

3.2. Articulating the need for more resource-effective care

Although the restructuring of the public health sector post 1994 achieved substantial improvements in terms of access, rationalisation of health management and more equitable health expenditure, years later these early gains have been eroded by a *greatly increased burden of disease* related to HIV/AIDS, *generally weak health systems management*, *low staff morale* and the persistently *skewed allocation of healthcare resources* (Harrison, 2010). The result is poor health outcomes relative to total health expenditure and inefficient HCRM at all levels of care (both public and private).

Furthermore, Aktaş et al. (2007) found that the *effective utilisation of limited resources* by healthcare providers is a critical problem for healthcare management in developing countries. Therefore, these issues should *not* be considered minor when national health reforms and programmes, such as the National Health Insurance policy in South Africa, are discussed (African Union Conference of Ministers, 2007).

In South Africa, public healthcare providers are classified into four levels of care:

- *academic or tertiary hospitals,*
- *district hospitals,*
- *regional hospitals, and*
- *primary clinics.*

A recurring problem is the high referral rates amongst these care providers. One study found that 75% of patient referrals were considered inappropriate by the care providers receiving the referred patients in the Eastern Cape (Odufuwa, 2010). This results in duplication of services or *unnecessary hospitalisations.*

In the private healthcare sector of South Africa a large scope for savings from reduced hospitalisations exists. McLeod *et al.* (2010) found that the number of hospital days per 1000 insured lives in South Africa is 20% higher than that of the United States. On the other hand, the average length of stay per 1000 insured lives in South Africa is 15% shorter than that of the United States. Therefore, it appears that a large number of inappropriate admissions, where care could just as effectively (and less expensively) be provided in an outpatient setting, are consistently recurring in the private healthcare sector of South Africa (Kinghorn, 1996). Through efficient coordination of care and the prevention of duplication of services and negative patient interactions, substantial cost savings could be attained.

Merkin (2011) states that duplicated healthcare services, service starvation and service excess are common problems in healthcare systems worldwide and formed part of the initial rationale to develop PAPAs. If these algorithms are applied with sufficient planning and implemented with sound decision-support systems, it may provide a simple solution to a growing, worldwide concern in healthcare.

3.3. State of institutional requirements

As mentioned in ***Section 2.5.4***, the institutional requirements for the implementation and operation of PAPAs are the non-physical components that enable the successful implementation of these evidence-based tools.

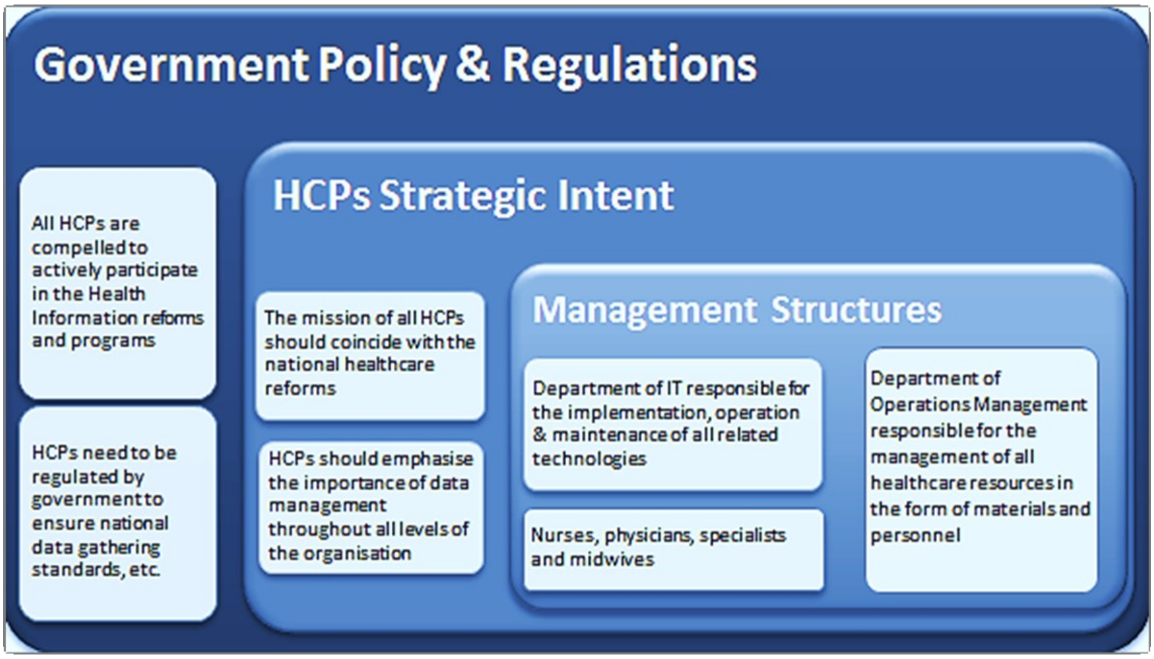


Figure 12 - Platform for evaluating the institutional requirements of PAPAs

Figure 12 summarises these institutional requirements and depicts a generic platform for implementation from an institutional point of view. Included in ***Figure 12*** is the role of management structures in the implementation of a PAPA care intervention strategy. However, the role of management and the availability of competent human resources are discussed under the operational requirements in ***Section 3.4***. The institutional requirements are:

- *organisational strategic intent, and*
- *regulatory legislation and government policies.*

3.3.1. Government policy and regulating legislation

Eysenbach (2000) stated that the ideal integration of healthcare technologies and its dependencies should incorporate government policy to curb perverse incentives such as the mismanagement of funds. Additionally, Friede *et al.* (1995) emphasised the critical roles that government and academic leaders play in the improvement of public healthcare delivery and necessitates a government's commitment to public health technologies and informatics, for successful implementation of interventions similar to PAPAs.

In essence, governments need to regulate healthcare providers (HCPs) to the extent that data collection is uniform and compulsory at every care level. The policies should also incorporate incentives for adherence to the regulations. If this is achieved, the application of PAPAs and the associated preventive care intervention strategies can form part of national healthcare reforms, which will improve the effectiveness of these interventions. However, the patient data requirements of PAPAs pose various barriers due to the limitations on the use of patient information that exist in most countries. This emphasises the critical role government policies play in the regulation of PAPAs and the associated data management practices. In South Africa, for example, the National Health Act 61 of 2003: Chapter 2(16) specifies that HCPs may examine user health records for the purpose of:

a) treatment with the sole authorisation of the user, and

b) study, teaching or research only with the authorisation of the user, head of the health establishment concerned and the relevant health research ethics committees.

The South African National Health Act specifies that national and provincial governments have concurrent legislative authority, enabling provinces to legislate on provincial health issues in terms of the Constitution (Carstens and Pearmain, 2007). For example, the process of applying PAPAs in the Western Cape as opposed to Mpumalanga might differ with regards to the individual provincial health legislation, which complicates the implementation of PAPAs on a national level. This necessitates the development of national health policies and legislation that would enable PAPAs to utilise patient information without any predetermined complications. In South Africa, the Department of Health have initiated efforts that commits to the restructuring of the healthcare system and has recognised the importance of *comprehensive policies* and *regulating legislation* in the success of reforming healthcare in the country (Bernstein, 2011).

3.3.2. Strategic intent of healthcare providers

Organisational change is predicated on managerial leadership and support, and these elements are critical for successful implementation of quality improvement in healthcare (Glickman *et al.*, 2007). The mission and vision of a HCP should be aligned with government policy and regulations, to establish and foster an environment which commits to:

- *the transformation from paper-based to electronically driven organisations, to enable extensive patient data analysis, and*
- *increased evidence-based decision making through the application of quality data management processes and accurate predictive models.*

Furthermore, the onus lies with key decision-makers and competent hospitals managers in these HCPs to recognise and drive the re-alignment of their organisation's strategic intent with that of the government's vision and mission statements.

The current tiered healthcare system in South Africa, with its great divide between the public and private sectors, results in flawed attempts to standardise data capturing processes, and evidence-based management and care on a national level (Bernstein, 2011). This necessitates the importance of aligning all healthcare providers' strategic intent (public and private) with the aforementioned government policies and regulations, to promote a wide-spread, organisational commitment to evidence-based care initiatives.

3.4. State of operational requirements

As previously established, the operational requirements for the implementation and operation of PAPAs include funding, information communication technology (ICT), electronic health records (EHRs), health information management systems (HIMS), and competent management and human resources.

In more than one instance the Eastern Cape is used as a representation of the state of the operational, and institutional, requirements of PAPA care interventions in the public sector of South Africa. The Eastern Cape is one of the most resource stricken provinces in South Africa, and therefore serves as a conservative estimate in this regard. On the other hand, the private healthcare sector is represented by the industry leaders of this sector, namely Mediclinic, Netcare, and Life Healthcare.

3.4.1. Funding

African countries spend substantially lower fractions of their gross domestic product (GDP)[2] on healthcare compared to developed countries (South Africa and the United States spent 8.3% and 15.4% of their GDP on healthcare respectively in 2011 (NationMaster, 2011)). Studies have shown that the majority of African countries *do* possess the financial capability to transform their public health systems with quality HIMS and ICT (African Union Conference of Ministers, 2007). In South Africa, healthcare expenditure is derived from three main sources (McIntyre, 2010):

- *public sector expenditures financed out of general revenue,*
- *private sector expenditures financed through medical schemes, and*
- *out of pocket payments.*

Figure 13 illustrates the distribution of healthcare finances in South Africa. The 8.3% of GDP spent on health by South Africa is split between 4.1% in the private sector and 4.2% in the public sector. The 4.1% spend covers 16.2% of the population, (8.2 million people) who are largely on medical schemes and the remaining 4.2% is spent on 84% of the population (42 million people), who mainly utilise the public healthcare sector (National Treasury, 2011).

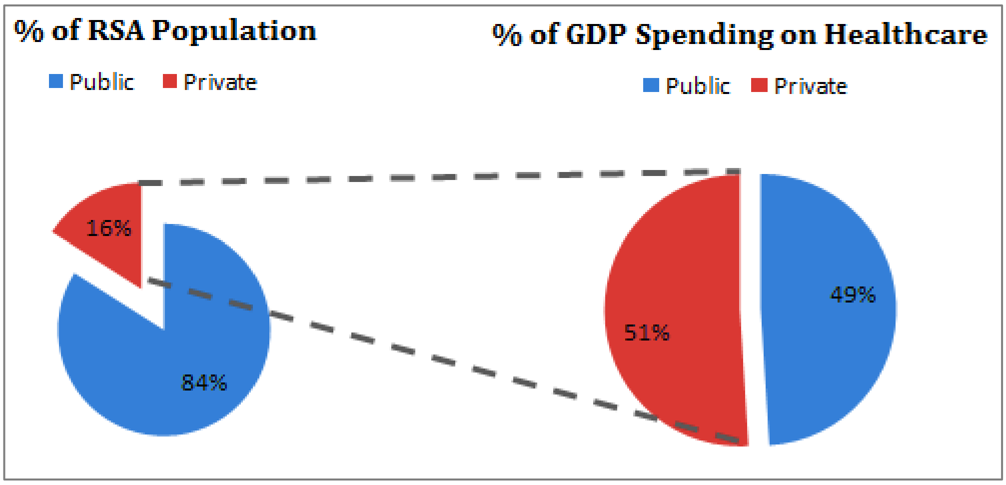


Figure 13 - Distribution of healthcare spending in the South African healthcare system

[2] Gross Domestic Product (GDP) – This is the market value of all final products (goods and services) produced in a country within a given period, usually a financial year.

Since 1994, healthcare spending has remained fairly stagnant in the public sector, compared to that of the private sector (McIntyre and van den Heever, 2007). From this perspective it is evident that healthcare resource availability in the public and private healthcare sectors differs in quite a substantial manner. Consequently, the effect on the availability of technological innovations and competent management are also measurably less in the public health sector as compared to the private healthcare system.

From 1996 to 2006, as depicted in ***Figure 14***, private hospital costs have increased by 121%, whilst over the same period, specialist costs have increased by 120% (Council for Medical Schemes, 2009). These increases are considered irrational and mainly attributable to the supplier concentration and competitive forces that are currently driven by the three industry leaders in the private sector of South Africa (Harrison, 2010). This means that the private healthcare sector will have to accept that the charging of exorbitant fees, completely out of proportion to the services provided, have to be radically transformed.

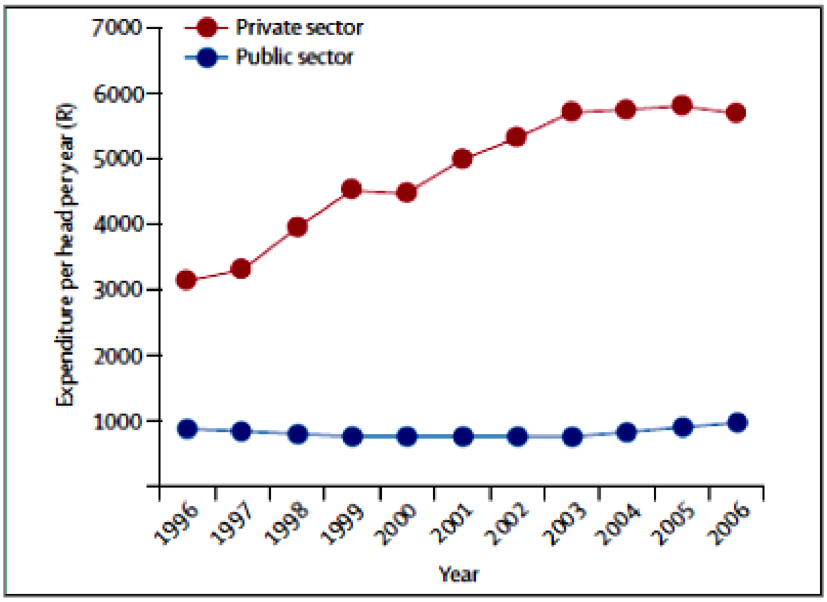


Figure 14 – Increased private expenditure per head per year in the South African healthcare system. Source: (McIntyre & van den Heever, 2007).

Similar to the state of human resource management in the public health sector of South Africa, financial departments are generally grossly under-resourced and lack the capacity to draw up or monitor budgets, control costs or expenditure, or monitor shrinkage and waste (von Holdt & Murphy, 2006). Budgets bear little relation to operational reality, and there is consensus that budgets are ‘meaningless’ as they are based on historical allocations rather than operational activity and realities (von Holdt & Murphy, 2006). Cost allocation and recording is still extremely weak and partial, particularly because information systems are so weak or even non-existent (von Holdt & Murphy, 2006). In most cases, financial systems are manual rather than digital, which makes real-time cost control and financial management impossible (von Holdt & Murphy, 2006).

Until recently, the private healthcare system in South Africa has thrived. However, with the proposed introduction of the new National Health Insurance (NHI) scheme, the private sector has come under immense scrutiny. The distribution of scheme spending and the availability of financial resources in the private healthcare sector are almost exclusively spent on private hospitals, as depicted in ***Figure 15*** (McIntyre, 2010).

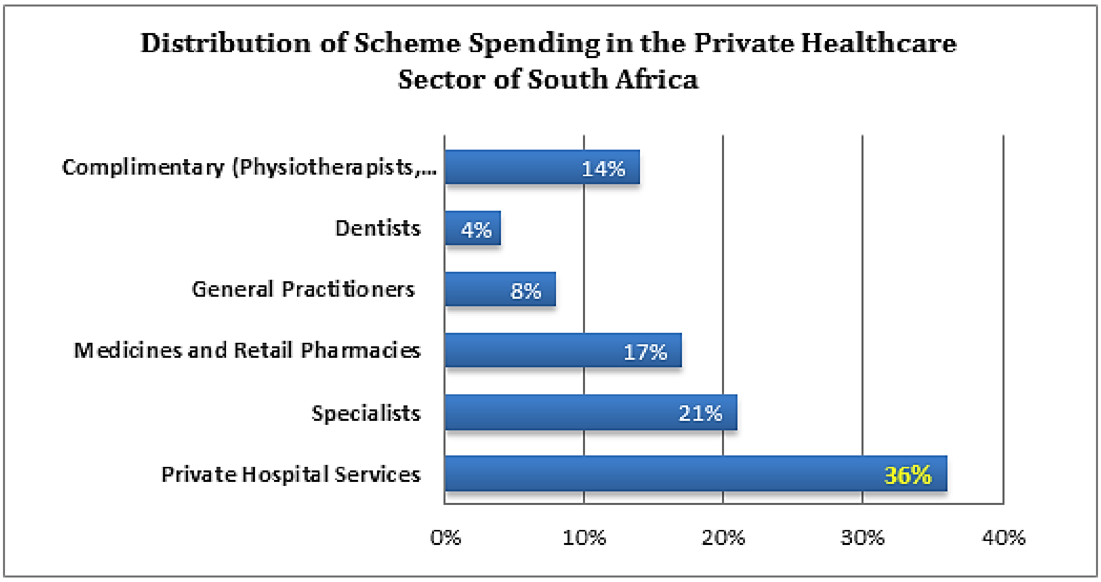


Figure 15 - Distribution of health insurance scheme spending in the private healthcare sector of South Africa in 2009 adapted from (McIntyre, 2010)

As a result, private hospitals have been identified as the main drivers of the escalating costs in the private healthcare sector over the past five years, and efforts have been initiated to bridge the gap between public and private healthcare spending in South Africa as documented in ***Section 3.5.1.***

3.4.2. Information and communications technology

ICT is defined as technologies that facilitate communication and the processing and transmission of information by electronic means (Marker *et al.,* 2002). The use of ICT in healthcare relates primarily to telemedicine health delivery practices, overarching health communication and the development of sector utilities (Marker *et al.*,2002). The Presidential National Commission on Information, Society and Development (2006) states that ICT applications such as e-health are suitable for addressing the digital divide between rural and urban populations, including rich and poor, young and old, males and females, and unequal distribution of health professionals, particularly in specialist healthcare provision.

ICT based healthcare projects like the "Africa Health Infoway" have been tried and tested by the WHO and aim to supply district managers and health workers with real time data to monitor and evaluate programs and healthcare resources, whilst enabling the general public to make informed decisions with regards to local health programs (UNIDO, 2010). Although the "Africa Health Infoway" is still in the developmental phase, it is ICT based projects similar to these, funded by governments and academia that could increase the opportunity for evidence-based care management practices to be successfully implemented in African healthcare systems (Research ICT Africa, 2011)**.** Various African countries have initiated efforts to implement ICT as depicted in ***Figure 16*** (Research ICT Africa, 2011). Although these technologies are seemingly available to Africa, very few ICT applications have made it past the pilot implementation phase. Therefore the use of ICT, adapted for efficient use in healthcare systems, remains a challenge.

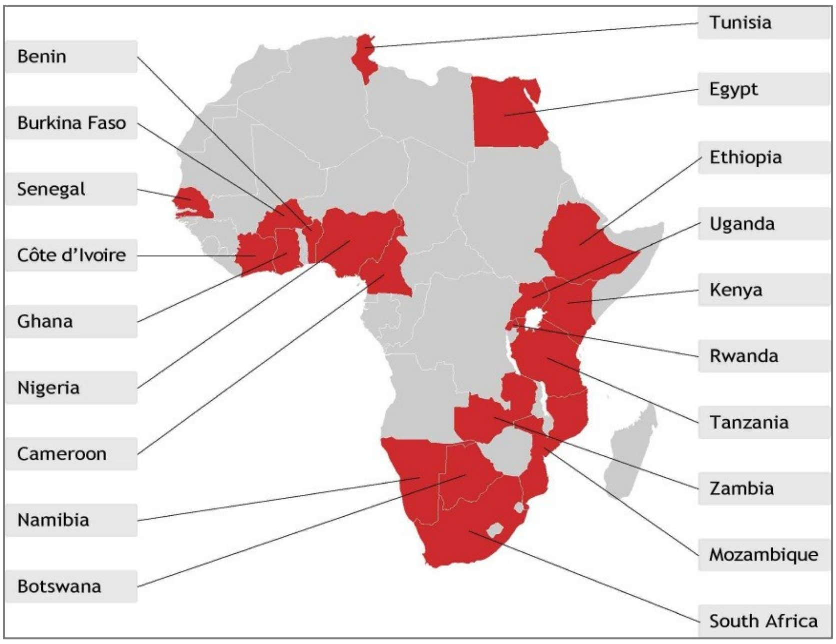


Figure 16 - African countries implementing ICT. **Source:** (Research ICT Africa, 2011)

In South Africa, Thom (2007) states that the Eastern Cape province is 'home to the poorest districts in the country', resulting in widespread poverty and lack of quality public services. Nonetheless, the province's Department of Economic Development and Environmental Affairs (2007) committed to attracting appropriately qualified employees to areas of service delivery where the greatest need exists. This is needed in order to sustain quality healthcare and to implement e-health solutions through telemedicine programs that support education, training and academic services in the Eastern Cape.

In spite of these efforts, the Eastern Cape health system has continued to be plagued by challenges such as *staff shortages*, *poor management* and *weak primary care*, coupled with *high levels of poverty* and unsatisfactory access to basic services such as piped water (Thom, 2007). Herselman *et al.* (2010) studied the extent to which ICT has been succesfully adopted in the public care sector of South Africa and congruently found that the major inhibiting barriers mostly related to the lack of *information*, *computer technology* and *internet connections* as tabulated in the ***Table 3***. The score percentages are representative of the percentage employees at the various healthcare providers that believe the individual barries (listed on the left-hand side of ***Table 3***) are the reasons for the failure to implement ICT at these facilitites.

Table 3 - Barriers to implementation of ICT in the South African public healthcare sector (Herselman et al., 2010)

	Public South African Healthcare Providers					
Barriers	**Tsilitwa Primary Clinic**	**Nessie Knight Regional Hospital**	**St. Lucy's Regional Hospital**	**Madizikane District Hospital**	**Neslon Mandela Academic Hospital**	**Average**
Lack of Computer Equipment	100%	100%	100%	100%	91%	**98%**
Lack of Computer Skills	0%	71%	67%	75%	82%	**59%**
Lack of Internet Connections	100%	100%	83%	88%	73%	**89%**
Old/unreliable equipment	100%	86%	100%	75%	64%	**85%**
Lack of Broadband Connections	0%	29%	17%	0%	9%	**11%**
Unsuitable working style	0%	0%	0%	0%	0%	**0%**
Cost	0%	0%	0%	25%	9%	**7%**
Fear of Computers	0%	0%	0%	0%	0%	**0%**
Lack of Information	100%	100%	100%	100%	100%	**100%**

ICT plays an intricate part in the supply of real-time data to PAPAs. These algorithms will retrieve and utilise patient datasets from various decentralised sources across an organisation. ICT is required to facilitate the distribution and communication of these datasets. Hence, these problems need to be eradicated before the public healthcare sector in South Africa becomes suitable for evidence-based care management tools similar to PAPAs.

In the private healthcare sector, however, healthcare data is transmitted daily to health insurers and medical scheme providers with the widespread availability of practice management software and information communication technology (Matshidze & Hanmer, 2007). HealthID from Discovery Health, a health insurance provider in South Africa, has developed the first ICT-based, mobile electronic health record application in South Africa (Discovery Health, 2012). The app aims to mobilise patient health records for ease of access to physicians in an effort to increase care delivery efficiencies. From this perspective, private healthcare providers in South Africa provide a sufficient technological platform to generate and communicate the results of computationally intensive predictive algorithms.

3.4.3. Electronic health records

Electronic health records (EHRs) are longitudinal electronic records of patient health information generated by one or more patient-practitioner encounters in any care delivery setting (The MITRE Corporation, 2006). According to Neves *et al.* (2008), EHRs play an important role in the effective use of archived patient information to support clinical practice and to generate new knowledge to improve clinical decision-making. Patient EHRs typically constitute patient demographics, causes of admission, progress notes and vital statistics, past medical histories, immunisations, and laboratory data. PAPAs demand the use of readily available electronically documented patient data. Since EHRs provide the most efficient platform for the retrieval of- and access to patient information, these technologies are considered a necessity in the application of PAPAs at a healthcare provider level.

In the public health sector of South Africa, patient data is rarely documented electronically. Although the situation varies considerably between hospitals and even between clinical departments, in general, *weak management and systems*, *fragmentation* and *lack of capacity* means that data collection in financial, clinical and HR departments is non-existent or suspect, which in turn means that the effective management of data is impossible (von Holdt & Murphy, 2006).

In 2003, South Africa initiated efforts to standardise the implementation of EHRs on a national level and subsequently devised a strategic framework for the implementation of a pilot program called EHR.za. ***Table 4*** lists the contents of the EHR.za initiative as proposed by the National Department of Health in South Africa. Seebregts and Mars (2008) stated that the implementation of EHRs in South Africa is growing rapidly, with a third of the provincial academic hospitals, nationwide, implementing computerised systems for managing patient health records electronically. Apart from the limited use of EHRs in South Africa, poor record-keeping and reporting of medical information, and inadequate information dissemination, is reportedly some of the major barriers to the use of operations research models in developing countries similar to South Africa (World Health Organisation, 2008). Therefore, the current lack of EHRs for the majority of less privileged South Africans remains a major barrier to the implementation of PAPAs in the public health sector. However, the maturity of the EHR.za initiative may render this barrier amenable to resolution.

Since 2004, the private healthcare sector has made significant improvements in patient data collection with the introduction of electronic data exchange processes (Matshidze & Hanmer, 2007). However, the lack of standardised data collection processes results in poor comparability and complicates the integration of data sources in various healthcare providers (Matshidze & Hanmer, 2007). Therefore, healthcare providers that have standardised electronic data collection processes will be able to reap the potential benefits offered by computationally-intensive predictive algorithms as a result of the quality of healthcare patient data repositories in these organisations.

Table 4 - The proposed contents of the electronic health record initiative in South Africa

Personal Details	Demographic Data	Past Medical History	Major Medical Events
• *Names* • *Unique Identifier* • *Physical + postal address* • *Postal code* • *Telephone numbers* • *ID number* • *Next of kin details* • *Guardian details* • *Date of birth* • *Insurer / med aid number* • *Insurer / med aid name* • *Employment* • *Level of education* • *Gender* • *Religion* • *Marital status* • *Number of children* • *Nationality* • *Blood groups* • *Allergies* • *Current chronic conditions* • *Current medication* • *Current medical conditions* • *Current practitioner* • *Immunisation status* • *Disability status* • *Pregnancy status* • *Smoking indicator*	• *Names* • *DOB/Age* • *Gender* • *Nationality* • *Addresses* • *Telephone contact(s)* • *Family linkage*	• *Diagnosis (multiple)** • *Treatments and procedures** • *Medications** • *Free text field* • *Healthcare institutions visited** • *Practitioner(s)** • *Dates of treatment/death** • *Encounter outcomes* • *Categorisations** • *Previous blood results (history + continuous updates)** • *Test results* • *Vaccinations* • *Confidentiality indicator*	• *Parity/Gravidity* • *Genetic markers* • *Predispositions to illness* • *Current treatment* • *Blood group* • *Allergies* • *Donor status* • *Episode history* *Sorted by encounters in reverse chronological order:* ❖ *Facility or institution ID** ❖ *Care provider ID** ❖ *ICD10 diagnoses** ❖ *Procedures (CPT4 or other agreed standard)** ❖ *Discharge Summary (LOS, procedure, preventive care)* ❖ *Medication (prescribed versus format)** ❖ *Lab results** ❖ *Imaging results time*

*EHR.za components coinciding with the claims data used for developing PAPAs.

3.4.4. Health information management systems

Health information management systems integrate data collection, processing, reporting, and use of the information necessary for improving health service effectiveness and efficiency through better management at every level of healthcare delivery (World Health Organisation, 2004).

The development and implementation of quality health information management systems in the public healthcare sector of South Africa have been compromised by the lack of ICT infrastructure, shortage of skills and demeaning organisational cultures (Williamson *et al.,* 2001). However, various HIMS solutions have been successfully implemented and have led to the identification of disparities with regards to healthcare resource allocations and equitable health service availability (Mars & Seebregts, 2008).

The District Health Information System (DHIS) in South Africa is designed to collect data from health facilities and share aggregated data with the higher levels of the public health system (Williamson *et al.,* 2001). The DHIS provides decision-support at three levels (Williamson et al., 2001):

- *Data collection, validation and distribution to higher levels of public care*
- *Disease trends and indicators are identified and reported to relevant decision makers*
- *Higher-level policies, to monitor and improve healthcare outcomes, are established.*

Garrib, *et al*. (2008) found that the culture of information documentation and dissemination in the public sector of South Africa has been one of the major pitfalls of the DHIS. The study concluded that further training and support for operational staff members were required for the DHIS to function as intended (Garrib, et al., 2008).

Although the use of HIMS are becoming more widespread at every care level in South Africa, major barriers still compromise the effectiveness of these information systems and will compromise the successful utilisation of PAPAs on a national level.

Healthcare providers in the private healthcare sector of South Africa have been found to implement health information management systems tailored to the operational requirements of each organisation (Matshidze & Hanmer, 2007). These health information management systems were required as part of a strategy to develop a national health information management system (NHIS) for South Africa in 1994 (Matshidze & Hanmer, 2007). However, due to lack of collaboration between various stakeholders in the public and private health sectors, no sub-system integration occurred, which resulted in a flawed attempt to standardised data collection processes on a national level (Matshidze & Hanmer, 2007). The eHR.za initiative, as previously mentioned, could provide an important and effective mechanism for standardising patient data collection and dissemination on a national level and render the barriers to implementation of PAPAs amenable to resolution.

3.4.5. Management structures and competent human resources

The role of management in healthcare has become increasingly critical in the past few decades, as the inter-dependencies of relevant departments in a healthcare provider have become more complex in the information age (Glickman *et al.*, 2007). As PAPAs affect various divisions and management structures within HCPs, the necessity of well-integrated management structures and the availability of competent human resources are crucial for the optimal implementation and operation of PAPAs.

The human resource management function is critically important and cardinal for the efficient and effective operation of a hospital as an organisation (Chandra Sekar, 2008). However, this function heavily depends on the availability of competent human resources by means of quality training, development and management of these valued assets. In the United States the ratio of management and support workers in healthcare per thousand population is 24.76, which is substantially better compared to that of South Africa (0.51) (Global Health Observatory, 2011).

The World Health Organisation (WHO) believes that *incompetent management* may be the main bottleneck in the implementation and operation of new technologies and predictive analytics in African healthcare systems (World Health Organisation, 2008). Some of the managerial issues identified include:

- *poor adherence to policy recommendations,*
- *poor record-keeping and reporting of information,*
- *poor information dissemination,*
- *ethical issues, and*
- *marketing and advocacy of healthcare policies and regulations.*

These problems articulate the critical role that management plays, not only in the successful introduction of new healthcare technologies, but in the application of evidence-based care initiatives that functionally utilise these technologies.

The South African public healthcare system is fraught with resource allocation problems (Zere, 2006), ineffective management structures (African Union Conference of Ministers, 2007) and constrained innovation capabilities (Dahlman, 2006). These problems are often aggravated and overshadowed by major healthcare pandemic issues, such as the management and treatment of HIV, tuberculosis, malaria and various other infectious diseases.

Managerial issues have been inadmissible in various efforts to transform the public health systems in South Africa, especially with the introduction of health information management systems and ICT. von Holdt and Murphy (2006) stated that hospital managers have no control over staff numbers, profiles and mix. The staff establishment for each institution is set by the provincial head office, which lays out in minute detail the number of staff to be employed in each staff category, preventing the flexible management of recruitment, employment and promotion of human resources. This results in skewed allocations of human resources and a starvation of services at various levels of care. Accoring to von Holdt and Murphy (2006) management has no power to vary HR availability in response to changing operational requirements or to meet the needs of new organisational strategies.

From an “equitable healthcare for all” perspective, the private sector represents a significant reservoir of human resources compared to that of the public healthcare sector, as depicted in ***Figure 17***. Ideally, the public sector should have an average of 80% of the available healthcare providers in the country, in relation to the percentage of individuals that utilise public health services. However, Johnston and Spurrett (2011) stated that the challenge is to find strategies that broaden access to this reservoir of human resources in the private healthcare sector, but policy makers should refrain from taking over the private sector “lock, stock, and barrel”.

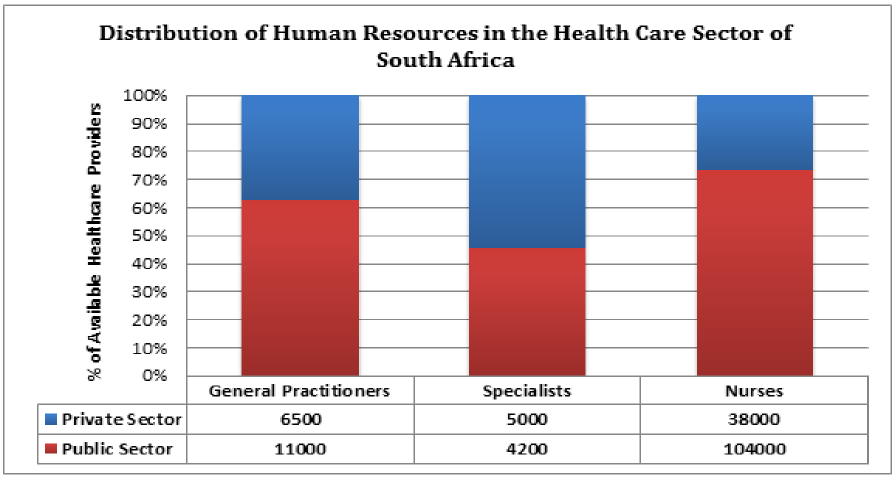


Figure 17 - Distribution of human resources in the South African healthcare system adapted from (Johnston & Spurrett, 2011)**.**

There is no doubt that beneficiaries of private medical insurance have access to much better healthcare than those who depend solely on the public sector. However, the private sector (Johnston & Spurrett, 2011):

- *has significantly smaller human resources than its critics claim,*
- *reduces the burden on the public sector,*
- *has less 'excess capacity' than has been claimed, and*
- *faces input costs and barriers to market activities which drive up prices.*

The lack of competent human resources in the public healthcare sector will undoubtedly compromise the efficiency and effectiveness of PAPAs in this sector. The absence of quality healthcare managers, doctors, nurses and support workers will remain a major barrier to the implementation of PAPAs, until efforts are initiated to educate and train these individuals to a globally acceptable standard. The private healthcare sector, however, has proven to possess the necessary human resource requirements and can provide a suitable managerial platform to implement and operate PAPAs successfully.

3.5. Future prospects

The future of South African healthcare delivery is on the verge of the biggest reform since the inception of the post-apartheid government in 1994. Firstly, this section introduces the new National Health Insurance (NHI) scheme as proposed by the South African Department of Health and evaluates the potential impact of this new healthcare delivery model on the utilisation of evidence-based tools similar to PAPAs. Lastly, five global trends that are expected to change healthcare delivery are viewed from a South African perspective.

3.5.1. South African national health insurance scheme

The Department of Health in South Africa released its green (policy) paper on National Health Insurance (NHI) in August 2011. The paper proposes a new model for providing equitable healthcare to every South African citizen.

3.5.1.1. Basic outline

The NHI scheme aims to dispose of the tiered (public and private) healthcare system of South Africa by establishing a National Health Insurance fund (NHIF). The NHIF will be a government-owned, publicly administered entity. It will be a single-payer entity with provincial offices to nationally negotiated contracts with all appropriately accredited and contracted care providers

(Department of Health, 2011). The main responsibility of the NHIF will be to pool funds and use these funds to purchase health services on behalf of the entire population from contracted public and private healthcare providers (Department of Health, 2011).

The overall emphasis will be on primary healthcare systems to broaden the access to basic care services, with an augmented focus on health promotion and ***preventive care*** (Ritz, 2011). These services will be delivered via a district health system incorporating municipal clinics, schools and accredited private healthcare facilities (Ritz, 2011).

3.5.1.2. Cost

The initial cost is estimated at R130 billion, increasing to R215 billion by 2020 and R225 billion by 2025 (Department of Health, 2011). This investment cost estimate should be viewed in the context of South Africa's total healthcare expenditure per year (including medical aid contributions) of R92 billion in 2010 (Department of Health, 2011).

The NHI plan assumes that increased expenditure will be partially offset by a decline in contributions to private medical aid schemes as SA residents will be entitled to NHI services. The green paper, however, is vague regarding the funding of the scheme and clarity in this regard is expected in the white (implementations) paper expected at the end of 2012.

Furthermore, some ambiguities within the National Health Insurance policy paper exist regarding the cost of healthcare in South Africa. For example, Johnston and Spurrett (2011) found that up to 35% of the population is served by the private healthcare sector, as opposed to the claimed 16% (Department of Health, 2011), if out-of-pocket payments and medical scheme members are included. Evidently, the cost to implement NHI will be substantial and the expected return on investment is worth investigating in future research projects.

3.5.1.3. Implementation

The NHI scheme will be implemented over a period of fourteen years, in three distinct phases. The first phase introduces pilot implementation schemes to ten districts. Thereafter, additional districts will be added to the scheme in phase 2, depending on the audited results of the pilot implementations. Phase 3 will focus on optimisation of the model until it reaches maturity (Department of Health, 2011). The pilot phase will last for five years during which the public healthcare system is to be strengthened and the NHI fund established (Ritz, 2011). ***Table 5*** summarises the districts that were selected for the pilot implementation phase.

Table 5 - District pilot implementation of the NHI scheme in the South African healthcare system

Province	District	Population
Eastern Cape	*OR Tambo*	1,353,349
Mpumalanga	*Gert Sibande*	944,694
Limpopo	*Vhembe*	1,302,107
Northern Cape	*Pixley ka Seme*	192,157
Kwa-Zulu Natal	*uMzinyathi*	514,840
Kwa-Zulu Natal	*uMgungundlovu*	1,066,150
Western Cape	*Eden*	558,946
North West	*Dr K Kaunda*	807,752
Free State	*Thabo Mofutsanyane*	832,172
Gauteng	*Tshwane*	2,697,423
Total population covered by NHI pilot implementation		**10,269,590**

Additional districts will be added to this list according to 1) the success of implementation in each respective province, 2) a revised needs assessment, and 3) the capacity of contracted service providers in the proposed districts (Department of Health, 2011).

3.5.1.4. Potential benefits

Apart from providing equitable healthcare to South Africans, the NHI promotes various other potential benefits that are relevant to the implementation and operation of patient-admission predictive algorithms. The NHI scheme induced various developments in the fields of HIMS, EHRs, and ICT. Firstly, an integrated and enhanced district health management information system (DHMIS) is expected provide quality data sources for improved clinical decision making. The new DHMIS will contribute towards the determination of the population's health needs and outcomes, based on an electronic platform linked with the NHI membership database and contracted healthcare providers' databases (Department of Health, 2011). The DHMIS policy focuses on seven (7) high level priority areas, namely (Department of Health, 2011):

- *Health information coordination and leadership;*
- *Key Indicators;*
- *Data security;*
- *Data dissemination and use, and*
- *Health information system resources.*

Furthermore, the establishment of the eHealth strategy South Africa (2012-2016), is considered an enabling factor for the successful implementation of the NHI scheme. The eHealth strategy incorporates and promotes mHealth, telemedicine and all information communication technologies (ICTs) used to support and strengthen healthcare.

The successful implementation of the new DHMIS and national eHealth strategy will provide a sufficient technological platform for PAPAs to utilise patient information on a national level, which will greatly enhance the effectiveness of the algorithms. However, due to the massive resource capacity constraints in the lower-tiered public healthcare sector, interceding with every high-risk patient as part of a national strategy to promote preventive healthcare is unlikely.

3.5.2. Five major trends in healthcare delivery worldwide

Globally, the healthcare delivery models are changing at a rapid rate. Major forces driving these changes have been the availability of powerful technologies, the increased focus on containing costs in a downturned economy, and the growing demand for quality public sector services (McIntyre, 2010). The following section details some of the major trends in healthcare that are expected to change the way healthcare is delivered on a global scale.

3.5.2.1. Risk management and accountability

Patient care is moving away from an “episodic model” to a continuum, with an emphasis on *prevention*, *wellness* and *management* (Shea, 2012). Analysts believe that the establishment of Accountable Care Organisations (ACOs) and patient-centred medical homes will shift the patient and financial risk of admission to hospital to these organisations. Shea (2012) stated that the biggest challenges these organisations will face, relate to:

- *finding a suitable platform to engage with patient populations,*
- *engaging individuals to stay healthy or successfully promote self-care management,*
- *investing in clinical decision-support and business intelligence tools to provide actionable information and alerts, and*
- *restructuring the declining fee-for-service business models.*

Healthcare providers in developed countries are in the process of improving their current customer relationship management functions, and exploring the various predictive analytic tools to effectively identify and manage patients at risk of admission to hospital.

3.5.2.2. Retail insurance markets

The World Health Organisation (WHO) has called upon governments to re-evaluate and restructure their healthcare systems to provide equitable healthcare for all (World Health Organisation, 2008). Henceforth, various policies, acts and laws have been instated in the past 5 years focused on the provision of these services. For example, South Africa, as previously mentioned, is in the process of implementing National Health Insurance and the United States has committed to the Affordable Care Act, enabling greater health insurance coverage for the United States population.

If this trend persists, it is expected to result in a mass customisation of personal health insurance coverage plans. Therefore, from a health insurance provider perspective, an increased number of new market entrants will be focused on providing these retails services directly to customers (Shea, 2012). Therefore, to maintain a competitive advantage in the retail health insurance sector, these organisations will strive for improved accuracy in ***patient-risk identification*** and management, whilst providing competitive premiums, with a low-cost structure (Shea, 2012).

3.5.2.3. Virtual care and tele-health

Rapidly evolving healthcare technologies (broadband, cloud-based solutions, telemedicine, *etc.)* have traversed the barriers to receive specialist and general care in the developed world. "Virtual care" and tele-health will dramatically alter the way patients and providers interact and provide a means to limit the amount of unnecessary costs associated with a centralised care system and improve personalisation with customised care services (Marwaha & Savas, 2012).

Furthermore, the development of mobile health applications has received prodigious attention of late and this trend is expected to continue in the following decade (Collins, 2012). More than 9000 mobile health applications are publicly available for download. However, commercial healthcare providers have refrained from entering this market due to risk of violating patient information security (Collins, 2012). A potentially untapped market is waiting to be exploited. Collins (2012) believes that mobile health apps have the potential become powerful medical tools and the commercial inception thereof, as part of a virtual care delivery strategy, will bring about a major change in the way healthcare is delivered.

3.5.2.4. Conglomerates, diversification and integration

Traditional business models, where healthcare provider groups, pharmaceutical suppliers, and health insurance providers operate as separate entities, is expected to change as part of a strategy to capitalise on best-practise methods and improve healthcare delivery (Shea, 2012). This vertical integration and diversification of value offerings is the start of healthcare conglomerates dominating developed markets and providing business and technical agility that accommodates accelerated transformation (Shea, 2012).

3.5.2.5. Large datasets, health analytics and business intelligence

The increased availability of large datasets and the application of healthcare analytics have provided valuable insight into disease management and innovative service design (Shea, 2012). Furthermore, analytics and predictive modelling has improved customer analysis, care and risk management at the population level, and lead to improved clinical outcomes (Shea, 2012). However, as previously mentioned, the future opportunity to generate clinical insights, improve care delivery and reduce costs through large datasets will depend on how well healthcare organisations and policy makers deal with structural, security and privacy barriers to using patient data.

The future of data mining, predictive modelling and risk stratification will continue to evolve with the increased availability of clinical data. A move towards near-real-time data, care data exchanges between healthcare providers with cloud-based[3] solutions, and *immediate analytics* will provide more efficient and effective evidence-based clinical decision-making and improve patient outcomes (International Telecommunication Union, 2010).

3.6. Summary

The objective of this chapter was to establish whether a definite need for PAPAs exists in both the private and public healthcare sectors of South Africa, and if these sectors are fit for applying PAPAs. ***Table 6*** summarises the findings of this section and serves as a platform for evaluating the potential value-add of PAPAs to healthcare providers in South Africa ***(Chapter 4.3)***, and developing an implementation framework for the use of predictive modelling and preventive care services in private healthcare organisations in South Africa ***(Chapter 6)***.

In essence, both the public and private healthcare sectors in South Africa demonstrate a need for improved healthcare resource management functions. The private healthcare sector will experience an increased demand for clinical services due to the new NHI scheme, which may result in constrained resource capabilities and further complicate HCRM. The public healthcare sector has seen an increased burden of diseases that have overshadowed problems such as weak

[3] Cloud-based technologies are platforms of information and communication infrastructure that enable the storage and retrieval of data from any platform connected to the “cloud”

health systems and resource management. Furthermore, the high number of referrals amongst care providers in the public sector results in a duplication of services, and in most cases constrains the healthcare delivery process.

With regards to the feasibility of applying PAPAs and PCIS in the South African healthcare system, the public sector is considered unfit due to its incapability to satisfy the institutional and operational requirements of PAPAs. However, the proposed NHI scheme and the associated developments in the fields of ICT, HIMS, EHRs and training and development of healthcare professionals, will render the barriers to implementation of predictive models amenable to resolution. On the other hand, the private healthcare system has seen a progression of standardised electronic patient records and information management systems, providing a suitable technological platform for PAPAs. The availability of competent management structures and strong leadership, which commits to evidence-based medicine and management, fosters an institutional environment conducive to the successful implementation and operation of PAPAs.

The remaining chapters will focus on determining whether PAPA care intervention strategies will add significant value to ***private healthcare provider groups*** in South Africa. Therefore, a revised ***research question*** states; will the application of PAPA care intervention strategies add significant value to private healthcare providers in South Africa, through the improvement of healthcare provider performance?

Table 6 - Conclusion of the analysis of the scope for implementation and feasibility of applying PAPAs in the current South African healthcare system

	South African Healthcare System	
	Public Sector	***Private Sector***
Scope for implementation?	**Yes;** • *Increased burden of diseases results in starved healthcare services at various care levels* • *Weak resource management function results in skewed allocations of healthcare resources* • *High referral rates result in a greater number of unnecessary hospitalisations and duplication of care services*	**Yes;** • *Increased demand for healthcare services with the proposed NHI scheme* • *High perceived rates of unnecessary hospital service utilisations (unnecessary hospitalisations)* • *Constrained resource expenditures with the proposed NHI contract service provider agreement*
Feasibility of applying PAPAs?	**No;** • *Failure to nationalise the use of EHRs, HIMS & ICT at all levels of care* • *A broad lack of skills and managerial competency in the implementation and operation of relating technologies*	**Yes;** • *EHR, HIMS and ICT infrastructure are suitably available* • *Strong leadership and effective managerial competencies are present* • *Trends in evidence-based medicine and management are becoming increasingly popular amongst industry leaders*
Result	*NHI is a positive step towards the nationalisation of EHRs, HIMS and ICT at various key levels of care. However, a strong emphasis should congruently be placed on educating skilled individuals from primary level to increase the pool of skilled healthcare professionals in the public sector.*	*Potential value-add of PAPAs need to be determined for private healthcare providers. A support framework for computationally intensive algorithms needs to be developed and validated to aid in the implementation of PAPAs and various similar OR solutions.*

4. The design and development of the value-add methodology

In ***Chapter 3*** it was established that 1) a definite need for improved healthcare resource management exists in the private healthcare sector of South Africa, and 2) the private sector satisfies the institutional and operational requirements for the successful implementation of patient-admission predictive algorithms. Therefore, the following chapters will focus on the design and development of a quantitative model to determine the potential value-add of a PAPA care intervention strategy *to private healthcare providers* (hospitals) in South Africa.

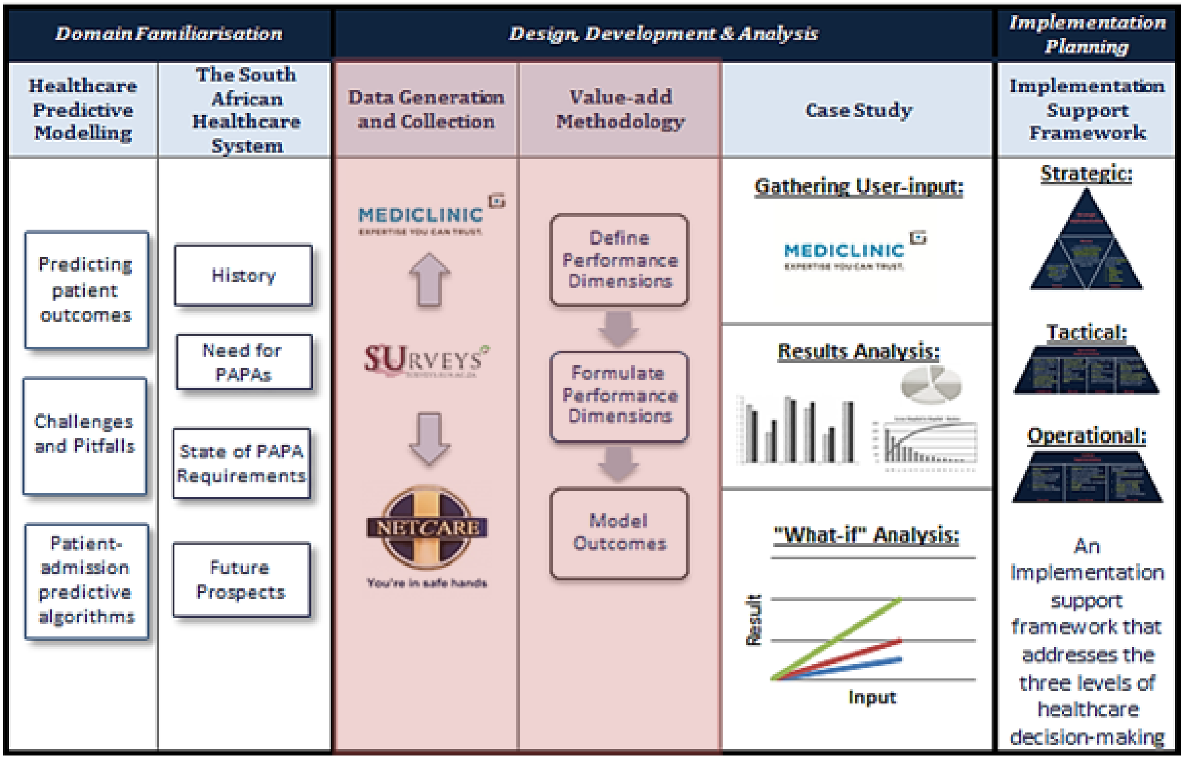


Figure 18 - Reviewing the project methodology: the value-add model

Figure 18 is a review of the project methodology, and depicts the design, development and analysis phase. The case study is performed in ***Chapter 5*** and will conclude this phase of the project methodology.

This chapter focuses on the rationale and methods utilised to design and develop the value-add model. A brief overview of the *methodology* is supplied, the data generation processes required for design and development of the value-add model are discussed, and, finally, the value-add model is presented.

4.1. Introduction

In an effort to answer the research question, it was decided to develop a quantitative model to evaluate whether a PAPA care intervention strategy might improve the performance of private healthcare providers in the South African healthcare system. For the purpose of this study, healthcare provider performance is considered from a systems perspective. This enables the identification of a large number of **performance indicators**, from various managerial perspectives. From ***Figure 19***, five major categories of hospital performance measurement are identified:

- *Customer (patient) – focused outcomes*
- *Employee-focused outcomes*
- *Healthcare and process-focused outcomes*
- *Leadership outcomes*
- *Financial and market-focused outcomes*

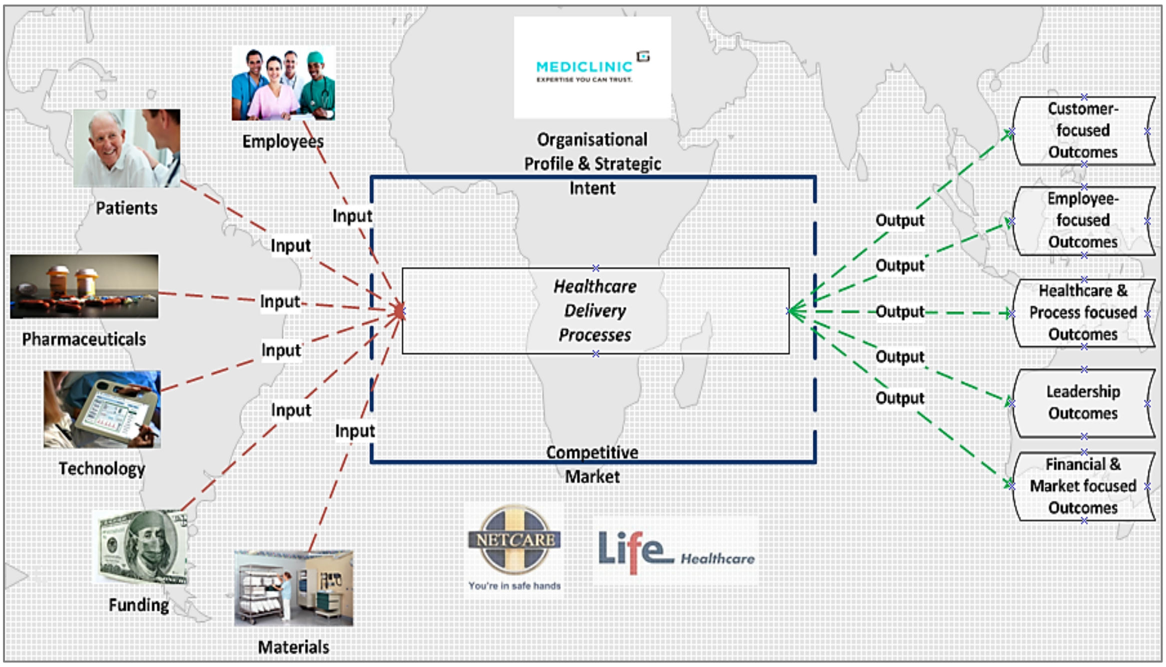


Figure 19 - A systems perspective on hospital performance measurement

Figure 20 illustrates the value-add methodology in the form of a flow chart. To determine whether a PAPA care intervention strategy will improve healthcare provider performance, it should firstly be determined what the current performance foci of these organisations are. To achieve this, it is essential to ascertain the **key performance indicators** (KPIs) in the above mentioned performance measurement categories, which are currently of a high priority to private healthcare providers in South Africa. Furthermore, we need to identify the current factors that compromise these organisations' ability to perform with regards to these high-priority KPIs, in order to determine whether a PAPA care intervention strategy might eradicate or alleviate the burden of these factors on healthcare provider performance. Therefore, it is desirable to document at least one major performance compromising factor (PCF) per KPI.

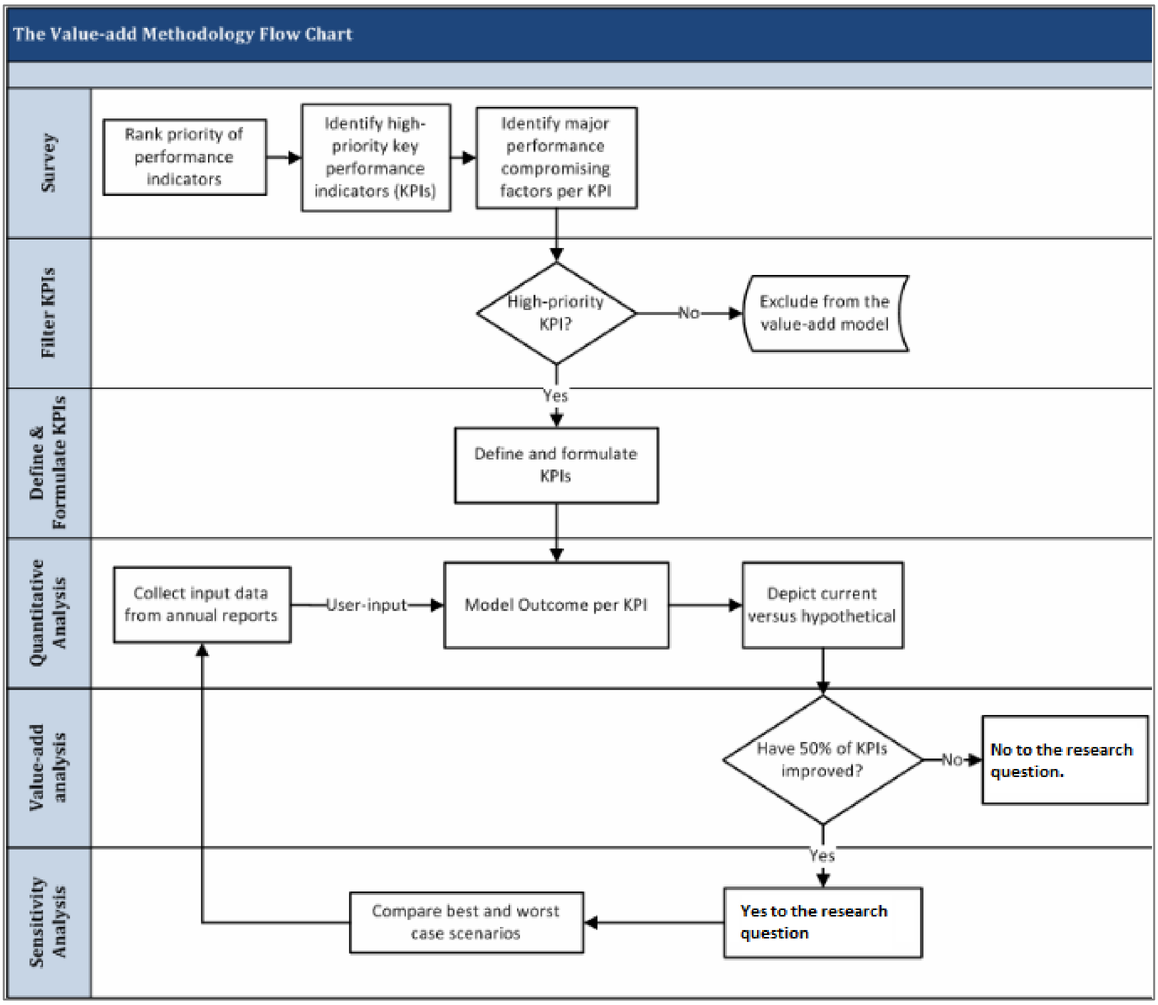


Figure 20 - A flow chart of the logic behind the development of the value-add methodology

It was decided to distribute surveys to the leading private healthcare provider groups in South Africa to determine these high priority KPIs and performance compromising factors (PCFs).

Focusing on the high-priority KPIs provides a scope that enables the definition and formulation of these performance dimensions for the purpose of quantitatively determining the potential value-add of PAPAs.

Input data for the value-add model is mostly gathered from healthcare providers' annual reports. The required information is supplied to the defined KPI formulas to compute the movements in each KPI. The model output depicts these movements of each KPI and subsequently compares the current performance scenario with that of hypothetical implementation of a PAPA care intervention strategy.

From the flowchart in ***Figure 20,*** the outcome of the research question posed will be determined according to impact of the PAPA care intervention strategy on the high-priority KPIs; if more than 50% of the KPIs are positively impacted, the research question will be answered positively, and *vice versa*.

4.2. Data generation and collection: survey results analysis

This section details the data generation and analysis plan for identifying the current performance foci and major performance compromising factors of private hospital groups in South Africa. Firstly, an overview of the survey is provided, documenting the objectives, method, and enabling factors for successfully distributing the survey. Secondly, the standard pre-analysis methods are discussed. Thereafter, summaries of the response rates per healthcare provider and category are depicted and the results are combined for a comparative analysis. Lastly, major performance compromising factors are identified for each high-priority KPI.

4.2.1. Survey overview

The survey aims to gather healthcare performance criteria data from private healthcare provider groups in South Africa (Medi-Clinic, Life and Netcare) that can be used to study the extent to which a PAPA care intervention strategy is able to improve healthcare provider performance. Currently, these market leaders capture close to 80% of the South African market, with Netcare (30%), Mediclinic (25%), and Life healthcare (25%) respectively (Felet *et al.,* 2012). Therefore, these organisations are a fair representation of the private healthcare sector in South Africa.

The development and distribution of a survey is considered an effective tool for gathering and analysing this data in the most efficient and effective manner possible. The survey was e-mailed to the various hospitals within the above mentioned groups across South Africa and respondents were able to electronically respond to the surveys within a given timeframe. The survey responses were analysed and graphically depicted with the help of the web-based e-Survey service (SUrveys) provided by Stellenbosch University, which is available to support academic staff and postgraduate students conducting academic research.

As previously mentioned, the survey was designed with the intention of gathering qualitative data on the categorical importance of a list of healthcare performance indicators, and the major performance compromising factors per KPI. Likert scales were used to rank the importance of a KPI relative to the other KPIs in the same category. These scales are more commonly referred to as 5-point ranking scales that aim to obtain a participant's preferences or degree of agreement with a statement or set of statements (Bertram, 2007). The list of key healthcare performance indicators in ***Table 7*** constitutes the data used to populate the survey. Each criterion was ranked by a hospital manager according to the performance indicator's current priority in his or her particular hospital.

The survey, included in ***Appendix B***, was distributed to healthcare managers with the following attributes and supplementary documents:

- *cover letter,*
- *confirmation of ethical clearance from the Health Research Ethics Council* ***(Appendix C)****,*
- *statement of confidentiality,*
- *clear and concise instructions on how to answer the survey,*
- *a properly motivated incentive to complete the survey (a copy of the results), and*
- *contact details of the primary researcher*

Survey results were gathered over a period of a month. Timely reminders were sent to the respondents on a weekly basis to improve the response rate, although the majority of the results were gathered in the first two weeks.

Table 7 - List of healthcare performance indicators for the design and development of the survey (National Institute of Standards and Technology, 2012)

Healthcare Performance Criteria			
Healthcare & Process Outcomes	**Employee-focused Outcomes**	**Patient-focused Outcomes**	**Financial & market-focused Outcomes**
Patient-focused health care results: • Adherence to patient safety practices • Treatment protocols • Care plans • Critical pathways • Care bundles • Medication administration • Patient involvement in decisions • Timeliness of care • Information transfers and communication of treatment plans and orders • Coordination of care across practitioners and settings	**Workforce Capability and Capacity:** • Staffing levels across organisational units • Certification to meet skill needs • Organisational restructuring • Job rotations • Improvement in local decision making • Workforce knowledge sharing	**Patient and Stakeholder Satisfaction:** • Retention rates • Gains and losses of patients and stakeholders and their accounts • Patient and Stakeholder omplaints • Complaint management and resolution • Patient and stakeholder perceived value based on healthcare quality, outcomes and cost	**Marketplace Performance:** • Market share • Market share growth • Market position • Earnings per share • Charitable donations grants received • New services and markets entered • New populations served • % income derived from new healthcare services or programs
Operational process effectiveness results: • Improved cost savings at processes • Higher productivity by using internal or external resources • Internal responsiveness indicators (cycle and turnover times) • Utilisation rates • Waste reduction (Reduction in repeat diagnostic tests, pharmaceuticals, medical waste) • Cost reductions • Supply chain indicators (inventory reductions, quality improvement, Six Sigma initiative results, improved electronic data exchange, reductions in supply chain management costs)	**Workforce Climate:** • Safety • Absenteeism • Staff turnover • Organisational culture • Commitment to organisational change initiatives (implementation of evidence-based care processes)	**Patient and Stakeholder Engagement:** • Patient and stakeholder assessment of access, ease of use & courtesy in service interaction • Patient & stakeholder advocacy for your health care service offerings • Awards, ratings and recognition	**Financial Performance:** • Return on Investment (ROI) • Operating margins • Profitability by market segment or patient or stakeholder • Liquidity • Debt to Equity ratio • Cash on hand • Asset utilisation • Cash flow • Bond ratings • Revenue • Budget performance • Profit or losses • Net assets • Debt leverage • Cash to cash cycle time

4.2.2. Pre-analysis

In general, four preparatory steps are required before a valid data analysis can be executed. These preparatory steps are:

1) *data validation,*
2) *partitioning the responses,*
3) *standard analysis, and*
4) *data coding.*

These steps ensure that the results generated from the survey are valid and enable the estimation of population statistics. *Data coding* is not necessary in this case, as all of the results are in the same format (i.e. Likert scale response data).

Step one revolves around the validation of the survey results data, where the survey responses are checked for consistency and completeness. The survey was designed to prohibit respondents to submit incomplete responses. However, ambiguities in the response data were still evident and were managed with the built-in “Data Report Wizard” filter function (https://surveys.sun.ac.za.) For example, if response were uninformative (“don’t know”) these responses were flagged and filtered from the response data and sample sizes were adapted accordingly.

The survey was designed to automatically partition the responses which might have induced complexity into the interpretation of the results. The partition was successfully introduced by asking respondents to select the survey category that mostly related to their level of expertise (operations, finances, patients or employees).

Methodological and statistical texts clearly state that for ordinal data one should employ the median or mode as the measure of central tendency, because the arithmetical manipulations required for calculating the mean (and standard deviation) are inappropriate where the numbers generally represent verbal or textual statements. Therefore, the mean (and standard deviation) are inappropriate for ordinal data. In addition, ordinal data may be described using frequencies or percentages of response in each category, which was the preferred method for calculating the required indices in the following chapters.

4.2.3. Hospital response rates

The survey was distributed to two private healthcare provider groups in South Africa[4]:

- *Mediclinic, and*
- *Netcare*

Two different methods were utilised to distribute the surveys to each group. For Mediclinic, a distribution list containing 52 hospital manager email addresses was used to distribute the e-survey with great effectiveness. For Netcare, the survey was sent to the research committee at Netcare, whom, in return, distributed the survey to the relevant managers of the Group's 57 hospitals. The survey was distributed to the following individuals:

- *General managers,*
- *Financial managers,*
- *Operational managers,*
- *Human resource managers, and*
- *Clinical managers*

The maximum number of responses expected was 260 and 285 for Mediclinic and Netcare respectively. ***Figure 21*** represents the percentage of responses from each group.

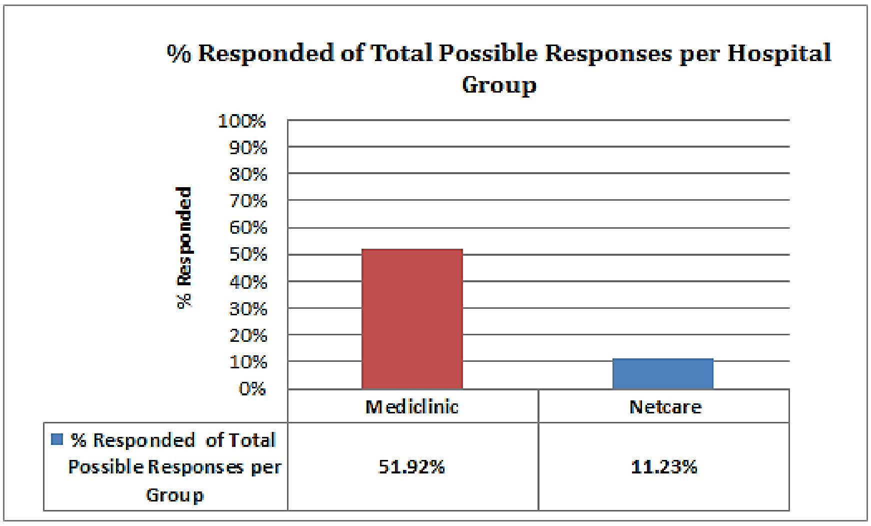


Figure 21 - Percentage of survey responses distributed per healthcare provider group

[4] It should be noted that the third dominant market force in the private health care sector of South Africa, Life Healthcare, was also contacted for participation in the surveys, but declined the invitation.

The weak response rate at Netcare is mainly attributable to the lack of direct communication to the abovementioned healthcare managers. The 50% response rate from Mediclinic is commendable and enabled statistically-sound sample analyses. Therefore, the total number of responses received was distributed according to the profile depicted in the pie chart in ***Figure 22***.

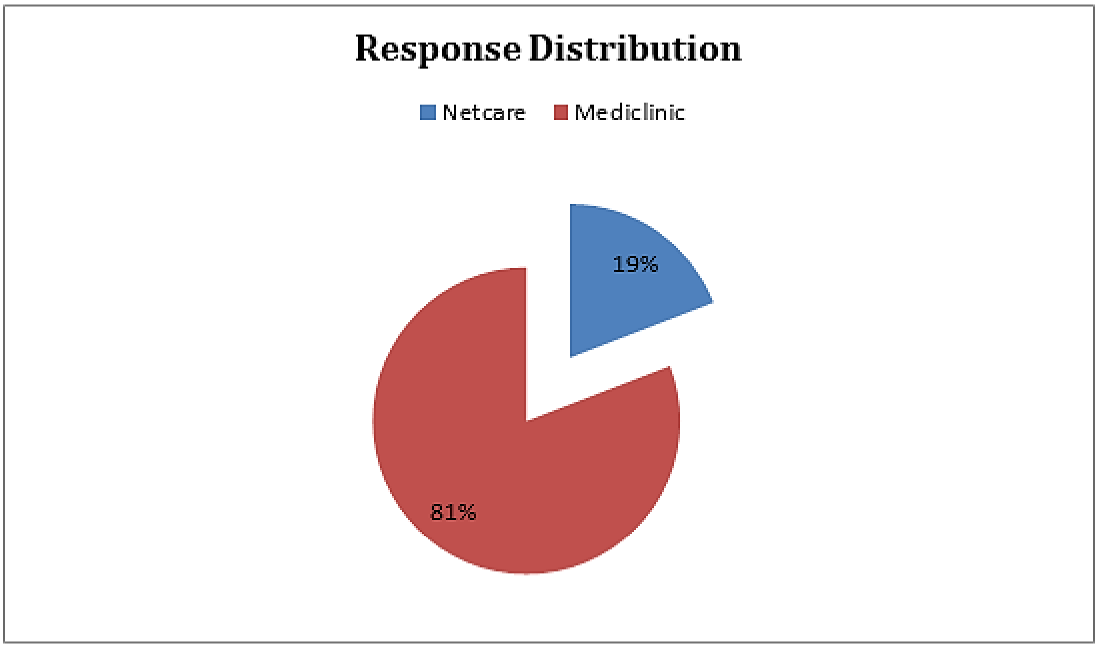


Figure 22 - Distribution of total number of survey responses per healthcare provider group

In total, **167 responses** were received from the following managers; general & operational managers (25%), financial managers (28%), human resource managers (23%), and clinical outcome managers (24%).

The results from this data analysis will illustrate a definite bias towards Mediclinic. However, this is not necessarily considered a major drawback for the survey, as the response data gathered from the Netcare respondents are not contradictory to that of the Mediclinic respondents (see ***Section 4.2.4***).

4.2.4. Test for independence – Netcare versus Mediclinic

The Mann-Whitney U-test is a non-parametric statistical hypothesis test for assessing whether one of two samples of independent observations tends to have different values than the other (Shier, 2004). The aim of this test of hypothesis is to establish whether it is statistically sound to combine the results received from Netcare and Mediclinic **(H_{0M})**.

Four samples of data were randomly selected from the survey results; two samples of 8 Mediclinic and Netcare responses each from the "Preventing future unnecessary hospitalisations" and "Higher Operating Margin" questions were respectively used for the test. Please note that "MC" denotes Mediclinic and "N" denotes Netcare.

Table 8 – Mediclinic Mann-Whitney U-test for Independence: Sample 1

Healthcare and Process Outcomes																
Preventing Future Unnecessary Hospitalisations																
Rank -ordered:	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5
Origin Sample:	MC	N	MC	N	MC	N	MC	N	N	MC	MC	N	N	N	MC	MC
UMC = 27.5																

Therefore, the value of independence for Mediclinic (U_{MC}) is 27.5. The significance of this figure depends on U_N, the value of independence for Netcare.

Table 9 - Netcare Mann-Whitney U-test for Independence: Sample 2

Healthcare and Process Outcomes																
Preventing Future Unnecessary Hospitalisations																
Rank -ordered:	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5
Origin Sample:	MC	N	MC	N	MC	N	MC	N	N	MC	MC	N	N	N	MC	MC
UN = 26.5																

From ***Table 8*** and ***9*** it is evident that U_N is smaller than U_{MC}. Therefore, the U-stat for this test equals 26.5 (U_N). In test two, samples were taken from the "Higher Operating Margin" responses and the corresponding value of independence was 24.5.

From the critical value table, as appended in ***Appendix D***, with n_1 and n_2 equal to 8 and the level of significance (α) equal to 0.05, the U-stat value equals 13. For H_{0M} to be rejected, U_N has to be smaller than 13. However, U_N equals 26.5 and 24.5 for test one and two, respectively. The survey results from Mediclinic and Netcare are not contradictory and can therefore be combined without a bias towards either healthcare provider group.

The following section focuses on the distribution of the response data per category and identifies the high-priority key performance indicators from a systems perspective. No distinction is made between the groups in this section, to protect the anonymity of the respondents and their organisations.

4.2.5. Top priority key performance indicators

From the five categories of hospital performance measurement that were identified, only four were surveyed to obtain a systems perspective of the current performance foci of in these categories:

1. *Healthcare and process outcomes;*
2. *Patient-focused outcomes;*
3. *Employee-focused outcomes; and*
4. *Financial and market-focused outcomes*

Leadership-focused outcomes were omitted from the survey, due to the limited possible number of responses obtainable from top-executives in the private healthcare sector of South Africa. The pie chart in ***Figure 23*** illustrates the distribution of responses received per category.

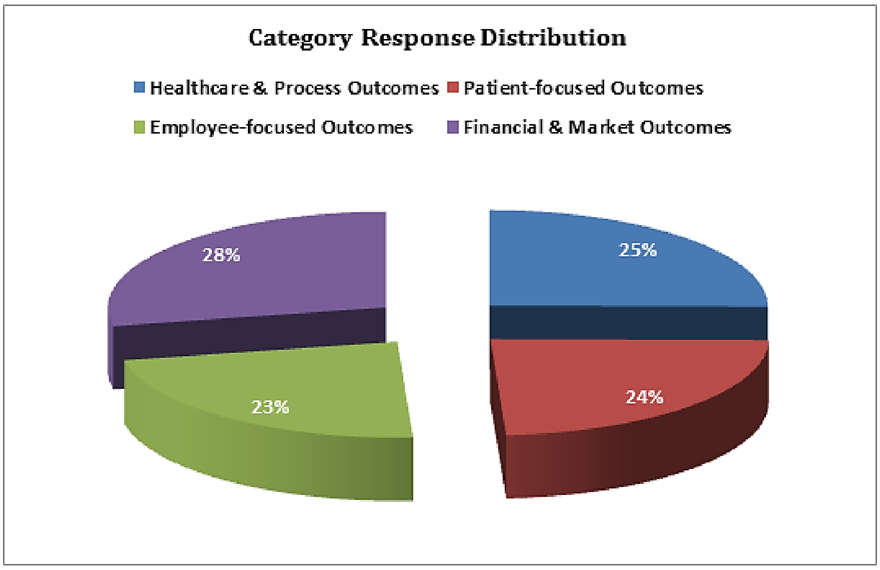


Figure 23 - Distribution of responses per category

Each category's respondents were asked to evaluate the *importance* of various key performance indicators to their organisations, which generated *priority indices* for all of the KPIs. Furthermore, respondents were asked to rate the *perceived ability* of PAPAs to aid in the performance improvement of their organisation with regards to each KPI. Therefore, a unique *PAPA ability index* was also assigned to each KPI. The indices were calculated according to ***Equation 2***:

$$I_j = \sum_{i=1}^{5} \left[\frac{c_{ij} \times R_i}{T} \right] \qquad \textbf{[Eq. 2]}$$

Where,

$I_j = \text{Priority or ability index per key performance indicator } (j)$

$i = \text{Likert scale rank}$

$c_{ij} = \text{Number of responses per rank per key performance indicator}$

$R_i = \text{Rank weight}$

$T = \text{Total number of responses}$

Table 10 serves as an example of the Likert scale used in the survey to achieve the ranking of the KPIs. The data generated from a Likert scale (summative scale) is ordinal. Therefore, the data is useful for ordering, prioritising or counting "items" *relative* to other items.

Table 10 - Likert ranking scale used in the survey for the prioritisation of KPIs

	Rank Patient satisfaction Performance Indicators							* Performance Compromising Factors (PCFs)
	Least		Average			Most		
	1	2	3	4	5	6	N/A	
Improved patient-retention rate	○	○	○	○	○	○	○	
Gains in patient accounts	○	○	◉	○	○	○	○	
Decreased number of patient complaint	○	○	○	○	○	○	○	
Higher patient satisfaction	○	○	○	○	○	○	○	
Other?	○	○	○	○	○	○	○	

There are a few weaknesses associated with Likert scales, one of which is the *central tendency bias*, where participants are inclined to avoid extreme responses skewing the actual representation of the data. However, in this case, the effect of the central tendency bias was reduced by requiring respondents to firstly ***identify*** a predetermined number of high-priority performance indicators from various groupings of KPIs in each category. Thereafter, each high-priority KPI, identified by the respondent, was ranked in relation to the other high-priority KPIs in the same category. Hence, the survey design ensured that definite high priority KPIs were evident from the survey responses. ***Figure 24*** supplies a summary of the category response rates, documenting each KPIs *priority* and *PAPA ability index*. The scatterplot is divided into four quadrants:

- *Discard,*
- *Missed the plot,*
- *Scope for improvement, and*
- *Focus*

Each KPI falls into a specific quadrant according to its *current importance* to private HCPs in South Africa, and the *perceived ability* of a PAPA care intervention strategy to improve the performance of these HCPs with regards to the individually listed KPIs. This classification will determine which KPIs will be utilised to determine the potential value-add of a PAPA care intervention strategy.

The "discard" quadrant represents the performance indicators that are not of a high priority to healthcare providers relative to the other performance indicators, and have a low perceived ability to be improved with the implementation of a PAPA care intervention strategy.

The "missed the plot" quadrant represents the performance indicators that have a perceived ability to be improved with the implementation of a PAPA care intervention strategy, but are currently a low priority to private healthcare providers in South Africa.

The "scope for improvement" quadrant represents the current key performance indicators that are of a high priority to healthcare providers in South Africa, but have a low perceived ability to be improved with the implementation of a PAPA care intervention strategy. Therefore, a scope for improvement in the development of predictive models that aim to improve these KPIs exists.

Finally, the "focus" quadrant represents the KPIs that are currently of a high priority to private healthcare providers and are expected to improve with the implementation of a PAPA care intervention strategy.

From ***Figure 24***, it is evident that sixteen KPIs fall within the *"focus"* quadrant. Due to the complexity of modelling the impact of a PAPA care intervention strategy on sixteen KPIs, it was decided to refine the list of KPIs by considering only those with *priority* and *PAPA ability indices* greater than 60***.*** These KPIs are summarised in ***Table 11***. A full description of the scatterplot results is tabulated in ***Appendix D.***

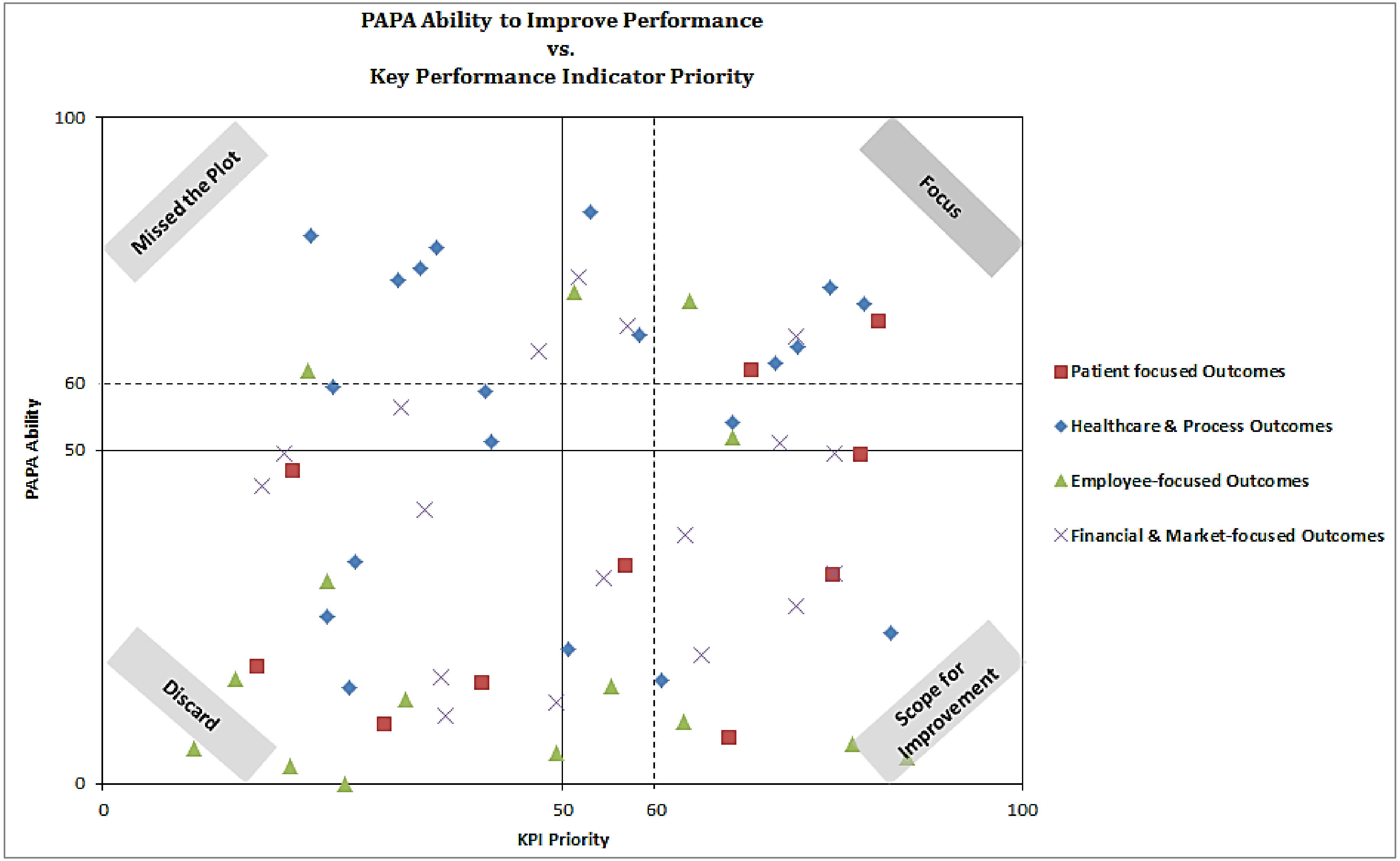


Figure 24 – Focus classification of KPIs according PAPA ability and priority

Table 11 - Summary of the high-priority and PAPA ability index key performance indicators

Key Performance Indicator	Priority Index	PAPA Ability Index
Improved patient-practitioner relationships	84.38	69.38
More efficient and financially viable inventory levels	79.17	74.40
Higher Operating Margin	75.38	67.02
Improved care coordination	75.60	65.48
Efficient and effective staffing levels	63.82	72.37
Improved patient-retention rate	70.63	61.88

Sixteen KPIs fall within the *"Scope for Improvement"* quadrant, which provides a platform for future predictive modelling research in the field of healthcare performance improvement. These KPIs are summarised in ***Table 12***.

Table 12 - Summary of the "Scope-for-improvement" key performance indicators

Key Performance Indicator	Category of Outcomes	Priority Index	PAPA Ability Index
Decreased work-related accidents	*Employees*	87.50	3.95
Decreased absenteeism	*Employees*	81.58	5.92
Higher % of certified staff members (nurses)	*Employees*	63.16	9.21
Greater commitment to organisational change	*Employees*	55.26	14.47
Higher Return on Investment (ROI)	*Financials and Markets*	79.62	49.47
Higher Earnings per Share (EPS)	*Financials and Markets*	79.60	31.38
Improved market position or sector growth	*Financials and Markets*	75.42	26.60
More efficient levels of cash on-hand	*Financials and Markets*	63.34	37.26
Improved cash flow	*Financials and Markets*	54.40	30.85
Higher % market share	*Financials and Markets*	65.12	19.15
Improved adherence to patient safety practice	*Healthcare and Processes*	85.71	22.62
Improved internal responsiveness	*Healthcare and Processes*	82.50	49.38
Improved adherence to treatment protocols	*Healthcare and Processes*	50.60	20.24
Improved access to healthcare services	*Patients*	60.71	45.48
Higher patient advocacy for firm's services	*Patients*	79.38	31.25
Gains in patient accounts	*Patients*	68.13	6.88
Decreased number of registered complaints	*Patients*	56.88	32.50

An additional weakness of Likert scales is a phenomenon called the *acquiescence bias, which* occurs when participants agree with certain statements as presented by the researcher in the survey objective, simply to satisfy the researcher. In this case, it is expected that KPIs such as *"preventing future unnecessary hospitalisations"*, *"higher cost savings at key healthcare processes"* and *"decreasing unrecyclable waste production"* were included in the initial group of high-priority KPIs, merely as a result of the *acquiescence bias.* Therefore, these KPIs will be removed from the value-add analysis. The following subsection will focus on the identification of the major PCFs for the KPIs to be considered in the remainder of the study.

4.2.6. *Major performance compromising factors*

Major performance compromising factors (PCFs) are factors that compromise the ability of a hospital to perform well in terms of a particular key performance indicator. Eradicating or limiting the effect of PCFs will benefit healthcare providers in a major way and is likely to improve hospital performance.

Determining PCFs for each KPI provides a basis for evaluating the potential impact of a PAPA care intervention strategy on healthcare provider performance. If any of the major PCFs for a KPI relate to healthcare resource management, then a basis for evaluating the potential value-add exists. For example, a "lack of time to coordinate care" is a major PCF for *"improved care coordination"*. Therefore, the basis for evaluation for this KPI will depend on the relationship between the *time* available to coordinate care and the KPI's formula as documented in ***Section 4.3.2***. However, if a KPI's major PCFs do not relate to healthcare resource management, then no apparent basis for evaluation exists, and it becomes increasingly difficult to determine the impact of the PAPA care intervention strategy on this particular KPI. In this study, the major PCFs for the *"timely delivery of care"* performance indicator had no direct relationship to healthcare resource management. Therefore, this KPI was not included in the tabulated list of value-add KPIs in ***Table 11.***

Survey respondents were asked to state the single biggest PCF for each KPI they ranked. A free text analysis tool (http://www.tagcrowd.com) was used to separately evaluate the survey responses for each KPI, in order to identify the keywords (PCFs). The tool simply calculates the proportion (p) of the words occurring most in a given paragraph. "Word clouds" can also be used to visually depict the results, as illustrated in ***Figure 25***.

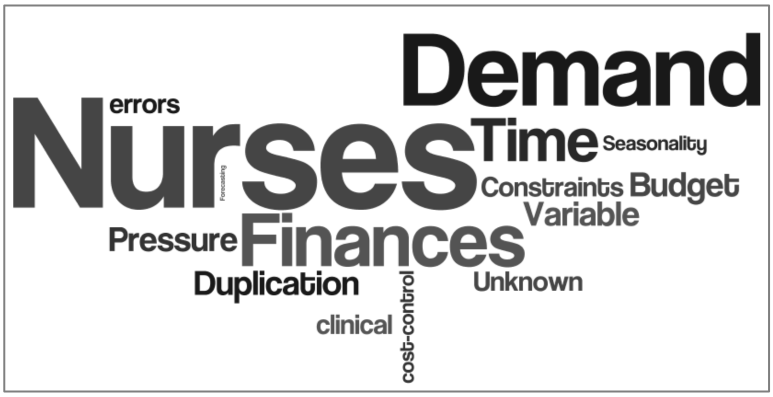


Figure 25 - A word cloud of the PCFs for the "staffing level efficiency and effectiveness" KPI

The remaining PCFs were either considered incomprehensive, unsuitable for analysis or recurring too infrequently to be included as major PCFs in the final analysis. Future research could explore the relationship between PCFs and KPIs in greater depth.

Table 13 provides a summary of the 1^{st}, 2^{nd}, and 3^{rd} biggest performance compromising factors per KPI, according to the survey respondents. The biggest performance compromising factors for "staffing levels" are associated with demand, finances, and time. These PCFs have supplementary tag words that aid in the comprehension of each PCF. For example, "variable", "seasonal", and "unknown" are the tag words that were most frequently associated with the demand PCF. Cumulatively these word associations accounted for 36.84% of the PCFs listed for the "staffing levels" KPI, resulting in "demand" being the single largest PCF for this KPI.

The following subsections will utilise these PCFs per KPI to determine a basis for evaluating the potential impact of a PAPA care intervention strategy on private healthcare provider performance in South Africa.

Table 13 - Summary of the major performance compromising factors for the focus KPIs

KPI	Category	1st PCF		2nd PCF		3rd PCF	
		p	Factors	*p*	Factors	*p*	Factors
Staffing Levels	*Employee-focused Outcomes*	36.84%	Demand: • *Variable* • *Seasonality* • *Unknown*	31.57%	Finances: • *Pressure* • *Constraints* • *Budget*	13.16%	Time: • *Constraints* • *Duplication* • *Clinical Errors*
Inventory Levels	*Health care & Process-focused Outcomes*	33.33%	Demand: • *Forecast* • *Non-critical Items* • *Variable* • *Safety Stock*	28.57%	Suppliers: • *Lead time* • *Dependability* • *Priority*	21.42%	Nurses: • *Lack of Skill* • *Responsibility* • *Commitment*
Care Coordination	*Health care & Process-focused Outcomes*	28.57%	Patients: • *Uninformed* • *Passive* • *Slack*	28.57%	Time: • *Constraints* • *Priority*	11.90%	Communication: • *Unclear* • *Lack of structure*
Operating Margins	*Financial & Market-focused Outcomes*	36.17%	Service lines: • *Not profitable* • *Inefficient* • *Critical*	34.04%	Human Resources: • *Cost* • *Training* • *Overtime*	10.64%	Duplication: • *Procedures* • *Tests* • *Errors*
Patient-practitioner Relationships	*Patient-focused Outcomes*	32.50%	Time: • *Constraints* • *Priority*	25.00%	Capacity: • *Throughput* • *Efficiency*	12.50%	Specialisation: • *Increased* • *Demand*
Patient Retention Rates	*Patient-focused Outcomes*	17.50%	Communication: • *Weak* • *Intimacy*	15.00%	Finances: • *Price* • *Variable*	12.50%	Courtesy: • *Unacceptable* • *Lack*

4.3. Value-add model

This section concludes the design and development of the PAPA value-add model. Firstly, the value-add model is introduced, articulating the objectives of the model and establishing some key concepts associated with the design of the quantitative model. Lastly, the performance dimensions of the model are defined to provide a better understanding of each KPI, and formulated to enable a quantitative analysis of the impact of a PAPA care intervention strategy on each KPI.

4.3.1. Introduction

The value-add model utilises the survey results of the previous section, providing performance dimensions in the form of priority-ranked KPIs. The model utilises a combination of Microsoft Excel's Visual Basic programming and standard spread-sheet functions, to seamlessly evaluate the impact of various care intervention strategies, and to ultimately propose a superior basis for intervention.

The model is designed to provide a comparison between a hospital's current state of performance and the estimated impact on hospital performance when applying a PAPA intervention strategy. The model requires analysts to provide input data regarding the current performance of the hospital and consequently measures the impact of applying the preventive care intervention strategy to various degrees.

In ***Figure 26,*** a Pareto analysis was conducted on a dataset obtained from the Hospital Association of South Africa (HASA) to identify the procedures, treatments, and tests (PTTs) that are responsible for the majority of hospitalisations in the private healthcare sector of South Africa (van Eck & Besesar, 2009).

Due to the large number of varying procedures, treatments, tests, causes of admission, length of stay, and cost and expense structures in a hospital, the "value-add" model was restricted to solely focuses on the major PTTs. The associated length of stay, costs and revenue, and average inventory requirements of these PTTs will be utilised to model the quantitative impact of preventing unnecessary hospitalisation on healthcare provider performance. Five major PTTs were identified in the Pareto analysis:

- *Evaluation and management,*
- *Pathology and laboratory,*
- *Medication,*
- *Surgery of the cardiovascular system, and*
- *Radiology*

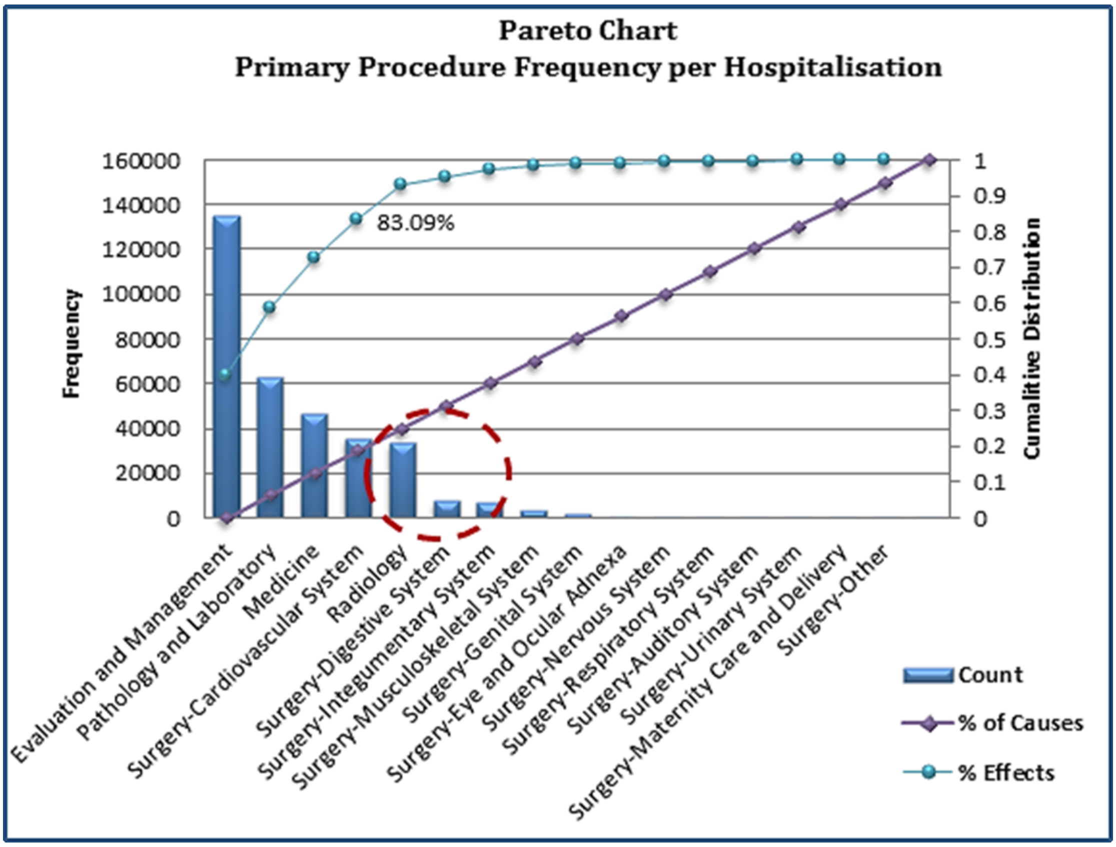


Figure 26 - Identifying the major procedure groups for consideration in the value-add model

Furthermore, the model's output is based on an assumption that a healthcare provider intercedes with patients on a predetermined basis. In essence, this assumption requires healthcare providers to establish the basis on which they intend to intercede with patients. This basis for intervention is an estimate of the proposed number of at-risk patients the healthcare provider intends to intercede with. Therefore, the basis for intervention is a function of the number of ***predicted unnecessary hospitalisations*** and the ***resource capacity*** of the healthcare provider to intercede with these patients. Hence, according to the estimated resource capacity to intervene, healthcare providers will establish a target intervention rate.

The number of patients a healthcare provider intercedes with is therefore a key decision-variable in the implementation and operation of a PAPA intervention strategy. Furthermore, it is assumed that whenever a patient intervention takes place, the probability of that patient being admitted to hospital in the coming year, is insignificant.

The remaining sub-sections separately define each key performance indicator, formulate the objective functions for each KPI and elaborate on the methods used to depict and analyse the model outputs.

4.3.2. Defining and formulating the performance dimensions

Defining the performance dimensions will ultimately enable the quantification and measurement of each KPI in the value-add model, articulating the need to firmly comprehend each performance dimension. Furthermore, formulating the performance dimensions enable the quantitative analysis of the impact on each identified KPI. Each equation utilises user-input data to generate unique results for a variety of scenarios. The equations range from simple linear relationships and step functions to exponential probability distributions.

4.3.2.1. Staffing level efficiency and effectiveness

A hospital's workforce is considered the most valuable asset in the organisation, as it directly affects the quality of care and service delivery (Subba Rao, 2008). At the front-end of a hospital's workforce, is the nursing staff. The efficiency and effectiveness of the nursing staff majorly affects the quality of care and clinical outcomes in a hospital (Sekar, 2008). The efficiency and effectiveness of hospital staffing levels is a function of the amount of clinical time nurses waste on unproductive clinical tasks (Institute of Medicine, 2006). Therefore, the efficiency and effectiveness of staffing levels (nurse levels) is a key priority for any healthcare provider, a fact that was reiterated by the survey results in ***Chapter 4***.

In the context of the study, unproductive clinical tasks refer to the *time* nurses spend on unnecessary hospitalisations, which could have been prevented if the necessary preventive care measures were performed.

"Staffing level efficiency and effectiveness" is the only workforce-focused performance indicator in the value-add model at present, and is, therefore, considered a critical performance dimension in the analysis of the potential value-add of PAPAs.

This performance dimension is a function of nurse capacity and the clinical labour time wasted on unnecessary hospitalisations. Various factors have an impact on workforce productivity. However, for the purpose of this study the equation for nurse productivity isolates the impact of unnecessary hospitalisations on workforce productivity and is therefore not an indication of the *overall* productivity of the workforce.

As previously stated, the model evaluates the impact of a preventive care intervention strategy based on the results of the PAPA. The decision to intervene is represented by the percentage of high-risk patients, identified by the PAPA, which a healthcare provider intends to intercede with. The impact of the PAPA care intervention strategy on nurse productivity is estimated by ***Equation 3.***

$$\mathbf{P_{Nurse}} = \left(\mathbf{1 - N_{admit} \times P_U \times \frac{[(1-P_I)\times L \times t_{Std} + P_I \times t_I]}{N_n \times S_{week} \times W_{year} \times t_{Std}}}\right) \times \mathbf{100\%} \qquad \textbf{[Eq. 3]}$$

Where,

$P_{Nurse} = Nurse\ productivity$

$N_{admit} = Number\ of\ annual\ admissions$

$P_U = Percentage\ of\ unnecessary\ hospitalisations$

$P_I = Healthcare\ provider's\ intervention\ strategy\ percentage$

$L = \ Average\ associated\ length\ of\ stay\ per\ PTT\ \ (days)$

$t_{Std} = National\ standard\ of\ nursing\ care\ hours\ per\ patient\ day\ (4.5\ hours)$

$t_I = Time\ to\ intercede\ with\ patients\ (hours)$

$N_n = Number\ of\ full - time\ employed\ (FTE)\ nurses$

$S_{week} = Number\ of\ shifts\ per\ week$

$W_{year} = Number\ of\ labour\ weeks\ \ per\ annum$

Note that when the P_I equals 0, the scenario depicts that of the current impact of preventable hospitalisations on workforce productivity. This level of workforce productivity serves as a benchmark to evaluate the impact of various intervention strategies on staffing level efficiency and effectiveness.

4.3.2.2. Financial operating margin

The operating margin (earnings before interest, tax, depreciation and amortisation (EBITDA) margin) is considered one of the major indications of a company's profitability (Bernanke, 2009).

In the private healthcare sector of South African, operating margins are increasingly important due to the expected strain on future revenue streams as a result of the proposed National Health Insurance scheme.

A hospital's operating margin is defined by the amount of expenditure as a percentage of revenue attained or generated from direct patient care (Jangaiah, 2008). The survey results identified the financial operating margin to be the sole financial performance indicator in the "focus" quadrant to potentially be affected by the implementation of PAPAs. Therefore, this KPI is currently considered highly relevant to financial managers at private healthcare provider groups in South Africa, and forms a critical part of the value-add model.

The financial operating margin of any healthcare provider is a function of the provider's operating income and expenses, generated and effected by clinical patient care. Each hospital admission can therefore be depicted by a revenue and cost component.

The value-add model uses the average patient revenue and expenditure per hospitalisation and evaluates the impact of interceding with patients given the expected revenue and cost associated with the intervention strategy (see ***Equation 4***).

$$\textbf{Operating Margin} = 1 - \frac{C_{patient}}{R_{patient}} \times \left[\frac{(1 - P_U \times P_I) + (P_U \times P_I \times C_R)}{(1 - P_U \times P_I) + (P_U \times P_I \times R_R)}\right] \qquad \textbf{[Eq. 4]}$$

Where,

$C_{patient} = Average\ operating\ expenditure\ per\ hospitalisation$

$R_{patient} = Average\ revenue\ per\ hospitalisation$

$P_U = Percentage\ of\ unnecessary\ hospitalisations$

$P_I = Healthcare\ provider's\ intervention\ strategy\ percentage$

$C_R = Ratio\ of\ cost\ to\ intervene\ versus\ admit$

$R_R = Ratio\ of\ revenue\ to\ intervene\ versus\ admit$

If P_I equals 0, the financial operating margin is simply the total operating expenditure as a percentage of the total patient revenue. These values are easily attainable in the financial statements of any healthcare provider and will be utilised as benchmarks in the output analysis of ***Section 4.3.4***.

4.3.2.3. Inventory service level

This performance dimension is the first of two healthcare and process outcome performance indicators in the value-add model. Various inventory service level types exist, however for the purpose of this study the β service level measurement is applicable. The type-II (β) service level is a measurement of the levels of inventory that seldom result in stock-out events for critical items, but do not require excessive amounts of safety stock to meet the target service level (Parker & DeLay, 2008).

The number of stock-out events mainly depends on the level of safety stock and the variability in demand. Therefore, the value-add model will provide valuable insight into the new levels of safety stock required with the implementation of a PAPA care intervention strategy and the expected decrease in stock-out events to potentially improve service levels.

Cheng and Whittemore (2008) stated that the average inventory service level distribution of hospitals, as a function of service factor, is depicted by ***Figure 27.*** This exponential distribution models the inventory service level against the service factor (level of safety stock divided by the standard deviation in safety stock). The distribution also states the assumption that if a hospital carries no safety stock, the probability of a stock out event occurring (type II inventory service level) equals 50%. In order to estimate the inventory service level, the service factor and the corresponding level of safety stock, need to be determined first.

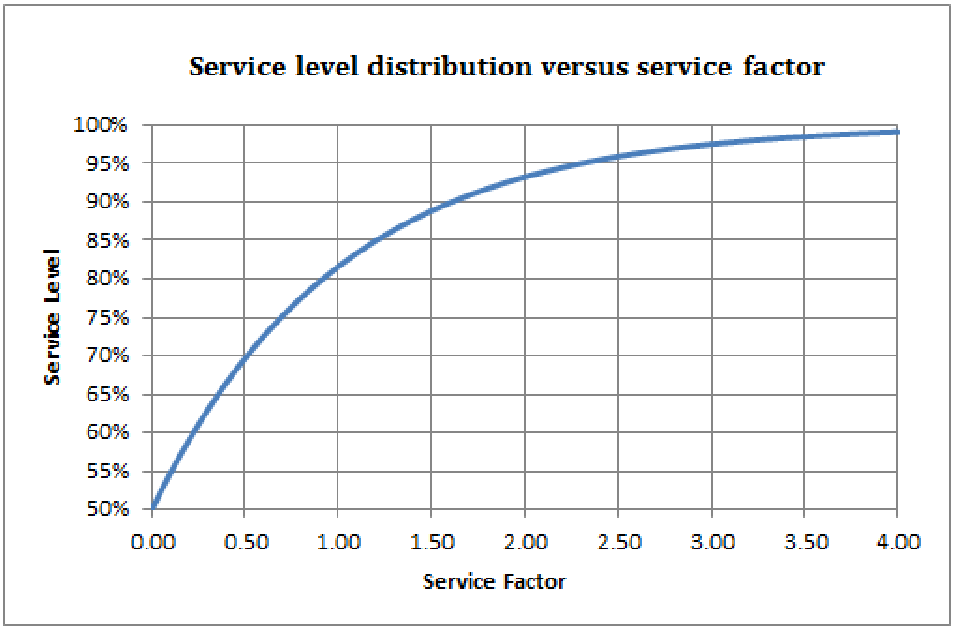


Figure 27 - Current inventory service level distribution as a function of the service factor adapted from (Cheng & Whittemore, 2008)

The level of safety stock is a function of the period demand, hence, the value-add model generates inventory demand forecasts on the basis of the minimum and maximum expected period demands.

The annual inventory demand was modelled according to the seasonality of in-hospital admission rates. In essence, three distinguishable levels of demand are present in the private healthcare sector of South Africa (Council for Medical Schemes, 2009):

- *Low-season (January, June, July and December),*
- *Mid-season (February, March, August and September) and*
- *Peak-season (April, May, October and November)*

These various inventory demand periods enabled the estimation of minimum, maximum and average inventory demand per annum, which is essential for the calculation of the safety stock level and the subsequent service factor that determine the inventory service level. The Monte Carlo principle was used to generate random inventory demand forecasts for each month in the year. Simply stated, the value-add model generates a range of possible inventory demand figures for each month, uniformly distributed between the historical minimum and maximum expected demand forecasts per month (f_n). The actual demand per month (a_n) and the demand forecast per month (f_n) are used to calculate the standard deviation in the demand forecasts. In essence, the standard deviation is the square root of the variance in the demand forecasts (Tratar, 2009). The lead time factor is estimated by the square root of the delay (in months) between inventory reorder decisions points (Tratar, 2009). The equation for determining service factor is illustrated by ***Equation 5.***

$$\boldsymbol{Service\ Factor = \frac{Safety\ Stock}{\sigma_f \times T_{lead}}} \qquad \textbf{[Eq. 5]}$$

Where,

$$Safety\ Stock = Amount\ of\ safety\ stock\ required$$

$$\sigma_f = Standard\ deviation\ of\ the\ demand\ forecasting\ error$$

$$T_{lead} = Lead\ time\ factor$$

The corresponding service level is then calculated by utilising the cumulative normal distribution function with the random variable (x) equal to the service factor (Tratar, 2009).

It is expected that healthcare providers are able to schedule their resources more efficiently and effectively due to a decreased variability in the demand as a result of the known number of patient interventions. Less variability in demand results in an increased inventory service level given the level of safety stock remains relatively constant.

4.3.2.4. Clinical care coordination

Clinical care coordination is the other healthcare and process outcome performance indicator in the value-add model. Care coordination relates to the ability of healthcare providers to effectively communicate discharge summaries, preventative care measures, healthcare needs and medicinal administration plans to patients after discharge, with the aim of preventing future unnecessary hospitalisations (Bodenheimer, 2008). Coordination of care is a function that helps ensure that the patient's needs and preferences for health services and information sharing across people, functions, and sites are met over time (Bodenheimer, 2008).

Care coordination is a qualitative measure based on what is described as the three-care transition measure (CTM-3) index (Parry *et al.*, 2008). CTM-3 is an indication of whether a healthcare provider emphasises the importance of preventive care, in the aim of decreasing the probability of patients being readmitted to hospital (also considered as unnecessary hospitalisations).

The index is a combination of three major quality indicators that revolve around the healthcare provider's ability to provide quality care coordination. Patients are required to rank their healthcare provider's care coordination ability according to the following requisites (Parry, *et al.* 2008):

- *The hospital staff took my preferences and those of my family or caregiver into account in deciding what my healthcare needs would be when I left the hospital.*
- *When I left the hospital, I had a good understanding of the things I was responsible for in managing my health.*
- *When I left the hospital, I clearly understood the purpose for taking each of my medications.*

A study on the future of care coordination and the use of the care transitions measure found that a direct relationship between patient CTM-3 scores and the time physicians spend on care coordination, exists (Parry, *et al.* 2008). Physicians that spent more time on communicating discharge summaries, medicinal requirements, and preventive care plans to patients when they leave hospital, generally resulted in higher CTM-3 scores and a slight decrease in re-hospitalisation rates (Parry, *et al.* 2008).

Physicians providing out-patient preventive care services to individuals, solely focus on providing the necessary care and guidance that will decrease the risk of admission to hospital for these individuals. Therefore, in the value-add model, the time spent on intervening with patients as part of the PAPA preventive care intervention strategy, was assumed to be time spent on care coordination. The linear relationship between time spent on care coordination and the CTM-3 index was used to determine the levels of care coordination ***Equation 6*** determines the adjusted time per hospitalisation spent on care coordination (t_{PAPA}), with the implementation of a PAPA care intervention strategy.

$$\boldsymbol{t_{PAPA} = (1 - P_U \times P_I) \times t_{current} + P_U \times P_I \times t_I} \qquad \textbf{[Eq. 6]}$$

Where,

$P_U = Percentage\ of\ unnecessary\ hospitalisations$

$P_I = Healthcare\ provider's\ intervention\ strategy\ percentage$

$t_{current} = average\ time\ physicians\ currently\ spend\ on\ care\ coordination$

$t_I = Time\ to\ intercede\ with\ patients\ (hours)$

The following step function was estimated based on the linear relationship that exists between the time spent on care coordination and the corresponding level of care coordination (see ***Table 14***).

Table 14 - Associated level of care coordination given the time spent on care coordination

Time Spent on Care Coordination (minutes)	CTM-3 Index	Level Index
Less than 3	*Strongly Disagree*	*1*
3 – 8	*Disagree*	*2*
8 – 15	*Somewhat*	*3*
15 – 25	*Agree*	*4*
More than 25	*Strongly Agree*	*5*

The aim of the value-add model is to determine whether the intervention strategy will improve the average care coordination level, given the increased time spent on care coordination through the provision of out-patient preventive care services.

4.3.2.5. Patient-practitioner relationship

Patient-practitioner relationships are defined as the perceived quality of care in the form of courteous service interactions as opposed to the number of registered patient complaints due to discourteous service interactions (Forrest et al., 2002). The patient-practitioner relationship performance indicator is one of the major factors that affect patient satisfaction in healthcare providers and is the first of two patient-focused outcome performance indicators. Due to the increase in clinical specialisation over the past two decades, healthy patient-practitioner relationships have been on the decline (Forrest *et al.,* 2002).

Hence, with the proposed intervention strategy, practitioners will more frequently be able to spend more time with high-risk patients to provide preventive care, and in all probability improve patient-practitioner relationships. The value-add model will quantitatively explore the impact of the PAPA intervention strategy on patient-practitioner relationships and qualitatively analyse the potential benefit.

As previously mentioned, the increased specialisation in healthcare has resulted in a decline of patient-practitioner relationships. In previous years, individuals were inclined to consult their family physician or general practitioner regarding any illness or ailment.

The modern era, however, has seen a dramatic decline in the number of general practitioners and family physicians due to the fact that patients are more knowledgeable on their diseases and would therefore consult specialists directly, without the aid of a GP. It is assumed that the increase of courteous interactions of patient and practitioners on a pre-determined basis (as is the case with out-patient preventive care plans), will improve the relationship between patient and practitioners. This relationship between time spent on preventive care interventions and patient-satisfaction, is depicted in ***Figure 28***. Note that when the time spent on intervention equals zero (i.e. no intervention occurs), the patient satisfaction for the intervened patients equals the current patient satisfaction in the hospital (80% in ***Figure 28***).

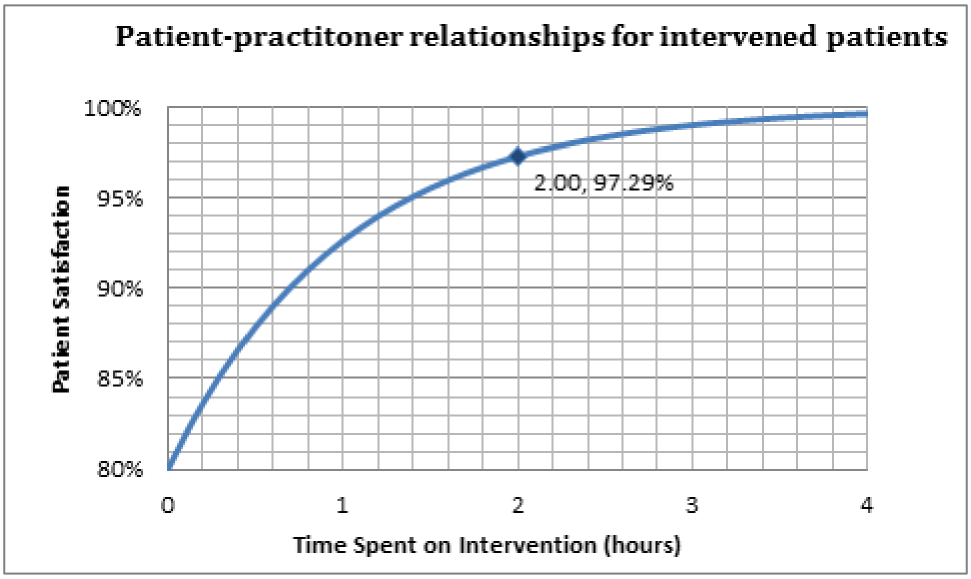


Figure 28 - Patient satisfaction distribution for intervened patients

The exponential distribution in ***Figure 28*** is used to determine the level of satisfaction experienced by patients that have been intervened with (S_{PAPA}), given the amount of time healthcare practitioners spend on these preventive care interventions. ***Equation 7*** estimates the overall patient satisfaction with the implementation of a PAPA care intervention strategy.

$$\boldsymbol{S_{new}} = \mathbf{S_{current}}\,(\mathbf{1} - \mathbf{P_U} \times \mathbf{P_I}) + \mathbf{S_{PAPA}} \times \mathbf{P_U} \times \mathbf{P_I} \qquad \textbf{[Eq. 7]}$$

Where,

$S_{new} = Overall\ patient\ satisfaction$

$S_{current} = Current\ patient\ satisfaction\ (\%)$

$S_{PAPA} = Intervened\ patient\ satisfaction\ given\ intervention\ time\ (\%)$

$P_U = Percentage\ of\ unnecessary\ hospitalisations$

$P_I = Healthcare\ provider's\ intervention\ strategy\ percentage$

The value-add model will explore various possible scenarios regarding the extent to which patient intervention is required, in order to deliver acceptable patient satisfaction levels with regards to the relationship between the healthcare practitioner and patient.

4.3.2.6. *Patient retention rate*

The established patient base for any healthcare provider is never permanent. Therefore, the patient retention rate refers to the ability of a healthcare provider to retain its established patient base and hence ensure future work from previously consulted patients (Hirsch & Gandolf, 2011).

The patient retention rate is a function of the number of patient accounts lost in a period due to a change in patient preference for clinical hospital services (Hirsch & Gandolf, 2011). The evaluation of this performance dimension is based on the assumption that interceding with patients on a preventative care basis will increase the probability of retaining those patients (Hirsch & Gandolf, 2011).

Patient retention rates are crucial for retaining and increasing market share, especially in a competitive private healthcare sector similar to South Africa's. Major factors that result in a decline of patient retention rates, as depicted in ***Table 13***, are due to the lack of scheduled follow-up visits and the patient's adherence to these follow-up visits. It is expected that the implementation of PAPA care intervention strategies will alleviate some of these performance compromising factors.

Equation 8 utilises the distribution in ***Figure 29*** to determine the patient retention rate for the intervened patients $(\mathrm{R}_{\mathrm{PAPA}})$, given the time spent on intervening with patients. In this distribution, it is assumed that if no patient intervention occurs, the probability of retaining the patient is 50%.

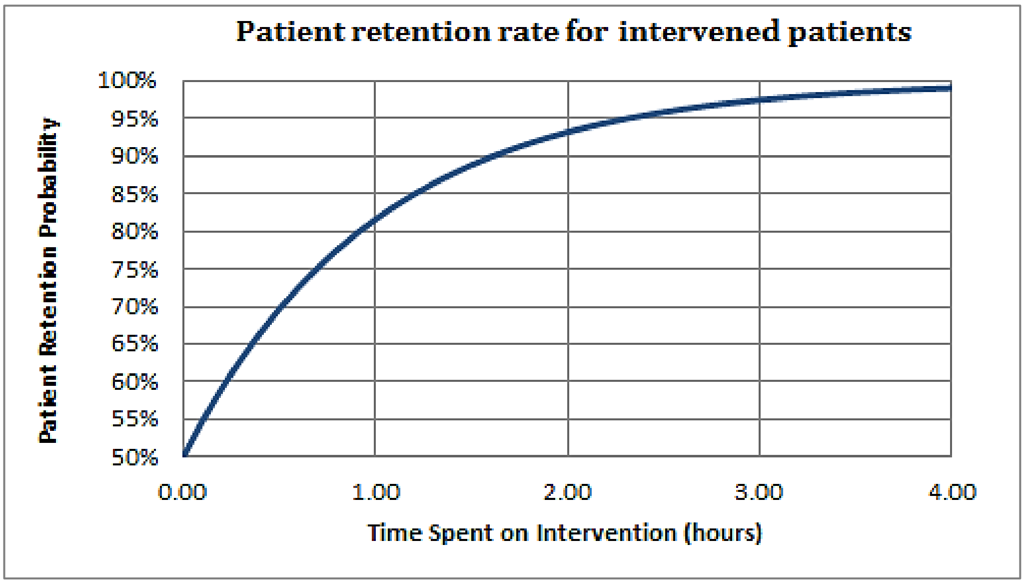


Figure 29 - Patient retention distribution for intervened patients

Equation 8 estimates the overall patient retention rate, given the new probabilities of retaining patients that form part of the PAPA care intervention strategy.

$$R_{Patient\ Retention} = \mathbf{R}_{\mathbf{current}}\,(\mathbf{1} - \mathbf{P}_{\mathbf{U}} \times \mathbf{P}_{\mathbf{I}}) + \mathbf{R}_{\mathbf{PAPA}} \times \mathbf{P}_{\mathbf{U}} \times \mathbf{P}_{\mathbf{I}} \qquad \textbf{[Eq. 8]}$$

Where,

$R_{current} = Current\ patient\ retention\ rate\ (\%)$

$R_{PAPA} = Intervened\ patient\ retention\ rate\ given\ intervention\ time\ (\%)$

$P_U = Percentage\ of\ unnecessary\ hospitalisations$

$P_I = Healthcare\ provider's\ intervention\ strategy\ percentage$

The value-add model will explore various possible scenarios regarding the extent to which patient intervention is required, in order to deliver acceptable patient retention rates.

4.3.3. Generating the model output

The preceding sections of this chapter have focused on 1) determining the performance dimensions of the value-add model (high priority KPIs), 2) identifying major performance compromising factors for each KPI, and 3) defining and formulating each KPI to enable the quantitative estimation of the impact of a PAPA care intervention strategy on these high priority KPIs. In order to evaluate the model output, a firm understanding of the model is required before proceeding to the analysis phase. The model is broken down into three major steps, as depicted in ***Figure 30.***

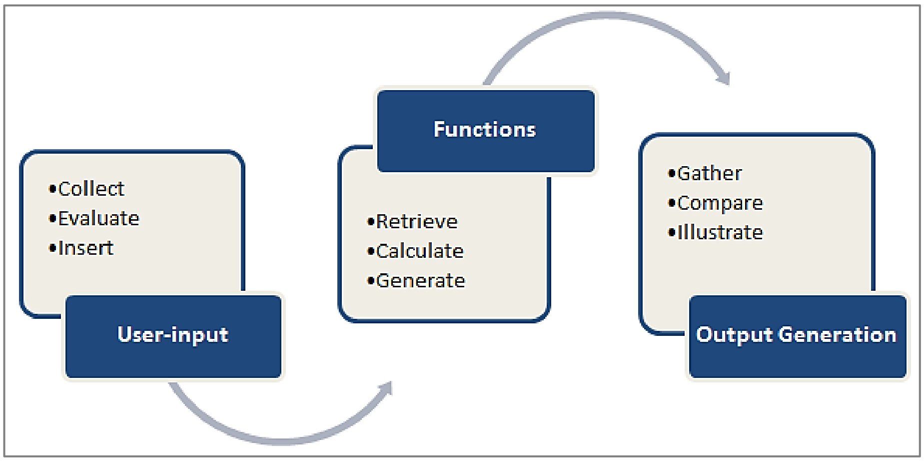


Figure 30 - Value-add model: Process to generate performance impact results

Firstly, user-input is collected with the aid of a seven user-forms, as depicted in ***Figure 31***. Screenshots of the remaining user-forms are illustrated in ***Appendix E***.

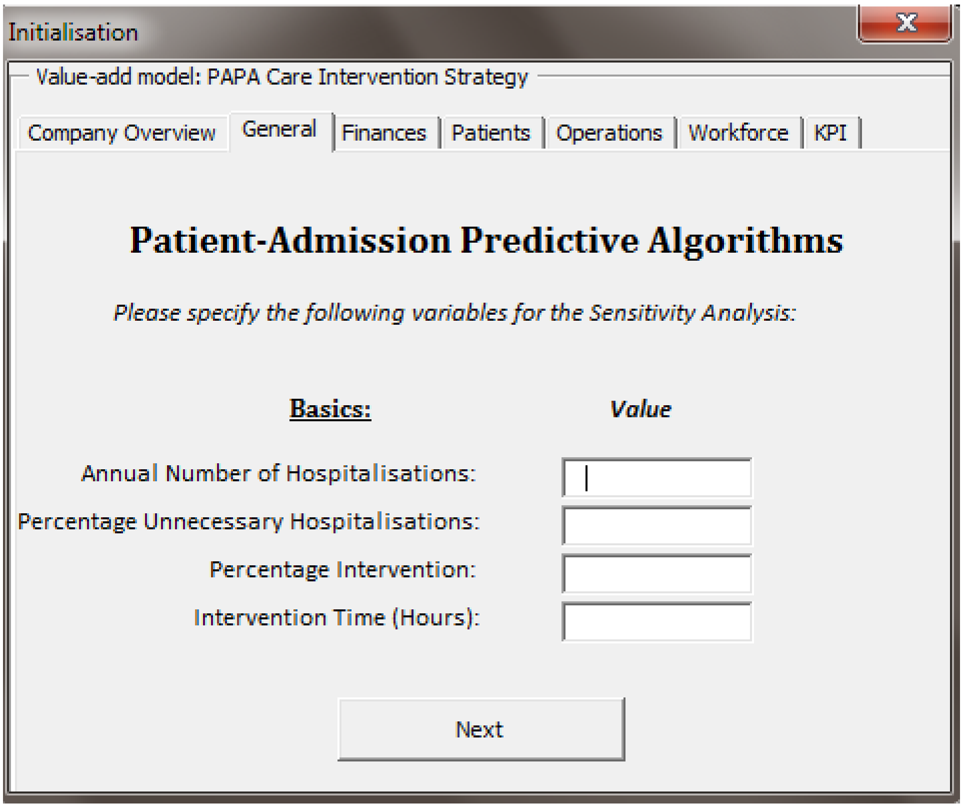


Figure 31 - Value-add model: User-input forms

The data is evaluated for completeness and form with various macro-enable data validation techniques, as depicted in the ***Figure 32***. The information is inserted into various Excel worksheets, from which the KPI functions can retrieve the required data.

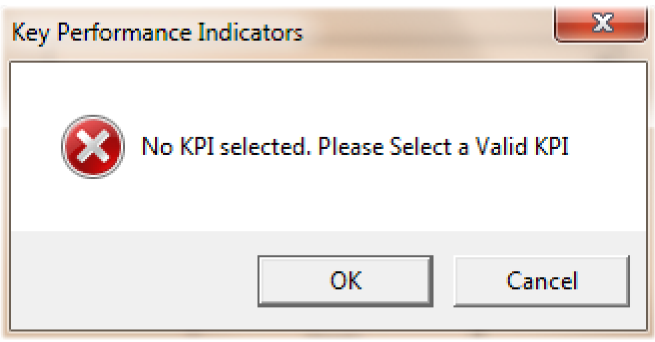
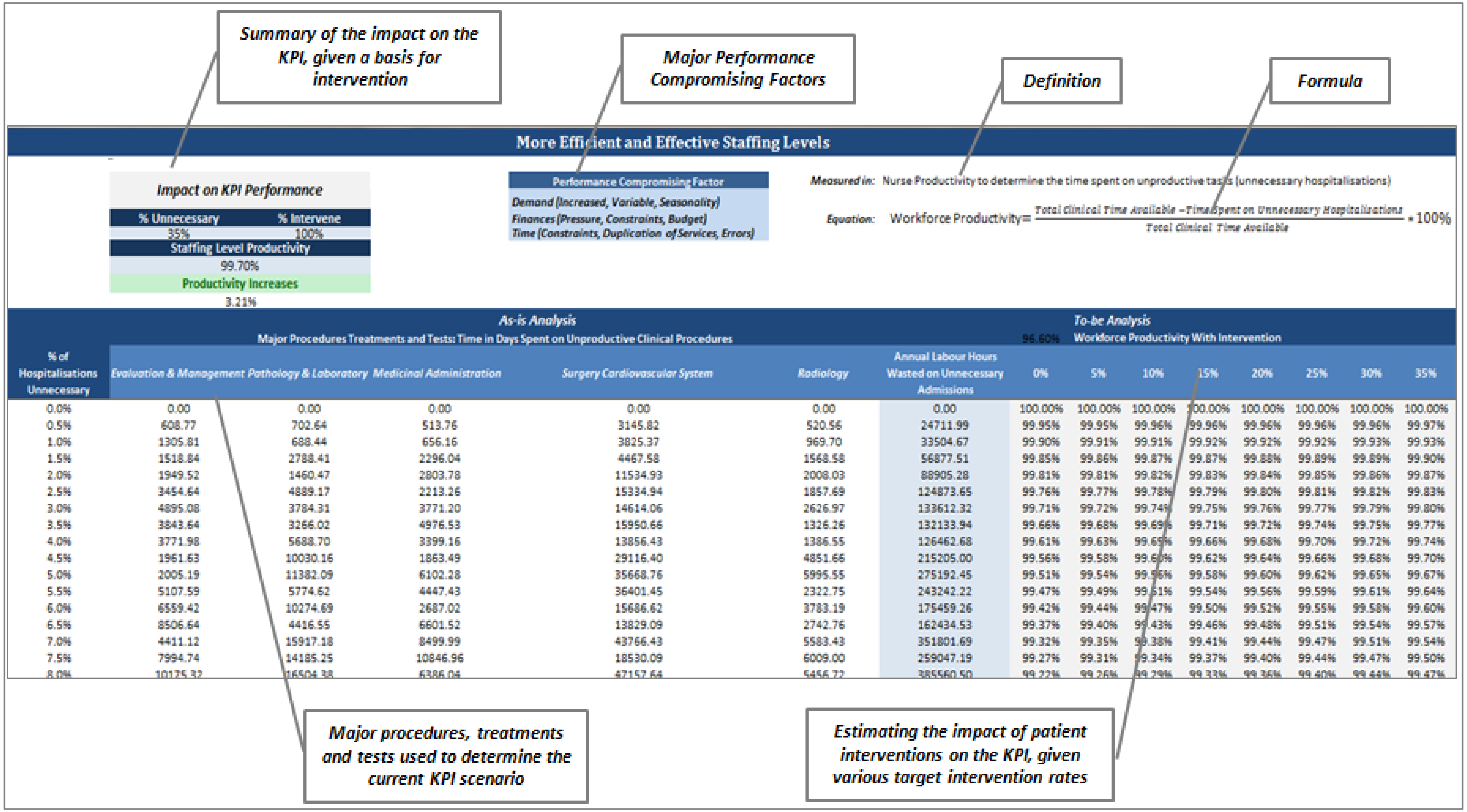


Figure 32 – Validating user-input data

The second step of the value-add model revolves around the quantification of the estimated impact on each KPI, given the current user-input. The KPI formulas generated in ***Section 4.3.2,*** retrieve the stored data, and calculate the results for the current scenario. This process was modelled through a combination of worksheet functions as illustrated in ***Figure 33*** on ***page 87***. Each KPI has a separate worksheet that constitutes the following elements:

- *The definition of the key performance indicator,*
- *The major performance compromising factors,*
- *The formula used to measure the key performance indicator,*
- *The analysis of the current situation,*
- *The analysis of the impact of a PAPA care intervention strategy, and*
- *A window that summarises the impact of the PAPA care intervention strategy*

Lastly, the model retrieves the results generate for each KPI; compares the "as-is" and "to-be" performance scenarios; and graphically depicts the comparative results for each KPI in a suitable chart as depicted in ***Section 5.2***.



% of Hospitalisations Unnecessary	As-is Analysis – Major Procedures Treatments and Tests: Time in Days Spent on Unproductive Clinical Procedures: Evaluation & Management	Pathology & Laboratory	Medicinal Administration	Surgery Cardiovascular System	Radiology	Annual Labour Hours Wasted on Unnecessary Admissions	To-be Analysis – 96.60% Workforce Productivity With Intervention: 0%	5%	10%	15%	20%	25%	30%	35%
0.0%	0.00	0.00	0.00	0.00	0.00	0.00	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
0.5%	608.77	702.64	513.76	3145.82	520.56	24711.99	99.95%	99.95%	99.96%	99.96%	99.96%	99.96%	99.96%	99.97%
1.0%	1305.81	688.44	656.16	3825.37	969.70	33504.67	99.90%	99.91%	99.91%	99.92%	99.92%	99.92%	99.93%	99.93%
1.5%	1518.84	2788.41	2296.04	4467.58	1568.58	56877.51	99.85%	99.86%	99.87%	99.87%	99.88%	99.89%	99.89%	99.90%
2.0%	1949.52	1460.47	2803.78	11534.93	2008.03	88905.28	99.81%	99.81%	99.82%	99.83%	99.84%	99.85%	99.86%	99.87%
2.5%	3454.64	4889.17	2213.26	15334.94	1857.69	124873.65	99.76%	99.77%	99.78%	99.79%	99.80%	99.81%	99.82%	99.83%
3.0%	4895.08	3784.31	3771.20	14614.06	2626.97	133612.32	99.71%	99.72%	99.74%	99.75%	99.76%	99.77%	99.79%	99.80%
3.5%	3843.64	3266.02	4976.53	15950.66	1326.26	132133.94	99.66%	99.68%	99.69%	99.71%	99.72%	99.74%	99.75%	99.77%
4.0%	3771.98	5688.70	3399.16	13856.43	1386.55	126462.68	99.61%	99.63%	99.65%	99.66%	99.68%	99.70%	99.72%	99.74%
4.5%	1961.63	10030.16	1863.49	29116.40	4851.66	215205.00	99.56%	99.58%	99.60%	99.62%	99.64%	99.66%	99.68%	99.70%
5.0%	2005.19	11382.09	6102.28	35668.76	5995.55	275192.45	99.51%	99.54%	99.56%	99.58%	99.60%	99.62%	99.65%	99.67%
5.5%	5107.59	5774.62	4447.43	36401.45	2322.75	243242.22	99.47%	99.49%	99.51%	99.54%	99.56%	99.59%	99.61%	99.64%
6.0%	6559.42	10274.69	2687.02	15686.62	3783.19	175459.26	99.42%	99.44%	99.47%	99.50%	99.52%	99.55%	99.58%	99.60%
6.5%	8506.64	4416.55	6601.52	13829.09	2742.76	162434.53	99.37%	99.40%	99.43%	99.46%	99.48%	99.51%	99.54%	99.57%
7.0%	4411.12	15917.18	8499.99	43766.43	5583.43	351801.69	99.32%	99.35%	99.38%	99.41%	99.44%	99.47%	99.51%	99.54%
7.5%	7994.74	14185.25	10846.96	18530.09	6009.00	259047.19	99.27%	99.31%	99.34%	99.37%	99.40%	99.44%	99.47%	99.50%
8.0%	10175.32	16504.38	6386.04	47157.64	5456.72	385560.50	99.22%	99.26%	99.29%	99.33%	99.36%	99.40%	99.44%	99.47%

Figure 33 - Worksheet for the "staffing level efficiency and effectiveness" KPI

4.3.4. SWOT analysis

The purpose of the swot analysis is to critically analyse some of the major strengths, weaknesses, opportunities and threats of the value-add methodology. The key **strengths** of the value-add methodology relate to:

- *Data was gathered from industry-leading care providers*
- *Systems approach to provide a strategic management perspective on the application of PAPAs*
- *Qualitative & quantitative methods were integrated to gauge and understand the potential value-add of PAPA care intervention strategies*

The major **weaknesses** mostly revolve around the width and depth of the methodology and the results analysis:

- *Lacks depth in the analysis of a variety of factors affecting each KPI*
- *Lacks the ability to evaluate the relationship between the identified KPIs*
- *Limited scope with regards to number of KPIs evaluated*

The **opportunities** for future researchers are substantial, and the value-add methodology provides a suitable framework from which to investigate these major opportunities:

- *Opportunity for researchers from various disciplines to conduct in-depth analysis on the relationship between KPIs & PCFs*
- *Opportunity to investigate the social acceptance and practical application and operation of these algorithms in a competitive healthcare environment*

Finally, the **threats** to the value-add methodology signify the importance of questioning and verifying the validity of the work done:

- *Methodology incorporates no statistical analysis to validate the research findings*
- *Surveys pose the threat of receiving responses that are either ambiguous or skewed towards certain themes (acquiescence bias).*

5. Mediclinic case study

The established value-add methodology and quantitative model (***Chapter 4***) aim to estimate the potential value-add of a PAPA care intervention strategy to private healthcare providers in South Africa. With a review of the project methodology (***Figure 34***), the resulting impact on hospital performance, with the implementation of a PAPA care intervention strategy, is validated with a case study of one of the leading private healthcare provider in South Africa, Mediclinic. The results are analysed in an effort to responds to the research question whereby scenario testing will be used to evaluate the range of key input variables that will alter the outcome of the initial analysis and response to the research question. The chapter is concluded with a discussion of the various model constraints, to provide perspective on the scope of the value-add model.

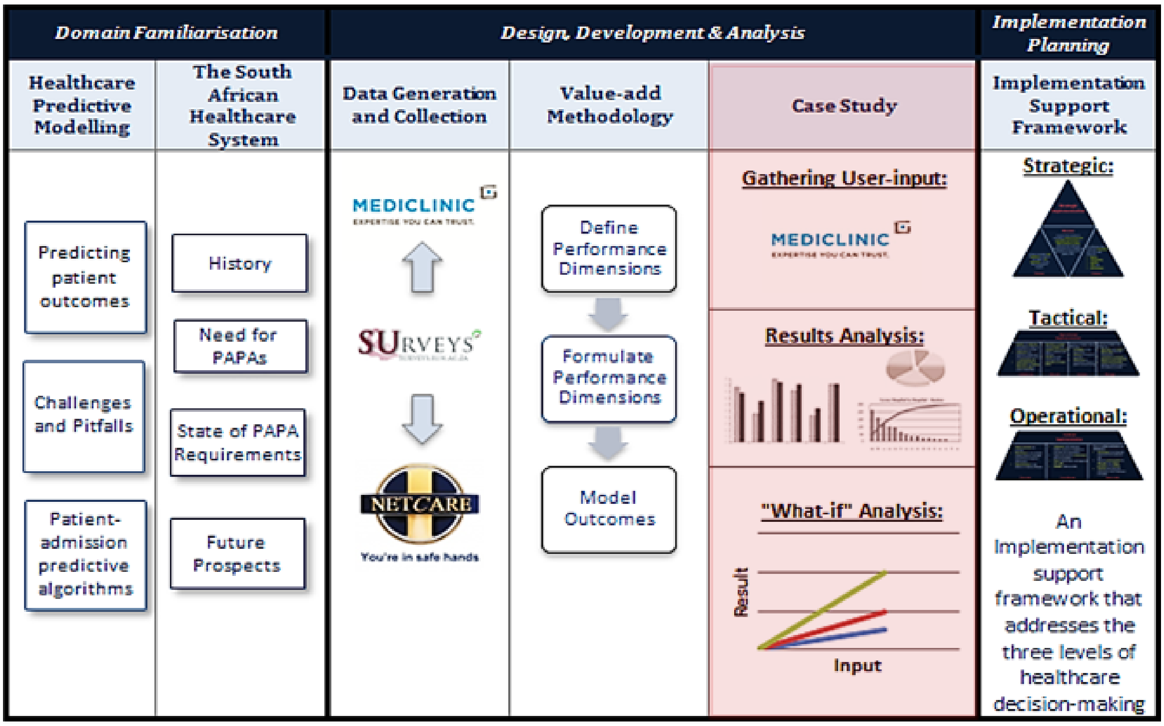


Figure 34 - Reviewing the project methodology: the case study

The model collects user-input data, based on Mediclinic's most recent performance reviews, to estimate the impact on each performance dimension, and depicts the results graphically, to enable the effortless analysis thereof.

5.1. User-input

Table 15 provides a summary of the input data that was used in the evaluation of Mediclinic's performance. The majority of the data was gathered from Mediclinic's annual performance review report, published in April 2012 (MediClinic, 2012). The published report is freely available for download on the company website, and documents most of the organisations' performance metrics of the past financial year.

Table 15 - Mediclinic case study: User-input data

User-input	*Category*	*Value*
Annual Number of Admissions	*General*	105 000
Percentage of Hospitalisations Unnecessary		35%*
Planned Percentage of Patients to Intercede with		90%
Estimate Duration of Patient Interventions (hours)		1.5*
Revenue from Patient Care/Hospital Services	*Finance*	R 956m
Hospital Operating Expenses		R 256m
Ratio of Cost to Intercede versus Admit		10%*
Ratio of Revenue to Intercede versus Admit		8%*
Patient Admission Growth Rate	*Patients*	3.3%
Number of Patient Accounts Closed		6 050*
Percentage Deceased		72%*
Patient Satisfaction Rate		75%
Average Cost of Goods Sold	*Operations*	646 m
Average Inventory on Hand		129 m
Required Inventory Service Level		85%
Percentage Safety Stock		20%
Current Time Spent on Care Coordination (minutes)		8*
Current Number of Full-time Employed Nurses	*Employees*	9050
Number of Shifts per Week		6
Average Duration of Shifts		7.5
*Assumed or Benchmarked		

A number of user-inputs were not captured in the annual reports of Mediclinic and were benchmarked from competitors in local, and other similar markets in the world. Some of the user-inputs were based on future estimates. For example, the *percentage of unnecessary hospitalisations*, *ratio of cost and revenue to intercede versus admit*, and the *estimated duration of interventions,* were all based on logical estimates for a preventive care intervention strategy. These key input variables will also form part of the scenario testing in ***Section 5.4***, to determine the resulting impact of varying these input-variables. The model serves as an *indication* of the potential impact PAPAs might have on Mediclinic's performance and, therefore, the exactness of the data used is to a certain extent less significant.

5.2. Results

The results are presented separately for each key performance indicator. A summary of the results is supplied in ***Section 5.3*** in an effort to interpret the total value-add of a PAPA intervention strategy from a strategic management perspective.

5.2.1. Staffing level efficiency and effectiveness

The implementation of a PAPA care intervention strategy in Mediclinic is estimated to improve nurse productivity with 2.19% from 97.28% to 99.40%, as depicted in ***Figure 35***. This equates to an additional 4.17 hours of clinical care, which nurses can spend on each hospital admission at Mediclinic.

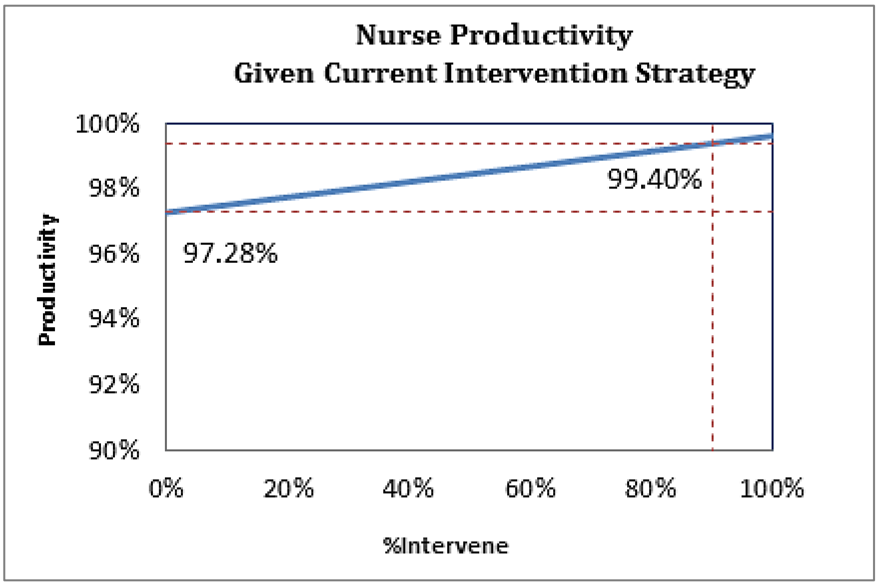


Figure 35 - Value-add model output: Nurse productivity

From ***Figure 35***, it is evident that nurse productivity increases linearly with an increase target intervention rate. Therefore, an optimal intervention strategy, which results in the greatest increase in nurse productivity, is a 100% target intervention rate. Reviewing the equation for this performance dimension (***Equation 3***), a decrease in the estimated duration of PAPA patient interventions will also benefit nurse productivity. Although this intervention strategy will improve staffing level efficiency and effectiveness, it may negatively impact some of the other KPIs.

5.2.2. Financial operating margin

The implementation of a preventive care intervention strategy in Mediclinic will result in a ***decrease*** of the financial operating margin. Mainly due to the decrease in revenue associated with preventive care interventions as opposed to admitting these individuals to hospital, the operating margin is estimated to decrease with 0.31% from 73.22% to 72.99%. This decline in operating margin can be represented by a decline in patient revenue of R7.8 million or an increase in operating expenses of R2.1 million. If patients are admitted to hospital unnecessarily, healthcare providers generate the same revenue, and expend the same costs as opposed to the unavoidable and vital hospital admissions. However, as the percentage of unnecessary hospitalisations increase, given a specific target intervention rate, operating margin will vary according to ***Equation 4.*** Hence, the estimated impact of a PAPA care intervention strategy on the financial operating margin of Mediclinic is depicted in ***Figure 36***.

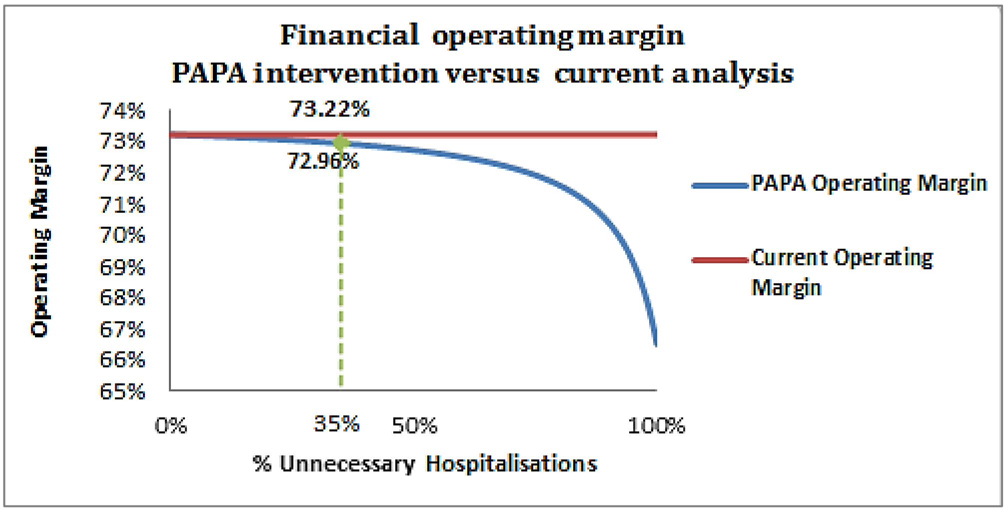


Figure 36 - Value-add model output - Operating margin

The optimal intervention strategy revolves around the maximisation of profit (revenue *less* cost) generated by these patient interventions. The current cost and revenue ratios (10% and 8%) will not result in increased operating margins, regardless of the target intervention rate. Therefore, healthcare providers should carefully plan the cost and revenue structure of the preventive care intervention strategy, to ensure that these patient interventions contribute to the increase in operating margin.

5.2.3. Inventory service level

The inventory service level is expected to increase with 5.9% from 80.23% to 84.95% as documented in ***Figure 37***. The amount of safety stock required to fulfil this level of service is reduced from R1.94 million to R1.33 million, mainly due to the decreased variability in demand.

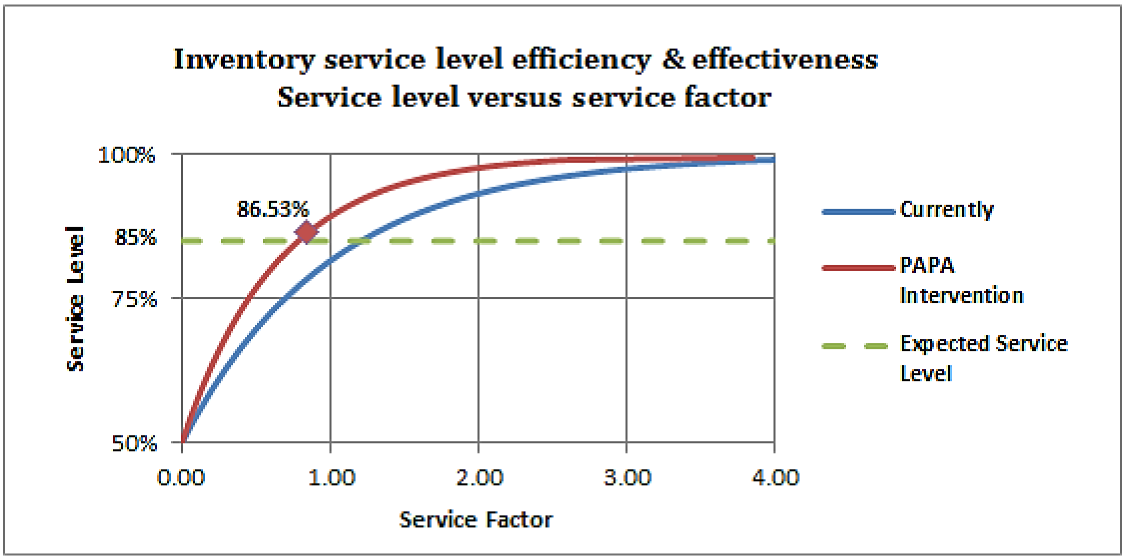


Figure 37 - Value-add model output: Inventory level

The increased inventory service level can be represented by the number of stock-out events that decreased from roughly 2 million stock-out events per year to 1.5 million. The optimal intervention strategy, requires a 100% target intervention rate, which will result in an inventory service level increase of 7%, or an additional decrease in stock-out events of 100 000 per annum, given a constant service factor (level of safety stock).

5.2.4. Clinical care coordination

The implementation of a PAPA care intervention strategy will improve the level of care coordination in Mediclinic from the “Somewhat” to “Strongly Agree” state, as a result of the 310% increase in time spent on care coordination for the intervened patients. This substantial increase was expected due to the assumption made, which stated that the time spent on interceding with patients, in the provision of preventive care, was considered time spent on coordinating care as well.

An optimal intervention strategy for improving care coordination requires a 100% target intervention rate. However, from the step-function graph in ***Figure 388,*** it is evident that no change in the expected CTM-3 index will occur if a 100% intervention strategy is adhered to, since the average care coordination per patient, with the implementation of the PAPA care intervention strategy, equals 25.68 minutes. Therefore, further analysis could explore the extent to which patient intervention time can be reduced in order to maintain this level of care coordination.

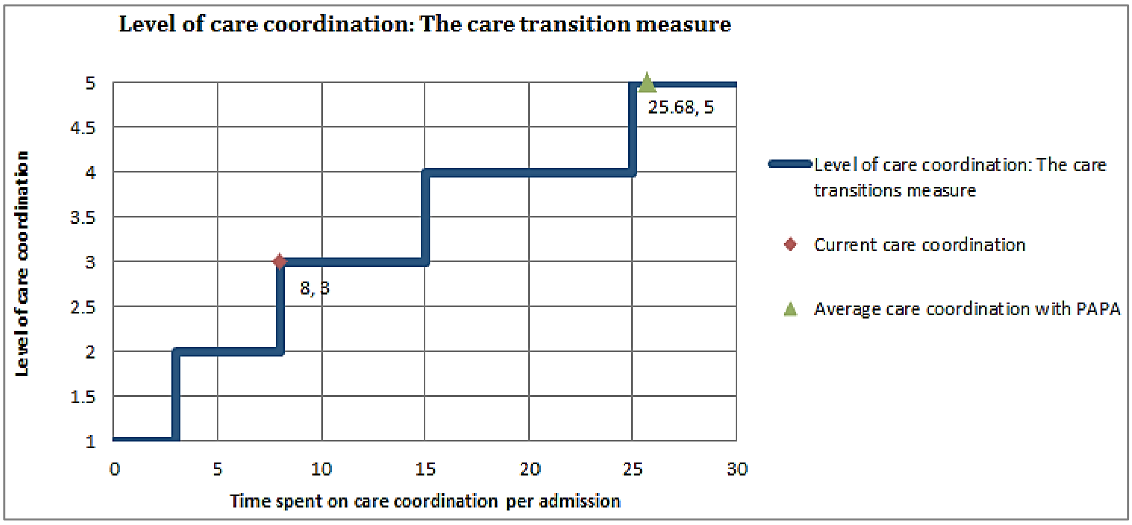


Figure 38 - Value-add model output: Care coordination

5.2.5. Patient-practitioner relationship

Applying the PAPA care intervention strategy with the current target intervention of 90%, the number of courteous, clinical patient-practitioner interactions is set to increase by 10% from 75% to 82.51%. This is as a result of the high patient satisfaction rate (94%) associated with an intervention time of 1.5 hours, as depicted in ***Figure 39***. Therefore, patient-practitioner relationships are expected to improve substantially.

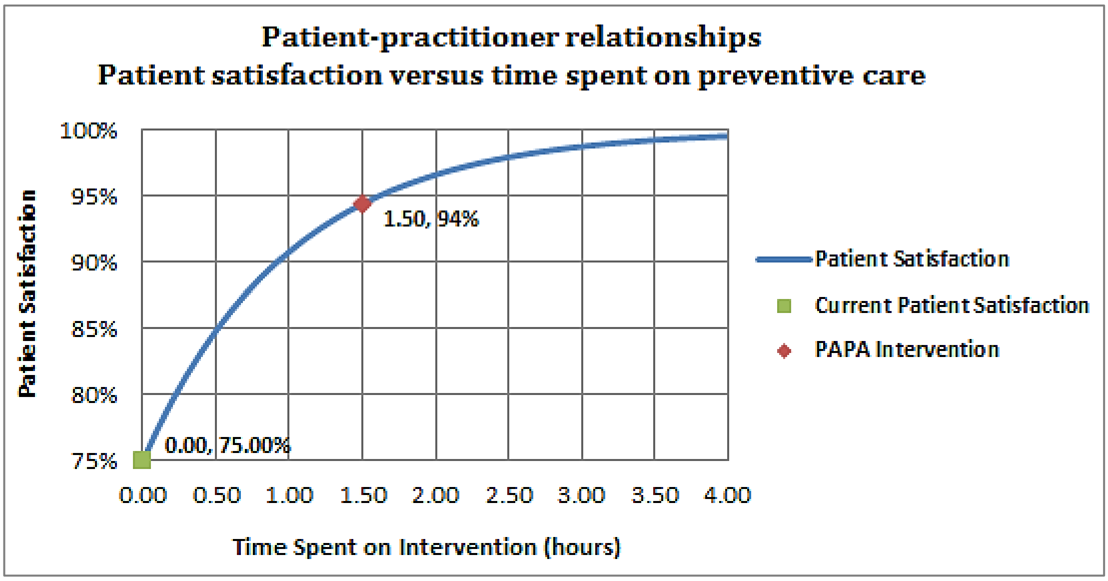


Figure 39 - Value-add model output: Patient-practitioner relationships

The optimal intervention strategy for the improving patient-practitioner relationships requires a 100% target intervention rate and an increased intervention time. This intervention strategy will further increase patient-satisfaction with 11% (from 75% to 83.34%). In practice, this relates to a decreased number of clinical service interaction complaints of up to 3000 per annum.

5.2.6. Patient retention rate

Figure 40 represents the patient retention rate distribution for the intervened patients. The corresponding patient retention rate, with the duration of intervention equal to 1.5 hours, equals 88.84%. Utilising ***Equation 8****,* with the current patient retention rate equal to 98.33%, a PAPA care intervention strategy is estimated to increase the patient-retention rate with 0.23%. This increase is represented by an additional 70 patient accounts and possible future work for Mediclinic South Africa.

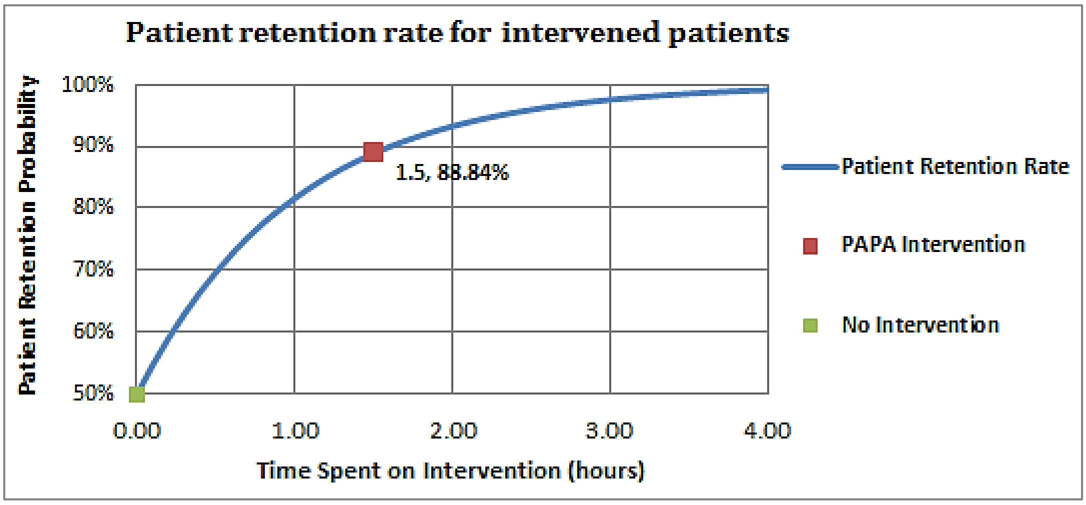


Figure 40 - Value-add model output: Patient-retention rate

An optimal intervention strategy revolves around the maximation of time spent on intervention (4 hours) and a 100% target intervention rate. This strategy will effect a 0.26% increase in the patient retention rate.

5.3. Summary of the results

A holistic view of the impact of the PAPA care intervention strategy on Mediclinic's performance provides sufficient evidence to affirm the research question. Five from the six key performance indicators are positively affected with the implementation of the PAPA care intervention strategy. The following three KPIs illustrated significant improvements:

- *The level of care coordination (+313.7%)*
- *Inventory service level (+6.1%), and*
- *Patient-practitioner relationships (+10%).*

Furthermore, incremental improvements were documented in the following two key performance indicators:

- *Staffing level efficiency and effectiveness (+2.8%), and*
- *Patient retention rates (+0.23%).*

A slight decrease, however, was estimated for the financial operating margin, where the value-add model calculated a 0.3% decrease for this KPI.

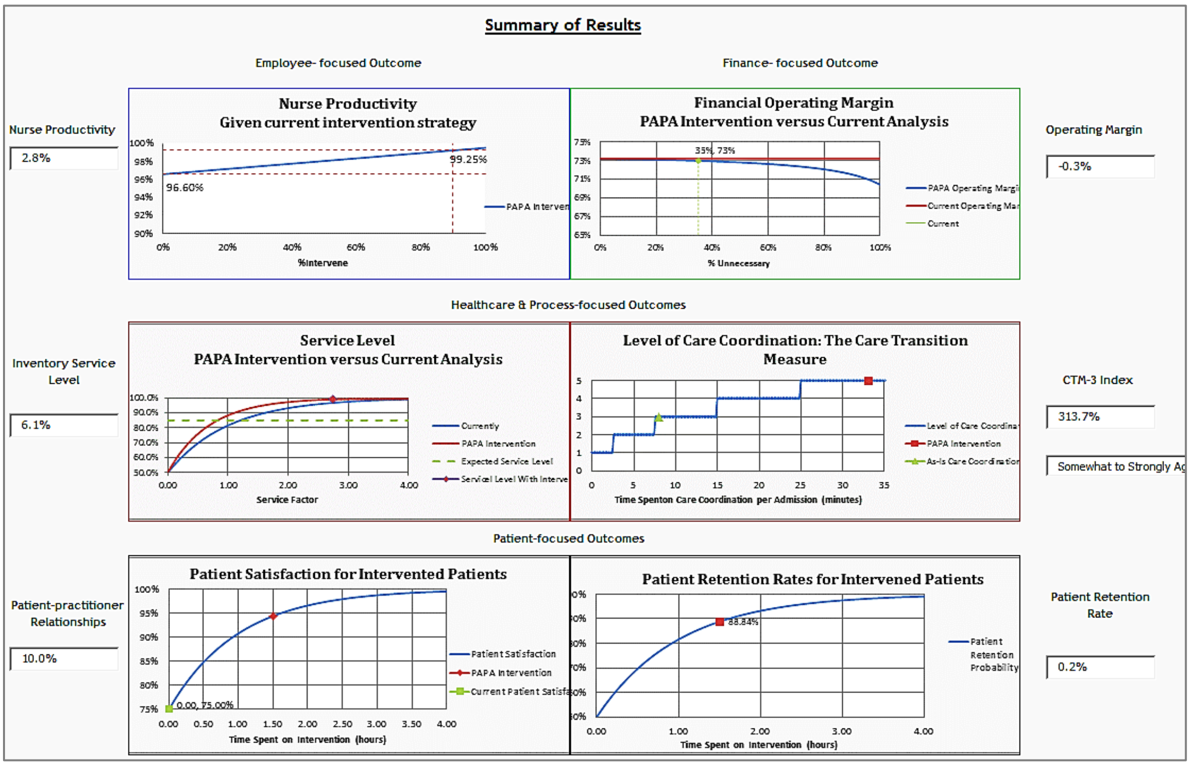


Figure 41 - Summary of the case study results

Therefore, with the majority of KPIs positively impacted by the implementation of the PAPA care intervention strategy, it can be concluded that *the research question has been positively affirmed*. The following section will compare best, base, and worst case scenarios, by varying some of the key user input variables to determine whether the response to the research question will change under these conditions.

5.4. Scenario testing

The results generated in the preceding section are indicative of the base-case scenario and provides valuable insight into the potential impact of a PAPA intervention strategy on the performance of a private healthcare provider group similar to Mediclinic South Africa. A simple scenario testing, or "what-if analysis", was conducted to determine the resulting impact of worst- and best-case scenarios. ***Table 16*** lists the various input variables used for the three separate scenarios and ***Table 17*** provides a summary of the scenario analysis.

Table 16 - "What-if" analysis: Input variables

Input-variables	What-if Analysis		
	Worst case	Base case	Best case
Basis for intervention	40%	75%	100%
Intervention time	30 minutes	60 minutes	120 minutes
Cost ratio to intervene versus admit	15%	10%	8%
Revenue ratio to intervene versus admit	5%	8%	15%

Table 17 - "What-if" analysis: Results summary

Key Performance Indicators	What-if Analysis: Results Analysis		
	Worst case	Base case	Best case
Staffing Levels	+1.41%	+2.43%	+3.21%
Operating Margin	**-0.57%**	**- 0.24%**	**+1.22%**
Inventory Service Level	+3.31%	+5.17%	+7.14%
Care Coordination	+37.40%	+165.75%	+221.00%
Patient-practitioner Relationships	+4.20%	+8.34%	+11.13%
Patient Retention Rate	**-0.28%**	**+0.20%**	**+0.26%**

Slight decreases were witnessed in the worst-case scenarios; *financial operating margin* and *patient retention rate* decreased by 0.6% and 0.3% respectively. This was largely attributed to the expected revenue and cost associated with a preventive care intervention strategy. Overall, the implementation of a PAPA care intervention strategy, given a worst case scenario, generates positive results, where four out of the six KPIs are positively impacted. Therefore, the revised research question is affirmed under worst-case scenarios as well.

In conclusion, considering the estimated impact on the healthcare and process-focused outcome category, a PAPA care intervention strategy is expected to increase the discipline of healthcare resource management as initially expected. The final section of the design, development, and analysis phase focuses on the value-add model constraints.

5.5. *Model constraints*

Three major model constraints are evident in the value-add model. Without these model constraints, the level of complexity would have exceeded the limitations of this study and considered too time-consuming for the purpose of this study. It is, however, essential that these model constraints are briefly reviewed.

The model is based on the assumption that a healthcare provider has limited resource capacity. Therefore, the available finances, labour and inventory are all constrained to a limited capacity throughout the analysis period. The limited capacity constraint enables the value-add model to limit the variability in future demand, labour requirements and financial sources. Various unknown factors, especially in the field of healthcare, may affect the level of available services.

Furthermore, the model utilised two separate Pareto analyses to enable a focused analysis of 1) the major components affecting hospital performance and 2) the total extent to which hospital performance is affected by identifying the various key components of the major procedures/treatments/tests performed in private healthcare providers in South Africa.

The aim of the value-add model is to determine the potential impact that PAPAs might induce on hospital performance, and therefore the quantitative results of the model should merely resemble a suitable level of accuracy to draw feasible conclusions regarding the expected outcomes of applying a PAPA care intervention strategy. The what-if analysis provided a means to determine whether the order magnitude, or direction, of each outcome significantly differs with varying input variables. Since these components remained fairly stable under various case scenarios, the results generated by the value-add model were considered sufficient for the purpose of this study.

6. *Implementation framework*

Patient-admission predictive algorithms require an implementation support plan or framework to function optimally. The lack of proper support, either in the form of decision support systems or simple implementation frameworks, commonly results in failed pilot implementation studies.

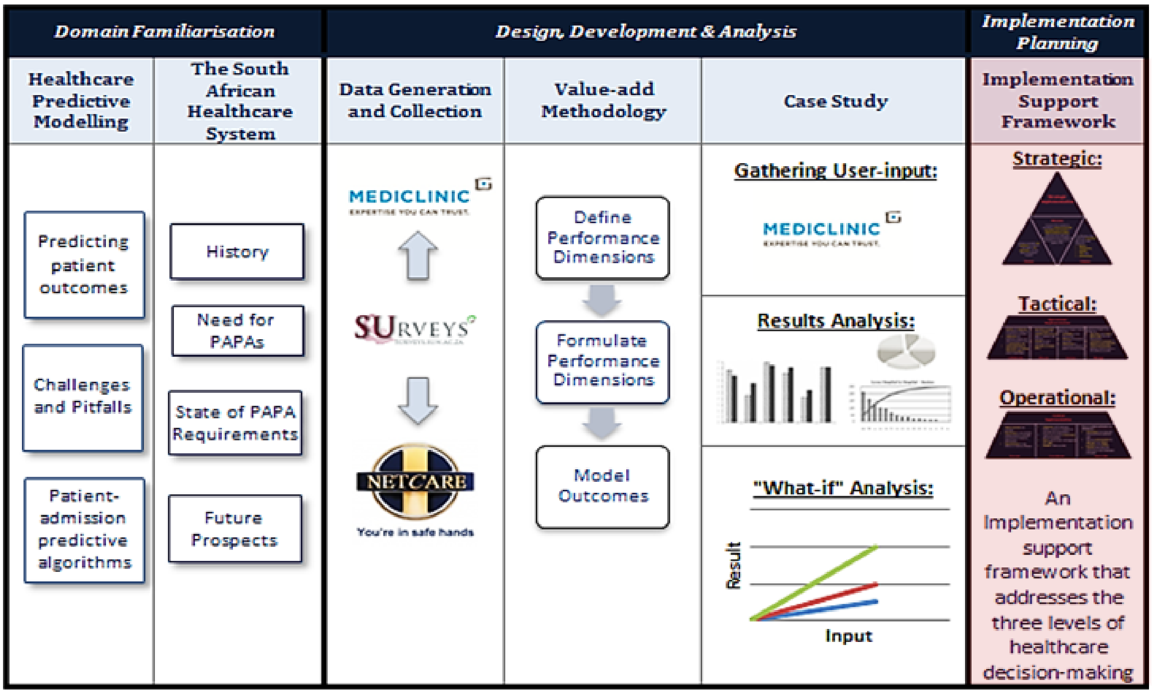


Figure 42 - Reviewing the project methodology: implementation framework

It is essential to provide a framework for implementation that guides the key-decision makers in the organisation to increase the potential value-add of the PAPA, as depicted in ***Figure 43***. Both the key decision-makers in healthcare applying the predictive models, and the data analysts responsible for the design and development of these tools, regularly disregard this step in the utilisation of predictive models.

Implementation plans are regarded as equally important to designing and developing the model and all relevant stakeholders need to be cognisant of the following principles in the implementation of predictive algorithms:

- *Leadership is required to strategically align the algorithm's objectives with the organisation's business model (Strategic)*
- *Operational management is responsible for managing the venture as a collaborative business project as opposed to a purely a statistical exercise (Operational)*
- *Practical considerations in the project execution need to be accounted for (Tactical)*

A brief overview of a suggested implementation framework is supplied in ***Section 6.1***, which illustrates the current frameworks and methodologies that were utilised (combined) to develop this practical implementation framework. The remainder of the chapter elaborates on the major decision-making processes of three levels of management in a healthcare provider required to successfully implement PAPA care intervention strategies, and enhance the probability of leveraging the potential value-add PAPAs offer. The chapter is concluded with a summary of the findings, which includes a graphical illustration of the framework itself.

6.1. Overview

The development of an implementation framework for the computationally-intensive PAPAs required a review of the current available frameworks for implementation regarding preventive care intervention strategies and predictive models similar to PAPAs. The most common support frameworks were aimed at leveraging the value of predictive algorithms from a risk management, industry-wide health insurer's perspective (Masud & Moks, 2009) and were frameworks that solely focus on the implementation of preventive care strategies from a government perspective.

6.1.1. Healthcare predictive modelling framework

As previously depicted in Chapter 1, ***Figure 5*** represents the implementation and utilisation of predictive modelling in a healthcare environment. The framework focuses on three key aspects: knowledge, values and ethics, and application (De Gruy, 2000).

Knowledge generation with the use of predictive modelling heavily depends on the capturing and managing of patient data. Data mining processes are central to the successful development of accurate predictive models. Therefore, healthcare provider groups are required to commit to the standardisation of data mining techniques in an effort to utilise the vast amount of patient data currently captured in private healthcare.

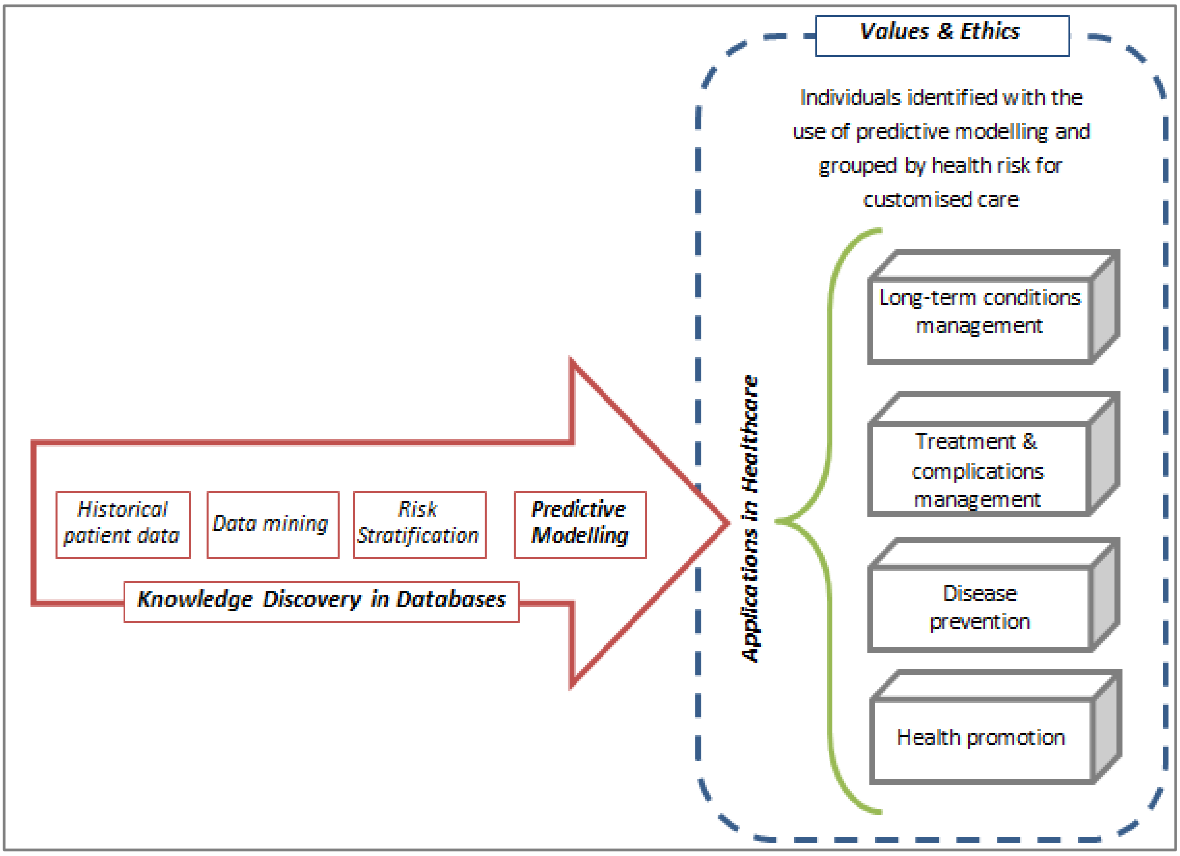


Figure 5 – Overview of healthcare predictive modelling adapted from (De Gruy, 2000)**.**

Deciding to group individuals according to their risk of admission and subsequently providing preventive care solely to the individuals at the highest risk of admission, will question the transparency in healthcare provider's decisions to intervene with these patients. Therefore, a PAPA care intervention strategy has the potential to *violate ethical and moral guidelines*. Healthcare providers need to re-align their strategic intent and incorporate values that commit to transparency in decision-making and strive to improve the health of all individuals with the use of evidence-based tools such as PAPAs.

6.1.2. Preventive care framework

The move form a "sick care" to a truly "health care" system requires the successful implementation of preventive care on a national level (Merkin, 2011). However, the indecision of healthcare providers to fully implement or incorporate preventive care services in their value offerings is mainly due to the lack of standardisation and proliferation of guidelines that currently exist (Chen, 2009)*:*

- *Eminence-based or evidence-based (PAPAs) interventions?*
- *Internal value offering or outsourced responsibility?*
- *Tailored to resource capacity and ability, to provide a division separate from in-patient care?*
- *Develop, implement and mature process or secondary responsibility?*
- *Continuous re-evaluation of at-risk patients or scheduled interventions with the majority of the patient population?*

The framework in ***Figure 43*** identifies the roles preventive care services and high-risk case management practices play in the delivery of quality, evidence-based healthcare. The framework is representative of a hybrid healthcare delivery system, where healthcare providers supply episodic and longitudinal care with a combination of primary, speciality and hospital care services (Milford & Ferris, 2012).

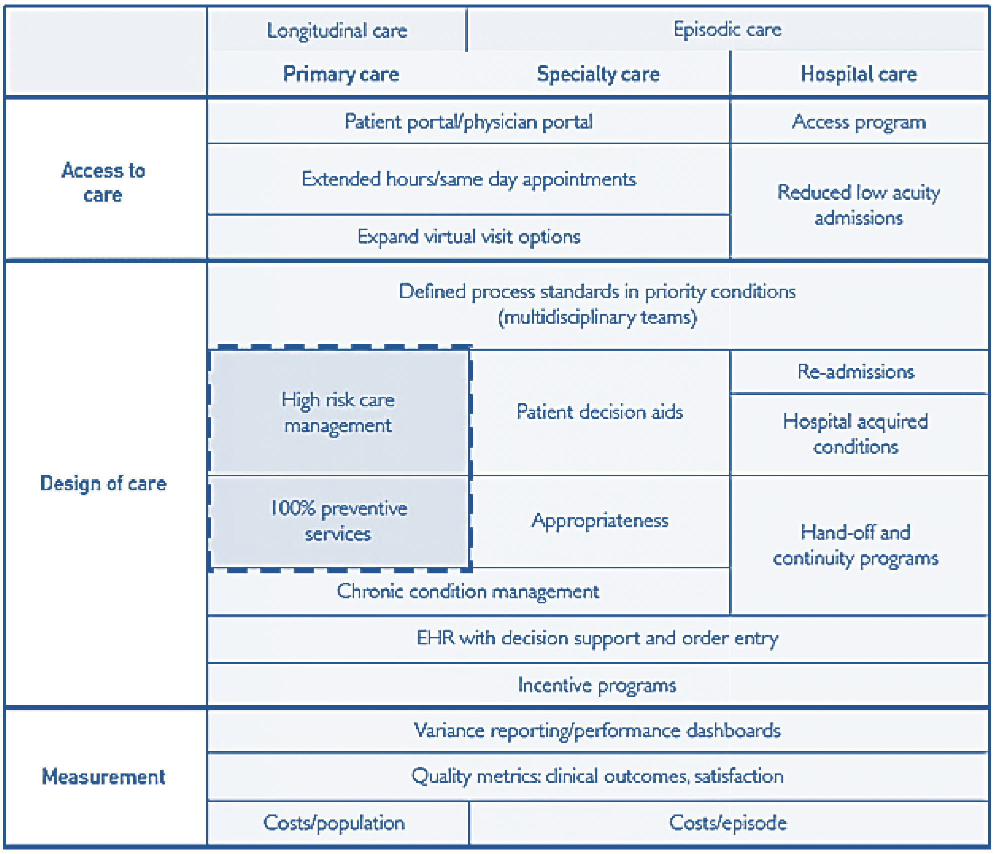


Figure 43 - Framework for implementing preventive care as part of a hospital's value offerings (Milford & Ferris, 2012)

It should be noted that Milford and Ferris (2012) utilised this preventive care framework in an effort to determine whether healthcare providers should outsource primary care services, which include out-patient preventive care interventions, to Accountable Care Organisation (ACOs) or provide these services in-house. In conclusion, Milford & Ferris (2012) identified three major components that should be considered before implementing a hybrid healthcare delivery system:

- *Provider's ability to provide access to preventive healthcare services,*
- *Expertise of current care delivery practices, and*
- *Measurement and analysis of key quality, financial, and clinical outcomes.*

PAPAs provide a *basis for intervention* that fundamentally eliminates some indecision to implement preventive care and supports the evidence-based tactics of the preventive care implementations framework in ***Figure 43***. Furthermore, the figure illustrates the need for defined process standards, especially with the implementation of preventive care services, as multidisciplinary teams may encounter disorganised working environments in an out-patient setting.

6.2. Levels of implementation

As mentioned earlier, the need to address the three levels of implementation are essential to improve the potential value-add of PAPAs and preventive care interventions. The following subsections discuss these levels of integration and implementation in greater depth, with an emphasis on the role each function plays to eradicate the known performance compromising factors.

6.2.1. Strategic

A healthcare provider's strategic intent is essentially represented by the vision, mission, and value statement of the organisation. It provides a means to vertically align an organisation's operational and tactical efforts (Bart & Hupfer, 2004) and has proven to be the main drivers of change and performance improvement in healthcare organisations (Biddiscombe, 2006).

The three private healthcare market leaders in South Africa (Netcare, Mediclinic and Life), all have vision, mission and value statements. However, a lack of preventive and self-care strategies in these statements evidently exist. ***Table 18*** provides a summary of these healthcare providers' strategic intent, as adapted from these organisations' websites. All the healthcare providers have a strong emphasis on the *quality* of care provision and are committed to a patient-oriented service approach.

Table 18 - Overview of the strategic intent of private healthcare providers in South Africa

	South African Private Healthcare Providers: Industry Leaders		
	MEDICLINIC EXPERTISE YOU CAN TRUST.	NETCARE You're in safe hands	Life Healthcare
Vision	*To be regarded as the most respected and trusted provider of hospital services by patients, doctors and funders of healthcare.*	*To become the leading African healthcare group, best known for delivering innovative, quality healthcare solutions to patients in every continent of the world and successfully broadening access to affordable, quality healthcare to as many South Africans as possible.*	*To be a world class provider of quality care for all.*
Mission	*To enhance the quality of life of patients by providing comprehensive, high quality hospital services.*	*Develop and implement successful solutions creating new healthcare horizons and delivering value to all stakeholders.* *Strive for excellence in a unique brand of patient care delivered by people who are passionate about the sanctity of life, personal respect and dignity.* *Invest in people, infrastructure and technology and establish lasting relationships with healthcare professionals.*	*Develop the breadth and depth of Life Healthcare's existing hospital network.* *Expand our coverage and penetration of the South African market.* *Position Life Healthcare for international expansion.* *Maintain Life Healthcare's commitment to world-class healthcare.* *Continue to enhance operational efficiencies.* *Implement sustainable human capital strategies and practices that meet the challenges of a dynamic commercial and legislative environment.*
Values	*Client Orientation* *Team Approach* *Mutual Trust and Respect* *Performance Driven*	*Care* *Dignity* *Participation* *Truth* *Passion*	*Passion for people* *Quality* *Performance pride* *Personal care* *Lifetime partnerships*

In order to successfully commit to new innovations and services, it is essential that the strategic intent of healthcare providers embrace and articulate the initiative to continuously improve hospital services, by offering *innovative solutions* that improve clinical outcomes and drive down costs. The only healthcare provider in South Africa that explicitly articulates a commitment to innovative healthcare services in their strategic intent also happens to be the healthcare provider with the biggest market share in the private sector of South Africa. ***Netcare*** explicitly states that the company supports the implementation of "innovative" healthcare solutions and are constantly looking for ways to create new "healthcare horizons".

The implementation of a new service offering, such as the PAPA-based preventive care strategy, requires a re-alignment of a company's value statement, starting with the vision of the company. The *vision* should articulate *a longstanding commitment* to provide quality in-patient (*clinical care*) and out-patient (*preventive care*) services:

"A vision to provide care and guidance to improve the health of all individuals, not only those admitted to hospital."

The *mission* of a company constitutes the ways in which a company plans to reach, or strive towards, its vision. Therefore, the re-alignment of a healthcare provider's value statement for the purpose of providing preventive, intervention care, will require a company's mission statement to incorporate a commitment to providing a variety of healthcare services, which include evidence-based, preventive patient care services:

"A mission that commits to providing a variety of clinical and preventive care services; a hybrid healthcare system tailored to the needs and requirements of all people to improve their quality of life."

The *values* of healthcare providers serve as a guideline in terms of acting on ethical and moral obligations. Healthcare providers may state that they commit to providing equitable care to all and that their mission is to improve the quality of life by providing innovative healthcare services, however, the value statement of an organisation provides a means to regulate these commitments. Therefore, it is essential to have a comprehensive value statement that compliments the mission and vision of a company, such as:

"Respect, transparency, integrity, trust, and courteousness are irrevocably part of the value statement. These values ensure that patients, employees and other stakeholders are always treated with respect, services rendered or provided are done with the sole purpose of enhancing patient care outcomes, and accountability of decisions are enforced and guided by patient satisfaction."

At the top of the decision-making and implementation hierarchy is the strategic intent of a healthcare organisation. A summary of the proposed implementation framework from a strategic point-of-view is depicted in ***Figure 44***. The strategic implementation framework provides a platform for the implementation of PAPAs in any healthcare provider setting. In an ideal scenario, healthcare providers should facilitate change management to the extent where a total managerial commitment to preventive care is achieved and transparency in decision-making is communicated vertically throughout the organisation.

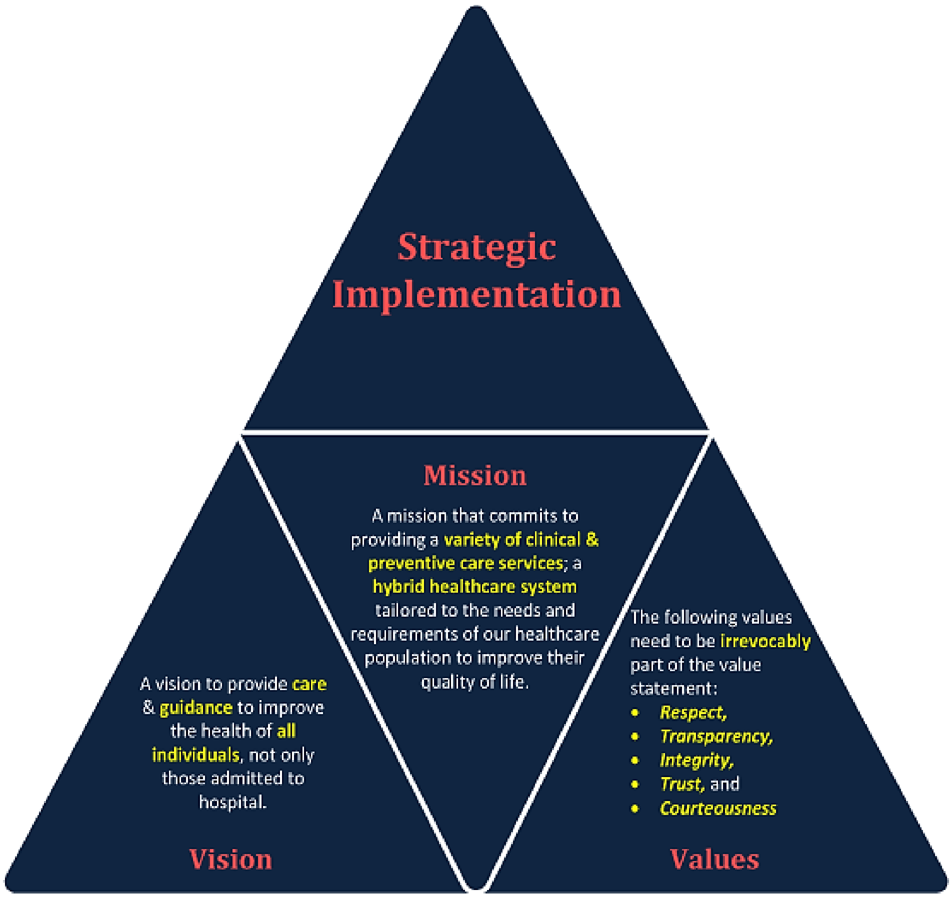


Figure 44 - PAPA preventive care intervention strategy: strategic implementation framework

The following subsection details the operational implementation framework and evaluates the managerial requirements to ensure a seamless implementation of PAPAs on a middle-management level.

6.2.2. Tactical

The tactical execution function in a healthcare organisation is the crucial link between the healthcare provider's strategic intent and physical patient care. Middle-management is responsible for managing inventory, human resources, financial resources and marketing and communications to enable quality patient care. ***Table 19*** is an indication of the current tactical foci of the industry leaders in the private healthcare sector of South Africa, as adapted from the organisations' latest annual reviews (Mediclinic, 2012; Netcare, 2011; Life Healthcare, 2011).

Table 19 - Review of the current tactical foci of private healthcare providers in South Africa

	South African Private Healthcare Providers: Industry Leaders		
	MEDICLINIC EXPERTISE YOU CAN TRUST.	NETCARE You're in safe hands	Life Healthcare
Tactical Reviews	***Finances*** *– Increase capital expenditure for capacity improvements and maintenance* ***Patients*** *– Improved patient satisfaction* ***Employees*** *– Increased training and development of nurses and skilled healthcare practitioners* ***Efficiency*** *– Leveraging clinical information system technology improved operational efficiencies* ***Sustainability*** *– Increased number of hospitals certified for ISO 14001 – 2004 Specification for Environmental Systems certification* ***Society*** *– Increased involvement, three-tiered project launched to provide surgical assistance to less privileged, educating the youth, volunteering at various hospitals across the R.S.A.*	***Finances*** *– Cost control initiatives, improve debt management, capital expenditure, and working capital* ***Patients –*** *Improve risk management of managed care patients* ***Inventory –*** *Activity-based productivity model, standardisation of consumables, and substitution of generic medications* ***Efficiency –*** *Improve resource dependability, availability, flexibility, quality, cost, and speed of response* ***Sustainability –*** *Reduce CO2-emissions from operations, and energy and water consumption*	***Finances –*** *Improved costs of sales management, investment in systems, analysis and reporting* ***Patients –*** *Implemented case management operating system to improve the delivery of care. Implemented iQ and Q^e* ***Employees*** *– Impilo IT system resulted in a more efficient staffing model. Training and development of employees increased.* ***Inventory –*** *Improved product utilisation management to increase the timeliness availability of services* ***Efficiency –*** *Impilo IT system improved access to patient records and increased patient care efficiency. Time and attendance monitoring was implemented, which further drove care efficiency increases.*

It is evident from this summary of tactical reviews of Mediclinic, Netcare and Life Healthcare that the implementation of PAPAs, and the associated intervention strategy, supports the current operations management practices in these organisations. Therefore, the implementation of a PAPA intervention strategy can be considered as a means to improve current hospital performance in the short- to medium term.

From ***Table 19*** it is evident that private healthcare providers in South Africa are committed to improving efficiencies with the use of case and risk management practices. The use of PAPAs, as part of a preventive care strategy, will supplement these efforts, add an additional dimension to the value offerings of healthcare providers, and improve the quality of care delivered. The tactical execution of a PAPA intervention strategy requires:

- ***collaboration*** *with various stakeholders,*
- ***scheduling*** *and* ***allocation*** *of vital healthcare resources,*
- ***analysing*** *the efficiency and effectiveness of the preventive care interventions, and*
- ***managing*** *newly generated patient data from preventive care interventions.*

Collaborating with the various managerial decision-makers, divisions of care, and patients is a critical step in the effective implementation of a PAPA intervention strategy. Firstly, patients at high risk of admission to hospital are identified and their clinical care needs and requirements are subsequently determined. Secondly, healthcare and middle managers collaborate with the relevant divisions of care in a participative role, to devise a detailed plan of intervention according the resource capacity of the hospital. Lastly, the target intervention rate and the detailed plans of action are communicated to the operational teams responsible for performing the various care interventions. These collaborative efforts will require a real-time communication infrastructure and planning system, similar to the cloud-based Impilio ICT system Life healthcare is currently implementing in their organisation.

When all of the relevant stakeholders have collaborated, the *scheduling* and *allocation* of essential resources for the intervention strategies will occur. Firstly, operations managers will be responsible for accurately estimating the vital healthcare resource (labour, inventory, and finances) requirements according to the communicated target intervention rate. Secondly, these vital resources will be assigned to the relevant preventive care teams (PCTs) responsible for intervening with the identified high risk patients.

Middle-management will be responsible for *analysing* the effectiveness and efficiency of the care interventions and continuously improving the preventive care strategy. It is vital to analyse and manage the contribution that the PAPA intervention strategy is making to hospital performance, isolating key performance indicators and evaluating the extent to which these KPIs have been affected with the implementation of PAPAs.

Healthcare managers will be required to *manage* newly generated patient data to the extent that the data is readily available for PAPA analysis, subsequently enabling the real-time identification and management of high risk patient indices. Newly generated patient data should be documented according to an established, organisationally standardised manner, to ensure that data is effortlessly validated and available for analysis. This is critical to the success of managing high-risk cases and achieving the benefits associated with preventive care.

Figure 45 is a summary of the tactical implementations framework, providing a suitable platform from which healthcare providers can coordinate the implementation of a PAPA intervention strategy in alignment with the strategic intent of the healthcare provider.

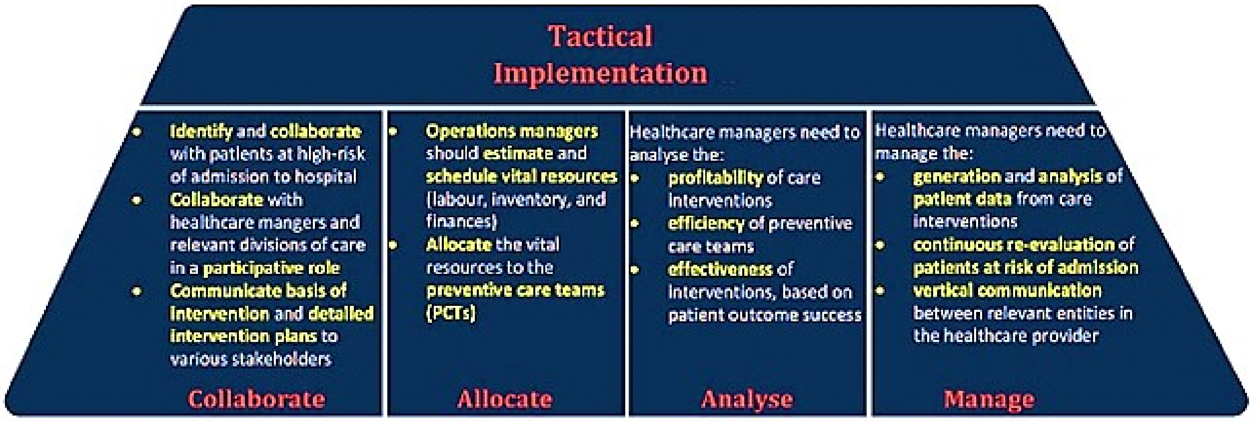


Figure 45 - PAPA preventive care intervention strategy: tactical implementation framework

6.2.3. Operational

Operational execution mainly depends on the manner in which physicians and nurses apply themselves to the tasks at hand. The PAPA intervention strategy requires the establishment of preventive care teams (PCTs) that consist of a combination of physicians and nurses customised to the care needs of the individuals they are scheduled to intercede with.

According to the results from the value-add analysis in ***Chapter 5***, it is essential that the PCTs *execute* the PAPA preventive care strategy in a *patient-oriented manner*. Customised care plans to improve specific health outcomes will differentiate PAPA intervention strategies with current healthcare delivery models, providing a platform to deliver quality care representative of the standard of “in-hospital” clinical care, without the inconvenience of a hospitalisation. Furthermore, the success of PAPA care interventions, from a hospital performance perspective, revolves around the ability of the PCTs to *act* with *responsiveness* and *decisiveness* in providing preventive care. Adherence to the scheduled duration of each intervention, the basis and schedule for intervention, and the resource expenditure per intervention will largely determine the success of PAPA intervention strategies from an operational point-of-view. The majority of hospital performance measurements are established on an operational level, articulating the importance of accurate *execution* in care delivery.

PCTs have the additional responsibility of *coordinating* the individual’s care requirements in collaboration with the individual and their spouses, family and caregivers. Care coordination is the act in which the PCTs ensure that individuals and caregivers are educated in their care requirements. Effective care coordination will improve adherence to self-care disciplines such as medication administration, exercising and dietary requirements, and promotes healthy living to decrease the risk of admission to hospital. PCTs will typically need to devise short- and long-term care plans according to the individual's risk profile. Furthermore, PCTs can schedule and communicate follow-up visits with these individuals and encourage these individuals to promote their health statuses through disciplined self-care strategies.

PCTs will *intercede* with a large number of individuals, estimated around 30 000 *per annum*[5] in a typical private healthcare provider group in South Africa. Since patient satisfaction levels and retention rates largely depend on the *courteousness* in care interactions, PCTs are required to fulfil the role *home-physicians* once held, with an additional ability to provide tailored specialist care according to the healthcare needs of each individual. Whilst maintaining a courteous attitude towards patients, it is essential that PCTs remain professional and tactful, and uphold the ethical guidelines of the Health Professions Council of South Africa (HPCSA). ***Figure 46*** represents the operational implementation framework for a PAPA intervention strategy.

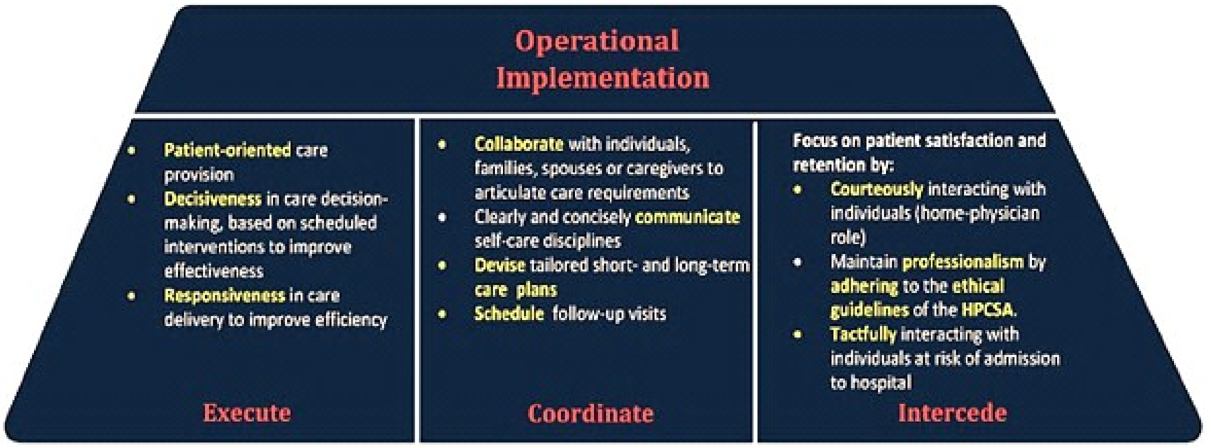


Figure 46 - PAPA preventive care intervention strategy: Operational implementation framework

The operational framework serves as guidance for the execution of PAPA care intervention strategy and concludes the implementation framework. A summary of the implementations framework is illustrated in the following section.

[5] Based on the current number of high risk patients and the target intervention rate

6.3. Summary

Patient-admission predictive algorithms have the potential to add significant value to the performance of healthcare providers. PAPAs, as evidence-based decision making tools, will provide valuable information to healthcare providers with regards to the expected number, and identification of patients at risk of admission to their hospitals. However, the knowledge generated from PAPAs is worthless without a suitable, proactive approach to utilise this information. The value of the implementation framework (***Figure 47***) is articulated by this need for a structured approach to utilise the knowledge generated through PAPAs, to effect the potential benefits of these tools.

The framework requires private healthcare providers to utilise the knowledge generated by PAPAs during the establishment of a *preventive care intervention strategy* (PCIS), in an effort to avert potentially unnecessary hospitalisations. The PCIS implores healthcare providers to:

- *have a tailored PAPA developed with local patient claims data,*
- *re-align their strategic intents to incorporate a commitment to preventive care services and evidence-based management practices,*
- *establish preventive care teams (PCTs),*
- *have PCTs collaborate with healthcare managers to accurately schedule and allocate vital healthcare resources,*
- *intercede with individuals according to the target intervention rate of the particular provider, in a courteous, professional, decisive, and responsive manner, and*
- *gather and validate newly generated patient data in an organisationally standardised manner to enable the seamless application of PAPAs.*

The implementation framework is a generic framework and its purpose is to serve as an indication of the synergy required to effect the potential benefits offered by two of the current trends in healthcare delivery worldwide; *healthcare predictive analytics* and *preventive care*.

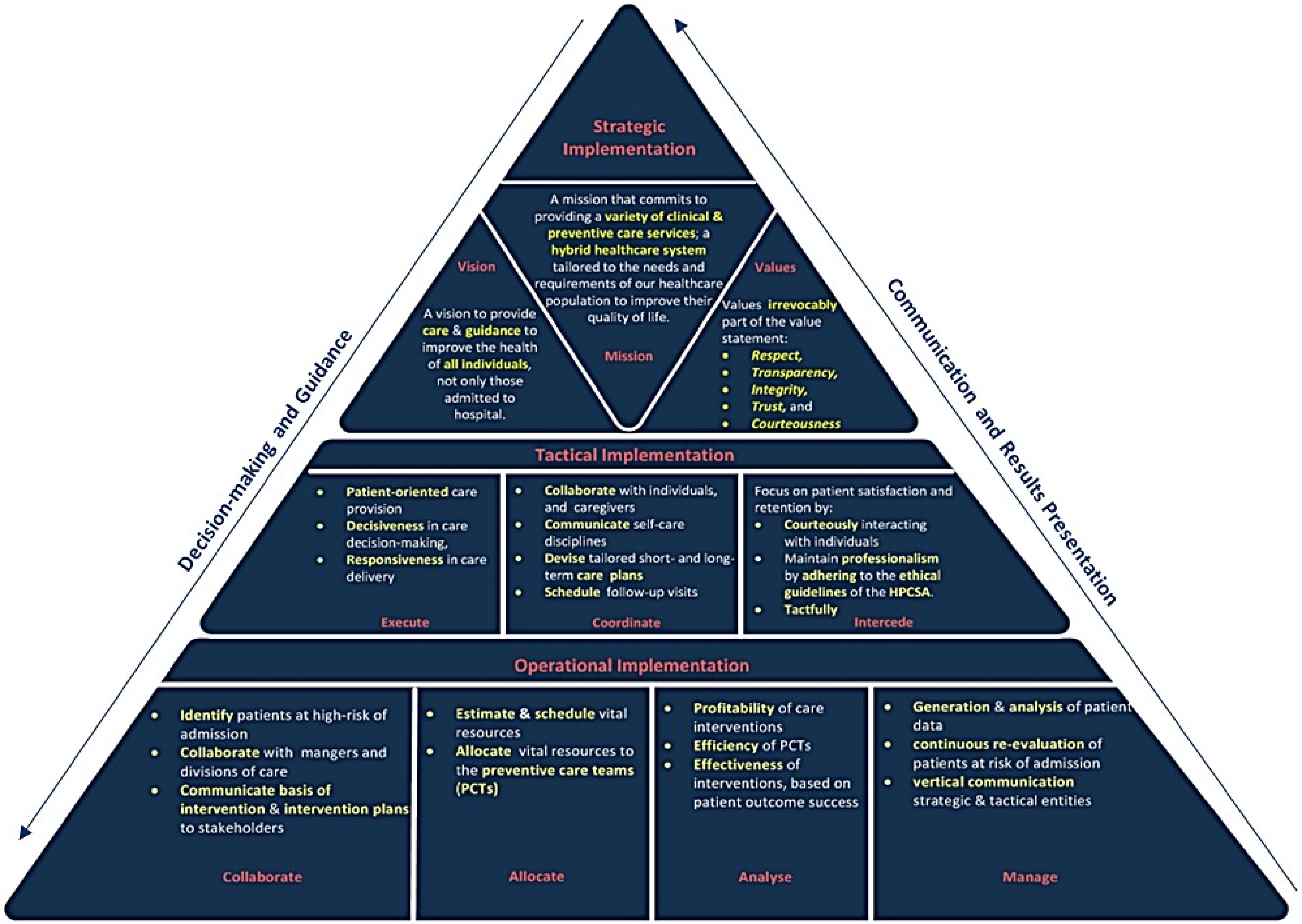


Figure 47 – Proposed PAPA implementation framework

7. Conclusions and recommendations

The South African healthcare system is currently undergoing reforms that will change healthcare delivery as it is known to its stakeholders. The great divide between public and private healthcare services has forced the South African government and the Department of Health to intervene and provide equitable healthcare to every South African citizen in the form of National Health Insurance. The implications of the proposed NHI scheme on the private healthcare sector are evident: *increased demand for healthcare services at lower profit margins* and *increasingly complex healthcare resource management*. The public healthcare sector of South Africa has been fraught with healthcare resource allocation problems since the tiered healthcare system took effect in 1994. In addition, the private health sector has seen longer stays in care units, more expensive medications, increased pathological testing, and longer length of stay indices for a number of key procedures, which has resulted in major increases in hospital costs and exorbitant health insurance premiums. Therefore, the need for interventions such as PAPAs, which aim to improve healthcare resource management, undoubtedly exists.

The barriers to implementation of PAPAs have been found traversable in the public healthcare sector of South Africa, provided that the implementation of the NHI scheme and its resulting developments (National Health Information System, Electronic Patient Records and training of competent healthcare managers) are successfully effected in the following ten to fifteen years. The private healthcare sector, given its technological infrastructure and the extent to which patient data is currently being captured, was found to be a suitable platform for PAPA implementation. It is unlikely that the standardisation of predictive analytics and PAPAs, as evidence-based management tools, will ensue in the public healthcare sector of South Africa in the near term, however, the total value-add of PAPAs to private healthcare providers in South Africa was to a large extent, unknown, and required a quantitative analysis to estimate the potential value-add of these decision-support tools.

The full benefit of applying PAPAs could only be established if these algorithms were used as part of a strategy to intervene with the individuals at high-risk of admission, in an effort to prevent these individuals from being admitted to hospital “unnecessarily”. A survey was conducted amongst two of the private sector industry leaders in South Africa, Mediclinic and Netcare. The survey established the current performance foci of the healthcare provider groups, expressed as relevant key performance indicators. Ultimately, six KPIs were identified from four different areas of hospital decision-making.

A value-add performance evaluation model was developed to measure the impact of various PAPA care intervention strategies on the identified KPIs. The value-add model was applied to Mediclinic, as part of a case study to determine the impact of a PAPA care intervention strategy on Mediclinic's performance. The majority of the KPIs were positively impacted by the implementation of this strategy, hence providing sufficient evidence to affirm the research question. Therefore, the application of PAPA care intervention strategies is expected to add significant value to private healthcare providers in South Africa, through the improvement of healthcare provider performance. Simple scenario testing produced thought-provoking results. It was evident from the results of the scenario testing that PAPA intervention strategies, even under unfavourable circumstances, will add significant value to the performance of hospitals.

The implementation support framework addresses three levels of decision-making in the application of a PAPA care intervention strategy. The framework combined best-practice guidelines from preventive care and predictive analytic frameworks. It is critical that strategic management commit to the increased use of evidence-based decision-making tools, such as PAPAs, to provide the basis for identifying and interceding with high-risk patients through the provision of preventive care services.

From a tactical point-of-view, the framework suggests that preventive care team (PCTs) should be established for interceding with patients illustrating high length of stay indices. The critical success factors relate to the ability of healthcare managers to collaborate with the relevant divisions of care and preventive care teams, and effectively schedule and manage care plans.

On an operational level, PCTs should focus on providing care that is responsive and decisive, but reinstate the role of the family-physician to improve patient-practitioner relationships. From a data management perspective, it is crucial that PCTs adhere to the standardised processes for documenting patient information, to ensure that PAPAs have access to the readily available patient data to improve the effectiveness of the preventive care intervention strategy.

Future work in the field of healthcare predictive modelling can investigate the relationships between major performance compromising factors and KPIs in greater depth. Secondly, the current performance foci of HCPs in the private healthcare sector of South Africa are partly captured in the “Scope-for-Improvement” KPIs. In essence, these KPIs provide a platform for future data analysts to improve HCP performance with the increased use of PM applications similar to the PAPA care intervention strategy.

Powerful predictive analytic tools, such as PAPAs, have the potential to alleviate some of the healthcare resource management difficulties that resource starved countries, similar to South Africa, struggle with. Future work should also explore the potential impact of a PAPA care intervention strategy on a national level. Utilising the value-add methodology developed in this thesis, researchers will be able to predict the potential value of evidence-based preventive care initiatives, and its resulting effect on managing patient health outcomes, to ultimately improve healthcare resource management.

A personal reflection on the process of delivering this thesis identified some of the major learning curves experienced over the past two years. Investigating the field of healthcare in South Africa instilled an even greater curiousness in the management and improvement of this sector. With the knowledge and expertise gained from studying the major factors contributing to ineffective healthcare resource management, the increase burden of diseases on the public sector, and the great divide between public and private providers, induced a feeling of responsibility towards the improvement of the South African healthcare system. From a technical perspective, the thesis contributed to the development of an attribute that I believe all engineers, specifically industrial engineers, should aspire to develop. In essence, the ability to identify, analyse, and resolve a problem from a holistic point of view, and suggesting a solution that factors in all the various areas of impact, was undoubtedly the major challenge in the delivery of this thesis.

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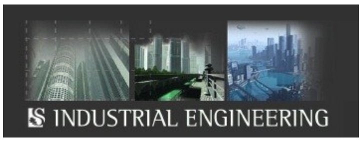
Appendix A

Abbreviation	***Term***	***Description***
MSC2a3	Miscellaneous 2	*External causes of injury; remaining supplemental classification of factors influencing health status and contact with health services*
METAB3	Other metabolic	*All other endocrine, metabolic and miscellaneous immune disorders (but not including systemic lupus erythematous or Rheumatoid arthritis)*
ARTHSPIN	Arthropathies	*Arthropathies and spine disorders (but no infections or auto-immune conditions)*
NEUMENT	Other Neurological	*All other neurologic problems and mental disorders (other than drug overdoses); senility*
RESPR4	Acute respiratory	*All other infections, joint infections and muscle infections, with the exception of hepatitis; unspecified fever*
MISCHRT	Miscellaneous cardiac	*Miscellaneous cardiac conditions and congenital heart disease*
SKNAUT	Skin and auto-immune disorders	*SLE, rheumatoid arthritis, skin disorders, & related autoimmune diseases, Sialoadenitis*
GIBLEED	Gastrointestinal bleeding	*Gastrointestinal haemorrhage; miscellaneous disorders of stomach and duodenum; diverticulitis; abdominal symptoms, nausea with vomiting; blood in stool*
INFEC4	All other infections	*All other infections, joint infections and muscle infections, with the exception of hepatitis; unspecified fever*
TRAUMA	All other trauma	*Traumatic injuries not included elsewhere, including head injuries without intracranial or subdural bleeds*
HEART2	Other cardiac conditions	*Diseases of pulmonary circulation and cardiac dysrhythmias*
RENAL3	Other renal	*All other renal diseases other than infections*
ROAMI	Chest pain	*Chest pain, myocardial infarction not specified*
MISCL5	Miscellaneous 3	*Miscellaneous non-cardiac congenital anomalies; miscellaneous symptoms other than fever; miscellaneous tooth and tongue disorders, miscellaneous diagnoses of pain*
COPD	Chronic obstructive pulmonary disorder	*Chronic obstructive pulmonary disorder and some less common respiratory conditions*
UTI	Urinary tract infections	*Urinary tract infections, not including pregnancy related ones*
ODaBNCA	Ingestions and benign tumours	*Non-gynaecologic benign neoplasms; drug overdoses, drug abuse, adverse drug reactions, and poisonings*
GYNEC1	Gynaecology	*Non-malignant, non-infectious gynaecologic diseases, including benign neoplasms*
FXDISLC	Fractures and dislocations	*All other fractures and dislocations, including pathologic fractures*
CANCRB	Cancer B	*All other malignant neoplasms not in Cancer A or gynaecologic ones (including Hodgkin's disease); radiation therapy and chemotherapy encounters where cancer not specified*
AMI	Acute myocardial infarction	*Myocardial infarction*
PRGNCY	Pregnancy	*Pregnancy and related conditions, including circumstances related to reproduction and development*
HEMTOL	Non-malignant hematologic	*Hematologic problems other than malignancies*
HEART4	Atherosclerosis and peripheral vascular disease	*Atherosclerosis (including that affecting pre-cerebral arteries) and other forms of peripheral vascular disease*
SEIZURE	Seizure	*Seizure disorders*
APPCHOL	Appendicitis	*Appendicitis, hernias, cholecystitis, and cholangitis*
CHF	Congestive heart failure	*Congestive heart failure and some related illnesses*
PNEUM	Pneumonia	*All forms of pneumonia; empyema; pleurisy; and lung abscess; also includes pulmonary tuberculosis; pulmonary congestion and hypostasis*
GIOBSENT	Gastrointestinal, inflammatory	*Gastrointestinal haemorrhage; miscellaneous disorders of stomach*

	bowel disease, and obstruction	*and duodenum; diverticulitis; abdominal symptoms, nausea with vomiting; blood in stool*
GYNECA	Gynaecologic cancers	*Gynaecologic malignancies other than ovarian cancer; female breast cancer*
STROKE	Stroke	*Stroke and post-stroke complications*
RENAL2	Chronic renal failure	*Chronic renal failure, end-stage renal disease, and kidney transplants*
FLaELEC	Fluid and electrolyte	*Typical fluid and electrolyte disorders and dehydration*
CANCRA	Cancer A	*Malignant neoplasms of respiratory tract and intra-thoracic organs; leukaemia, non-Hodgkin's lymphomas, and other histolytic malignancies*
MISCL1	Miscellaneous 1	*Miscellaneous conditions not classified previously*
HIPFX	Hip fracture	*Hip fracture*
METAB1	Diabetic ketoacidosis and related metabolic	*Diabetic ketoacidosis, with and without coma; hypoglycaemic coma; unspecified coma and alteration of consciousness*
PERVALV	Pericarditis	*Pericarditis and valvular heart disease*
LIVERDZ	Liver disorders	*Liver disorders, including hepatitis*
CATAST	Catastrophic conditions	*Catastrophic conditions, including dissecting aneurysms, cardiac arrest, respiratory arrest, all forms of shock except septic shock; intracranial and subdural haemorrhages*
PNCRDZ	Pancreatic disorders	*Pancreatic disorders*
PERINTL	Perinatal period	*All conditions originating in the perinatal period*
CANCRM	Ovarian and metastatic cancer	*Ovarian cancer and metastatic cancer*
RENAL1	Acute renal failure	*Acute renal failure, nephritic syndrome, and related conditions*
SEPSIS	Sepsis	*Sepsis, meningitis, septic shock, and major catastrophic infections*

Appendix B

Appendix B is a summary of the healthcare performance foci survey distributed to the industry leaders of the private healthcare sector in South Africa.



Language:

A survey on the use of patient-admission predictive algorithms (PAPAs) as part of a preventive care intervention strategy in the private healthcare sector of South Africa

Welcome!

Please take a minute to familiarize yourself with the subject matter as the survey roughly takes around 7 minutes to complete.

Overview:

The survey aims to establish the **potential value** of **patient-admission predictive algorithms (PAPAs)** to **private healthcare provider groups** in South Africa. PAPAs are designed to **identify patients at risk of admission to hospital**, given their historical in-patient, **health insurance data**. The output of the algorithm is an estimated **Length of Stay (LOS) index** for each patient in the database, which healthcare providers can use to identify patients at high-ris of admission to hospital.

Data analysts believe that PAPAs will enable healthcare provider groups to intercede with high-risk patients, **preventing unnecessary hospitalisations** from occurring and consequently provide a greater **evidence-based resource management platform**. It is claimed that these unnecessary hospitalisations resulted in **$30 billion of healthcare resource expenditures** in the United States in 2006 alone (http://www.heritagehealthprize.com/c/hhp).

Various studies have shown that the South African healthcare system is **fraught with resource allocation problems** and, with the introduction of the new **National Health Insurance Policy** in South

Africa, an increased demand in hospital services will indefinitely **complicate healthcare resource availability** at every care level.

Objective:

The survey is constructed to:

1. Identify **key performance indicators (KPIs)** from a systems engineering perspective;
2. Identify **performance compromising factors (PCFs)** that negatively affect the performance of a healthcare provider with regards to the aforementioned KPIs
3. Establish a possible **relationship** between the output of the PAPA algorithm and the PCFs

If this is achieved, the potential value of these algorithms to private healthcare provider groups can be established.

Please Note: The information acquired from this survey, is strictly confidential. At no stage in the research process will the user's personal information (name, job description, and organisation) be made available. The results are strictly used for the purpose of analysis and the personal information provides a means for validating the gathered data.

Key Points to Remember:

- PAPAs are an **evidence-based preventive care initiative**
- PAPAs **predict** and **identify** the patients at risk of admission to hospital, by calculating an estimated **Length of Stay Index (LOSI)** for each patient (in the patient database
- PAPAs aim to enable health care providers to **intercede with at-risk patients** (Patients with a high LOSI) , **preventing unnecessary hospitalisations**, which result in 'skewed' or 'unnecessary' allocations of health care resources

INDUSTRIAL ENGINEERING

*1. Question

The list below depicts four categories of **Key Performance Indicators (KPIs).** Please select the category that mostly relates to your field of expertise.

Select only one:

- ○ **Healthcare and Process Outcomes** (Chief Operating Officer/Operations Managers/General Managers/Doctors or Practitioners)
- ○ **Patient-focused Outcomes** (Chief Medical Officer/ Clinical Services Manager/ Nursing/ Client Services Managers)
- ○ **Employee-focused Outcomes**(Human Resource Managers)
- ○ **Financial and Market Related Outcomes**(Chief Financial Officer/Financial Managers)

Healthcare and Process Outcomes 1 of 3

***2. Question**

According to your best knowledge, please rank the Key Performance Indicators in their ***importance*** to your organisation from a ***patient-centred perspective***.

*Please rank these KPIs from **Least important(1) to Most Important(5)***

	Least		Average		Most	
	1	2	3	4	5	N/A
Adherence to patient safety practices						
Adherence to treatment protocols						
Efficient and effective medication administration						
Incorporating patient involvement in decisions						
Timeliness delivery of care						

***3. Question**

According to your best knowledge, please rank these Key Performance Indicators in their ***importance*** to your organisation from a ***patient-centred perspective***.

*Please rank these KPIs from **Least Important(1) to Most important(5)***

	Least		Average		Most	
	1	2	3	4	5	N/A
Effective communication of treatment plans and orders to patients						
Effective care coordination between practitioners and/or relevant divisions of care						
The ability to provide a variety of care bundles to patients						
Establishing and adhering to critical pathways in care delivery						
Preventing future "unnecessary" hospitalisations						

Healthcare and Process Outcomes 2 of 3

***4. Question**

Consider the KPIs you selected in the ***patient-focused outcomes*** category. *Please specify* ***Performance Compromising Factors (PCFs)*** *for these KPIs and rate* ***the perceived ability*** *of patient-admission predictive algorithms to eradicate these PCFs*

	*Performance Compromising Factors (PCFs)	*Would PAPA output aid in the eradication of the established PCFs? No 1	2	Possibly 3	4	Definitely 5
Adherence to Patient Safety Practices						
Adherence to Treatment Protocols						
Efficient and effective medication administration						
Incorporating patient involvement in decisions						
Timeliness delivery of care						
Effective communication of treatment plans and orders to patients						
Effective care coordination between practitioners and/or relevant divisions of care						
The ability to provide a variety of care bundles to patients						
Establishing and adhering to critical pathways in care delivery						
Preventing future "unnecessary" hospitalisations						

INDUSTRIAL ENGINEERING

***5. Question**

Which of the following **Key Performance Indicators (KPIs)** are regarded as the **most important** to your organisation from an **operational effectiveness perspective**?

Please select two:

- ☐ Higher cost savings at key healthcare processes
- ☐ Higher productivity with the use of more/less internal or external resources
- ☐ Improved internal responsiveness indicators (cycle and turnover times)
- ☐ Improved utilisation rates (machinery, staff, etc.)
- ☐ Decreasing unrecyclable waste production (repeated diagnostic tests, pharmaceuticals, obsolete procedures, etc.)

***6. Question**

Which of the following **Key Performance Indicators (KPIs)** are regarded as the **most important** to your organisation from an **operational effectiveness perspective**?

Please select two:

- ☐ More efficient and financially viable inventory levels
- ☐ Improved supplier product-offering quality
- ☐ Improved electronic data exchange processes
- ☐ Reductions in supply chain management costs
- ☐ Improved innovations rates (time to introduce new services, increased use of e-technology, etc.)

INDUSTRIAL ENGINEERING

Healthcare and Process Outcomes 3 of 3

***7. Question**

Consider the KPIs you selected in the ***process effectiveness outcomes*** category.*Please specify **Performance Compromising Factors (PCFs)** for these KPIs and rate the **perceived ability** of patient-admission predictive algorithms to eradicate these PCFs.*

	*Performance Compromising Factors (PCFs)	* Would PAPA output aid in the eradication of the established PCFs?				
		No		Possibly		Definitely
		1	2	3	4	5
Higher cost savings at key healthcare processes						
Higher productivity with the use of more/less internal or external resources						
Improved internal responsiveness indicators (cycle and turnover times)						
Improved utilisation rates (machinery, staff, etc.)						
Decreasing unrecyclable waste production (repeated diagnostic tests, pharmaceuticals, obsolete procedures, etc.)						
More efficient and financially viable inventory levels						
Improved supplier product-offering quality						
Improved electronic data exchange processes						
Reductions in supply chain management costs						
Improved innovations rates (time to introduce new services, increased use of e-technology, etc.)						

Patient-focused Outcomes 1 of 2

***8. Question**

Which of the following Key Performance Indicators (KPIs) are regarded as the *most important* to your organisation from a patient satisfaction perspective?*Please rank these KPIs from* ***Least Important (1)*** *to* ***Most Important (5)*** *and specify at least one* ***Performance Compromising Factor (PCF)*** *for each identified KPI.*

	* Rank Patient-Satisfaction Performance Criteria							* Performance Compromising Factors (PCFs)
	Least		Average			Most		
	1	2	3	4	5	6	N/A	
Improved patient retention rates	○	○	○	○	○	○	○	
Gains in patient accounts	○	○	○	○	○	○	○	
Decreased number of patient complaint registrations	○	○	○	○	○	○	○	
Higher patient satisfaction with regards to complaint resolution	○	○	○	○	○	○	○	
Higher perceived value of firm based on healthcare quality, treatment outcome and cost	○	○	○	○	○	○	○	
Other? Plea:	○	○	○	○	○	○	○	

9. Question

Which of the following **Key Performance Indicators (KPIs)** are regarded as the **most important** to your organisation from a **patient engagement perspective**?*Please rank these KPIs from Least Important (1) to Most Important (5) and specify at least one Performance Compromising Factor (PCF) for each identified KPI.*

Improved access to healthcare services	○	○	○	○	○	○	○	
Improved courtesy in care service interactions	○	○	○	○	○	○	○	
Higher patient advocacy for your firms healthcare service offerings	○	○	○	○	○	○	○	
Improved patient complaints management practices	○	○	○	○	○	○	○	
Improved patient-practitioner relationships	○	○	○	○	○	○	○	
Other? Plea:	○	○	○	○	○	○	○	

***10. Question**

Do you believe that the use of preventive care initiatives, similar to Patient-Admission Prediction Algorithms, have the ability to improve your organisation's patient-focused outcomes?

- Yes
- No

***11. Briefly elaborate on the extent to which you believe preventive care initiatives, similar to PAPAs, can improve patient-focused outcomes in your organisation.**

Maximum of 100 words.

***12. Question**

Briefly state why you believe preventive care initiatives, similar to PAPAs, are not feasible solutions to improve patient-focused outcomes in your organisation.

Maximum of 100 words.

Employee-focused Outcomes 1 of 2

***13. Question**

Which of the following Key Performance Indicators (KPIs) are regarded as the most important to your organisation from a workforce capability perspective? *Please rank from* ***Least Important (1)*** *to* ***Most Important (5)*** *and specify at least one* ***Performance Compromising Factor (PCF)*** *for each ranked KPI.*

	* Rank Workforce-capability Performance Criteria						Performance Compromising Factors (PCFs)
	Least 1	2	Average 3	4	Most 5	N/A	
More efficient and effective staffing levels across organisational units							
Higher % of certified staff members to meet skill needs							
Improved organisational restructuring (greater capacity without compromising quality of care)							
Higher % successful job rotations (cross-functional staff members)							
Other? Plea:							

***14. Question**

Which of the following Key Performance Indicators (KPIs) are regarded as the most important to your organisation from a workforce climate perspective? *Please rank from* ***Least Important (1)*** *to* ***Most Important (5)*** *and specify at least one* ***Performance Compromising Factor (PCF)*** *for each ranked KPI.*

Improved safety or a decrease in work related accidents	●						
Decreased absenteeism		●					
Improved staff turnover or employee retention rates					●		
Inclusive organisational culture				●			
Other? Plea:			●				

***15. Question**

Which of the following healthcare performance criteria are regarded as the most important to your organisation from a workforce involvement perspective?

Please select the 3 most important criteria.

- [x] Improvements in local decision making
- [ ] Greater commitment to organisational change initiatives
- [ ] Improved workforce knowledge sharing
- [ ] Greater transparency in hierarchical decision-making
- [ ] Improved workforce complaint management and resolution
- [ ] Improved training effectiveness
- [ ] Effective leadership development initiatives
- [ ] Other? Please specify.

***16. Question**

Please consider the KPIs you selected in the category Workforce Involvement Perspective. *Specify at least one **Performance Compromising Factor (PCF)** for each listed KPI and rate the extent to which you think **PAPA output** (Patient Length of Stay Indices) can aid in the alleviation of these PCFs.*

	Performance Compromising Factors (PCFs)	* Would the use of PAPAs aid in the alleviation of the established PCFs?					
		No		Possibly		Definitely	
		1	2	3	4	5	N/A
Improved Local Decision Making							
Greater commitment to organisational change initiatives							
Improved workforce knowledge sharing							
Greater transparency in hierarchical decision-making							
Improved workforce complaint management and resolution							
Improved training effectiveness							
Effective leadership development initiatives							
Other? Plea							

Financial and Market Outcomes 1 of 3

***17. Question**

Which of the following healthcare performance criteria are regarded as the most important to your organisation from a financial performance perspective?

Please select 2 criteria.

- ☐ Higher return on investments (ROI)
- ☐ Higher operating margins
- ☐ Higher profitability in all market sectors
- ☐ Improved debt to equity ratio
- ☐ More efficient levels of cash on hand

***18. Question**

Which of the following healthcare performance criteria are regarded as the most important to your organisation from a financial performance perspective?

Please select 2 criteria.

- ☐ Improved Asset Utilisation
- ☐ Improved Cash Flow
- ☐ Higher Revenues
- ☐ Higher % adherence to budget (budget performance)
- ☐ Other? Please specify. ______

***19. Question**

Consider the KPIs you selected from the financial performance perspective.*Please specify* ***Performance Compromising Factors (PCFs)*** *for these KPIs and rate the* ***perceived ability*** *of* ***patient-admission predictive algorithms*** *to eradicate these PCFs.*

	*Performance Compromising Factors (PCFs)	* Would PAPA output aid in the eradication of the established PCFs?				
		No		Somewhat		Definitely
		1	2	3	4	5
Higher return on investment (ROI)		○	○	○	○	○
Higher operating margins		○	○	○	○	○
Higher profitability in all market sectors		○	○	○	○	○
Improved debt to equity ratio		○	○	○	○	○
More efficient levels of cash on hand		○	○	○	○	○
Improved asset utilisation		○	○	○	○	○
Improved cash flow		○	○	○	○	○
Higher revenues		○	○	○	○	○
Higher % adherence to budget (budget performance		○	○	○	○	○
Other?		○	○	○	○	○

***20. Question**

Which of the following healthcare performance criteria are regarded as the most important to your organisation from a marketplace performance perspective?*Please select up to 2 criteria:*

- [ ] Higher % market share
- [x] Increased number of successful benchmark initiatives
- [ ] Higher Earnings per Share (EPS)
- [ ] Number of Charitable Donations or Grants received
- [ ] Improved market position or sector growth

***21. Question**

Which of the following healthcare performance criteria are regarded as the most important to your organisation from a marketplace performance perspective?

Please select up 2 criteria:

- ☐ Increased number of successfully entered markets
- ☐ Increased number of new services offered
- ☐ Increased number of new demographic populations served
- ☐ Higher % of income derived from new healthcare services or programs
- ☐ Other? Please specify. [ ]

***22. Question**

Consider the KPIs you selected from the marketplace performance perspective. *Please specify* ***Performance Compromising Factors (PCFs)*** *for these KPIs and rate the* ***perceived ability*** *of* ***patient-admission predictive algorithms*** *to eradicate these PCFs.*

	* Performance Compromising Factors (PCFs)	* Would PAPA output aid in the eradication of the established PCFs? No 1	2	Possibly 3	4	Definitely 5
Higher % market share	[ ]	○	○	○	○	○
Increased number of successful benchmark initiatives	[ ]	○	○	○	○	○
Higher Earnings per Share (EPS)	[ ]	○	○	○	○	○
Number of Charitable Donations or Grants received	[ ]	○	○	○	○	○
Improved market position or sector growth	[ ]	○	○	○	○	○
Increased number of successfully entered markets	[ ]	○	○	○	○	○
Increased number of new services offered	[ ]	○	○	○	○	○
Increased number of new demographic populations served	[ ]	○	○	○	○	○
Higher % of income derived from new healthcare services or programs	[ ]	○	○	○	○	○
Other? Plea	[ ]	○	○	○	○	○

From Stellenbosch University and the Department of Industrial Engineering, thank you for taking time to participate in this survey.

It is much appreciated!

For any queries please contact:

Mr Ruan Daffue

Cell: +27(0) 82 3707 297

E-mail: daff@sun.ac.za

Please Note: The information acquired from this survey, is strictly confidential. At no stage in the research process will the user's personal information (name, job description, and organisation) be made available. The results are strictly used for the purpose of analysis and the personal information provides a means for validating the gathered data.

Appendix C

Approval notice received on the application of ethical clearance for the survey of private healthcare providers in the South African healthcare system.

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Approval Notice
New Application

19-Apr-2012
DAFFUE, Ruan Albert

Ethics Refernce #: **S12/02/058**

Title: **Developing a strategic support framework for the implementation of Predictive Patient-admission Algorithms in the South African Healthcare System**

Dear Mr Ruan DAFFUE,

The **New Application** received on **24-Feb-2012**, was reviewed by members of **Health Research Ethics Committee 2** via Expedited review procedures on **17-Apr-2012** and was approved.
Please note the following information about your approved research protocol:

Protocol Approval Period: **17-Apr-2012 -17-Apr-2013**

Please remember to use your **protocol number** (**S12/02/058**) on any documents or correspondence with the REC concerning your research protocol.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

After Ethical Review:
Please note a template of the progress report is obtainable on www.sun.ac.za/rds and should be submitted to the Committee before the year has expired.
The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number projects may be selected randomly for an external audit.
Translation of the consent document in the language applicable to the study participants should be submitted.

Federal Wide Assurance Number: 00001372
Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel: +27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.
For standard REC forms and documents please visit: www.sun.ac.za/rds

If you have any questions or need further help, please contact the REC office at 0219389207.

Included Documents:
CVs
Declaration
Checklist

Appendix D

Key performance indicator	*Category*	*Priority Index*	*PAPA Ability Index*	*Quadrant*
More efficient and effective staffing levels across organisational units	*Employees*	63.82	72.37	Focus
Improvements in local decision making	*Employees*	51.32	73.68	Focus
Improved organisational restructuring (greater capacity without compromising quality of care)	*Employees*	68.42	51.97	Focus
Improved safety or a decrease in work related accidents	*Employees*	87.50	3.95	Scope for improvement
Decreased absenteeism	*Employees*	81.58	5.92	Scope for improvement
Improved workforce knowledge sharing	*Employees*	22.37	61.84	Missed the plot
Higher % of certified staff members to meet skill needs	*Employees*	63.16	9.21	Scope for improvement
Greater commitment to organisational change initiatives	*Employees*	55.26	14.47	Scope for improvement
Improved staff turnover or employee retention rates	*Employees*	24.34	30.26	Discard
Inclusive organisational culture	*Employees*	49.34	4.61	Discard
Higher % successful job rotations (cross-functional staff members)	*Employees*	32.89	12.50	Discard
Effective leadership development initiatives	*Employees*	14.47	15.79	Discard
Workforce complaint management and resolution	*Employees*	26.32	0.00	Discard
Improved training effectiveness	*Employees*	20.39	2.63	Discard
Greater transparency in hierarchical decision-making	*Employees*	9.87	5.26	Discard
Higher operating margins	*Financial & Markets*	75.38	67.02	Focus
Higher Return on Investment (ROI)	*Financial & Markets*	79.62	49.47	Scope for improvement
Higher % adherence to budget (budget performance)	*Financial & Markets*	51.76	76.06	Focus
Improved Asset Utilisation	*Financial & Markets*	57.02	68.62	Focus
Higher Revenues	*Financial & Markets*	73.62	51.06	Focus
Increased number of new services offered	*Financial & Markets*	47.36	64.89	Missed the plot
Higher Earnings per Share (EPS)	*Financial & Markets*	79.60	31.38	Scope for improvement
Improved market position or sector growth	*Financial & Markets*	75.42	26.60	Scope for improvement
More efficient levels of Cash on hand	*Financial & Markets*	63.34	37.23	Scope for improvement
Higher % of income derived from new healthcare services or programs	*Financial & Markets*	32.46	56.38	Missed the plot
Improved Cash Flow	*Financial & Markets*	54.40	30.85	Scope for improvement

Higher % market share	*Financial & Markets*	65.12	19.15	Scope for improvement
Increased number of successfully entered markets	*Financial & Markets*	35.04	40.96	Discard
Number of Charitable Donations or Grants received	*Financial & Markets*	19.74	49.47	Discard
Increased number of new demographic populations served	*Financial & Markets*	17.30	44.68	Discard
Higher profitability in all market sectors	*Financial & Markets*	49.36	12.23	Discard
Increased number of successful benchmark initiatives	*Financial & Markets*	36.78	15.96	Discard
Improved Debt to Equity Ratio	*Financial & Markets*	37.20	10.11	Discard
Timeliness delivery of care	*Process*	82.74	72.02	Focus
More efficient and financially viable inventory levels	*Process*	79.17	74.40	Focus
Effective care coordination between practitioners and/or relevant divisions of care	*Process*	75.60	65.48	Focus
Preventing future "unnecessary" hospitalisations	*Process*	52.98	85.71	Focus
Decreasing unrecyclable waste production (repeated diagnostic tests, pharmaceuticals, obsolete procedures, etc.)	*Process*	73.21	63.10	Focus
Reductions in supply chain management costs	*Process*	58.33	67.26	Focus
Higher cost savings at key healthcare processes	*Process*	68.45	54.17	Focus
Incorporating patient involvement in decisions	*Process*	36.31	80.36	Missed the plot
Efficient and effective medication administration	*Process*	34.52	77.38	Missed the plot
Adherence to Patient Safety Practices	*Process*	85.71	22.62	Scope for improvement
Improved innovations rates (time to introduce new services, increased use of e-technology, etc.)	*Process*	32.14	75.60	Missed the plot
Improved electronic data exchange processes	*Process*	22.62	82.14	Missed the plot
Effective communication of treatment plans and orders to patients	*Process*	41.67	58.93	Missed the plot
Higher productivity with the use of more/less internal or external resources	*Process*	42.26	51.19	Missed the plot
Improved utilisation rates (machinery, staff, etc.)	*Process*	25.00	59.52	Missed the plot
Improved internal responsiveness indicators (cycle and turnover times)	*Process*	60.71	15.48	Scope for improvement
Adherence to Treatment Protocols	*Process*	50.60	20.24	Scope for improvement
Establishing and adhering to critical pathways in care delivery	*Process*	27.38	33.33	Discard
The ability to provide a variety of care bundles to patients	*Process*	24.40	25.00	Discard
Improved supplier product-offering quality	*Process*	26.79	14.29	Discard
Improved patient-practitioner relationships	*Patients*	84.38	69.38	Focus
Improved access to healthcare services	*Patients*	82.50	49.38	Scope for improvement
Improved patient retention rates	*Patients*	70.63	61.88	Focus
Higher patient advocacy for your firms healthcare service offerings	*Patients*	79.38	31.25	Scope for improvement
Gains in patient accounts	*Patients*	56.88	32.50	Scope for improvement

Decreased number of patient complaint registrations	*Patients*	68.13	6.88	Scope for improvement
Higher perceived value of firm based on healthcare quality, treatment outcome and cost	*Patients*	20.63	46.88	Discard
Higher patient satisfaction with regards to complaint resolution	*Patients*	41.25	15.00	Discard
Improved patient complaints management practices	*Patients*	30.63	8.75	Discard
Improved courtesy in care service interactions	*Patients*	16.88	17.50	Discard

Appendix E

The Mann-Whitney U-test table of critical values is used to determine whether the Mediclinic and Netcare survey responses are contradictory or complimentary. The classification determined whether the responses could be grouped and analysed as a whole.

Table A5.07: Critical Values for the Wilcoxon/Mann-Whitney Test (U)

Nondirectional α=.05 (Directional α=.025)

n_1 \ n_2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	0	0	0	0	1	1	1	1	1	2	2	2	2
3	-	-	-	-	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8
4	-	-	-	0	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	13
5	-	-	0	1	2	3	5	6	7	8	9	11	12	13	14	15	17	18	19	20
6	-	-	1	2	3	5	6	8	10	11	13	14	16	17	19	21	22	24	25	27
7	-	-	1	3	5	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
8	-	0	2	4	6	8	10	13	15	17	19	22	24	26	29	31	34	36	38	41
9	-	0	2	4	7	10	12	15	17	21	23	26	28	31	34	37	39	42	45	48
10	-	0	3	5	8	11	14	17	20	23	26	29	33	36	39	42	45	48	52	55
11	-	0	3	6	9	13	16	19	23	26	30	33	37	40	44	47	51	55	58	62
12	-	1	4	7	11	14	18	22	26	29	33	37	41	45	49	53	57	61	65	69
13	-	1	4	8	12	16	20	24	28	33	37	41	45	50	54	59	63	67	72	76
14	-	1	5	9	13	17	22	26	31	36	40	45	50	55	59	64	67	74	78	83
15	-	1	5	10	14	19	24	29	34	39	44	49	54	59	64	70	75	80	85	90
16	-	1	6	11	15	21	26	31	37	42	47	53	59	64	70	75	81	86	92	98
17	-	2	6	11	17	22	28	34	39	45	51	57	63	67	75	81	87	93	99	105
18	-	2	7	12	18	24	30	36	42	48	55	61	67	74	80	86	93	99	106	112
19	-	2	7	13	19	25	32	38	45	52	58	65	72	78	85	92	99	106	113	119
20	-	2	8	14	20	27	34	41	48	55	62	69	76	83	90	98	105	112	119	127

Nondirectional α=.01 (Directional α=.005)

n_1 \ n_2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
3	-	-	-	-	-	-	-	-	0	0	0	1	1	1	2	2	2	2	3	3
4	-	-	-			0	0	1	1	2	2	3	3	4	5	5	6	6	7	8
5	-	-	-		0	1	1	2	3	4	5	6	7	7	8	9	10	11	12	13
6	-	-	-	0	1	2	3	4	5	6	7	9	10	11	12	13	15	16	17	18
7	-	-	-	0	1	3	4	6	7	9	10	12	13	15	16	18	19	21	22	24
8	-	-	-	1	2	4	6	7	9	11	13	15	17	18	20	22	24	26	28	30
9	-	-	0	1	3	5	7	9	11	13	16	18	20	22	24	27	29	31	33	36
10	-	-	0	2	4	6	9	11	13	16	18	21	24	26	29	31	34	37	39	42
11	-	-	0	2	5	7	10	13	16	18	21	24	27	30	33	36	39	42	45	46
12	-	-	1	3	6	9	12	15	18	21	24	27	31	34	37	41	44	47	51	54
13	-	-	1	3	7	10	13	17	20	24	27	31	34	38	42	45	49	53	56	60
14	-	-	1	4	7	11	15	18	22	26	30	34	38	42	46	50	54	58	63	67
15	-	-	2	5	8	12	16	20	24	29	33	37	42	46	51	55	60	64	69	73
16	-	-	2	5	9	13	18	22	27	31	36	41	45	50	55	60	65	70	74	79
17	-	-	2	6	10	15	19	24	29	34	39	44	49	54	60	65	70	75	81	86
18	-	-	2	6	11	16	21	26	31	37	42	47	53	58	64	70	75	81	87	92
19	-	0	3	7	12	17	22	28	33	39	45	51	56	63	69	74	81	87	93	99
20	-	0	3	8	13	18	24	30	36	42	46	54	60	67	73	79	86	92	99	105

U_{obt} is the lesser of the two calculated test statistics (U_1 & U_2). If $U_{obt} \le U_{crit}$, reject H_0.
Dashes (-) indicate that the sample size is too small to reject the Null Hypothesis at the chosen α level.

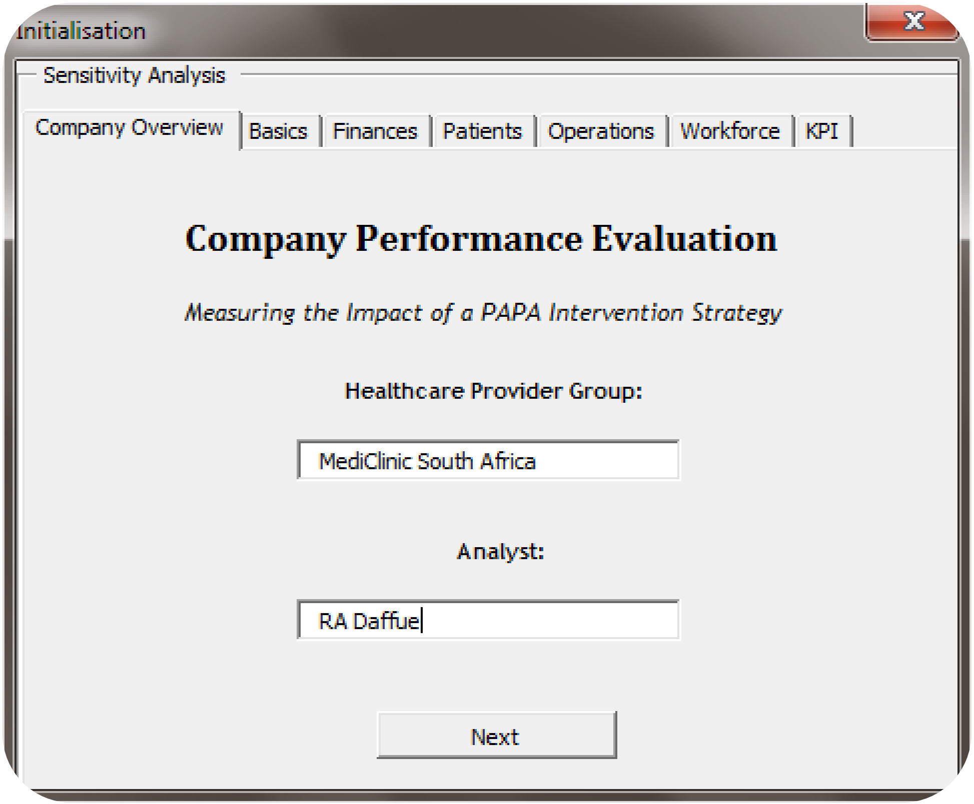
If n > 20 this table cannot be used. A **p** can be computed for U_{obt}, using the normal distribution approximation:

$$z_U = \frac{\left| U_{obt} - \left(\frac{n_1 n_2}{2} \right) \right|}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

Appendix F

Appendix F provides a summary of the Visual Basic programming in Microsoft Excel, which constitutes the key processes of value-add model as discussed in ***Chapter 5.***

An account is given of the user-forms developed for the purpose of gathering user-input data and depicting the model output in suitable charts.

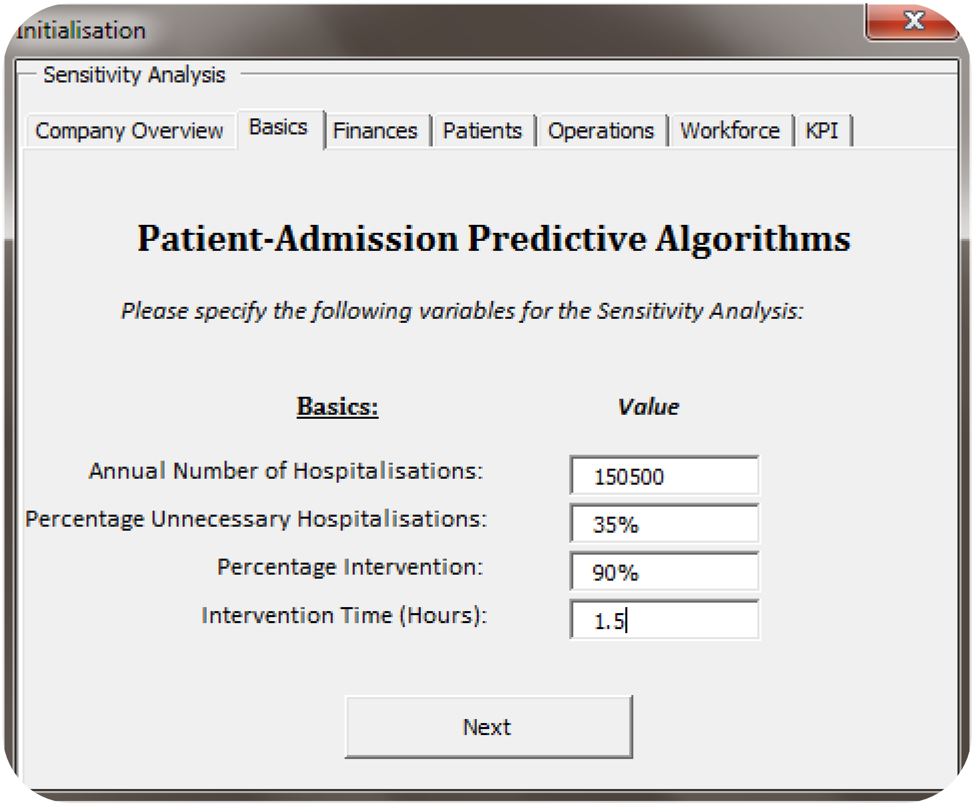


Model –input: User-forms

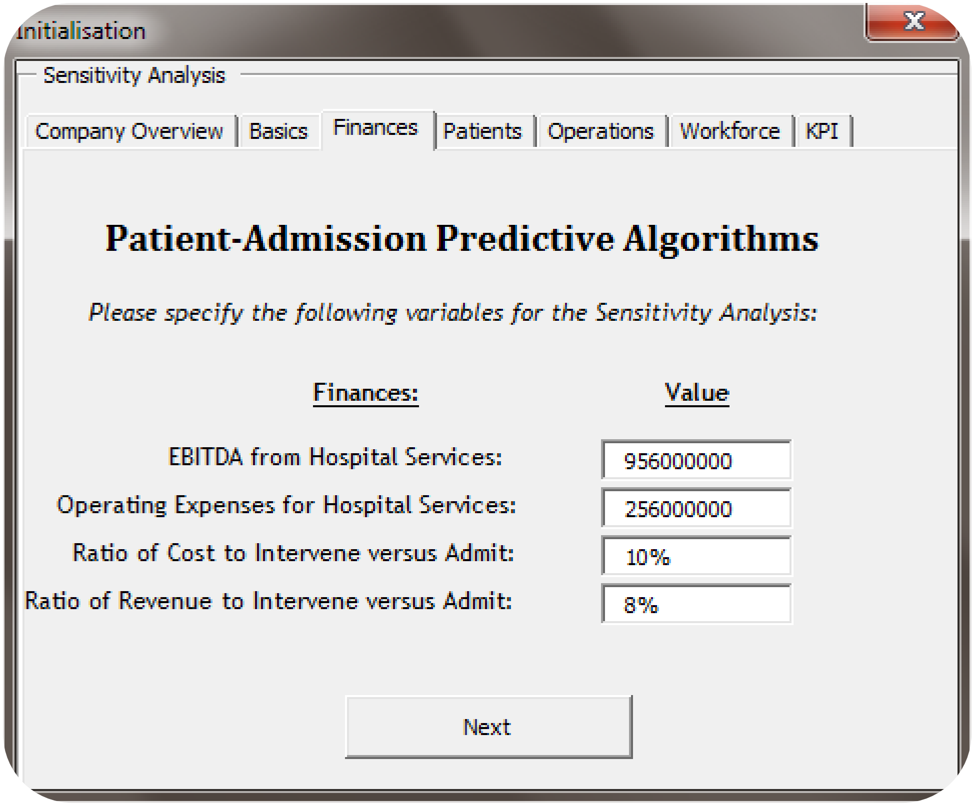
```
'First multi-page >> Collect HCP and analyst descriptions
Private Sub CompOverview_Click ()

        Sheets ("Start").Range ("J23").Value = TextBox1_Company.Value
        Sheets ("Start").Range ("J26").Value = TextBox2_Analyst.Value

        MultiPage1.Value = 1

End Sub
```

'Second multi-page >> Collect HCP group fundamentals and basis for intervention

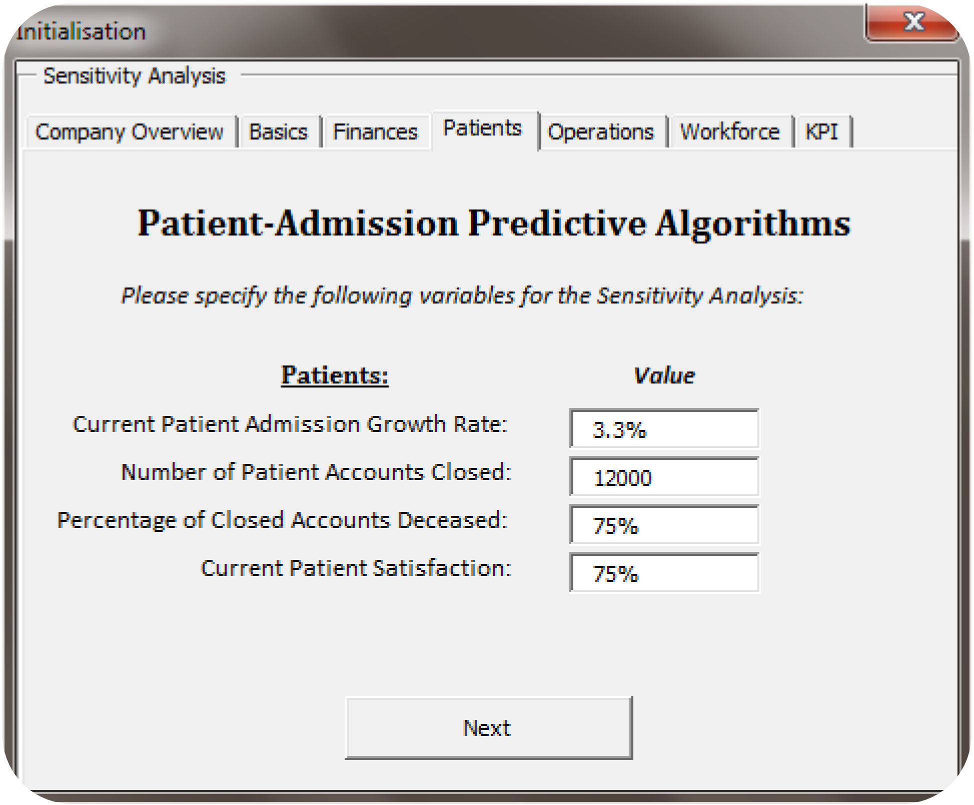
```
Private Sub Basics Click ()

        Sheets ("Info").Activate

        Range ("A2").Value = AnnualAdmissions.Value
        Range ("C5").Value = PercentageUnnecessary.Value
        Range ("D5").Value = PercentageIntervene.Value
        Range ("C5").Value = PercentageUnnecessary.Value
        Range ("F2").Value = InterventionTime.Value

        MultiPage1.Value = 2

        Sheets("Start").Activate

End Sub
```



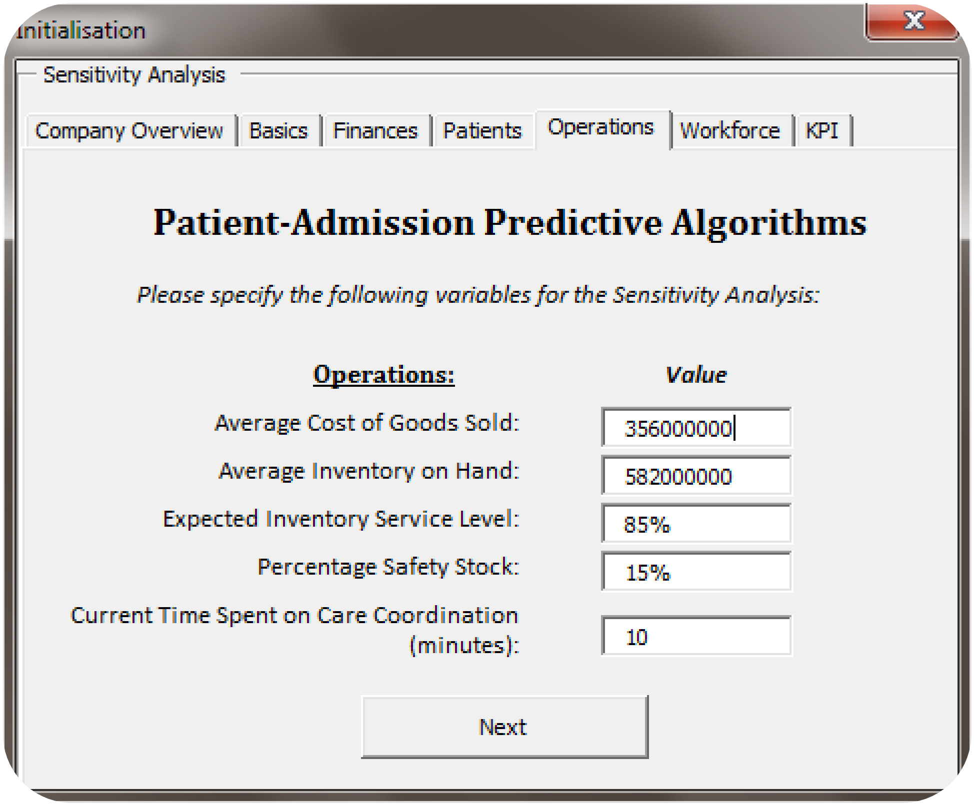
```
'Third multi-page >> Collect HCP group key financials and expected PCIS cost and revenue structure
Private Sub Finances Click ()

        Sheets ("Info").Activate

        Range ("A5").Value = OperatingIncome.Value
        Range ("B5").Value = OperatingExpenses.Value
        Range ("E5").Value = CostRatio.Value
        Range ("F5").Value = RevenueRatio.Value

        MultiPage1.Value = 3

        Sheets("Start").Activate

End Sub
```



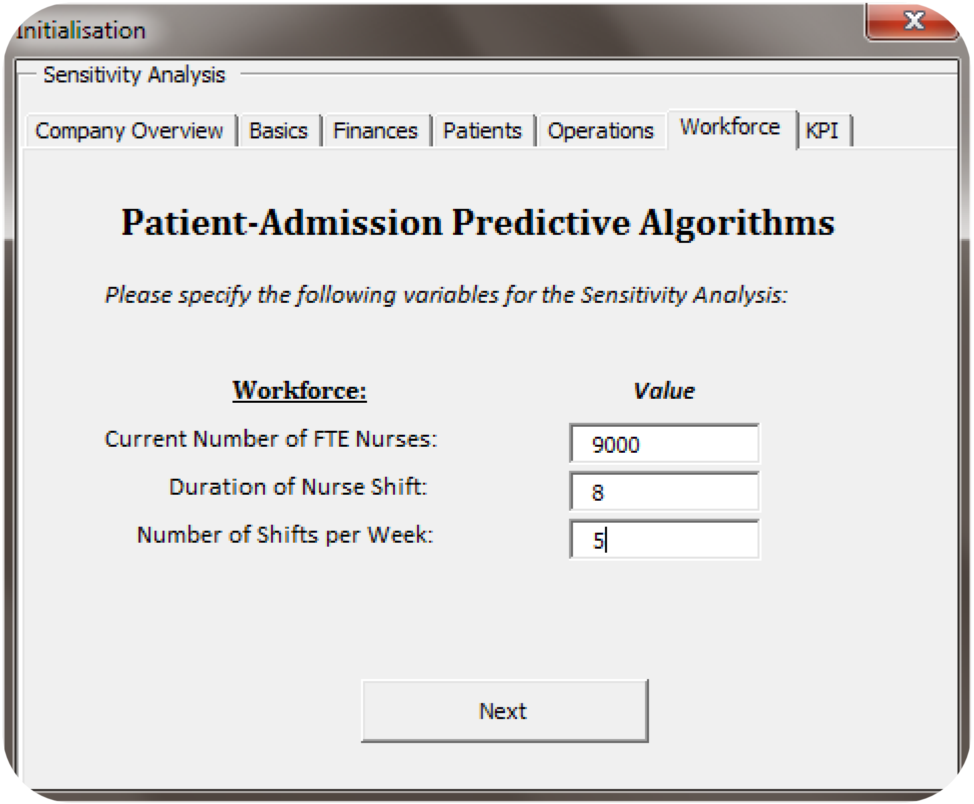
```
'Fourth multi-page >> Collect HCP group key clinical and patient variables
Private Sub Patients Click()

        Sheets ("Info").Activate

        Range ("F21").Value = PatientAdmissionGrowthRate.Value
        Range ("J21").Value = PatientAccountsClosed.Value
        Range ("K21").Value = PercentageDeceased.Value
        Range ("A25").Value = CurrentPatientSatisfaction.Value

        MultiPage1.Value = 4

        Sheets ("Start").Activate

End Sub
```



```
'Fifth multi-page >> Collect HCP group key operational variables, inventory and care coordination
Private Sub Operations Click ()

        Sheets ("Info").Activate

        Range ("A9").Value = ACGS.Value
        Range ("B9").Value = AIOH.Value
        Range ("C9").Value = ExpectedServiceLevel.Value
        Range ("D9").Value = PercentageSafetyStock.Value
        Range ("A13").Value = CurrentCareCoordinationTime.Value

        MultiPage1.Value = 5

        Sheets ("Start").Activate

'Monte Carlo Simulation of the clinical services and inventory demand
Sheets ("Inventory Levels").Activate

'Retrieve randomly generated numbers for monthly demand from worksheets
For i = 1 To 100
        Jan = Range ("B19").Value
         Feb = Range ("B20").Value
        ::
        ::
         :          :
         Nov = Range ("B29").Value
         Dec = Range ("B30").Value

        Range("B31").Offset(i, 0) = WorksheetFunction.Sum(Jan, Feb, March, Apr, May, Jun, Jul, Aug, Sep, October, Nov, Dec)  'Generate 100 iterations per month

  Next i
End Sub
```

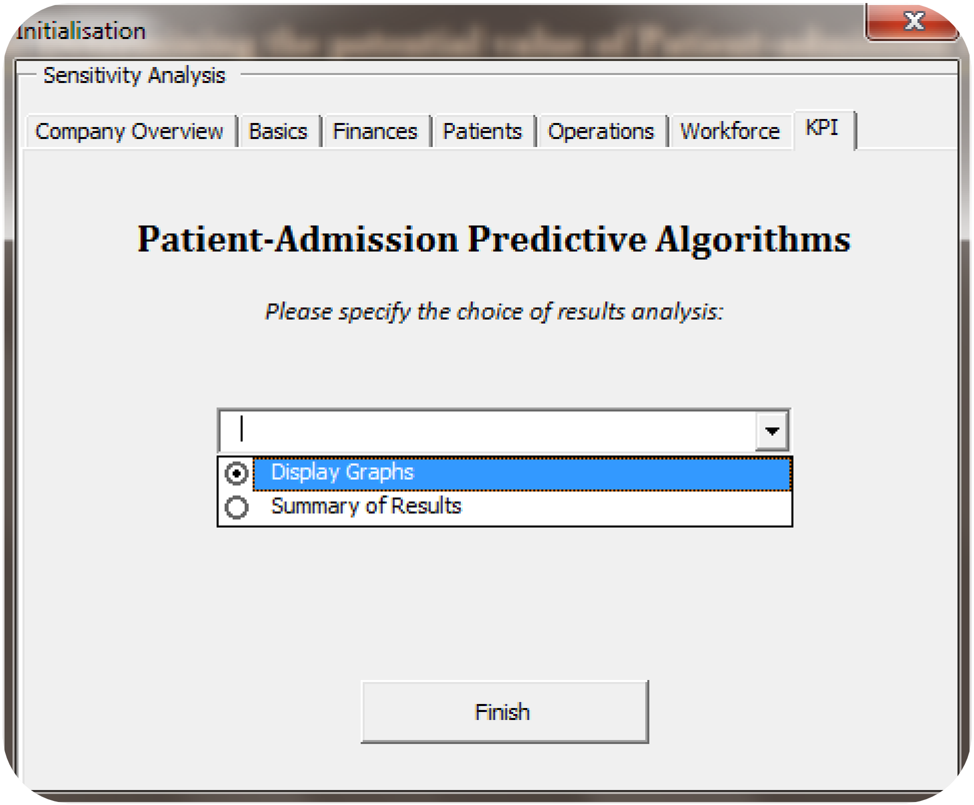


```
'Sixth multi-page >> Collect HCP group key employee-focused variables

Private Sub Workforce Click ()

        Sheets ("Info").Activate

        Range ("E2").Value = FTEs.Value
        Range ("C2").Value = ShiftDuration.Value
        Range ("D2").Value = ShiftsPerWeek.Value

        MultiPage1.Value = 6

        Sheets ("Start").Activate

End Sub
```



'Seventh multi-page >> Method of results presentation

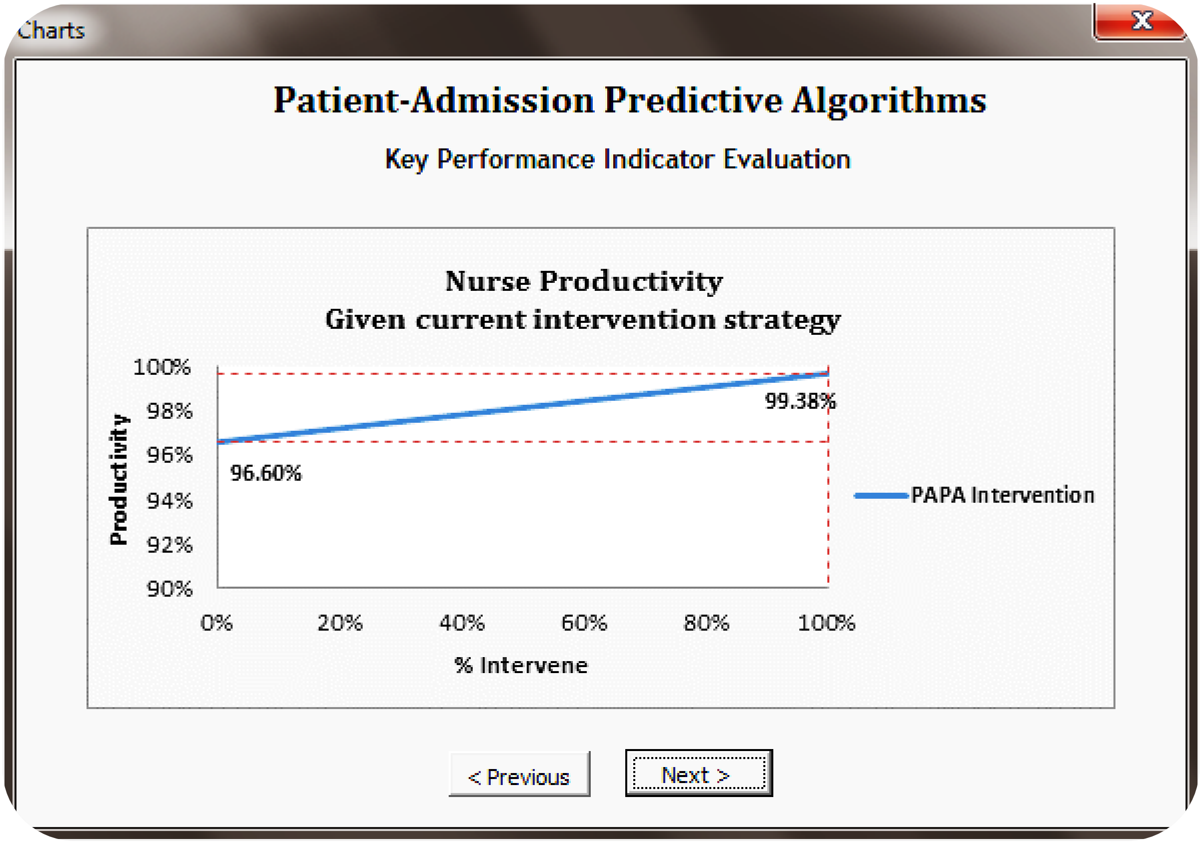
```
Private Sub KPI_Click ()

        KPI_CB.AddItem "Display Graphs"
        KPI_CB.AddItem "Summary of Results"

End Sub
```

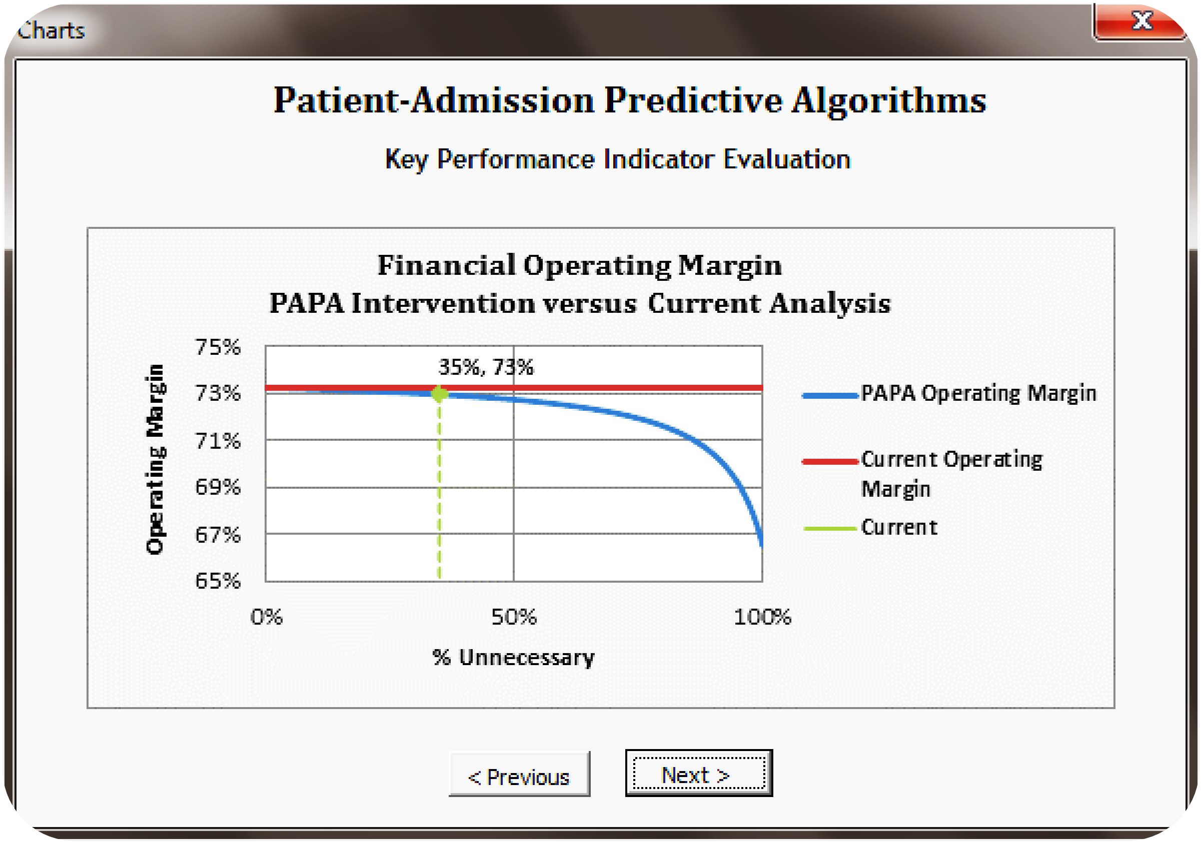


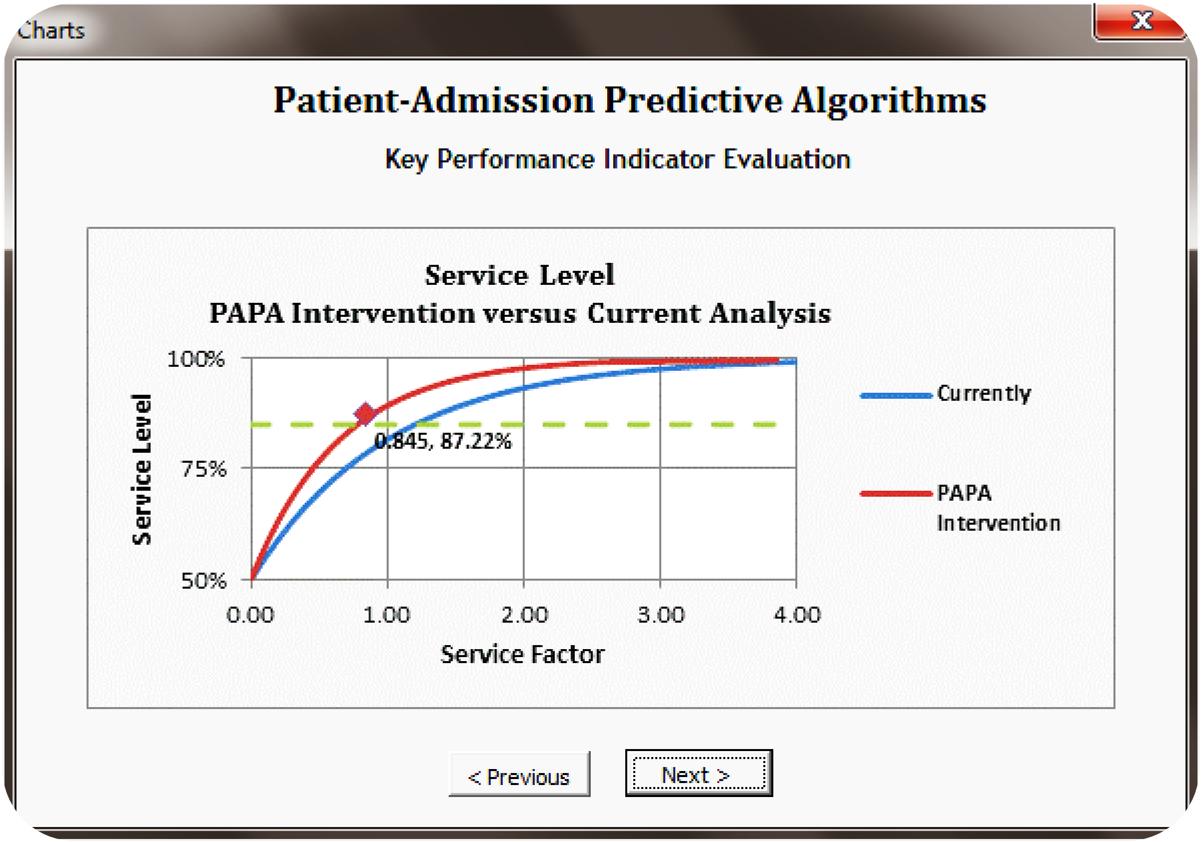
Model Output – Display Graphs

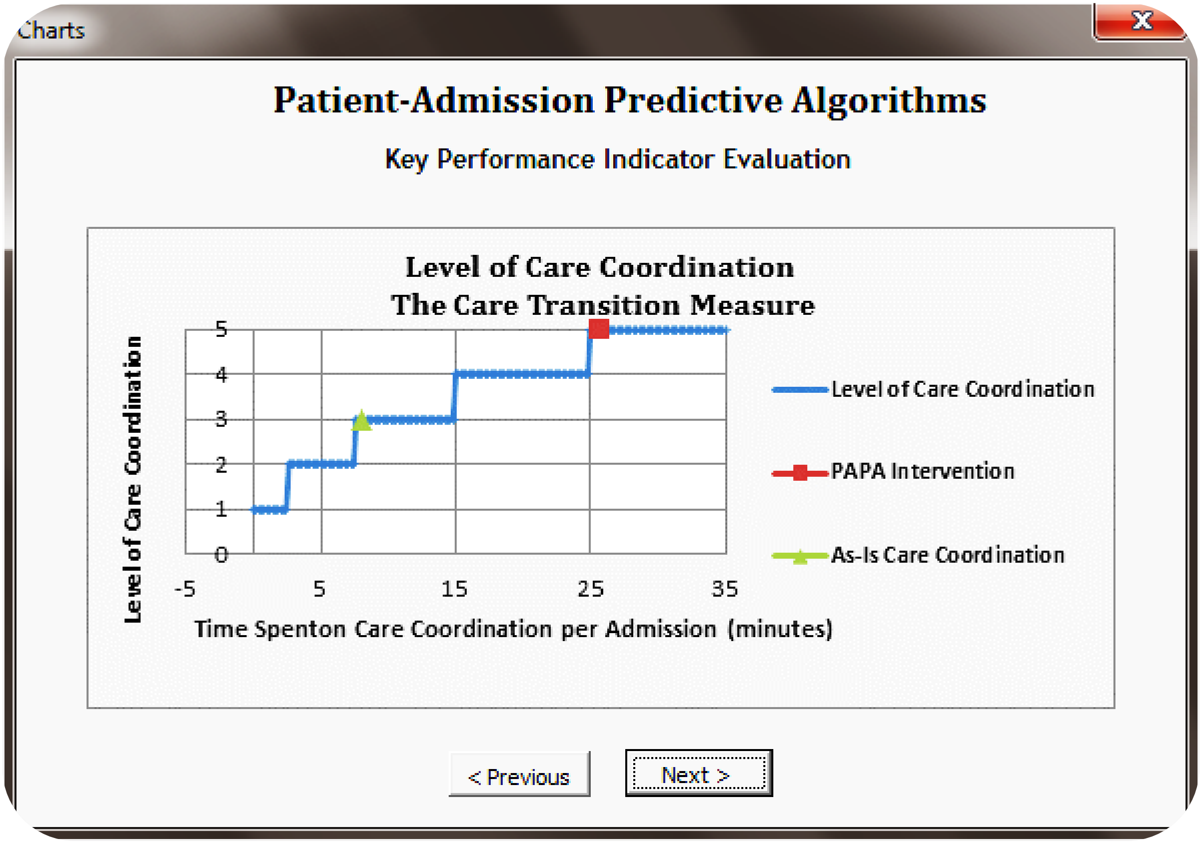
```
Dim ChartNum As Integer                     'Results Presentation >> Depict Single KPI Chart

Private Sub UserForm_Initialize()

    ChartNum = 1
    UpdateChart

End Sub

Private Sub PreviousButton_Click()           'Results Presentation >> Skip backwards through chart

    If ChartNum = 1 Then

        ChartNum = 6
    Else
        ChartNum = ChartNum - 1
        UpdateChart

End Sub

Private Sub NextButton_Click()               'Results Presentation >> Skip forwards through chart

    If ChartNum = 6 Then

        ChartNum = 1
    Else
        ChartNum = ChartNum + 1
        UpdateChart
End Sub
```

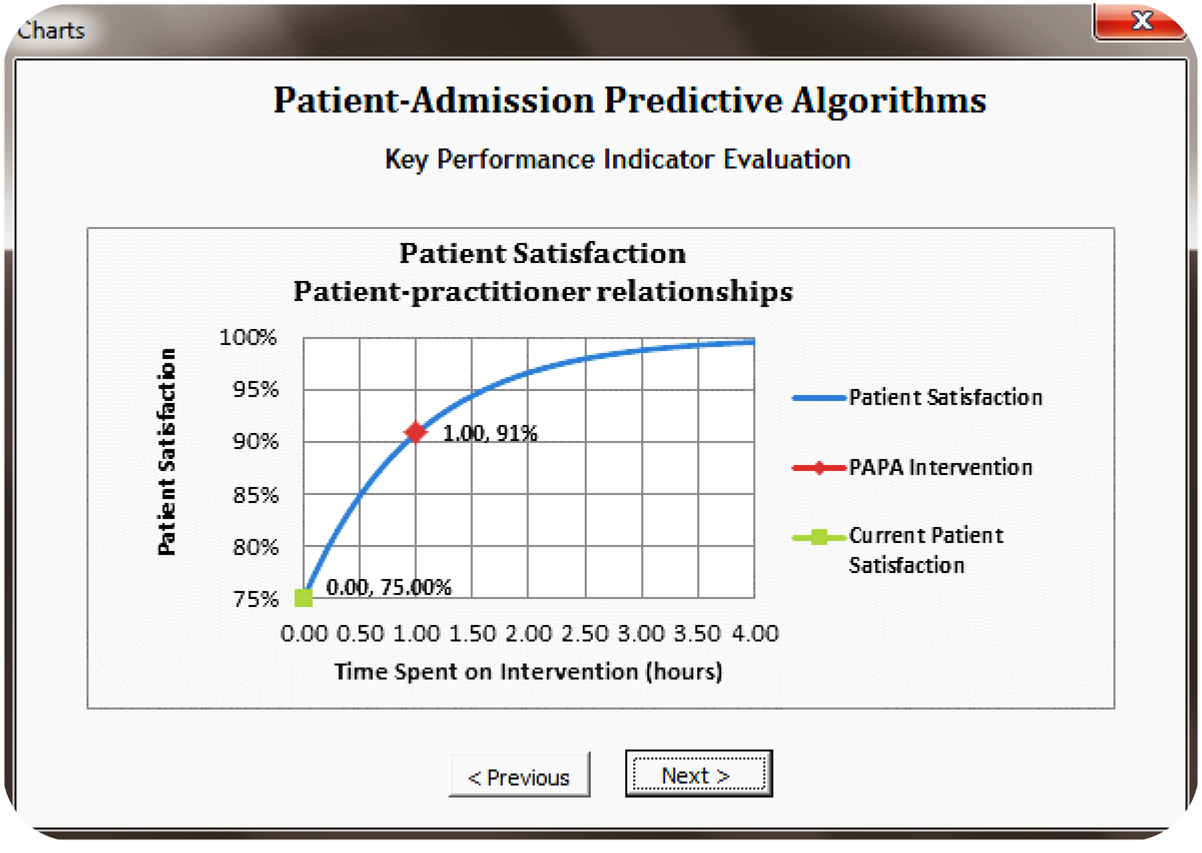
```
Private Sub UpdateChart()

        Set CurrentChart = Sheets("Charts").ChartObjects(ChartNum).Chart        ' Retrieve chart from worksheet
        CurrentChart.Parent.Width = 534                                              ' Set dimensions of chart tot display in user-form
        CurrentChart.Parent.Height = 234

        Fname = ThisWorkbook.Path and Application.PathSeparator and "temp.gif"  ' Recall Fname function

        CurrentChart.Export FileName:=Fname, FilterName:="GIF"                  ' Save chart as GIF

        Image1.Picture = LoadPicture(Fname)                                      ' Show the chart on the user-form

End Sub
```

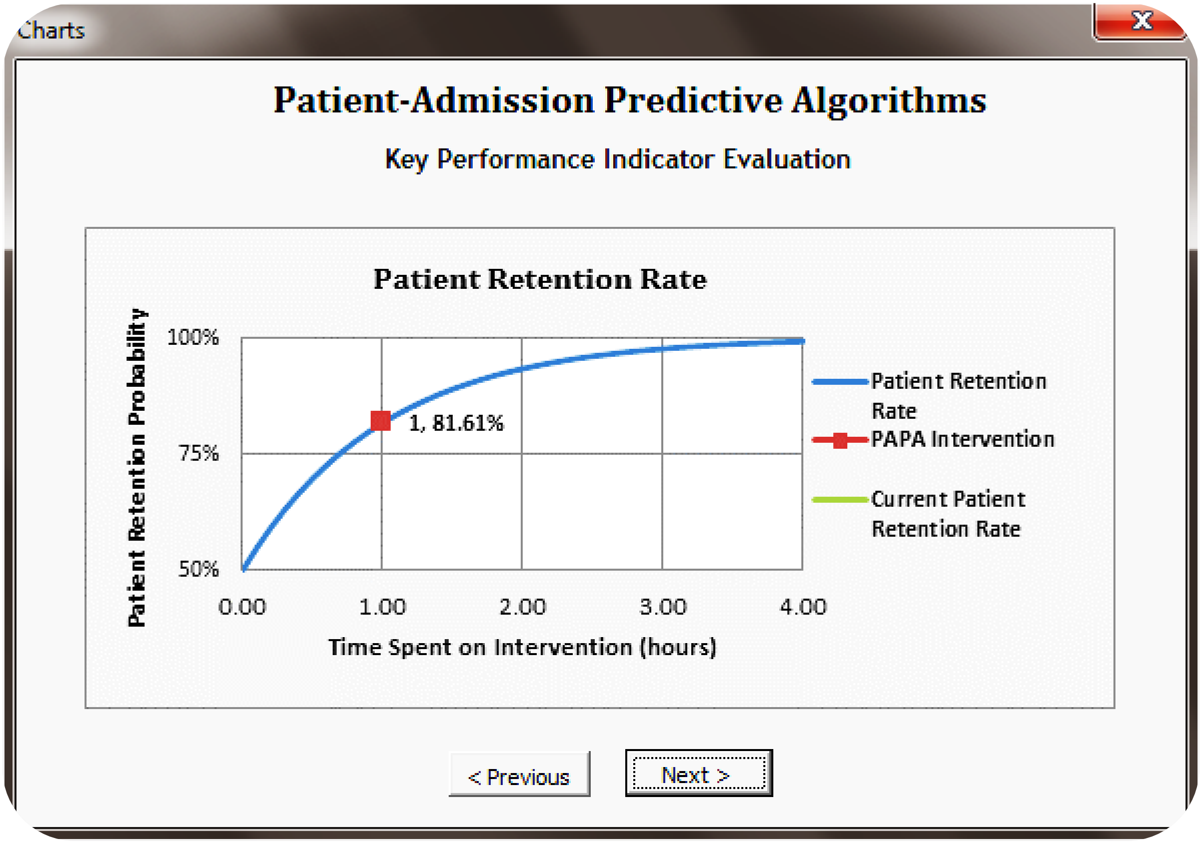

Charts
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Nurse Productivity
Given current intervention strategy
Productivity
100%
98%
96%
94%
92%
90%
0%
20%
40%
60%
80%
100%
% Intervene
99.38%
96.60%
PAPA Intervention
< Previous
Next >


Charts
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Financial Operating Margin
PAPA Intervention versus Current Analysis
Operating Margin
75%
73%
71%
69%
67%
65%
35%, 73%
0%
50%
100%
% Unnecessary
PAPA Operating Margin
Current Operating Margin
Current
< Previous
Next >


Charts
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Service Level
PAPA Intervention versus Current Analysis
100%
75%
50%
Service Level
0.845, 87.22%
0.00
1.00
2.00
3.00
4.00
Service Factor
Currently
PAPA Intervention
< Previous
Next >


Charts
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Level of Care Coordination
The Care Transition Measure
Level of Care Coordination
0
1
2
3
4
5
-5
5
15
25
35
Time Spenton Care Coordination per Admission (minutes)
Level of Care Coordination
PAPA Intervention
As-Is Care Coordination
< Previous
Next >

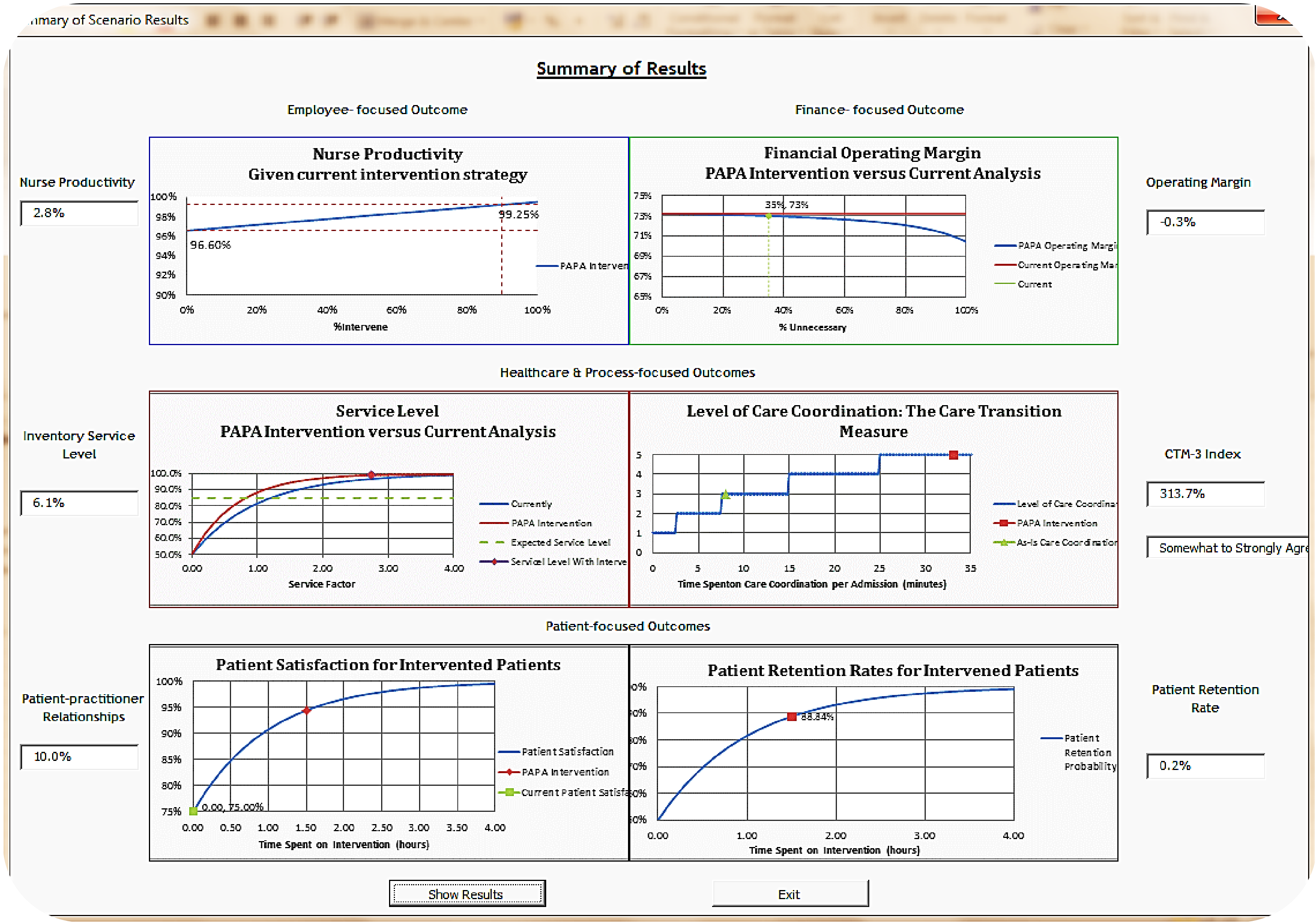

Charts
X
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Patient Satisfaction
Patient-practitioner relationships
Patient Satisfaction
100%
95%
90%
85%
80%
75%
1.00, 91%
0.00, 75.00%
0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00
Time Spent on Intervention (hours)
Patient Satisfaction
PAPA Intervention
Current Patient Satisfaction
< Previous
Next >


Charts
Patient-Admission Predictive Algorithms
Key Performance Indicator Evaluation
Patient Retention Rate
Patient Retention Probability
100%
75%
50%
0.00
1.00
2.00
3.00
4.00
Time Spent on Intervention (hours)
1, 81.61%
Patient Retention Rate
PAPA Intervention
Current Patient Retention Rate
< Previous
Next >

Model Output – Summary of KPI Graphs

Private Sub CommandButton2_Click()

```
TextBox_NP.Tag = Sheets("Charts").Range("L33")                         'Assign sheet values to User-from textboxes
 TextBox_OM.Tag = Sheets("Charts").Range("L34")
 TextBox_ISL.Tag = Sheets("Charts").Range("L35")
 TextBox_CC.Tag = Sheets("Charts").Range("L36")
 TextBox_CCT.Text = Sheets("Charts").Range("M36")
 TextBox_PPR.Tag = Sheets("Charts").Range("L37")
 TextBox_PRR.Tag = Sheets("Charts").Range("L38")

 TextBox_NP.Text = Format(TextBox_NP.Tag, "0.0%")          'Format Textbox Output Values to Percentages to display the percentage changes
 TextBox_OM.Text = Format(TextBox_OM.Tag, "0.0%")
 TextBox_ISL.Text = Format(TextBox_ISL.Tag, "0.0%")
 TextBox_CC.Text = Format(TextBox_CC.Tag, "0.0%")
 TextBox_PPR.Text = Format(TextBox_PPR.Tag, "0.0%")
 TextBox_PRR.Text = Format(TextBox_PRR.Tag, "0.0%")


 Set Chart1 = Sheets("Charts").ChartObjects(1).Chart          'Repeat this process for all of the charts

 Chart1.Parent.Width = 500                                  'Chart dimensions
 Chart1.Parent.Height = 200


 Fname1 = ThisWorkbook.Path and Application.PathSeparator and "temp1.gif" 'Recall Fname1 function assigned to figures
 Chart1.Export FileName:=Fname1, FilterName:="GIF"          'Save chart as GIF


 Image1.Picture = LoadPicture(Fname1)                        'Show the chart
```


Summary of Results
Employee- focused Outcome
Finance- focused Outcome
Nurse Productivity
2.8%
Nurse Productivity
Given current intervention strategy
99.25%
96.60%
PAPA Interven
%Intervene
Financial Operating Margin
PAPA Intervention versus Current Analysis
35%, 73%
% Unnecessary
Operating Margin
-0.3%
Healthcare & Process-focused Outcomes
Inventory Service Level
6.1%
Service Level
PAPA Intervention versus Current Analysis
Currently
PAPA Intervention
Expected Service Level
Service Factor
Level of Care Coordination: The Care Transition Measure
Time Spenton Care Coordination per Admission (minutes)
CTM-3 Index
313.7%
Patient-focused Outcomes
Patient-practitioner Relationships
10.0%
Patient Satisfaction for Intervented Patients
0.00, 75.00%
Patient Satisfaction
PAPA Intervention
Time Spent on Intervention (hours)
Patient Retention Rates for Intervened Patients
88.84%
Patient Retention Probability
Patient Retention Rate
0.2%
Show Results
Exit