Picture Archiving and Communication Systems in the South African public healthcare environment:

A suitable structure and guidelines to assist implementation and optimisation

by
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Thesis presented for the degree of *Masters in Engineering in the Faculty of Industrial Engineering at Stellenbosch University*

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Summary

South Africa has a great number of patients and not enough medical expertise to attend to their patient needs. The South African Department of Health (DoH) has recognised the potential benefit of the Picture Archiving and Communication System (PACS) to address the health needs of rural patients who do not have access to specialised medical care. PACS allows specialist remote access to patient information to assist the diagnosis and treatment process remotely. South African healthcare institutions have been implementing PACS for over a decade, in an attempt to address the health needs of rural patients that do not have access to specialised medical care. Despite numerous deployment attempts, and the DoH's support for PACS, the system is not operating successfully in South Africa. PACS was chosen due to its proven success as an appropriate technical system in most international hospitals of first and third- world countries (van Wetering, 2008) (Horri, 2010). However, specifications, guidelines and best practice operational methods for the appropriate PACS technical structure are lacking in South African literature and in governmental strategies. Additionally, there are no guidelines for implementation or support for hospital decision makers to manage the system and enterprise change.

The purpose of this thesis is to (a) define a PACS technical and operational structure suited for the South African public healthcare environment and, (b) to develop guidelines for implementation and optimisation of PACS for managing the system and the enterprise change and progressively reach the defined structure.

A combination of literature research, field observations and focus group discussions led to the understanding of the current ("As-Is") PACS healthcare delivery system in South Africa and its barriers. Three types of PACS structures were found to be currently available: a DICOM-only image management system; a vendor supplied PACS; and a super-PACS.

It was found that currently very few PACS systems in South Africa are operational and integrated with other healthcare institutions. This was due to a combination of factors: a) the complex, long chain of interdependent process steps and domains; b) vendor imposed limitations and propriety data formats; in combination with c) a lack of governing standards to ensure integration of digital PACS systems within the healthcare delivery environment; and lastly d) key decision makers lack the expert knowledge necessary to make informed decisions to deploy and manage PACS optimally.

Further research led to establishing the ("To-Be") PACS technical and operational structure suited for the South African public healthcare environment. Research has shown that the suited PACS technical and operational structure is a hospital-owned PACS system, free from vendor-imposed limits. The system consists of two databases, one with patient information and the other with patient images. The two databases are integrated by a hospital-owned server, which accesses the separate data files by means of patient identity keys.

The requirements for the PACS implementation and optimisation guidelines for managing the system and the enterprise change to progressively reach the defined structure were developed. Different Enterprise Architectural Frameworks, as improvement and optimisation guidelines, were considered and compared in accordance with the requirements established. A maturity model (MM) was deemed as the appropriate framework to offer guidelines for managing PACS implementation and optimisation in the public medical sector of South Africa. After establishing that the available MMs were not sufficient in process or technical system detail, a new MM was developed for the deployment and maturation of PACS.

The study was validated by means of usability study, user acceptance and goal checking, through focus group discussion and expert review. Users found the model to be a suitable deployment and optimisation guide, as well as a strategic planning tool. Verification was achieved by means of requirement analysis and consistency checking through the focus group discussions. It was found that it is needed to define a PACS technical and operational structure is suited for the South African public healthcare environment and that the guidelines for implementation and optimisation of PACS for managing the system and the enterprise needs to change to reach the defined structure functional. Implementing the use of PACS MM to reach the defined structure in South Africa will assist in improving healthcare delivery in South Africa and improving PACS system operation.

Opsomming

Suid-Afrika het 'n groot aantal pasiënte en nie genoeg mediese kundiges om aan hul pasiënt behoeftes te voorsien nie. Die Suid-Afrikaanse Departement van Gesondheid (DvG) erken die potensiële voordeel van ‘n Foto Argief en Kommunikasie Stelsel (PACS) om die gesondheidsbehoeftes van alle Suid-Afrikaners aan te spreek – tot die landelike pasiënte wat nie toegang tot gespesialiseerde mediese sorg het nie. PACS laat spesialiste toe om toegang te kry tot afgeleë pasiënt inligting, en daardeur fasiliteer dit die diagnose- en behandelingsproses. Suid-Afrikaanse gesondheidsorginstellings poog al vir meer as ‘n dekade om PACS te implementeer, om daardeur die gesondheidsbehoeftes van landelike pasiënte wat nie toegang tot gespesialiseerde mediese sorg het nie, aan te spreek. Ten spyte van talle ontplooiings pogings, en die DvG se steun vir PACS, is die stelsel steeds nie suksesvol in Suid-Afrika nie. PACS is gekies as ‘n oplossing, as gevolg van die sisteem se bewese sukses as 'n geskikte tegniese stelsel in meeste internasionale hospitale in eerste en derde wêreld lande (van Wetering, 2008) (Horri, 2010). Suid-Afrikaanse regering strategie en literatuur het egter ‘n gebrek aan spesifikasies, riglyne en beste- praktyk operasionele metodes vir die toepaslike PACS tegniese struktuur. Benewens is daar geen riglyne vir die implementering en ondersteuning van die stelsel en die onderneming se verandering vir hospitaal besluitnemers nie.

Die doel van hierdie tesis is om (a) 'n PACS tegniese en operasionele struktuur, geskik vir die Suid-Afrikaanse openbare gesondheidsorg omgewing te definieer, en (b) riglyne vir die implementering en afronding van PACS vir die bestuur van die stelsel en die onderneming se verandering teen doel om progressief die gedefinieerde struktuur te bereik.

'n Kombinasie van literatuur navorsing, veldwaarnemings en fokusgroepbesprekings het gelei tot die begrip van die huidige ("as- is") PACS gesondheidsorg proses in Suid-Afrika en die hindernisse daarvan. Drie tipes PACS strukture is tans beskikbaar in SA: 'n DICOM (net-mediese- beelde) beheer stelsel, 'n verkoper verskafde PACS, en 'n super-PACS.

Deur uitgebreide navorsing is daar gevind dat baie min PACS stelsels in Suid-Afrika tans operasioneel en geïntegreer is met ander gesondheidsorg instellings. Dit was te danke aan 'n kombinasie van faktore: a) die kompleks, lang ketting van interafhanklike proses stappe en gebiede; b) ondernemer opgelê beperkings en ordentlikheid data formate; in kombinasie met c) 'n gebrek aan beheer standaarde integrasie van digitale PACS stelsels om te verseker binne die lewering van gesondheidsorg-omgewing, en laastens d) sleutel besluitnemers nie die

deskundige kennis wat nodig is om ingeligte besluite te sit en te bestuur PACS optimaal te benut.

Verdere navorsing het gelei tot die vestigting van die geskikde("to-be") PACS tegniese en operasionele struktuur, vir die Suid-Afrikaanse openbare gesondheidsorg omgewing. Die geskik PACS tegniese en operasionele struktuur bestaan uit ‘n hospitaal-besitde PACS stelsel, vry van ondernemer-opgelegde grense. Die stelsel bestaan uit twee databasisse, een met 'n pasiënt inligting en die ander met dei pasiënte se mediese beelde. Die twee databasisse geïntegreer deur 'n hospitaal-besitde-rekenaarbediener, wat toegang tot die afsonderlike data lêers het deur middel van die unieke pasiënt nommers.

Die vereistes vir die PACS implementering en afrondings riglyne, vir die bestuur van die stelsel en die ondernemings veranderinge, is ontwikkel. Verskillende ondernimings argitektuur raamwerke is oorweeg en vergelyking in terme van hulle vermoe om aan die gesigde vereistes et voldoen. As ‘n resultaat is die volwassenheid model (MM) beskou as die toepaslike raamwerk om riglyne vir die bestuur van PACS implementering en afronding in die openbare mediese sektor van Suid-Afrika te bied. Na die beskikbare MMs geasseseer was en nie voldoende bewys is, was 'n nuwe MM ontwikkel vir die implementeering en afronding van PACS.

Die studie was gevalideer deur middel van die bruikbaarheid studie, gebruikers aanvaarding en doelwit asseseering, deur middel van fokusgroep besprekings en kundige oorsig. Gebruikers het gevind dat die model geskikte as implementeerings en afrondings gids, sowel as 'n geskikte strategiese beplanning hulpmiddel is. Verifikasie is bereik deur middel van vereiste-ontleding en konsekwentheid analiseering deur die fokusgroep besprekings en spesifikasie analise. Die PACS tegniese en operasionele struktuur wat definieer was, is geskik vir die Suid-Afrikaanse openbare gesondheidsorg omgewing en dat die riglyne vir die implementering en afronding van PACS funksioneel is . Die implementering en gebruik van die gedefinieerde struktuur deur mideel van die PACS MM in Suid-Afrika, sal help in die verbetering van gesondheidsorg dienslewering en die verbetering van PACS stelsel operasie.

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Glossary

Terminology	Description
PACS	Picture Archiving and Communications Systems
MM	Maturity Model
ICT	Information and Communication Technology
SA DoH	South African department of health
DICOM	Digital images and communication in medicine
GP	General practitioner
PACS SC	PACS Service Class
TCP/IP	Transmission Control Protocol/ Internet Protocol
AE	Application Entity
SCP	Service Class Provider
SCR	Service Class Receiver
OD	Object Definition
UID	Unique identifier
ID	Identity document
HL7	Health level 7
NIMM	NHS infrastructure maturity model.
PMM	PACS Maturity Model developed by van Wetering
TMSMM	Telemedicine service maturity model
IT	Information technology
IS	Information system
HIS	Hospital information system
EA	Enterprise Architecture
EAF	Enterprise Architecture Framework

ZEF	Zachman Enterprise Framework,
TOGAF	The Open Group Architecture Framework
FEA	Federal Enterprise Architecture
GM	Gartner Methodology

1 Introduction

1.1 Background

The South African population is socio-economically divided, with clear distinctions based mainly on wealth and location (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011). The country has excellent medical resources, but in the public medical sector, advanced resources and specialist medical care are limited to tertiary hospitals located in metropolitan areas. The majority of the South African population falls in the low-income bracket and the far-flung geographical extremities of much of the country, which frequently leads to vast distances being covered to report for tertiary medical care. Thus, many citizens are not gaining access to these hospitals, and are therefore denied proper, specialised healthcare services (Doubell A. , 2011). Due to the country's current fiscal and economic conditions, these limiting factors will not be overcome easily and will continue to block the way for specialised medical resources to reach those who need treatment (Doubell A. , 2011) (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011) (Jennett, Gagnon, & Brandstadt, 2010).

Numerous sources (Doubell P. A., 2011) (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011) (Jennett, Gagnon, & Brandstadt, 2010) (Mars, 2009) (Marthinussen, Mr, 2012) (Reed, 2010) agree that the above-mentioned problem can be overcome by facilitating specialists with full access to patients' clinical information and diagnostic data, enabling specialists to remotely assist local doctors, working in far-off locations. In this way, rural patients will be diagnosed and treated locally, without having to travel to a tertiary hospital for initial diagnostic purposes, resulting in more patients being treated.

To allow specialists access to remote patients' medical information, healthcare departments need to implement digital medical-image sharing between clinicians. This process becomes a burden due to: (a) the resource-intensive and lengthy chain of human interaction, prone to human error, needed to share patients' medical images; in addition to (b) the complex format, size and critical nature of the medical imaging data. The advances in technology led to the development of a digital medical-image management system that allows sharing of digital medical images, called Picture Archiving and Communications Systems (PACS).

PACS was developed to allow the secure digital storage and transfer of complex medical images throughout the healthcare delivery process. It consists of hardware and software for management, storage and transfer protocols (Schulze, et al., 2007) (Bick & Lenzen, 1999)

(Huang H. , 2004). PACS, therefore, makes complex medical images accessible in a digital format from multiple locations and so eases the process of healthcare delivery.

The South African Department of Health (DoH) has recognised the potential benefit of PACS in addressing the health needs of the country and reaching more rural patients, and therefore promotes and funds its implementation in the public health sector of South Africa. Despite the numerous deployment attempts and the DoH's support for PACS, the system is not operating successfully; in fact, few PACS systems are operational in South Africa (Doubell P. A., 2011).

Overcoming the initial obstacles for the implementation of a digital system in organisations has has been a topic of study since the first computers were used (Patterson, 2005). Numerous sources (Umble, et al., 2003)(Nah, 2006)(Otieno, 2010)(Peterson, 1994)(Cook, 2000)(Dorsey, 2005) agree that the critical success factors for a new digital system to operate in an enterprise can be grouped into the following solutions: (a) clear vision and goals; (b) the commitment of top management; (c) the appropriate technical and operational solution and lastly; (d) proficient project and change management.

1.2 Problem statement

Healthcare departments in South Africa have been attempting to implement PACS in hospitals for over ten years. Implementing PACS in South Africa is one of the SA DoH's main objectives in their 2012 eHealth strategy (DoH, 2012). It is clear that the South African DoH's PACS vision is to improve the healthcare environment in South Africa (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011)(DoH, 2012).

PACS was chosen due to its proven success as an appropriate technical solution in international hospitals (van Wetering, 2008)(Horri, 2010). However, specifications, guidelines and best practice operational methods for the appropriate PACS technical structure are lacking in South African literature and in governmental strategies. Additionally, there are no guidelines for implementation or support for hospital decision makers to manage the system and enterprise change.

1.3 Purpose

The purpose of this thesis is to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure

1.3.1 Research objectives

In order to reach the purpose of thesis the following objectives were set:

1. Investigate the current South African public healthcare environment to define the barriers for PACS deployment and operation.
2. Define a technical- and operational- PACS structure, suited for the South African public healthcare environment that will overcome the current barriers, identified in (1).
3. Define the requirements for PACS implementation and optimisation guidelines, which will assist hospital decision makers to manage the system and the enterprise change and progressively reach the defined structure.
4. Assess the five common Enterprise Architecture frameworks for suitability to the requirements defined in objective 3.
5. Investigate available Maturity Models for suitability to PACS optimisation within the South African public healthcare environment.
6. Acquire an appropriate PACS maturity model with implementation and optimisation guidelines for decision makers in the South African healthcare environment to progressively reach the state formerly defined.

Figure 1: Goal steps

1.3.2 Research methodology

In order to reach the purpose of this thesis, a problem-oriented approach was followed in an iterative process to finally reach a desired outcome of defining a PACS technical and operational structure suited for the South African public healthcare environment and developing guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. Mouton (2001) defines this approach as *problem focused continual research*, used to iteratively build and evaluate intermediate solutions, in order to extend existing capability limitations, until the desired model is reached.

The final model is then verified against the defined design specifications established, and partially validated against the initial problem's result requirements. The research methodology is explained in more detailed, regarding every chapter, in the next section 1.4.1.

1.3.2.1 Document structure

This research was conducted with an iterative approach, continually contributing to each of the objectives, the final findings were grouped and each objective was addressed in a single section of the thesis. Therefore, the thesis consists of nine interrelated parts; first the introduction, then six parts, which each addresses an objective and its relevant sub-research, and finally the validation, verification and conclusion.

1. Investigate the current South African public healthcare environment to define the barriers for PACS deployment and operation.

In this chapter, the current South African public healthcare environment was investigated to define barriers for PACS deployment and operation through the following;

Firstly, in Chapter 3, a general study of the South African public healthcare environment and a study on the available PACS products were conducted. A combination of a comprehensive literature study, industry interviews and multiple telemedicine conference attendings led to the understanding of the public healthcare environment. The outcome of the study identified the general steps involved in the PACS healthcare delivery system and the associated technical PACS workflow. The current available off-the-shelf PACS products were examined by combination of literature research and expert review.

Secondly, in Chapter 4, the current healthcare delivery systems of three South African public hospital groups were closely examined. A focus on these three hospital groups across two provinces determined the status quo of their current PACS healthcare delivery systems and the barriers obstructing the optimal functioning of their healthcare delivery systems. This section highlights technical and operational gaps in the South African public healthcare System. Lastly, the barriers faced in the South African public healthcare environment were transformed to user needs for the South African public health care delivery process, listed in 4.2

2. Define a technical- and operational- PACS structure suited for the South African public healthcare environment that will overcome the current barriers, identified in (1).

The technical and operational PACS structure, suited for the South African public healthcare environment, to overcome the current barriers, was defined by:

Firstly, in Chapter 5, the desired technical and operational PACS healthcare delivery structure, suitable for the South African healthcare environment was established. This was done through an extensive research study, which built on the technology available and the current healthcare system barriers. The current system was adjusted, using the available technology and South African hospital environment characteristics to ultimately reach the desired technical and operational structure. The result of Chapter 5 was a technical PACS structure and an accompanying operational workflow method that would allow for an effective, streamlined PACS healthcare delivery system in South Africa.

3. Define the requirements for PACS implementation and optimisation guidelines, which will assist hospital decision makers to manage the system and the enterprise change and progressively reach the defined structure.

In Chapter 6 the PACS healthcare delivery system is addressed in further detail by looking at the management difficulties faced, together with the lack of technical knowledge and scientific literature to support implementation and management of PACS in South African hospitals. Therewith the suitable requirements for implementation and optimisation were developed, using knowledge of the current system and the desired structure, as well as enterprise development literature.

4. An assessment of the five common Enterprise Architecture frameworks - investigating their suitability to the requirements defined in chapter 6 (objective 3).

In Chapter 7 the definition of Enterprise Architecture (AE) is discussed, as appropriate to this thesis. Five common AE frameworks (Zachman Enterprise Framework, The Open Group Architecture Framework, Federal Enterprise Architecture, The Gartner Methodology, and Maturity Models) are compared by, scoring their performance on each of the requirements defined in chapter 6.

7. Investigate available Maturity Models for suitability to PACS optimisation within the South African public healthcare environment.

A literature study, regarding current the definition and purpose of MMs and the current MMs in healthcare (NHS Infrastructure Maturity Model, PACS Maturity Model, Telemedicine Maturity Model) was used to examine Maturity Models for suitability to the South African public PACS healthcare delivery process. (Chapter 8)

8. Acquire an appropriate PACS maturity model with implementation and optimisation guidelines for decision makers in the South African healthcare environment to progressively reach the state formerly defined.

From the knowledge gained through empirical and literature research, a new maturity model was developed for the deployment and maturation of PACS, best suited for the needs of the South African healthcare delivery system. Firstly, the dimensions and components of such a model were addressed in Chapter 9, and secondly the PACS MM, consisting of descriptive development plateaus of the PACS healthcare delivery system, were addressed in Chapter 10. To assist maturation and accompany the PACS MM levels, prescriptive development guidelines were established to guide hospital decision makers in improving PACS to a higher maturity level. These development guidelines are addressed in the second section of Chapter 10.

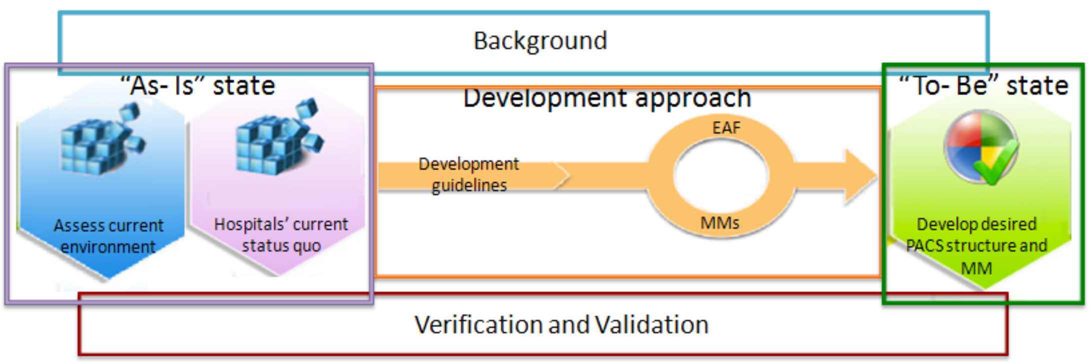


Figure 2: Thesis structured argument methodology

To complete the thesis structure, the structured argument attending to the research objectives was commenced by an introduction and concluded by verification validation and conclusion. The introduction addresses the origin and definition of technology used in medicine, with an emphasis on PACS and the South African background. This chapter addresses the need for PACS, and the vision of the South African DoH, as well as their commitment and support to PACS. The introduction is attended to in Chapter 2. The argument is concluded in Chapter 11 with a verification and validation of the PACS technical and operational structure and MM for the South African public healthcare environment. The study was validated by user acceptance, usability tests and goal checking. This was conducted by means of a case study and focus group discussions. Users found that the model was a suitable deployment and optimisation guide, as well as a strategic planning tool. Verification was achieved by requirement analysis, consistency checking and methodology analysis. This was conducted by means of literature research and analysis of the case study output. Lastly, chapter 12 addresses the outcome, shortfalls and the conclusion of the thesis.

The previously stated structure forms the methodology of the thesis whereby research (developing a framework to assist the deployment and maturation of PACS within the South African public healthcare environment) was addressed. The structure of the methodology is illustrated in **Figure 3**.

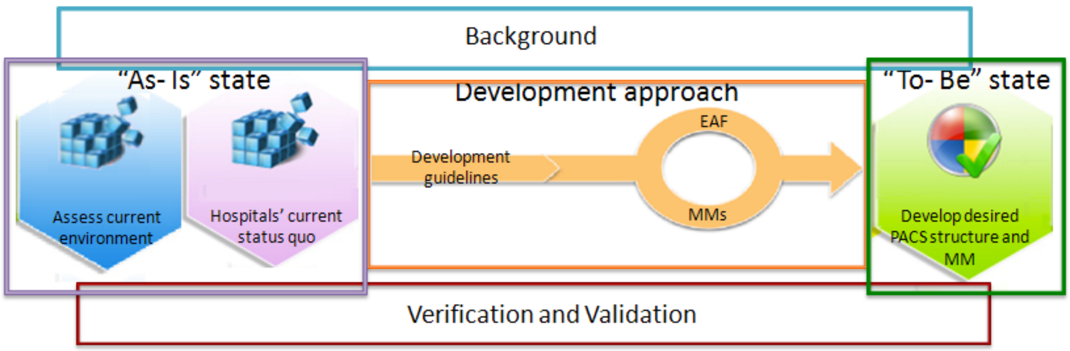


Figure 3: Thesis Methodology

As illustrated in the methodology, in the next chapter, the thesis starts with an introduction to the origin and definition of technology used in medicine, with an emphasis on PACS, as well as the history of PACS implementation in South Africa.

2 A background to technology being used to assist healthcare over distance

In the problem statement it was highlighted that PACS was chosen due to its proven success as an appropriate technical solution. Furthermore, the DoH has a vision for PACS implementation and supports it. In this chapter it is stated that PACS is not currently implemented successfully in South Africa, due to a lack of an appropriate technical and operational structure, support and guidelines for implementation and optimisation of PACS in South Africa. Before the current situation is examined for barriers to PACS, this chapter addresses the history of telemedicine, the history of PACS and the DoH's PACS vision in South Africa, as shown in Figure 4.

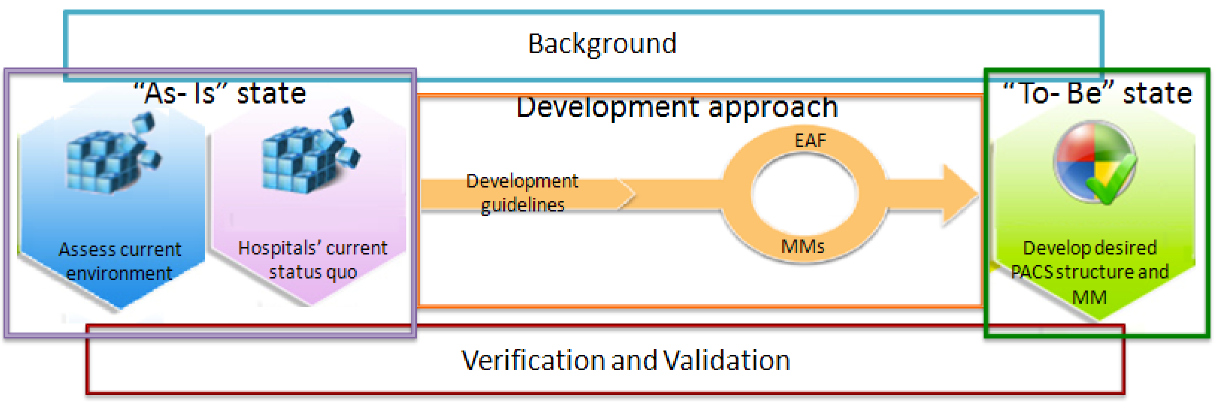


Figure 4: Background methodology

2.1 Telemedicine

The use of technology, to facilitate remote healthcare delivery, can be traced back to the 19th century (Patterson, 2005). One of the first published accounts occurred in the early part of the 20th century, when electrocardiograph data were transmitted over telephone wires (Patterson, 2005). In the 1960s, largely driven by the military and space research development, technology advanced rapidly and made its way into the medical field (Currell, 2000). Examples of early milestones include the use of television to facilitate consultations (Benschoter RA, 1965) and even the provision of expert medical advice via telephone (Dwyer, 1973).

In the 1970s the term "telemedicine" was accepted as a direct equivalent of "medicine over a distance". Since then many other similar terms have been coined: eHealth (electronic health), mHealth (mobile health), teleHealth (health over a distance). All these terms imply that some form of technology is used to increase patient access to medical care and/or information, thereby improving the patient's health outcome.

Acknowledging that there is not merely one correct term or all-encompassing definition, four elements (relevant to the concept of *'healthcare over a distance'*) were highlighted by a 2007 World Health Organization study of 104 peer-reviewed definitions (Sood, Mbarika, Jugoo, Dookhy, Doarn, & Prakash, 2007):

1. "Its purpose is to provide clinical support.
2. It is intended to overcome geographical barriers, connecting users who are not in the same physical location.
3. It involves the use of various types of information and communication technology (ICT).
4. Its goal is to improve health outcomes."

For the purpose of this study, the original term *telemedicine* will be used and the definition of the American Telemedicine Association will apply: *Telemedicine is the exchange of medical information from one site to another via ICT to improve access to medical services* (American Telemedicine Association, 2012).

Recent progress in telemedicine, and increasing availability and utilisation of ICTs by the general population, are rapidly creating new possibilities for healthcare service and delivery, sparking widespread interest among healthcare providers (Patterson, 2005) (Currell, 2000). This is the trend in developed as well as developing countries (Wootton, Jebamani, & Dow, 2005). The interest shown locally has been on the part of the SA Department of Health (DoH), as they recognise the potential of telemedicine, and PACS in particular, to deliver better healthcare to the rural areas.

2.2 Picture Archiving and Communication Systems (PACS)

PACS is a medical-image management system, developed to allow secure inter-operable storage and transferral of medical images within and between healthcare enterprises (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 1 – What is PACS?, 2007) (Bick & Lenzen, 1999) (Huang H. , 2004).

A PACS consists of hardware for storage and transfer, and software for data storage formats and transfer protocols. Together the system acquires its medical images digitally, from the imaging modalities (e.g. computed tomography, magnetic-resonance imaging, ultrasound and standard X-ray) and processes the images and accompanying data to model for storage. The system stores the processed data in a central archive to make it available on request. Clinicians can therefore gain access to data for analysis and image interpretation via a network link (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 1 – What is PACS?, 2007) (Bick & Lenzen, 1999) (Huang H. , 2004) (Van der Wetering & Batenburg, 2009). The basic PACS structure, with the elemental PACS components, can be seen in Figure 5.

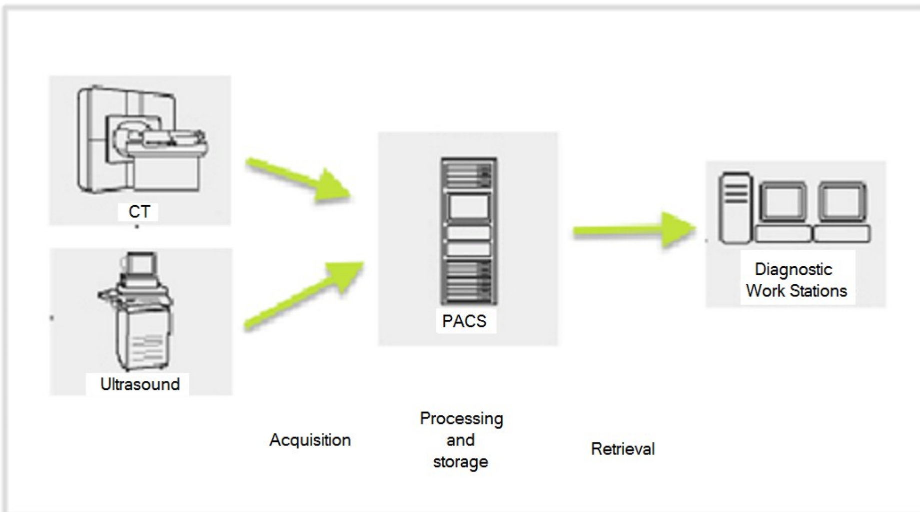


Figure 5: The basic PACS structure

PACS started out as a digital, image-sharing system that handled only digital medical images in DICOM (digital imaging and communications in medicine) format (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 2 - Why should we change to PACS?, 2007). DICOM is an industry standard format for the storage and transfer digital medical images, which contains network communications protocol and file-format definition. The first standard DICOM contained only two-dimensional image data (such as x-rays and sonar slices), but later developed, to contain all imaging data (including sonars and nuclear-based medical results). With the development of digital imaging data, new PACS viewers emerged with a multitude of post-processing capabilities, such as Doppler measurements, bone-density analysis, time studies and four-dimensional (three-dimensional over time) image processing (Huang H. , 2004). As medical-imaging capabilities and the data sharing and viewing capabilities of PACS advanced, users throughout the healthcare-delivery domain became positive towards the use of digital images and started requesting, accessing or using digital medical images.

PACS, however, only shared digital medical images and no patient history information. It therefore restricted diagnostic capability (Huang H. , 2005) (Marthinussen, Interview:

Telemedicine in Eastern Cape, 2012). The PACS structure has thus been developed to incorporate some additional patient information (Huang H. , 2005).

2.3 South African healthcare environment and DoH PACS vision

South Africa's gross socio-economic inequalities, and disparate demographic circumstances, place immense strain on the ability of the healthcare system to reach all of the population (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011). The country has excellent medical resources, but unfortunately distribution favours urban areas, where specialist hospitals are situated. The structure of healthcare system in SA consists of three levels of hospitals that interoperate to treat patients (SA Department of Health , 2010). Districts hospitals (tier 1) make up the first level of admission, with general care and general practitioners being made available. Patients in rural areas go to the local district hospital, where they are diagnosed and treated as far as is possible. If the district hospital cannot diagnose or treat the patient, the patient is sent to the appropriate regional hospital (tier 2). Regional hospitals provide care, which requires the intervention of basic specialists and general practitioners (or a single specialist service). At a regional hospital the most suited specialist, qualified to examine or treat the patient, is identified. If patients are diagnosed and able to be treated at the district hospital, they are sent back for treatment, otherwise they are treated at the regional hospital, or if further diagnosis or specialist treatment is needed, they are sent to the specialist hospital (tier 3). The number of patients admitted to hospitals that need to be examined by specialists, rises exponentially for every hospital tier (i.e. specialised level). Higher tiered hospitals are consequently far more congested; therefore, wherever possible, patients are sent back to rural hospitals to be treated. Tier 3 hospitals provide specialist facilities and specialist care, and only receive patients on referral form tier 1 and 2 hospitals, or in cases of emergency. Tier 3 hospitals are mostly situated in urban areas where they have the necessary resources and facilities to receive all the incoming patients. Where possible, patients are sent back to referring hospitals for treatment, due to the high demand for specialist care, that are limited. As these facilities and their specialists cannot attend to the needs of all patients, the SA DoH emphasises PACS as a tool in assisting medical information and image sharing between these facilities, thereby allowing specialists to support local doctors in diagnosing rural patients. This remote diagnosis would avoid the unnecessary referral of patients for diagnosis only, and allow patients (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011).

A high birth rate and an increased prevalence of diseases like TB and HIV are common in rural areas where medical facilities are scarce. In South Africa, about 60% of financial and human healthcare resources are absorbed by only 20% of the population (Department of Health, 2010). The previously stated conditions result in a great number of patients in rural areas not gaining access to urgent specialised medical resources with the current healthcare system structure. Rural hospitals cannot attend to the needs of all the patients and need assistance from specialist hospitals. The figures for South Africa are not clear, but Africa is estimated to have spent in excess of R55 billion (or 8.5% of its gross domestic product (GDP)) on health services in the 1998/9 financial year (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011). However, despite relatively high national expenditure, the health status of the South African health system rates comparatively lower than that of other countries, including even some from third world sectors (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011).

South Africa recognised the potential of telemedicine to deliver healthcare to rural areas and in 1998, the first phase of the implementation of South African telemedicine began, guided by the National Strategy for Telemedicine. The objectives of the strategy focused on obtaining a more effective health system with high-quality, cost-effective healthcare and making specialist healthcare more accessible than it had previously been (Khoja, Scott, Casebeer, Mohsin, Ishaq, & Gilani, 2007) (Department of Health, 2010). In 1999 the DoH initiated 28 pilot telemedicine projects, in six different provinces. The initial focus of the projects was on tele-radiology, together with tele-ultrasound, telepathology and tele-ophthalmology in several provinces, including Limpopo, Free State, Eastern Cape, Northern Cape and Western Cape. Most of these original pilot projects have been discontinued, except for some tele-radiology and tele-dermatology projects (Department of Health, 2010). Today, tele-radiology and tele-dermatology are seen as the two most promising telemedicine projects, greatly due to the availability of PACS along with theoretical evidence to warrant the possibility of sharing medical images. Many people in healthcare are, however, becoming disillusioned by these failed promises. In practice, the projects have not reached nearly their expected results and the SA PACS status quo currently lags about ten years behind our first world counterparts (van Heerden, Lockhat, Bam, & Fletcher, 2011).

Most hospitals in SA have either obtained PACS or are trying to do so. Unfortunately, the system is not operating successfully (Doubell P. A., 2011) (Marthinussen, Interview: Telemedicine in Eastern Cape, 2012). The current South African DoH telemedicine strategy emphasises PACS as an area of focus, which should be operational between governmental hospitals by 2016 (SA Deaprtment of Health , 2012).

2.3.1 The reasons for using PACS

Medical images are used throughout the healthcare delivery process at different times and in different locations (this is discussed in more detail in section 3.1). PACS is necessary to eliminate the dependency on hard-copy printed images and patient files and to ease the workflow, by digitally managing and transferring the patient images and accompanying patient information. Furthermore, digital images can be transferred immediately over distances, whereas hardcopy images cannot. However, allowing specialist access to rural patient information, to assist diagnosis, is not the only advantage to PACS. Below is a list of additional reasons why PACS is essential to improving overall healthcare delivery in South African hospitals:

- Ineffective diagnosing techniques are currently being used. Patients are sent from rural hospitals to specialist hospitals to be diagnosed; the specialists are situated at these specialist hospitals. The patients are then sent back to rural hospitals for treatment, because specialist hospitals cannot treat everybody who is referred to them. Sometimes a simple treatment such as managing TB or cholesterol medication is called for, or a minor operation must be performed, or an opinion on the state of an unborn baby is needed. If specialists can do this from the hospitals where they are based, without having the patient transported to where they are situated, it would save a great deal of time and money and allow specialists to see more patients.
- Hard-copy images can only be in one place at a time. If a referring clinician wants an opinion or an examination performed, the clinician, radiologist and the relevant images should be present at the same venue at the same time to allow them to proceed. The paper-based image management system is a very resource-intensive approach and is dependent on a long chain of human interaction, which often fails.
- Not all images can be printed; specialised imaging equipment generate large numbers of images or three dimensional motion clips that remain digital. In the short term, the complete study is available for reporting, but in the long run the results are comparatively suboptimal.
- Lost information: Hard-copy information is more difficult to back up and access, due to human error in the execution of organisational aspects, such as filing and information management. This results in not being able to make a comparison or having to repeat the examination. It has been proven that, within a film-based department, a radiologist refers to the previous imaging examinations in only 56% of cases, whereas in a digital

department the same radiologist will refer to the previous imaging examinations in 86% of cases.

- Poor comparisons: Making comparisons is dependent on having both the current and previous imaging examination available and in good quality. Lost images result in unnecessary repeat examinations which could lead to additional, unnecessary radiation exposure to the patient, as well as wasting resources, including: human, time and monetary. It is estimated that at Tygerberg Hospital, as many as 5 - 7% of imaging examinations are performed to replace lost images (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 2 - Why should we change to PACS?, 2007).
- Limitations of film: An image is not always taken perfectly the first time; this results in unusable under- or over- exposed films. Tygerberg Hospital wastes 34 848 films per year; that equates to R97 574.40 per year (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 2 - Why should we change to PACS?, 2007).
- Delayed clinical decision-making: The time delay associated with finding patient information and obtain specialist opinion, result in delayed clinical decision-making, which can often be to the detriment of the patient.
- Cost of storage: Multiple resources are required for the physical storage of imaging examinations in such a way that they can be easily retrieved for future use. This includes the filing packaging, the filing room indexing system, the physical space required for storing, the filing clerks and the porters responsible for the transport of images. At Tygerberg Hospital, R35 000 is spent on filing packaging annually and there are 63 full-time employees responsible for filing patient images. A storage room of over 900m² is required for only two years' worth of x-rays (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 2 - Why should we change to PACS?, 2007).
- Cost of film: The following statistics are quoted from a recent survey of the Department of Radiology at Tygerberg Hospital. Firstly, there is the cost of developing film, which includes the darkroom assistants (at R350 000 per year), the chemicals used for development (R306 000 per year), the cost of the film (R1 641 384 per year) and maintenance costs (R67 812 per year). Secondly, there is the cost of printing on the laser camera (R1 000 000 per year) and equipment maintenance costs (R207 128 per year). Lastly there is the matter of time lost by radiographers developing film, while they could be performing more imaging examinations (Schulze, Greyling, Hayes, & Andronikou, Talking PACS: Part 2 - Why should we change to PACS?, 2007).

The advantages of PACS are: superior patient care; improved comparison; faster clinical decision-making (leading to shorter hospital stays); less unnecessary radiation exposure; and decreased waiting times across the board. There is also increased access available to rural patient diagnosis and a decreased need to transfer patients, thereby increasing the number of patients accessed by specialists.

2.3.2 Department of Health vision for PACS in South Africa

Implementing PACS in South Africa is one of the SA DoH's main objectives in their eHealth strategy (DoH, 2012). The DoH aims to improve patient's access to specialised medical care by allowing specialist to access patient medical information and assist patient treatment and diagnosis, remotely. This will increase the speed of treatment and decrease patient's chances of mortality. Additionally, the DoH sees the advantage that PACS will improve patient treatment workflow and decrease treatment costs by decreasing the need for patient re-examinations, referals and specialist relocation. Thereby improving the overall public healthcare system in South Africa, which is a SA 2012 millennium development goal (South African Department of Health, 2013)

After establishing that PACS is operational in most international hospitals of first and third- world countries (van Wetering, 2008)(Horri, 2010) along with the support offered by SA DoH for PACS, there is theoretical proof for PACS' success in South Africa. In practice, however, PACS' success has not yet been achieved in South Africa. Healthcare departments in South Africa have been attempting to implement PACS in hospitals for over ten years.

In this chapter it was indicated that PACS was chosen as a solution for the South African health system problems due to its advantages for the country and its proven success as an appropriate technical solution word-wide. However, specifications, guidelines and best practice operational methods for the appropriate PACS technical structure are lacking in South African literature and in governmental strategies. The next chapter will look specifically at the South African health care system and the barriers for PACS deployment and operation.

3 The current ("As-Is") PACS healthcare delivery structure in the South African public healthcare environment

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. This chapter focuses on objective one and thus addresses in more detail the current (“As-Is”) PACS healthcare delivery system in South Africa and the barriers faced. In the chapter the generic PACS healthcare delivery process in South African public healthcare environment is discussed and the current off-the-shelf PACS products available and their limitations, as seen in the methodology in Figure 6.

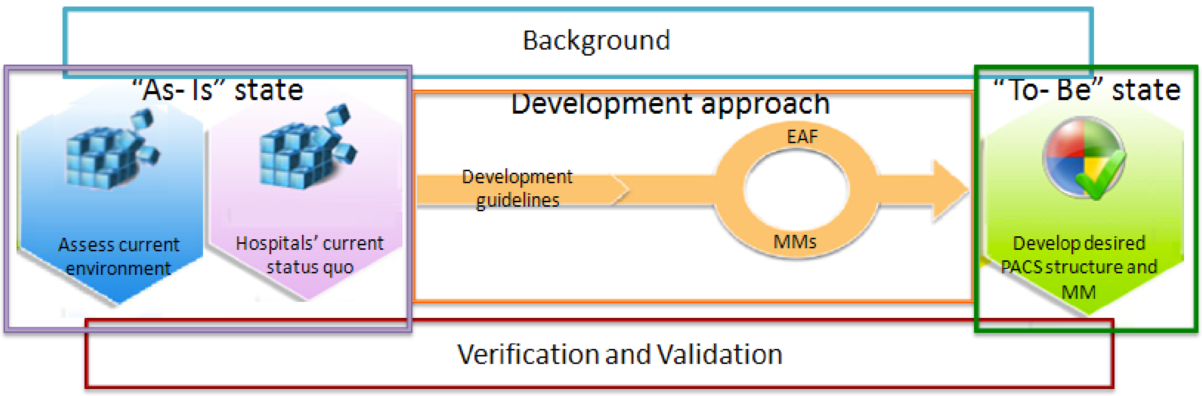


Figure 6: “As- is” methodology

3.1 The general PACS healthcare delivery process

Before assessing PACS it is necessary to establish where PACS would be used in hospital in South Africa. For the purpose of this thesis, the general PACS healthcare delivery process is the medical / healthcare process of treating patient where PACS is used, or would be used when implemented. The general PACS healthcare process was established in a previous study (Triegaardt, M., 2010) to be the following: The PACS healthcare delivery process starts with the arrival of a patient in need of treatment. The clinician examines the patient and could possibly suggest that the patient requires an imaging examination in event the patient is then sent to the imaging modality. This is where medical images enter the healthcare delivery process for the first time and the healthcare delivery process, for purposes of this study project, commences. The clinicians at the imaging modality will then briefly again examine the patient and capture the image with the imaging modality. The image is generated and the clinician examines it, together with the patient information or medical history, to make an informed diagnosis (Doubell P. A., 2011).

If the clinician cannot make a diagnosis, the image is sent to a specialist to assist in making a diagnosis, or the patient is referred to the specialist. As soon as the treatment procedure has been decided on, the patient is sent for treatment (Doubell P. A., 2011). In the case of a treatment, which requires physical medical procedures, the clinician performing the procedure needs to analyse the images and information. Often the images need to be at hand during treatment, in order to visualise the area that needs to be treated (for example, in performing an operation on a broken arm, the image needs to be present to locate the bone fragment). The image is therefore used throughout the healthcare delivery process by different users and at different locations.

The imaging healthcare delivery process is narrowed down to the six fundamental steps that form all of the above operations.

- Healthcare delivery step 1: Capture patient image
- Healthcare delivery step 2: Transmit patient image and data
- Healthcare delivery step 3: Store patient image and data
- Healthcare delivery step 4: Retrieve patient image
- Healthcare delivery step 5: Analyse patient image
- Healthcare delivery step 6: Compile patient feedback

Figure 7 illustrates the fundamental steps of patient imaging healthcare delivery.

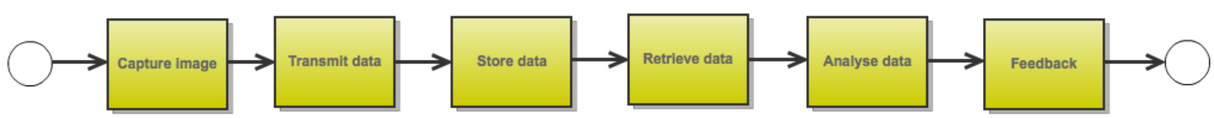


Figure 7: Patient imaging healthcare delivery process steps

The six fundamental steps are broken into secondary steps to describe in more detail the patient imaging healthcare delivery process. The clinician and imaging equipment firstly captures the image and then the software forms the image in digital format to be displayed on the modality (it is then ideally used digitally, or else less ideally the image is burned to a CD or printed to hardcopy). A clerk performs the printing task when necessary. The image is linked to the patient's information in the patient file (whether it is a hardcopy or electronic patient file). The image is then filed and the file is sent for storage. The file is stored (ideally on a digital archive or else, less ideally in a hardcopy filling room).

To retrieve the image, the patient file is accessed (the hardcopy file or the digital image file). The primary clinician or a referral specialist can access the file. If this is a hardcopy file, however, it is only accessible to the clinicians of the hospital that the study was done in. The clerk fetches the file in the filling room and brings it to the clinician. The necessary patient information and images are retrieved from the file and analysed to form a diagnosis. If more information is necessary, the clinician either refers the patient back to have additional images taken, contacts a specialist to assist with the image diagnosis or, if the patient can still not be diagnosed, the patient can be referred to a further specialist for an examination to be performed.

On the other hand, if a diagnosis is made, the conclusion or feedback is compiled in the patient file and filed together with the image. The file is sent back to storage and the patient is sent for treatment. In the same manner, the clinician performing the treatment procedure can then access the patient file and again compile feedback on the treatment procedure, which will be included in the patient file.

Figure 8 shows the process steps involved in each fundamental step, as well as the data resources used and the role-players of each step. Process steps are represented by rectangles, the data (patient information, doctor information, images) that are used at each step, is represented by a diamond shape and the user performing each step is represented by a circle, with arrows representing the process flow.

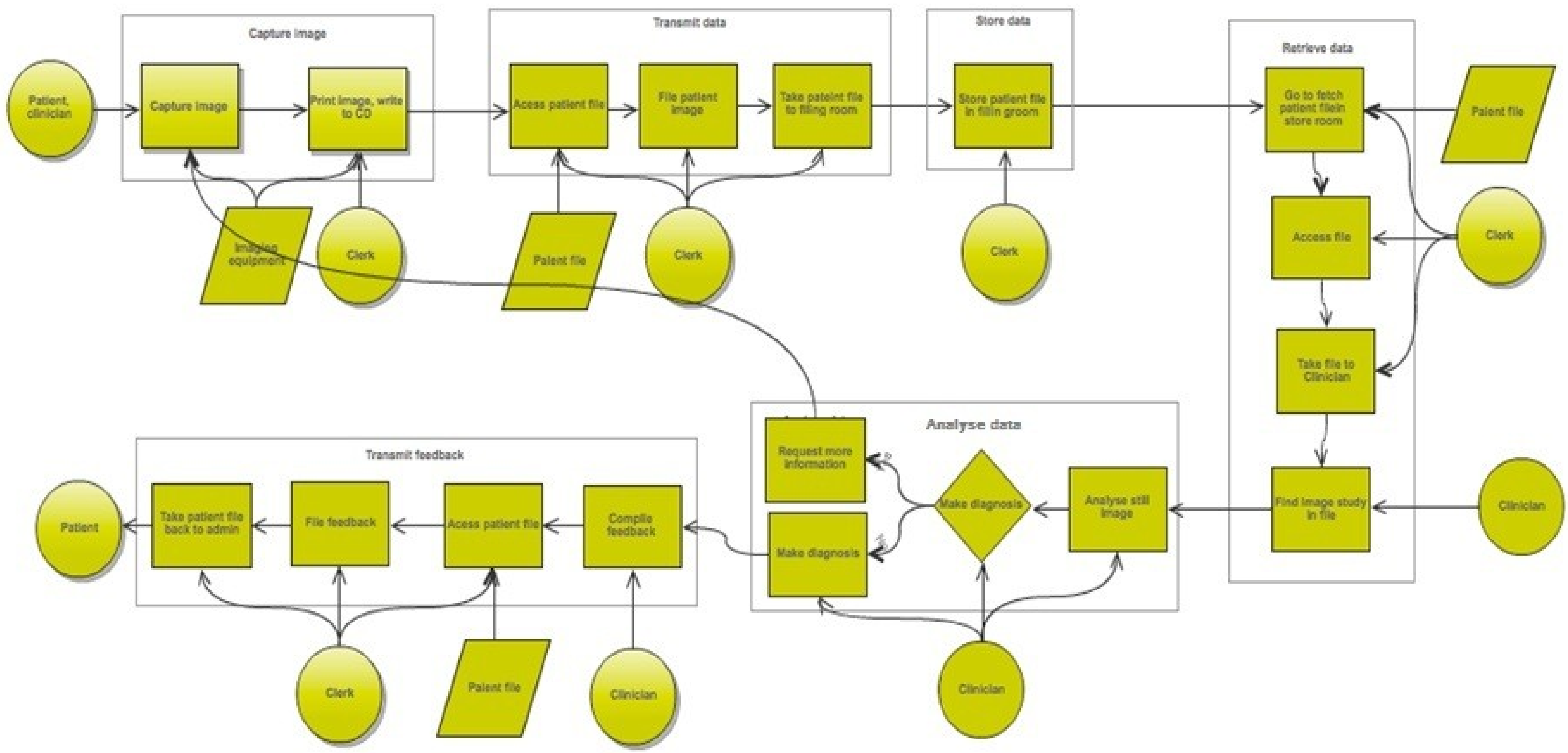


Figure 8: Workflow, information, images and users of the general PACS healthcare delivery process

3.2 The generic technical PACS structure

In order to better understand the healthcare delivery process, the technical PACS architecture and system components, as well as how they fit into the care delivery process, are discussed below.

PACS, the information system responsible for the acquisition, storage, distribution and viewing of digital images throughout the healthcare delivery process, consists of:

- Hardware devices: Imaging modalities, as well as archive and viewing stations;
- Network: The connective system operating between these devices to communicate the digital clinical images.
- Software: Each device on the PACS network has software controlling its operations. Each application is geared to produce, transfer, save and request the digital clinical images.

These are illustrated in the Figure 9 below.

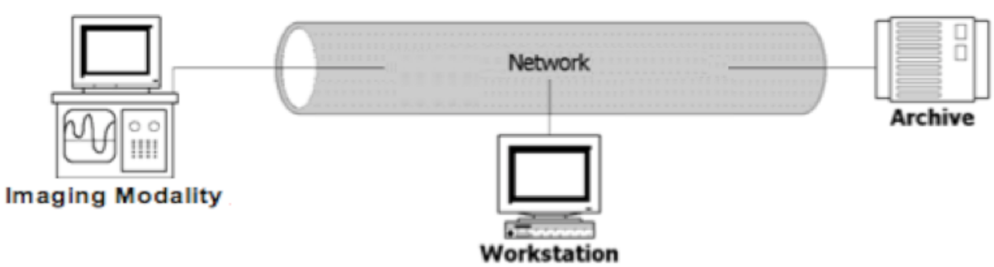


Figure 9: The basic PACS network

For each of these PACS operations, the PACS software performs a specified PACS service class (SC) action: to create digital images, PACS Create SC; to store digital images, PACS Storage SC; to search, access and recall the digital images, PACS Query/Retrieve SC; and lastly to analyse and adjust the images for diagnosis support, Reconstruct SC.

The PACS software is loaded onto the clinician's workstation and the storage archive, as well as the imaging devices. The PACS network architect then configures a network, using Ethernet cables to connect the devices to one another and the network itself. The network is heavily restricted by protocol, to allow only limited access and thus ensure patient health-record security.

Devices communicate via the network using TCP/IP (Transmission Control Protocol/Internet Protocol). The architect gives each device on the network an Application Entity (AE) title, specifying the services it offers, the transfer formats it sustains and its Internet protocol (IP) address on the network. For each SC, one device acts as the Service Class Provider (SCP) and the other acts as the Service Class Receiver (SCR). A request is sent form the SCP, with its AE title, to the SCR IP address. If the SCR accepts the request (its AE title coincides with the request, thus recognizing the IP address, offering the service and supporting the format), the operation proceeds, if it rejects the AE (or even just one format or service requested), the whole operation is terminated.

3.3 The generic operational PACS structure

The generic operational PACS structure, demonstrating how the IT system operates within the healthcare delivery process, is illustrated in the following example.

The operational workflow steps were defined as, steps:

1. An imaging examination is performed, producing a set of images, called a study.
2. The study is sent to the PACS archive to be stored.
3. A workstation queries the PACS archive to retrieve the study.
4. Analysis is done on the image by a clinician and the images are reformatted to support the diagnosis. This is done at the workstation and the reconstructed images are sent back to the archive, where they are merged with the rest of the study.

These steps are illustrated in the flow diagram in Figure 10 below, again with rectangular shapes representing the actions performed and diamond shapes the resulting process output. Each of these processes is discussed in detail below.

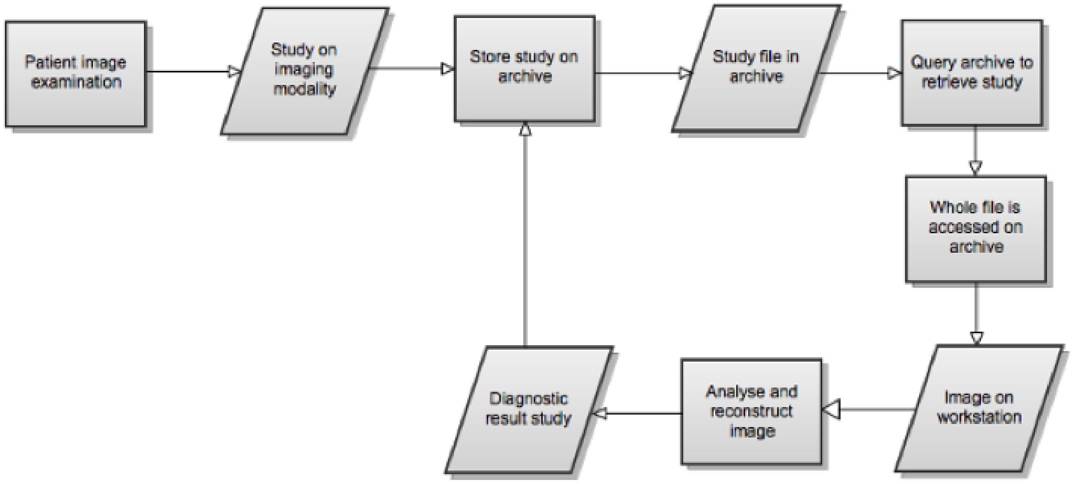


Figure 10: Technical steps in PACS workflow

3.3.1 Workflow step 1: Imaging modality generates study

After an imaging examination is completed (relating to health care delivery step 1: Capture image and step 2: transmit the data shown in Figure 7) the software within the imaging modality will create a digital image with images or a set of images/slices (when a three-dimensional image is produced) from the raw data, called a study, using PACS to create SC. Each image or slice is an object consisting of pieces of information called tags. Furthermore, each tag has a name and a value, as can be seen in Figure 11 and Figure 12 below.

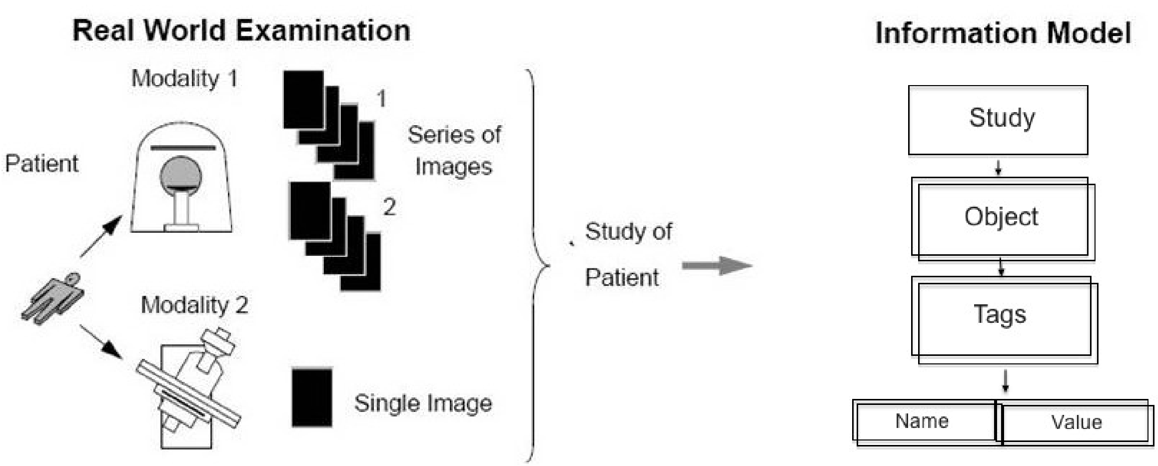


Figure 11: Creation of a digital image study

Data tags

Name	Value
Study date	2012-02-14
Modality	CT
Pixels	100023

Figure 12: Example of the composition of a data tag

For each type of study, there is an Object Definition (OD) that specifies the required tags for the object. There are image and non-image tags. Image tags are numerical image data and the non-image tags are the study demographics, such as type of study, study date, imaging modality used and hospital where the study was performed. Each OD also specifies that an object and study have a unique identifier (UID), produced by the software. Therefore, for each type of imaging examination, the modality will use the specific examination's OD as a template for how the object should be created. An example of the tags specified in an OD is shown in Figure 13 below.

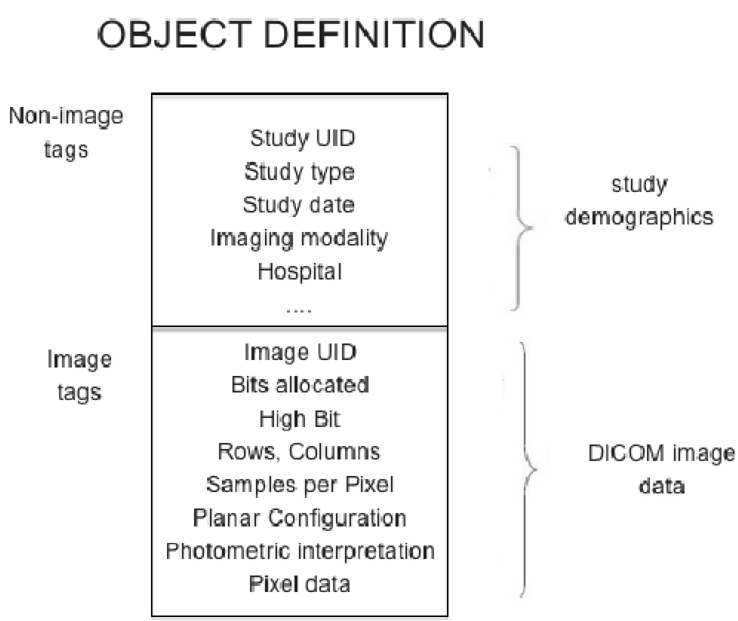


Figure 13: Object Definition (OD) tags

The imaging modality software, supplied by the PACS provider, determines the OD. All the software of digital medical imaging machines in South Africa require DICOM image conformance. DICOM specifies a certain format to produce the digital image data; nevertheless, it does not specify the format of study demographic (or non-image) data. Each PACS architect is free to decide which demographic data a study should request or record, thus a non-coherent element is still present in PACS, as inter-hospital communications vary due to the difference in ODs.

3.3.2 Workflow step 2: Imaging modality sends study to archive

After the digital study has been generated, the imaging modality software needs to send the study to a remote archive, using the PACS Storage Service Class. The network is shown in Figure 14 below. This relates to healthcare delivery step 3: Store the data, shown in Figure 7.

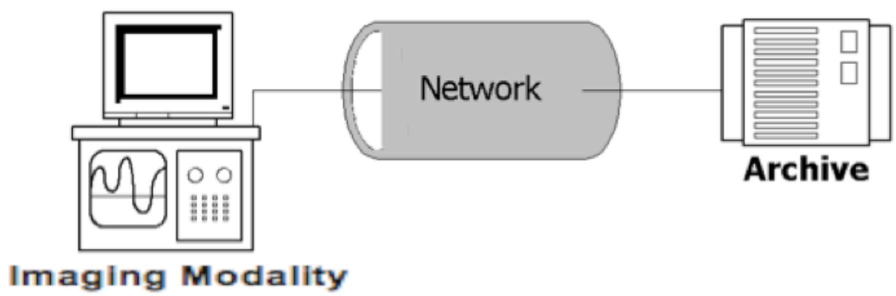


Figure 14: Imaging modality sends data to archive: storage network

The imaging console will request a destination and the additional data needed in order to save the study; for example patient name or patient ID. Again the data requested depends on the format of the image archive files, which is set up by the PACS architect.

Before any data is sent, the SCP (in this case the imaging modality software) will send its request to the SCR (in this case the archive) containing the AE title for the operation:

- The remote archive IP address (obtained for the archive destination selected);
- Its own imaging modality network IP address;
- The service requested, which will be the OD it wishes to store and the additional data it has acquired; and
- The encoding format of the data for transmission, for example, uncompressed or compressed.

The SCR (in this case the storage archive) interprets the AE title request. If its IP is correct, it responds if it recognises the SCP IP address and supports the services and transfer format specified in the AE title. A file is then created for the image/set of images, in accordance with the archive file format. An example of the tags used in a PACS patient file is shown in Figure 15 below, illustrating the non-image tags that are in proprietary format and the image tags that are in standard DICOM format.

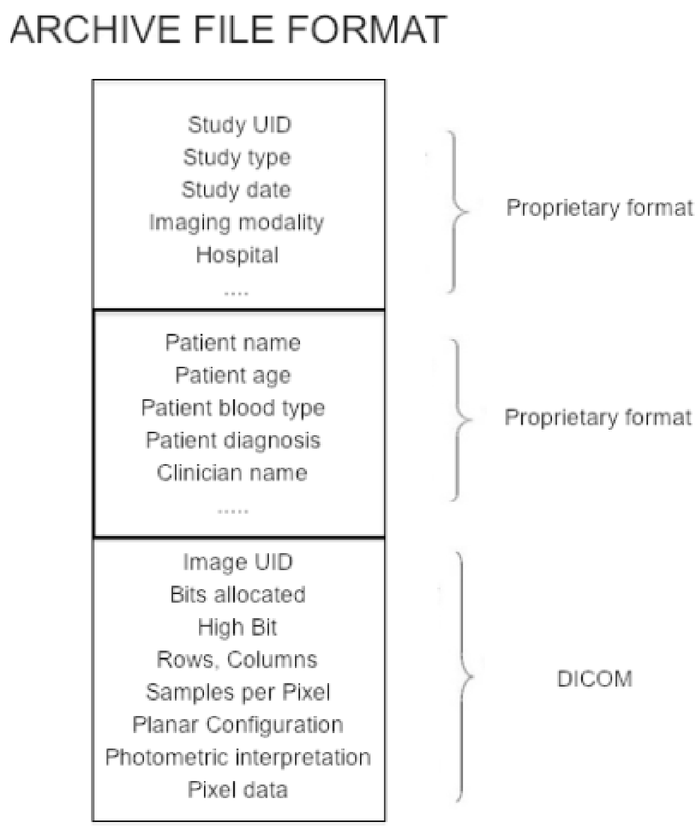


Figure 15: PACS archive patient file format

It is important to note here that each vendor's archiving file format is a proprietary solution. Each object tag is stored with a field name and its data value. The field names are numerical, but the tags essentially contain data information, be it image or non-image. In each proprietary solution, fields and field names are different, causing great interoperability problems with archive registry and repository.

3.3.3 Workflow step 3: Workstation retrieves study from archive

When a clinician, working on a remote workstation, requires access to a study from the archive, he/she uses workstation software to perform a PACS query/retrieve SC to call up a study; the network is shown in Figure 16 below. This PACS step relates to the care delivery step 4: Retrieve data, and step 5: Analyse data, as seen in Figure 7.

Figure 16: DICOM query/retrieve network

The workstation's software supplies an interface where the clinician can input the fields of interest to search the database for the study. (The fields offered by the interface are determined by the PACS vendor of the workstation software).

The software (SCP) then queries the archive database (SCR) with its AE title, namely:

- The remote archive IP address;
- Its own workstation network IP address;
- The service requested would be a query with the data tags specified by the clinician and the OD requested from the database; or
- The encoding format of the image transmission, for example uncompressed or compressed.

The archive database (SCR) interprets the request, if its IP is correct, it responds if it recognises the workstation (SCP) IP address and has the data-relevant tags (field names) in its storage file format and supports the transfer format requested. The operation will proceed; the database will be searched for the files matching the relevant tag values and the objects will be returned to the workstation. The clinician can select the study or image of interest. The files are then returned to the workstation, as shown in Figure 17 below.

Patient Name	Patient ID	Date of Birth	Sex	Study	Accession	Study Des...	Referring Physician	Date	Time	Modality	Images
HSA Aorta Angio			M			ABD	FREISCHLAG	1993/05/13	09:08	CT	199
HSA Circle of Willis		MR	M			CIRCLE O...	WEISS	1993/04/21	09:55	MR	93
HSA Facial Bone 3D			M			HEAD	DR.NEIL FELDST...	1994/10/12	12:00	CT	55

Figure 17: Query results

3.3.4 Workflow step 4: Workstation sends reconstructed data to archive

The last PACS workflow step relates to the healthcare delivery Step 6: Feedback, as seen in Figure 7. After receiving the data, the clinician can select the study or image of interest on the workstation. The image is then analysed for diagnosis, post-processing is performed (multi-planar reconstructions or image meta-data tags are requested) to make a diagnosis after the key images (supporting diagnosis) are annotated. The reconstructed data (forms additional data, as the originals are always kept) are then sent back to the archive as new images with new image and study UIDs, but the same patient UID (if present) remains. See Figure 18 below.

Figure 18: Workstation sends reconstructed data to archive

The post-processing and reconstruction options available depend on the workstation's PACS software provider and the meta-data available on the archive.

3.4 The current PACS products available

In South Africa there are currently many PACS suppliers and systems available. These can be categorised into three groups: a DICOM-only, image-management system; a vendor-provided PACS; and a Super PACS.

1. A DICOM-only, image-management system consists of a DICOM archive that stores only imaging data and meta data about the imaging modality, automatically generated during the examination. The DICOM-only image management system is interoperable between modalities and viewing stations of any vendor, but only shares and stores PACS image data according to study modality, date and time (Horri, 2008).

   The problem with the DICOM-only, image-management system is that it contains no additional patient data, limiting the clinician's ability to make an informed diagnosis. Additionally is that accessing images is challenging, owing to the difficulty in retaining the exact study date and time. A hardcopy patient file needs to specify the exact time and modality of the study or else it is nearly impossible to access the patient image. Another limitation of the DICOM system is that DICOM viewers do not have additional processing functionality and, therefore, do not have enough reconstruction options to do the necessary examination of complex images, such as Doppler measurements or bone-density analysis (Huang H. , 2005).

2. A vendor-provided PACS, is a proprietary extension of a DICOM archive, designed by a PACS vendor to incorporate study and patient demographic data. The vendor-provided PACS software stores the data in a proprietary format. Even though all imaging modality software, internationally, must conform to standard DICOM functionality, DICOM only specify the format for the digital image data not the non-image data. Therefore, even though vendor-provided PACS have patient and study non-image data together with the image data saved in patient file, different vendors' formats and achieve structures for the non-image data differ. There are many different PACS vendors supplying different PACS architectures. Each PACS vendor has his/her own proprietary software and archiving format, with vendor-specific architecture for document registry and repository purposes. Even though the image files are saved in the same format (due to the restrictive DICOM specifications), the non-image files are not. Unfortunately the PACS market is a saturated one, with high costs involved and great financial benefits for vendors. Consequently PACS vendors patent their software and customise them just enough to coerce customers to continue using their product exclusively and remain dependent on their 'expertise'. The file format for the PACS archive is a proprietary solution. The tags supplied in vendors' file formats differ in availability and file names, causing great interoperability issues. A particular non-image tag, saved in vendor-specific format, may be acceptable to vendor A software, but vendor C's product may not display images correctly when analysing and reconstructing images. The PACS supplied by vendors suffer from this flaw. They have a single proprietary format storage database that has to be shared for all patient and image data, this leads to integration errors for different vendors.

Additionally, different departments require different patient information for diagnosis (for example, the patient's name, heart rate, blood pressure, blood type, skin condition, tumour location, etc.). Therefore different departments' PACS archives need to be integrated. In addition, the clinician types in information in every text field that is then added to the image. This adds to the possibility of human-error-prone data being processed. Spelling oddities, or even the peculiar use of capitals, cause files to become inaccessible or, in some instances, files that belong to the same patient gets split. A full patient medical history is needed for a completely informed diagnosis. However, PACS does not allow for this, because only limited information (form a single departments at a time) is added to images. Different hospitals' PACS cannot integrate if the same PACS vendor is not used.

3. A Super PACS is a third-party enterprise that manages the whole PACS data archive and file format, to ensure integration between separate systems and patient data file integrity. They receive standard PACS study files and manage them on their own system, which consists of a patient database and an image database.

The previously stated results in a vendor-specific patient image data repository and registry, allowing each query to access all the data it needs, but unfortunately only in the vendor's format. The predicament of having a third-party enterprise managing PACS files results from the non-image data (as well as the file registry and repository) being saved in a specific enterprise-proprietary format and needing to be accessed with workstation viewer software, from that specific vendor only.

The net result of this type of architecture is that it accomplishes data sharing across an enterprise. The enterprise must, however, be populated totally by PACS of that single third-party vendor, starting off with the imaging machines and their accompanying software.

Additionally, the further cost of accessing or reconstructing data becomes very high. As technology changes, systems need to change too, along with the requirements of the PACS architecture. However, the vendors that manage the data do not always offer the necessary options (such as integrating with another system or other type of data) or, when they do, it is always at extra cost. When the time comes to replace the vendor product with the latest PACS, hospital/PACS owners will have to spend significant amount of money if they prefer to move away from their existing vendor. The vendor will not pass the files on in a neutral format, but will leave it to the owner to migrate those files, at additional cost and difficulty, from the existing format to that of the next vendor. Therefore, as soon as a third-party vendor manages PACS, owners are trapped in using that vendor exclusively, unless they pay an exorbitantly high "release fee".

Due to the escalating need for PACS integration in South African hospitals, PACS suppliers/vendors are exploiting the lack of key decision makers' technical knowledge in the public healthcare environment. Using the lack of technical knowledge, they are coercing public healthcare institutions into complicated contracts involving systems and software. Consequently clients, whom lack expert knowledge, are bound to suboptimal service contracts for up to 5-year periods. This is derailing the sustained progress in developing PACS, and the accompanying data management system, in public hospitals in SA.

After establishing the general PACS healthcare delivery process, the technical and operational structure and the available off-the-shelf PACS products in the South African public healthcare environment, the next chapter looks at the specific PACS structure in three South African hospital complexes in more detail to identify the PACS barriers faced.

4 The current ("As-Is") PACS healthcare delivery system in South African public healthcare institutions

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. The previous chapter considered a combination of literature and expert review to determine the general current ("As-Is") PACS healthcare delivery process and the technical and operational PACS structure, as well as the PACS products available. This chapter continues with objective 1, shifting the focus towards specific current ("As-Is") provincial PACS healthcare delivery system. The chapter looks at the technical and operational PACS structure in hospitals, as well as its healthcare delivery process, to identify the barriers obstructing its effective functioning.

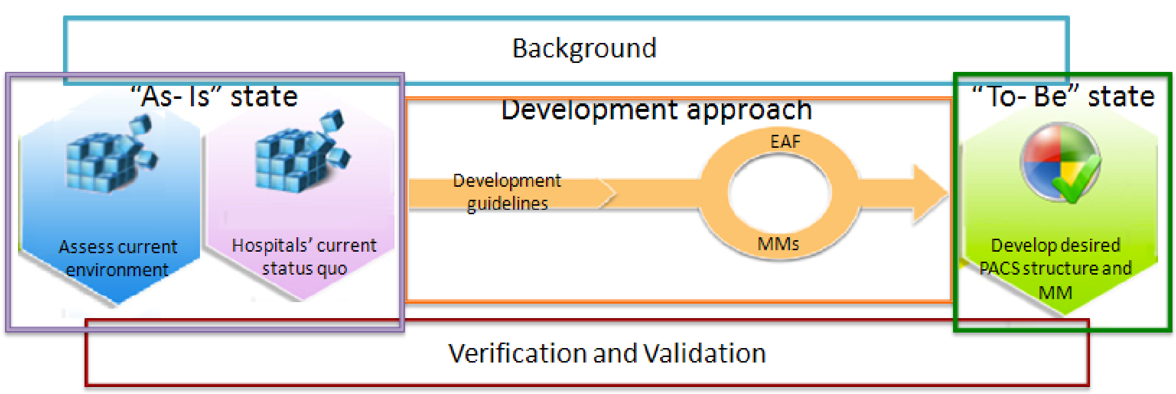


Figure 19: Current status quo methodology

During 2010 and 2011 hospitals in South Africa, which had deployed PACS, or were at least in the process of deploying PACS, were identified and approached regarding visitation. The process started at Tygerberg, in April 2010, as a connection had been established due to previous research being conducted there. Additionally, Tygerberg hospital is the leading establishment in PACS exploration in the Western Cape and is also the official tertiary and educational hospital of the Western Cape (Doubell P. A., 2011). At that time, Tygerberg has established an attempt at a connection with the Paarl and Worcester hospitals' PACS. The hospitals in Paarl and Worcester were also contacted and visited, in November 2010. To form a more complete concept of the PACS situation in SA, hospitals from another province were included in the study. Dora Nginza, Livingstone and Port Elizabeth Provincial hospital were included, as the University of Stellenbosch already had an established connection with the telemedicine administrator of the Eastern Cape and the hospitals were visited for the visited time in November 2011.

4.1 The current PACS public healthcare process

The current PACS healthcare delivery systems were examined by visiting different public healthcare institutions. Members, ranging from PACS administrators, admin staff, nurses, doctors and the hospital CEOs took part in a structured discussion to form an idea of the state of their current PACS healthcare delivery process.

Sections 4.1.1, 4.1.2 and 4.1.3 report on observations made from the Western Cape and Eastern Cape provinces respectively. This is followed by a combined root cause analysis (section 4.2), which takes into account all the barriers, obstructing optimal functioning, observed.

4.1.1 Tygerberg hospital

The Western Cape's PACS was observed, starting with Tygerberg Hospital and the PACS connection hospitals in Paarl and Worcester. Tygerberg hospital receives most of the patients being referred for specialist care and has therefore a considerable amount of images produced and processed at the hospital. Researchers at Tygerberg have done a great deal of PACS research and experimentation for implementation purposes ahead of other due to their high image management burden.

After visiting Tygerberg hospital it was found that all the necessary medical imaging machines, viewing stations, network and archives were available and state-of-the-art. They obtained PACS software form the PACS vendor, called iSite. Philips architects set up their PACS network within the radiology department and configured the systems so as to connect to all their radiology equipment and radiology workstations. Therefore the PACS structure at Tygerberg hospital was a vendor-provided PACS – type.

This particular PACS system, operational in Tygerberg Hospital, was only used in the radiology department and they experienced interoperability problems when they attempted to connect to other departments. The iSite archive file format does not cater for other hospital departments and the iSite that Tygerberg purchased from Phillips was designed for a radiology department, supplying a storage archive format that supports radiology patient and study information only. The viewing software from iSite also supported only radiology image-processing functions. iSite does supply PACS archives for different departments but as a separate system, or else a mega-PACS data-file registry and repository management system (but with prohibitive costs associated with extra integration options) has to be acquired. They had the iSite archive on site, but no off-site data back-up or other systems in place in case of possible failure.

The iSite system was not integrated with a patient information system, as the platforms were too disparate. Doctors complained about the paucity of access to patient clinical information for diagnosis. Many errors were found with regards to typing and spelling errors of patients' names and conditions. In addition, the hospital did not operate with patient UIDs either. Clinicians accessed patient medical images by the examination date from the iSite PACS database. Different imaging machines sent data to the archive differently, causing storage failure, often in the form of lost images or duplicate patient files (i.e. no data integrity). Diagnosing capabilities were therefore suboptimal, as doctors could not access previous examinations, unless they knew the study date.

Although Tygerberg wanted to deploy PACS in the hospital and integrate it with their patient system, they admitted to having a lack of scientific proof and proper methods to follow the integration process. Furthermore, due to the critical nature and high risk for patients involved, they could not take a chance or stop the system to make the appropriate changes.

Old work methods were still being followed (patient study dates were kept in a hard-copy patient file, with all other patient information) with PACS only as a digital image storage system for medical examination. Due to the difficulty of operating the system and the fact that it was working sub optimally, images were often lost and the personnel considered PACS as an inconsistent, untrustworthy system. Needless to say, loosing images and patient data greatly increased the workload of admin staff and doctors, as patients needed to be re-examined. Due to the personnel regarding the introduction of PACS as an increase in their workload and a decrease in productivity, it made them hostile towards the system (World Health Organisation, 2012).

All the problems experienced with the current PACS architecture at Tygerberg Hospital are listed and grouped in Table 1.

Table 1: Tygerberg Hospital: current PACS setup, problems and reasons therefore

Hospital's PACS structure	Problems with hospital's PACS	General PACS problems
State of the art imaging hardware and iSite PACS software.	iSite for radiology department has problems connecting to other departments	PACS bought for a single department has only patient the information fields necessary for that department.
PACS archive in iSite's propriety format	Prohibitive costs associated with extending vendor's file format, so as to include extra patient fields	Management lack necessary expertise to understand complicated contracts involving inter-operability standards
	Limited post-processing capabilities	Vendor-viewing software capabilities are limited; there is an additional cost for additional capabilities
	Cannot integrate with hospitals that use different PACS vendor	Non-image data tags of different PACS vendors differ
Suboptimal diagnosing	Paucity of patient information added to images	System is only used in one department. Only contains the information of that department.
		PACS is not integrated with the patient information system.
Patient image files are accessed via study date	Difficulty accessing previous patient studies	System has no data integrity: There are human typing errors when entering patient information (The query can therefore frequently not pick up the patient study).

		No patient UIDs are used
		Field)
PACS is seen as an increase in employee workload and a decrease productivity	Users resist system because	Old patient care delivery work methods are still used, with PACS acting only as a digital storage system
PACS Archive is on site	No back-up patient image storage	Suboptimal management
PACS is not integrated with patient information system	No standardised method for integration available in South Africa	There are no governmental standards or standards
		Healthcare delivery is a critical system that cannot be stopped integrated without proven methods and standards.

4.1.2 Paarl and Worcester's hospitals

A connection with the PACS archive of Paarl and Worcester hospitals was in the process of being established. After visiting both hospitals it was found that Paarl had a vendor-provided PACS, Carestream, developed by Carestream HealhCare and Worcester was busy acquiring a PACS.

Paarl's Carestream system could access a patient file if the specific study date and time was sent to the appropriate doctor, but no other patient or study data could be accessed. Some post processing and reconstruction problems occurred, when complex, four-dimensional (3-D images that are time- related) DICOM image data were sent from the iSite PACS archive to the Carestream viewing software. This was due to specific meta-data tags that were necessary for Carestream viewing stations, being generated differently by the iSite PACS's storage service class (SC). The iSite and Carestream archives could not be integrated, as these had different architectures, data registry and repository archives. Paarl had one computer, which could access Tygerberg's images, where they ran Phillips' iSite software, but Tygerberg could not see Paarl hospital's images at all.

After visiting Worcester hospital, which was busy with a tender for PACS, it was alarming to note the lack in collaboration towards interoperability. There was no consideration in the tender for including interoperability with Tygerberg Hospital.

To achieve interoperability, hospitals need to standardise the format of transfer protocol; in file-content format and storage location, as well as the access method and key. However, there was blatantly no coordination to try and achieve a standard file registry and repository. Hospitals, as was clear from the investigation, functioned individually as separate clinical, non-profit organisations, which made decisions based on its own conclusions and discretion. Furthermore, there were seemingly no regulations from governmental authorities in place to ensure interoperability or communications between the hospitals or a person appointed to take responsibility to regulate standardisation of all these factors.

A tabulation of the problems experienced with the PACS architecture at these two connecting rural hospitals is listed in Table 2.

Table 2: Current system architecture, problems experienced and their causes at the rural hospitals of the Western Cape

Hospital's PACS structure	Problems with hospital's PACS	General PACS problems
Paarl had their own PACS supplied by a different vendor, Carestream	The iSite and Carestream archives could not be integrated	Different PACS architectures have different data registry and repository
		Non-image data is of different PACS architectures proprietary format.
	Cannot query files from Tygerberg's iSite	Non-image data format and tags of different PACS architectures differ
	Difficulty accessing image studies	Have to access each study by its study date, it is the only tag

		that is shared between different PACS systems
	Post-processing and reconstruction problems with complex DICOM image data from the iSite archive	Some complex images require non-image data for post-processing; systems do not share the format of these non-image data tags
Worcester was looking into a separate tender to acquire PACS	Lack of collaboration between institutes	Hospital management's ignorance with regard to the complexity of interoperability of PACS systems
		No communication between separate healthcare institutes
		No one takes responsibility for PACS project
		No government standard for PACS integration enforced
		Vendors exploiting the hospital decision maker's lack of IT knowledge with misleading data conformance statements
Hospitals function independently	No integration achieved	No government standard for data transfer and file format

4.1.3 The Eastern Cape hospital complex

The Eastern Cape hospital complex was visited last and it was found that they have telemedicine administrator, in charge of governing telemedicine projects. He regulates standardisation and ensures interoperability between separate institutions. Telemedicine administrator decided to appoint a Super PACS to ensure the sharing of patient medical information between the four East London and five PE-complex hospitals, but the system was unfortunately not optimal either. The telemedicine administrator contracted an external PACS provider, AGFA HealthCare, who supplied Impax 6 PACS system, to manage all the hospitals' patient image files and pay R80 per study processed.

Even though PACS was running and patient files could be accessed, the hospitals could not change or add patient images without incurring costs. This was not a cost-effective option that could be sustained in the long term. Furthermore, the contract was signed for a five-year term and the contractor did not supply all the viewing capabilities that the system advances required. In addition, support for the option to integrate PACS with the HIS and blood-analysis results system, when the time came to develop HIS, was lacking. The hospitals had no patient UID system; some departments used a temporary, internal patient UID for their PACS system, while others used patient names. They relied on AGFA to manage the patient database and ensure that patient files were accurate, valid, and consistent (which they referred to as 'database integrity').

Furthermore, the case of data ownership and data migration (reconstructing files from one vendor format to another) to a new PACS vendor was not considered in the contract and caused many issues. AGFA did not want to take the responsibility of migrating old patient data to a new format and a high fee was included for a new vendor to do this before starting up a new system. Suppliers are exploiting the lack of technical knowledge of decision makers and coercing medical institutions into complicated contracts, which involve systems and software; binding them to the supplier and respective services agreed to. Therefore, as technology advances, the system needs to be changed, but, as the system of the Eastern Cape was not adjustable, it was placing immense strain on workflow effectiveness. A tabulation of the problems experienced with the current PACS architecture in the Eastern Cape hospital network is listed in Table 3 below.

Management did not appoint new employees, like data managers and IT support staff, for IT operations. However, installing a new system leads to new tasks that need to be done. The telemedicine champion ('champion' being the driving force and co-ordinator and manager of a project) explained that the government does not allow the hospitals to assign new positions without a protracted application process. Applying for new 'posts' had to be done in the third term of that year for the following year, but it often took more than a year for the application to be accepted.

The champion also explained that standardised operating procedure (SOP) for work methods could not be developed for each task, as there were not enough employees to fill the task descriptions. Furthermore, there was no existing standardised procedure as proof to support the application for new posts. The champion did admit to using trial-and-error methods to develop SOPs but that they were not properly developed yet to find the best-practice methods.

In addition, some healthcare personnel were resisting the new PACS system. This was mostly due to small system changes they disliked, such as the uncomfortable ergonomic positioning of equipment, the impractical, inefficient work methods, or suboptimal network design, resulting in slow image retrieval during peak workflow periods. Others experienced technological difficulties with the foreign system. This could have been due to a lack of motivation or a fear of change, however, many complained about not having the necessary support for the technical problems they experienced. Strategic decisions concerning project responsibility, compatibility, scalability, maintenance and ease of upgrading was not considered by managers.

Table 3: The Eastern Cape hospital complex's current architecture, problems and their reasons

Hospital's PACS structure	**Problems with hospital's PACS**	**General PACS problems**
AGFA- Super PACS	Not a cost effective system	Hospital pays super PACS vendor for each image study that is added or changed
	System is not adjustable	PACS data archive in vendor super PACS vendor's format
		Long term, complex contracts with super PACS vendors.
	System is not standardised throughout the hospitals	Pay to add data storage tags of other departments.
	Data migration	Vendor enforces database integrity (owns data)
Head of telemedicine	Workflow not efficient	Decision makers lack expertise knowledge

		necessary to re-engineer workflow.
		Hospital has no standardised patient UID
	Lack of workforce with necessary skills (IT support)	Hospital management cannot appoint new positions at short notice
	Personnel resist system	Suboptimal design causes personnel to see PACS as an increase in workload and a decrease in efficiency
		Lack of motivation and support for personnel
	Suboptimal decision making	Decision makers lack of necessary knowledge
		No governmental operating standards
		Lack of operating standards and best practiced methods in literature

After assessing the current PACS healthcare delivery process at the individual hospitals, a root cause analysis study was performed to group the problems, which follows in the next section.

4.2 The Current PACS problems faced

When looking at the status quo of the hospitals visited, it was highlighted that digital image use in the healthcare delivery process stretches over a long range of incremental steps and has many influences that all need to support the new system. There are many reoccurring problems that manifest at all the hospitals. Because hospitals are such complex organisations, with many subsystems and components, deploying an IT system throughout the entire patient-care delivery process influences many components. To organize the problems and determine possible solution strategies, the problems encountered at each healthcare institute were grouped and illustrated in a fishbone diagram.

Taking into account the Organisational Dimensions of a hospital by van Wetering et al (A situational alignment framework for PACS, 2001) the 6m's of quality assurance by Dr Ishikawa the problems were grouped into the following hospital domains established:

- Man: User lacks motivation, competence, and training and for the new system; decision makers lack the knowledge and support to take optimal decisions; and there is a lack of collaboration between institutes and standards from government.
- Machine: Vendor-supplied PACS systems are not interoperable; systems are not designed ergonomically to suit all user needs; and the hardware obtained is not always scalable. Different users, department and institutes, require different system specifications and hardware is fixed in vendor proprietary format, restricting adjustability, interoperability and scalability.
- Method: Work methods are not redesigned to support new system needs and streamline workflow. New best-practice methods and standard operating procedures are not established or standardised.
- Material: There is no standardisation of storage format; repository or registry and vendors limit interoperability with propriety formats of non-image data.
- Money: Money is available but vendor contracts limit system adjustability and governmental systems limit the options that hospitals can spend resources on.

The fishbone diagram of each individual hospital's root cause analysis is illustrated in Figure 20, Figure 21 and Figure 22.

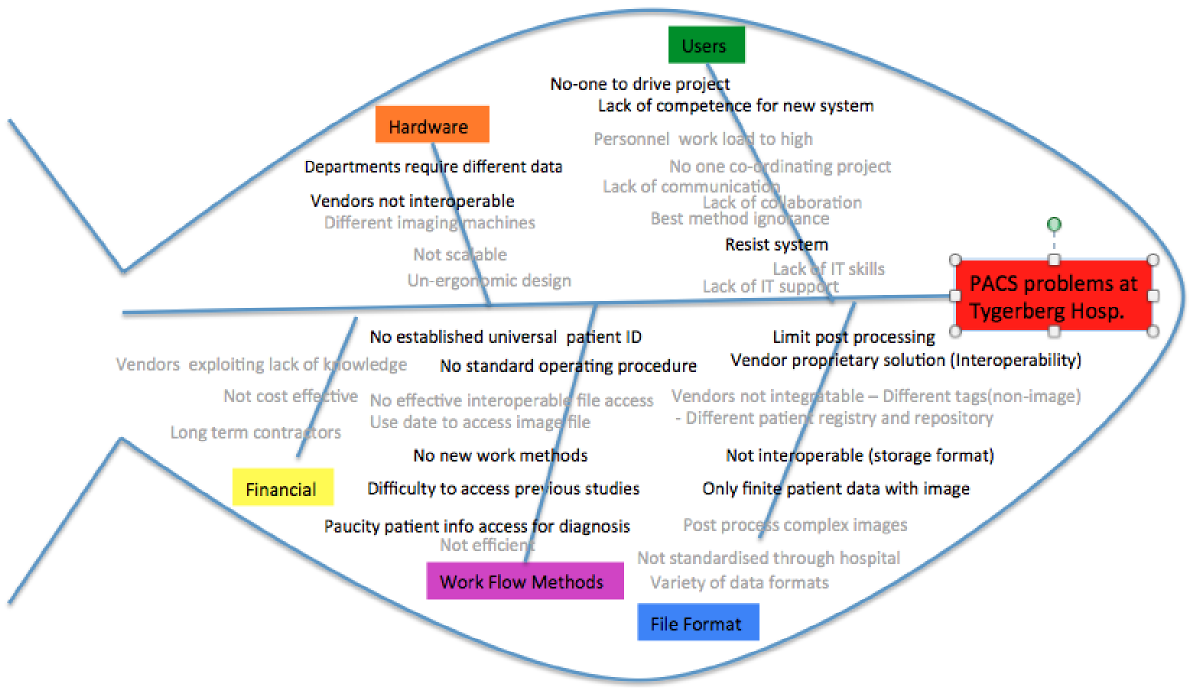


Figure 20: Fishbone of Tygerberg hospital's problems

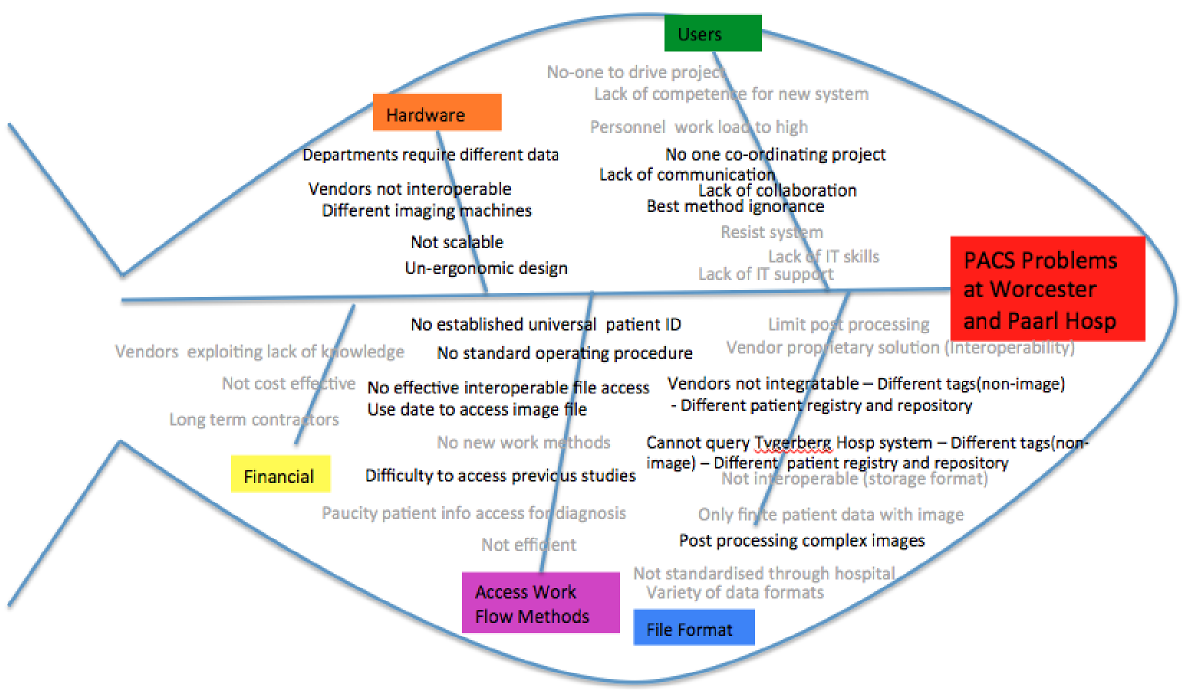


Figure 21: Fishbone of Paarl and Worcester hospital's problems

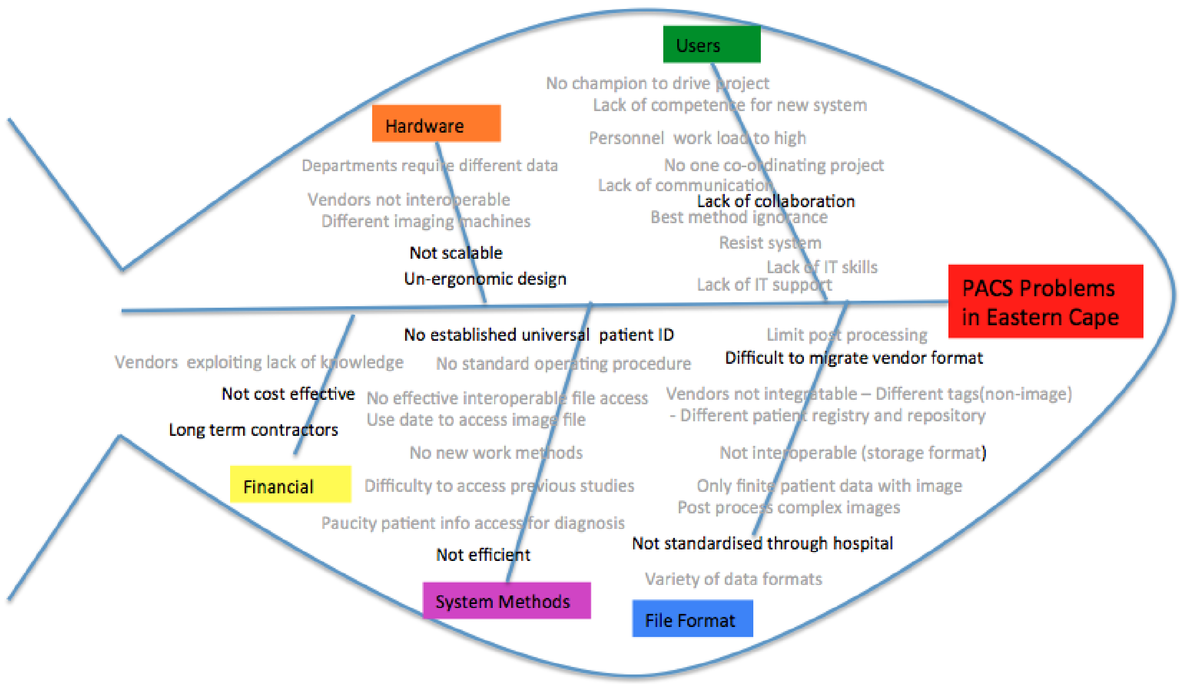


Figure 22: Fishbone of Eastern Cape hospital complex's problems

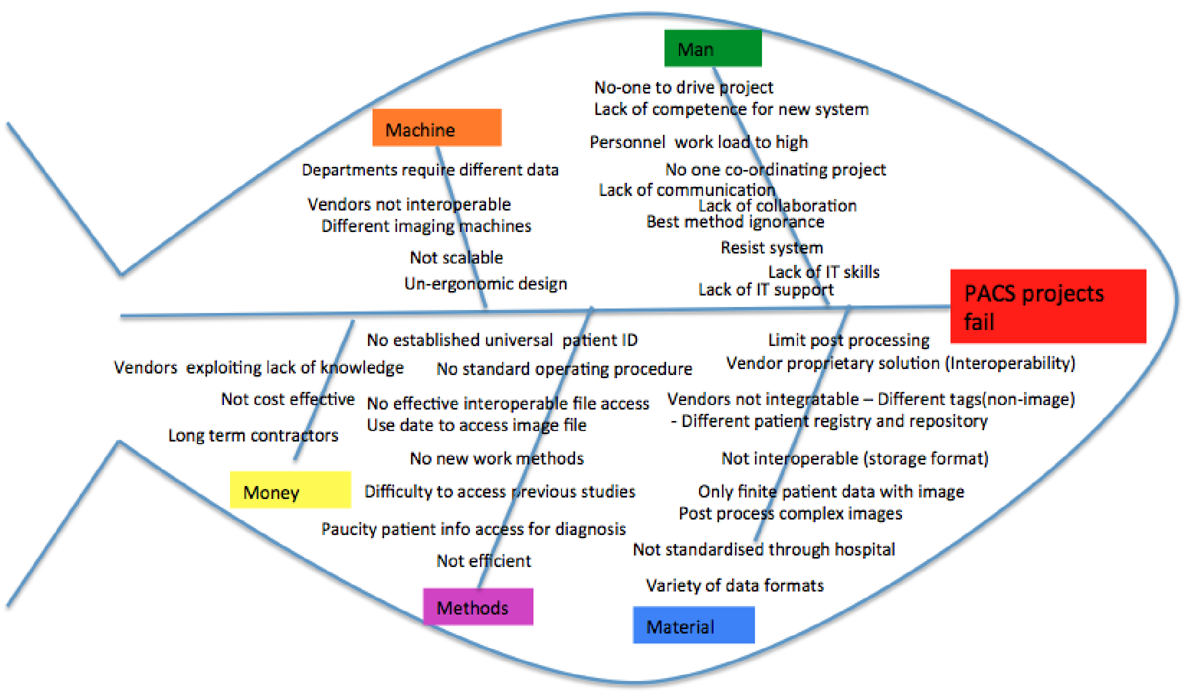


Figure 23: Figure of all three hospital's problems combined

The collective fishbone diagram (above) sums up the chapter's findings by showing all three hospitals' technical and operational PACS complexes. Figure 23 illustrates all the problems together, which confirms the statement that many components throughout the complex organisation were influenced by the implementation of PACS and that there isn't a single solution available. Many components have an influence, but all must be considered when designing the optimal system.

The following chapter is a discussion of the desired technical and operational PACS healthcare delivery system suited for the South African public healthcare environment.

5 The suitable ("To-Be") PACS technical and operational structure for South African public healthcare environment

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. This chapter (as seen in Figure 24) addresses the suitable PACS structure, by: (a) using the problems current barriers to set up design specifications for the PACS structure; and thereby (b) depicting the desired technical structure of such a system and lastly; (c) showing the operational workflow of PACS within the healthcare delivery process

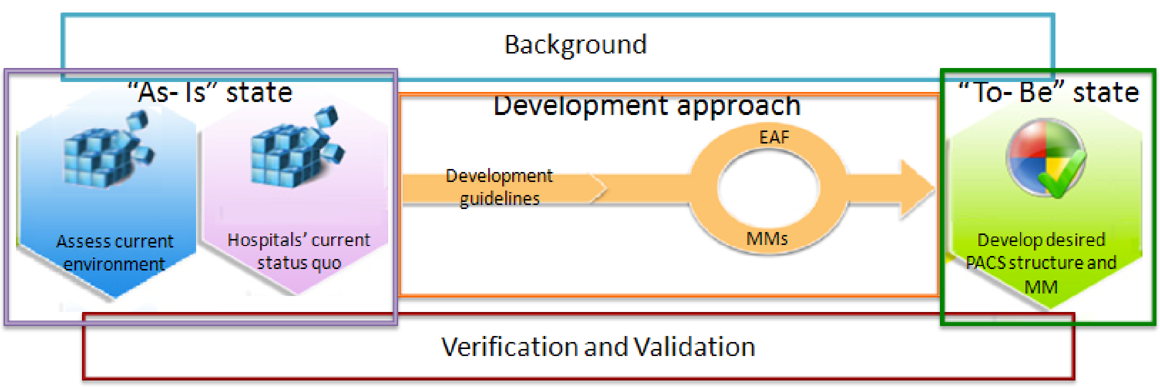


Figure 24: "To-Be" Methodology

5.1 The requirement for the suitable PACS structure

In order to define the suitable PACS healthcare delivery system for the South African healthcare environment it is necessary to fully comprehend the problems faced by users and design system requirement to overcome these problems. After assessing the "As-Is" state in the hospitals and analysing the available technology many user problems and needs were identified. These needs and barriers, together with a comprehensive literature study led to the development of the requirements for the PACS system. The following sections list the requirements development from each hospital complex visited.

5.1.1 Tygerberg hospital

Tygerberg hospital, having a vendor PACS that operates in isolation in one department, brought forward the necessity for a standard system that can be used throughout the hospital, which contains all patient data, together with patient images. Additionally, clinicians should be free to choose the viewing software they prefer, that offers them the set of processing capabilities they need. Lastly, hospitals should employ a data manager to manage and validate the archive and patient files, so as to ensure data integrity. The problems found at Tygerberg hospital is listed in the table below, with the correlating user need and system requirement.

Table 4: Tygerberg hospital's problems and associates system specifications

Problem	User need	System specification
Different departments require different patient information fields	All patient information fields must be included/allowed within the system	All patient information must be available
Unable to perform post processing and file transfer due to propriety file format	Standard file format must be used for non-image data	Stand file format non-image
Vendor viewing-software capabilities limited	Clinicians should be free to choose type of viewer that best suits their needs	Allow all viewers and viewing functionalities
PACS system designed for image sharing, not patient information	ALL patient information fields must be included/allowed in system	Repeat

Not integrated with patient information system	Patient information system, with all patient information available, must be integrated with PACS	Integrate patient information system
System has no data integrity *Human typing errors when entering patient data fields (query does not pick up all fields)	Data manager must manage archive to ensure integrity. Patient information system must be integrated with PACS to allow drop-down lists for patient information that illuminate human typing errors	Hospital manage own patient information system
Files are accessed via study date only	Inaugurate a patient UID system and store studies according to patient details, not according to study date	Patient UID
No patient UID used	Inaugurate patient UID throughout hospitals and province	National patient UID
Difficulty of image access and system complexity	Using standardised best-practice methods will ease work methods; allow for standardised teaching and user-friendly systems	Standard BP work methods

5.1.2 Worcester and Paarl hospital complex

Worcester and Paarl hospitals complex, having a different vendor PACS implementation structures at each hospital, brought forward the need for co-operation and interoperability standards between the separate institutions was highlighted. A standard file transfer method and a format that can interoperate between hospitals and different vendors must be developed. (As machines and PACS vendors are already established, they have to be made interoperable; they cannot just be re-obtained from the same vendor as before). The problems found at Worcester and Paarl hospitals complex is listed in the table below, with the correlating user need and system requirement.

Table 5: Worcester and Paarl hospital's problems and associates system requirements

Problem	User need	System requirement
Different architectures, data registry and repository	Standardise the file format: registry and repository	Standard data storage format
Non-image data not accessible	Separate patient database (non-DICOM), form image database (DICOM) and integrate with server.	Repeat
Have to access study by study data, only tag shared between systems	Inaugurate a patient UID system to store studies according to patient	Patient UID to access study
Some complex images require non-image data for post processing; systems do not share the storage of these data tags	Standardised file format must be used for non-image data	Repeat
Ignorance considering the complexity of interoperability	Interoperability standards should be put in place and persons responsible must be appointed	Integration manager
No communication between separate institutes	Persons responsible must be appointed to co-ordinate project	Appoint project manager
No one taking responsibility	Persons responsible must be appointed to drive project	Appoint Project manager
No government standards enforced	Best-practice interoperability standards must be developed	Repeat

5.1.3 Eastern Cape hospital complex

The Eastern Cape hospital complex, having a Super-PACS that is not cost effective and has contractual limitations, brought forward that even though there is interoperability management, total interoperability was still lacking. The hospital did not have freedom to structure and access their data as they desire. Vendors still limit the adjustability, scalability and interoperability by complicated contracts with hidden costs at every step. Hospitals must manage their own vendor-neutral archive and standard filing format with best-practice methods and standards to guide their decision-making. It became apparent that there is a lack of the necessary information and dexterity to make optimal decisions for PACS structure. Even though there was management, a solution with an archive that stores all patient images with non-image data, in a format that is interoperable between separate institutions and streamlines operations was still not reached. The problems found at Eastern Cape hospital complex is listed in the table below, with the correlating user need and system requirement.

Table 6: Eastern Cape hospital complex's problems and associates system requirements

Problem	User need	System Requirement
Pay per image study needs to change or add patient images	Hospitals must manage their own patient data archive and standard filing format	Hospital owned patient data
Data archive in vendor format	Hospitals must manage their own patient data archive and standard filing format	Hospital manage their own database not outsource it
Long term, complex contracts with vendors	Hospitals must manage their own patient data archive and standard filing format	Repeat
Vendor enforces database integrity (owns data)	Hospitals must manage their own patient data archive and standard filing format	Repeat

Data migration not in contract, nobody takes responsibility	Hospitals must manage their own patient data archive and standard filing format and not sign fixed term contracts	Repeat
Unable to manage system self	Standards must be developed to guide hospitals in making informed decisions and manage systems by themselves	Clear Database management guidelines
Hospitals cannot access all patient information at all departments	Store all data with standardised patient UID, throughout hospital	Repeat
Cannot appoint new positions at short notice	Standardised methods and guidelines will allow for effective long-term planning	Standard implementation methods
Suboptimal design causes employees to see PACS as an increase in workload and decrease in efficiency	Develop best-practice methods to and streamline workflow	Repeat
Lack of motivation and support	Champion to drive system	Repeat
Lacking necessary dexterity, knowledge and support for literature and governmental standards	Standards and relevant best-practice methods must be developed	Repeat

5.1.4 The Collective PACS system requirements

After assessing the "As-Is" state in the hospitals and analysing the available technology it was determined from the three studies that PACS healthcare delivery process consists of many interrelated steps and influence multiple hospital domains. All these domains and steps need to be aligned to optimise to process flow and support the system. To ensure all the components throughout the complex organisation are aligned to support the PACS healthcare delivery system and integration of separate institutions, a standardised solution is needed to store and share patient images with non-image data in a non-proprietary format that will assist hospital decision makers to deploy the systems and avoid ambiguous contracts. Therefore a standardised storage and transfer format of image and non-image data is needed and the images database must be integrated with the patient information database, while streamlining operations throughout the patient-care delivery process.

PACS stores patient images with finite patient information, while vendors limit the interoperability of this information through propriety non-image data formats. Doctors need access to all patient historic information, in each case, to make an informed diagnosis. To reap the full benefit of PACS, it must be integrated with the entire healthcare delivery process and patient database, not operate as an isolation system. PACS must be integrated with a patient information system which allows images to be stored in a vendor-neutral archive and which can be accessed by a universal patient ID number. The system must be scalable and adjustable by the hospital itself.

The system requirements were used to develop system specification:

Table 7: System requirements and specifications

System requirement	**Requirement domain**	**Design specification**
All patient information must be available	Material	Allow all data field/ scalable
Stand file format non-image	Material	Use HL7 for non-image data
Allow all viewers and viewing functionalities	Material/Machine	Vendor neutral storage format/ Different viewing software
Integrate patient information system	Material	Archive images (DICOM) & archive non-image data (HL7) & integrate server (HL7)
Hospital manage own patient information system	Men/Method	Appoint database manager
Patient UID	Material	Store image & non-image data under patient UID (HL7)

National patient UID	Method/Money	File patients and a unique patient number on arrival
Standard BP work methods	Method	Define standard best practiced methods
Standard data storage format	Material/ methods	Use DICOM for image data and HL7 for non-image data and operate server on HL7 standard
Patient UID to access study	Material/ methods	Store files under patient UID (HL7)
Integration manager	Men /Method	Appoint manager to interact with other departments / institutions
Project manager	Men	Appoint manager to co-ordinate project top-down
Project manager	Men	Appoint manager to drive project bottom-up
Hospital owned patient data	Method/money	Appoint data manager and manage own patient files
Hospital manage their own database not outsource it	Method/ Money	Hospital manage their own database
Clear Database management guidelines	Method/	Use HL7 standards
Standard implementation methods	Method	Assist long term planning

As seen in the table above all the problems that arose were converted into design specifications for a new system. Most of the specifications were categorised as being of the healthcare delivery process domains method or material. The previous stated fact supports the argument that with the correct working method, system design and data storage and transfer formats most of the problems faced can be overcome. Such a system must consist of the following:

5.2 The suitable PACS structure

The objective for PACS is the South African public healthcare environment is to share digital patient images between clinicians of any institute or hospital department, and thereby improve healthcare delivery. In order to reach the objective, the PACS suited for South Africa has to capture data from any imaging modality in DICOM format, and make the images available to specified clinicians by a patient UID, whereby the clinician can access all the patient information and images in the patient file.

The suited PACS healthcare delivery structure is compromised of the following: The system captures digital patient images in DICOM format from the digital imaging machine and transfers the images to the PACS database, in DICOM format. The transfer happens through HL7 protocols with a study UID, linked to the patient UID. A HL7 format server manages these images files; linking each patient UID to all the associated study UID's. Any additional data the hospital wishes to insert, such as a clinician UID, hospital UID or a referral type UID is added as information linked with patient and study UID on the patient database, also in HL7 format. The HL7 server integrates all the patient information on the patient database under patient UID with the patient images on the PACS database associated with the patient UID. Thereby, a clinician can access the server and request any allowed UID in question, whereby the server then recalls the file or files associated with that UID. From the patient file, the clinician will be able to access all the patient studies. When the study is assessed, the data is modified and the image file is stored in DICOM format in a PACS database with a new study UID. The server then notes the new study UID as results, and links it to the patient in question's file. The clinician can then, from the same system, add the diagnosis results to the patient file. The steps are illustrated in Figure 25 below.

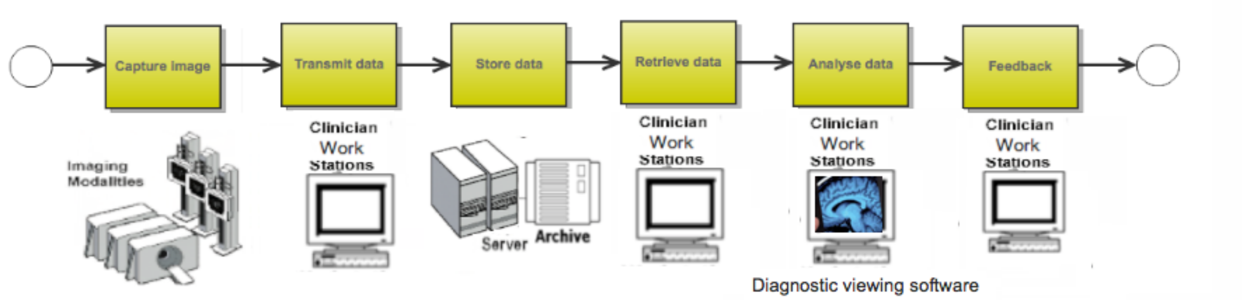


Figure 25: The suitable/ mature PACS health care delivery process steps

It is important to note that the suited PACS has a separate archive for patient images that is managed by the hospital itself. The archives are integrated between the hospitals enterprises by HL7 server. The server manages the data that is stored in the archive in separate files. A purchased PACS setup has the server commands within the PACS archive, but with the hospital setup the PACS archive uses its PACS service classes to only store, send and query DICOM image data, not patient data. The hospital server interrupts the network and sends non-image data to the patient file on the patient data archive before it can be stored on the PACS archive. The network is shown in Figure 26.

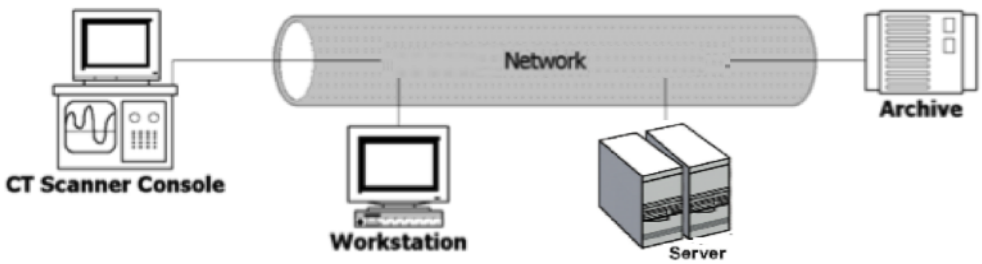


Figure 26: The suitable digital image management network

5.3 The suitable operational PACS structure

What follows is an example of how the suitable PACS structure is used within the workflow of a hospital at a software level. The PACS setup has an external server and therefore an extra step, and thus consists of five steps and not four as described in Section 3.3 The generic operational PACS . The five steps relate to the steps in the patient healthcare delivery workflow of digital images, shown in Figure 27.

1. An imaging examination is performed, producing a set of images, linked to study UID.
2. The patient file is created/accessed and linked to the study.
3. The study is sent to the archive to be stored under study UID, linked with the patient UID.
4. A workstation accesses the study through the archive.
5. Analysis is done on the image by a clinician and the images are reformatted (to support the diagnosis). This is done on the workstation and the reconstructed images are sent back to the archive where they are saved under a separate study UID, linked with original patient UID.

These steps are illustrated in the flow diagram in Figure 27 below, with diamond shapes representing the actions performed and rectangles the process resulting output. Each of these processes is discussed in detail below.

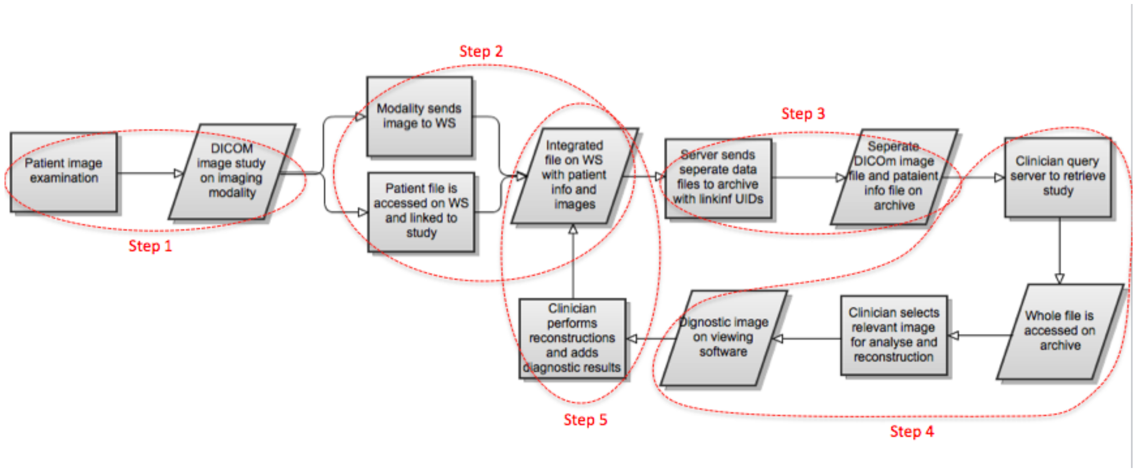


Figure 27: Technical steps in PACS workflow in patient care delivery process

5.3.1 Step 1: Imaging modality generated study

When the patient arrives, the imaging exam will be completed, as with the normal PACS system; the software (any vendor) within the imaging modality will use PACS to create a service class (SC) to generate a digital set of images/slices from the raw data, this is called a study. Each image/slice will consist of objects containing pieces of information called data tags as seen in Figure 28. All these tags will be in DICOM format. This procedure will happen just as before, resulting in a DICOM image but with a unique identifier (UID) as the study date and time, or for whatever reason the software is set up for.

Data tags

Name	Value
Image UID	2012-02-14
Modality	CT
Pixels	100023

Figure 28: Example of the composition of an suitable system data tag

The difference in this process is that only the Image tags are stored in the image file, patient information is saved in a separate patient file. The image Object Definition (OD), however, contains only the information necessary for the specific clinical image and it's UID, the non-image tags are aligned in separate files. An example of the image tags specified in an OD is shown in Figure 29 below.

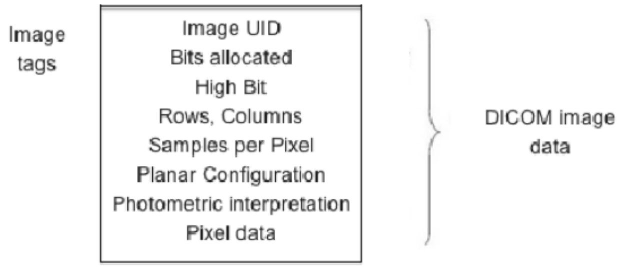


Figure 29: The suitable system Object Definition (OD) tags for the clinical patient image

The imaging modality software, supplied by the PACS provider, determines the OD. All the software of digital medical imaging machines in South Africa require DICOM image conformance. DICOM specifies a certain format to produce the digital image data, therefore modalities of all types will be able to access proceeds and interpret the images. The imaging modality sends the image directly to the accompanying workstation, with the DICOM image data and image UID, through the network as seen in Figure 30.

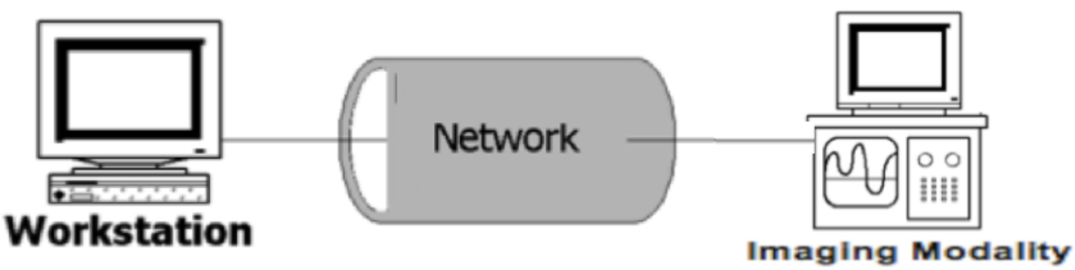


Figure 30: Imaging modality sends data to workstation through direct network

5.3.2 Step 2: Patient file is accessed and linked with image to send to archive

The hospital uses their own IT system architect to setup their system from the imaging modality to the workstation, to the server, and to the archive. The architect develops the system, according to the design specifications of, such that the PACS image database and patient information system is integrated on the workstation accompanying the imaging modality. Therefore the clinician can access the integrated system from his workstation, where he will select the patient ID from a drop down list, after searching the system with his ID number. There the clinician can add in any information concerning the patient. The system server will then save the patient information to the patient file, under the patient UID and the image information to the PACS image database in the image UID. The server will then link the image UID to the patient file. The image is thus linked to the patient file, resulting in all the information being stored in a patient centric format (i.e. a format that is accessible by querying about the patient ID). The workstation is connected to the server that manages the files, as shown in Figure 31. The hospital in-system architect will set up the server according to the HL7 specifications.

Figure 31: Workstation sends data to server: format network

If the system is developed according to HL7 standards, and the patient IDs used are universal, the PACS architect is free to decide which demographic data a study should request or record. Inter-hospital communications will be standardized due to DICOM interoperability and HL7 interoperability. The hospital can choose to add additional information to additional files, such as a physician file, referral file, and hospital file.

5.3.3 Step 3: The study is sent to the archive to be stored

After the digital study has linked the image and patient UID on the server, the server must send the study to the archive to be stored. Using the hospital created storage Service Class, as specified by HL7, the network is shown in Figure 32.

Figure 32: Server sends information to archive: storage network

The server will store patient data in a patient file under patient tags as specified by HL7, and the image data to an image file in a DICOM format. The separate files are stored in the archive in separate databases. The system is interoperable and can access complete images and any available patient data by using the patient's ID.

This system is controlled by a server, and therefore application entity (AE) titles do not need to be sent, as the server controls the data transfer internally according to HL7 specifications. It is an extranet network setup, secured by a virtual private network (VPN) for external access. The server controls who accesses which data on the network, allowing only designated specialists to access patient information.

A file is created for the images, patient information and any other information the hospital requests in its own file. An example of the tags used in a separate files, is shown in Figure 33, which illustrates the non-image tags in their separate files and the DICOM tags in DICOM image files.

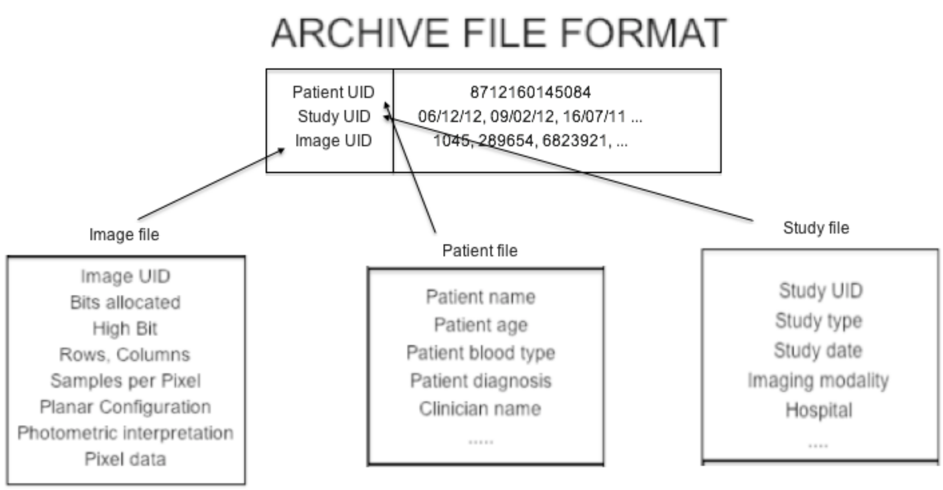


Figure 33: Suitable hospital archive patient file format

5.3.4 Step 4: Workstation retrieves study from server

When a clinician who works on a remote workstation requires access to a study from the archive, he/she uses any workstation software to perform a query/retrieve SC. The network is shown in Figure 34 below.

Figure 34: Suitable query/retrieve network

The workstation's software supplies an interface where the clinician can input the fields of interest, to search the database for the study. If the clinician can input the exact patient, study and image UID, the system accesses the image quickly. This is, however, only the case if the system server queries the database for the relevant information, and returns all the related fields.

Again there is an AE needed, as the server performs this task according to the HL7 specifications. The server will present the clinician with a file that is linked with all the patient information, previous studies and additional information that is available (provided the clinician has access to the information). The clinician can therefore open any historic examination and see all the patient information to make an informed diagnosis.

5.3.5 Step 5: Workstation send reconstructed data to archive

After receiving the data, the clinician can select the study or image of interest on the workstation. The image can then be analysed and post processed by any system because it is all DICOM data, with no non-DICOM image data restricting the processing capabilities. The clinician can also use the viewer which best suit their needs and which they find the easiest to use. There are even viewers available for iPhones and iPads that will be able to operate on the vendor compliant system. The reconstructed data (forms additional data, as a new study, and the originals are always kept on the server, as a previous study; all linked to the patient UID) is then sent back to the server as a new study or result study with new image UID. The server merely needs to add the image UID and new study UID to the patient file and any patient information (diagnosis) results are then saved to patient file. The network is shown in Figure 35.

Figure 35: Workstation sends reconstructed data to server

The server then sends the data to the archive where they are stored securely until they are needed again.

In this chapter the suited PACS technical and operational structure that will address the needs of the South African public healthcare environment was found to be a hospital-owned, vendor free system, integrated throughout the whole hospital and across hospital enterprises. In the next chapter guidelines to reach the defined structure was addressed.

6 Develop guidelines for implementation and optimisation of PACS

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. After defining the suitable PACS structure in the previous chapter, the following chapters address the guidelines for implementation and optimisation of the system to reach the defined structure. In this chapter the requirements for the PACS implementation and optimisation guidelines were established.

Figure 36 shows the methodology and the position of this chapter.

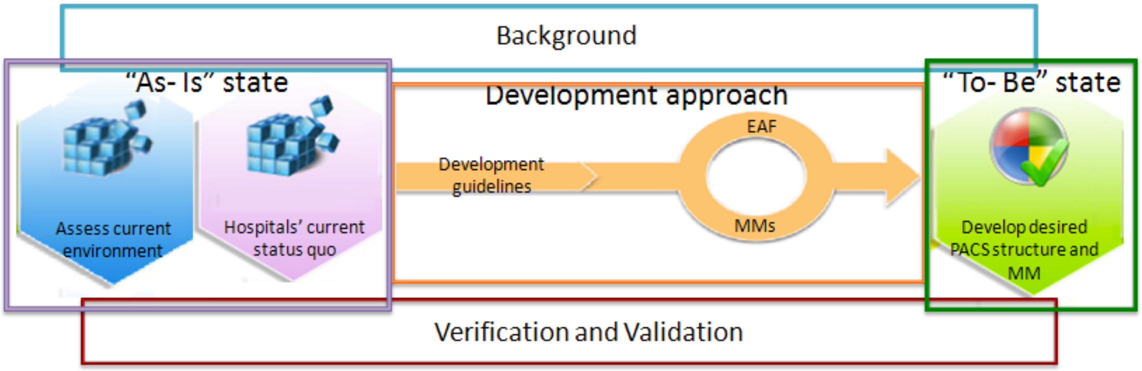


Figure 36: Development approach methodology

Assisting the development of PACS, a system aimed at integration between separate healthcare institutions, is particularly unique and complex due to the reasons that follow.

A framework for the development and improvement of the PACS healthcare delivery system is required to guide the process to reaching the desired integrated healthcare enterprise state. Assisting the implementation and development of a new system in a healthcare enterprise differs from enterprises in other domains, because of the criticality of the system's subjects and their dependence on the care-delivery process (Van der Wetering & Batenburg, 2009) (Van Dyk, Schutte, & Fortuin, 2012) (Fortuin, Edirruplige, Scuffham, van Dyk, Wynchank, & Triegaardt, 2011). Errors in patient care delivery cannot be allowed nor can the system be stopped to make adjustments to the setup (Doubell P. A., 2011) (SA Deaprtment of Health , 2012). Furthermore, the legal issues associated with decisions made and data shared, together with the privacy rights of the subjects involved, add to the uniqueness of healthcare enterprise systems (Doubell P. A., 2011) (Horri, 2008).

Most South African hospitals have already begun with the deployment (or an attempt at deployment) of some form of PACS (Doubell P. A., 2011) (SA Deaprtment of Health , 2012). The initial acquisition cost of PACS is substantial and involves many resources and process changes; therefore a hospital's current system cannot just be discarded, to obtain a new system that is integrated with a certain vendor – it needs to be adjusted to interoperate with all PACS vendor types across hospitals (Horri, 2008). Therefore, the framework must aim to first assess the current PACS setup and subsequently adjust it, in order to reach the desired, integrated state.

Each public healthcare enterprise in South Africa functions as a separate non-profit organisation (Department of Health, 2010). Even if the patients are shared between them, there remains a lack of joint decision-making and governmental strategy to ensure uniform standards for PACS deployment (Doubell P. A., 2011). The framework for PACS deployment must therefore be vendor neutral and introduce deployment standards and adjustment methods to ensure integration of all PACS setups.

PACS technology changes in concomitant with the continuous advances in medical imaging and ICT technology (Lines, 2011) (Van der Wetering & Batenburg, 2009). Therefore, the framework for deployment must make provision for technological advances and adjustments; all the while remaining specific enough to ensure integration.

The barriers are lists with their associated design specifications, in Table 8, below,.

Table 8: System barriers and design specifications for PACS guidelines

System barrier	Design specification
Critical system, cannot afford error	Avoid implementation errors with clear development guidelines
Data is subject to patient privacy rights	Ensure data privacy and responsibility, with applicable healthcare data privacy standards
No co-operation and integration between separate institutions	Ensure governance between separate institutions
Technology changes continually	Make provision for technological changes by being vendor neutral
All hospitals are on different PACS levels and structures	Must be suitable for any of the South African public hospitals by entailing all possible PACS states
Users are opposed to use complex implementation and optimization guidelines	Guidelines must be user friendly
All hospitals are on different PACS levels and structures and cannot integrate	Ensure integration between hospitals by offering best practiced methods and being vendor neutral

As a result the requirements for PACS implementation and optimization guidelines, which will guide the PACS healthcare delivery system from any current structure in South African public healthcare environment to the suited structure defined, were found to be:

1. Descriptive completeness
2. Development guidelines
3. Best practices methods
4. Vendor neutrality
5. Offer governance
6. Be user friendly
7. Be applicable to the healthcare environment, SA and PACS

PACS is no longer introduced into hospital enterprises solely to reduce the reliance on film-based radiology departments. Consequently, the PACS system has become an integrated component of the healthcare delivery system. The PACS healthcare delivery process consists of interrelated steps and influences various domains within the hospital. When implementing a comprehensive IT system in a critical environment, such as healthcare, it is important to align all the components of the system and manage the system change to reach to desired goal and minimise implementation errors.

In reengineering the enterprise, an approach to structure, manage and guide the system during IT implementation is called Enterprise Architecture (EA). There are numerous definitions and approaches to EA. Consequently, in the next chapter, a definition for AE was given and five common EA frameworks were considered to find an appropriate framework to assist the implementation and optimisation of PACS in the South African public healthcare environment.

7 Enterprise Architecture

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. In this chapter a definition is given for EA and different EA frameworks are compared to find the most appropriate implementation and optimisation-guide for managing the system and the enterprise change, and so, progressively reach the defined structure. The methodology illustration can be seen in Figure 37.

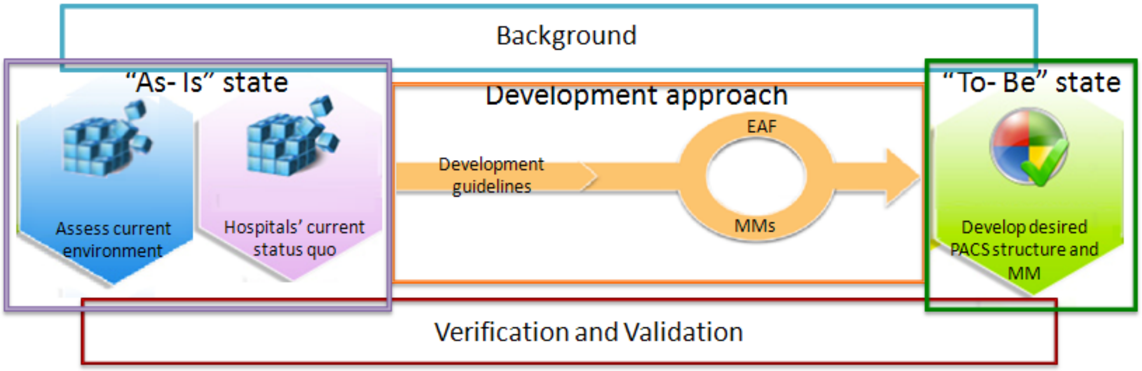


Figure 37: Development approach methodology

In reengineering the enterprise, an approach to structure, manage and guide the system during IT implementation is called Enterprise Architecture (EA). There are numerous definitions and approaches to EA as discussed below.

- 1994 IEEE conference on enabling technologies stated: EAs are methods to support information system development and enterprise reengineering.
- IEEE: Enterprise Architecture is a coherent whole of principles, methods and models that are used in the design and realization of an enterprise's organizational structure, business process, information system and infrastructure(Lankhorst, 2013)
- Harvard business school: The EA is an organizing logic for business process and IT infrastructure, reflecting the integration and standardization requirements of a company's operational model. The EA provides a long- term view of a company's process, system and technologies so that individual's projects can build capabilities – not just fulfil immediate needs.(Ross, et al., 2006)

Enterprise reengineering is similar to a building process where an architect is required to layout the structure. However, enterprise architecture lays out the structure that guides the reengineering. Sources agree that EA used to focus on IT system integration but current IT systems cannot be viewed in isolation, it needs to be aligned with the whole enterprise strategy and capabilities. (Ross, et al., 2006) (Lankhorst, 2013). By taking an enterprise-wide perspective across all domains and processes, an EA ensures the enterprise goals and objectives are addressed in a holistic way across all IT projects. For the purpose of this thesis EA will be defined as the enterprise reengineering approach when implementing an IT system to structure, manage and guide the enterprise to reach its suitable state.

Enterprise Architecture provides a design and roadmap for managing business components with an IT system. The Enterprise Architecture Framework (EAF) is a framework that models the EA (The Third Workshop on Enablign techologies: Enterprise architecture: definition, content, and utility, 1994). Consequently, five common EAFs were considered to find the most suitable framework to assist the implementation and optimisation of PACS in the SA public healthcare environment.

An EA typically produces deliverables such as:

- Current State Enterprise model
- Future desired State Enterprise model
- Architecture Roadmap that defines the initiatives required to migrate from the current state into the future state.

7.1 Enterprise Architecture Framework comparison

A number of Enterprise Architecture (EA) frameworks exist in the industry to address the different basic challenge of assessing, aligning, and organizing or defining technical and operational structures. The most common frameworks include the Zachman Enterprise Framework, The Open Group Architecture Framework (TOGAF), Federal Enterprise Architecture (FEA), The Gartner Methodology (GM), and Maturity Models (MMs).

7.1.1 Zachman Enterprise Framework (ZEF)

The Zachman Enterprise Framework (ZEF) is a type of framework, that provides a highly structured way to define an enterprise. Even though the ZEF is a formal, comprehensive taxonomy it doesn't offer any guidance for development or improvement of an enterprise system (A method to define an Enterprise Architecture using the Zachman Framework)**.**

7.1.2 Open Group Architectural Framework

The Open Group Architectural Framework (TOGAF) is a design approach that follows a cyclic process. The TOGAF begins with the understanding of the organisation's initial architecture, moving along the architecture through eight interrelated change management stages. Through managing the change, the TOGAF focuses on four enterprise levels: Business, Application, Data, and Technology (Comparison of the top four enterprise architecture methodologies, 2007) While the TOGAF is an applicable improvement model the key focus areas (or enterprise domains) differ greatly for a non-profit healthcare organisation. The TOGAF does not capture the system complexity and process steps involved in the South African public healthcare environment

7.1.3 Gartner Framework

The Gartner Framework (GF) is a general statement of the enterprise construct. The documentation of GF does not offer enough information for an organisation to start developing their internal EA competencies(Comparison of the top four enterprise architecture methodologies, 2007) It does, however, offer extensive constructs that can be used to organise an enterprise's thinking around the subject of architecture. The GF system and its information is of great value to researchers but not to the users who need specific guidelines and prescribed best practiced methods, which is what the South African public healthcare environment needs for PACS development (Ross, et al., 2006)

7.1.4 Federal Enterprise Architecture

The Federal Enterprise Architecture can be viewed as enterprise architecture, but some sources suggest it is a methodology for creating an enterprise architecture (Federal Enterprise Architecture, 2007). The FEA has been developed specifically for the USA Federal Government. FEA is a fragmented EA framework that currently spans five documents: a reference model, a methodology, a maturity model, a best-practices guide, together with considerations for ensuring the FEA is service-oriented(Ross, et al., 2006). The FEA, although thorough and comprehensive, isn’t user friendly and doesn’t offer clear development guidelines. Additionally, the FEA doesn’t adequately apply to the South African public healthcare environment needs, specifically for PACS development (Ross, et al., 2006).

7.1.5 Maturity Model Architecture

The Maturity Model Architecture can be viewed as a descriptive framework that guides a system from an ad-hoc to an optimised state. The MM is therefore a descriptive and prescriptive guide and if used across enterprises it also becomes a comparative framework. There is a variety of maturity models developed, some in the field of healthcare and even in PACS (Essman, 2009). However, a MM being very descriptive of the system’s current state and guidelines for future state cause MMs to be very limited to their specified field op development (Essman, 2009).

To select the appropriate AE model for management of development and process change of PACS implementation in hospitals, the five common AEs are rated according to the guideline requirements as defined in previous chapter. A comparison of the frameworks was completed by scoring each the requirements, which were found in the previous chapter for PACS implementation and optimization guidelines. The scores were obtained through research. Combining literature from the resulting scores are shown in Table 9 below.

Table 9: Criteria ranking for AE frameworks (1- bad, 2, fair, 3, good, 4- excellent)

Criteria	ZEF	TOGAF	GF	FEA	MM
Descriptive completeness	4	2	1	2	4
Best practiced methods	1	4	2	3	3
Development guidelines	1	4	2	4	4
Applicable/ adaptable to healthcare environment	2	2	2	1	4
Applicable PACS process	1	2	1	1	4
Applicable to the public SA environment	1	2	1	1	1
Vendor neutrality	2	4	1	2	4
Governance offered	1	2	3	3	2
User friendliness	2	1	2	1	2
TOTAL	**17**	**23**	**16**	**18**	**26**

Comparing the five common AEFs; Maturity Models (MMs) was deemed appropriate combination of requirement fulfillment. In an effort to provide a comprehensive, yet simple and user-friendly descriptive and prescriptive framework that applies to all PACS healthcare delivery systems within South African public healthcare environment, the Maturity Model was deemed appropriate. MM did, however, not score very high on governance, but it depends on what level it is used. The following chapter looks at MM's in more detail.

8 Maturity Model analysis

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. After deeming MM's as an appropriate tool to guide the implementation and optimisation of PACS in the South African public healthcare environment, in this chapter MMs will be discussed in more detail.

Figure 36 shows the methodology and the position of this chapter. This chapter firstly details at the definition, purpose and type of MM's available and secondly, assesses existing MMs for appropriateness to the South African PACS healthcare delivery environment.

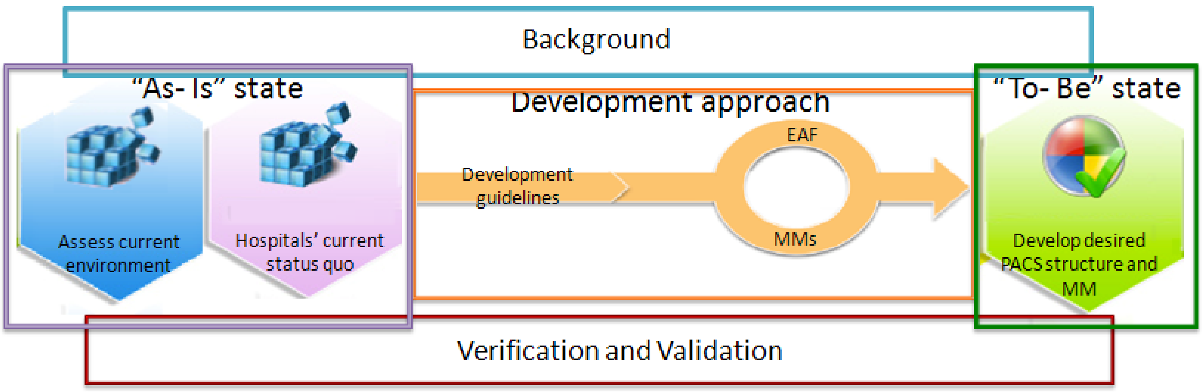


Figure 38: Development approach methodology

8.1 Maturity Model definition

Maturity models are models that describe the typical stages in the development of organisational capabilities. These stages, together, form an anticipated, logical path from an initial phase to a desired state of maturity (De Bruin, Freeze, Kaulkarni, & Rosemann, 2005) (Solli-Sæther & Gottschalk, 2010) (Poeppelbuss, Niehaves, Simons, & Becker, 2011). The term "maturity" adjusts its meaning within different organisations, according to their specific needs, but is loosely understood as organisational development toward the better and an adoption of 'good' (or more appropriate) practice (Fraser, Moultrie, & Gregory, 2002).

The early roots of maturity models can be found in multistage models, such as Maslow's hierarchy of human needs, Kuznets's theory of economic growth and Nolan' s stages-of-growth model for the growth of information technology in a business (Poeppelbuss, Niehaves, Simons, & Becker, 2011) (Solli-Sæther & Gottschalk, 2010). The first official maturity model was created by the US Defence Software Engineering Institute (SEI) as a framework to assess the capability of software contractors. There was a pressing need to ensure appointing only capable contractors, because projects kept running over budget and were completed far later than planned – if at all (Fraser, Moultrie, & Gregory, 2002). For the SEI, therefore, the term "maturity" relates to the degree of formality, standardisation and consistency of processes. They needed to know if their contractors were supplying consistent services with standardised systems. It soon became clear that the model could be applied to other processes too and today maturity models are employed in diverse domains and contexts to measure, plan, monitor and benchmark the evolution of systems within organisations (Fraser, Moultrie, & Gregory, 2002).

8.1.1 Types of maturity frameworks

The most basic maturity-analysis methods is Likert-like and hybrid questionnaires; all one-dimensional scaling method. These methods are primarily used in questionnaires to obtain a participant's degree of agreement with a set of statements concerning the aspect / domain that is being assessed. They are also used within maturity models and focus on scoring specific statement of "good practice" and not the system's over-all maturity (Essman, 2009)

A second type of maturity model is a maturity grid. Maturity grids assess multiple aspects / dimensions of a system to eventually and describe the overall level of maturity of the system. A maturity grid is a multi-dimensional model that describes the typical behaviour exhibited by a system at a number of levels of "maturity". This grid codifies what is regarded as best practice and poor practice and the transitional stages (Fraser, Moultrie, & Gregory, 2002). According to Maier et al, a typical maturity grid allows for the visualization of maturity levels; illustrating a number of levels of maturity in a simple, textual manner with descriptive text for the Maturity grids are descriptive frameworks, used for self-assessment purposes, they are not used as improvement tools. Companies often follow a number of approaches in parallel for improvement and maturity grid assessment may be used as one of these (Maier, Moultrie, & Clarkson, 2012).

Lastly capability maturity model where developed as compliance standard for certain organizations and gained widespread popularity. Capability maturity models, the most sophisticated and formal of the three types of maturity models, developed. CMM build on maturity grids by defining each level of maturity with a number of goals and key practices to reach a predefined level of maturity (or capability) (Mettler, Rohner, & Winter). Each level is defined by capabilities of the organisation. The extent to which the goals have been accomplished is an indicator of how much capability the organization has established at that maturity level (Mettler, Rohner, & Winter, 2010). CMM advanced to become a certification standard to measure an organisation's capability to perform a task (Fraser, Moultrie, & Gregory, 2002). CMMs measure. Cooke-Davies (Cooke-Davies, 2004) explains that the family of capability-maturity models measures "the extent to which an organization has explicitly and consistently deployed processes that are documented, managed, measured, controlled and continually improved."

These frameworks differ in purpose, from descriptive, prescriptive and comparative

8.1.2 Purpose of maturity models

According to Essman (Essman, 2009) all types of maturity models are descriptive – they provide a way of measuring the status quo. Some types of maturity models go further to suggest an improvement process that best suits the enterprise after determining the status quo, these are called prescriptive. Prescriptive models facilitate an improvement process that best suits the enterprise while remaining within the prescribed best practices parameters of the particular domain (Essman, 2009). De Bruin suggests there is a third purpose, namely comparative maturity models. A comparative model enables benchmarking across industries or regions and would enable the comparison of similar practices or process within and across organizations.

Pöppelbuss explain that a descriptive maturity model provide a snapshot of organization regarding its performance at a certain point. Prescriptive models then suggest and the best practiced step-by-step progression on the predetermined sequence of maturity stage (Poeppelbuss, Niehaves, Simons, & Becker, 2011). Thirdly, given sufficient historical data from a large number of assessment participants, the maturity levels of similar business units and organizations can be compared (Poeppelbuss, Niehaves, Simons, & Becker, 2011).

8.2 Existing telemedicine maturity framework

Various maturity frameworks for system implementation, evaluation and management have been developed in a multitude of environments, all with their own strengths and weaknesses. The maturity frameworks applicable for the telemedicine and the healthcare environment were identified as; NHS infrastructure maturity model (NIMM) and PACS Maturity Model (PMM), and the telemedicine service maturity model (TMSMM). In this article, these existing maturity frameworks are discussed with the purpose to assess their suitability for fostering of the PACS systems in the public healthcare domain of South Africa.

8.2.1 NHS Infrastructure Maturity Model (NIMM)

The NIMM is an IT infrastructure maturity model that was developed by the National Health Service (NHS) Technology Office, together with a number of different NHS IT Organizations in the United Kingdom (Savidas, 2009). The NIMM is internationally recognized descriptive MM, used to assess the capabilities of contractors for the NHS (becoming a comparative MM used as a compliance model for the NHS contractors). Therefore the NIMM fits the description of a CMM and is possibly the only on its type in the field of health systems at the present time. The NIMM has formal architecture that is shown in the simplified version in Figure 39.

Figure 39: NHS Infrastructure Maturity Level Summary (registered trademark of the department of health)

8.2.1.1 Suitability of the NIMM

The NHS is the governing body of the publicly funded healthcare systems in the United Kingdom. The NIMM was developed to assess compliance of contractors with the NHS needs, and therefor the healthcare needs of the United Kingdom (Savidas, 2009). The needs of UK, as first world country, differ greatly from SA, as a developing country. The NIMM is a model developed to assess contractors for NHS unlike before they are accepted, whereas the PMM will be developed to assist the management with the deployment and maturation of the current PACS system within the healthcare enterprise (Savidas, 2009). Even though the NIMM is an extensive, formal, globally excepted standard it does not fully capture the need of PACS systems in SA and therefore is not a relevant model to facilitate management to optimise PACS in a South African hospital enterprise.

8.2.2 The PACS Maturity Model

Van Wetering *et al* recognized the need for a framework to assist management with strategic guidance for PACS systems in Europe. They specifically considered management and business process alignment and developed a PACS maturity model (PMM) (Van der Wetering & Batenburg, 2009). The PMM is an example of a maturity grid, describing five levels of PACS maturity and the corresponding process focus (Van der Wetering, Batenburg, & Lederman, 2010). Van Wetering also developed a PACS Likert scale to form a concept of the users opinion on the state of the PACS healthcare delivery system. The model is then is extended to form a broad descriptive framework for strategic planning used for PACS deployment.

The outcomes of a PMM, according to van Wetering (Van der Wetering, Batenburg, & Lederman, 2010), is to optimise:

- Clinical Business Processes: Diagnosis process.
- Quality and Transparency: Simplicity, quality and transparency of workflow
- Information System: PACS Integration and System Robustness.
- Patient: Patient waiting time.

Resulting in a PMM, describing 5 levels of maturity as illustrated in Figure 40.

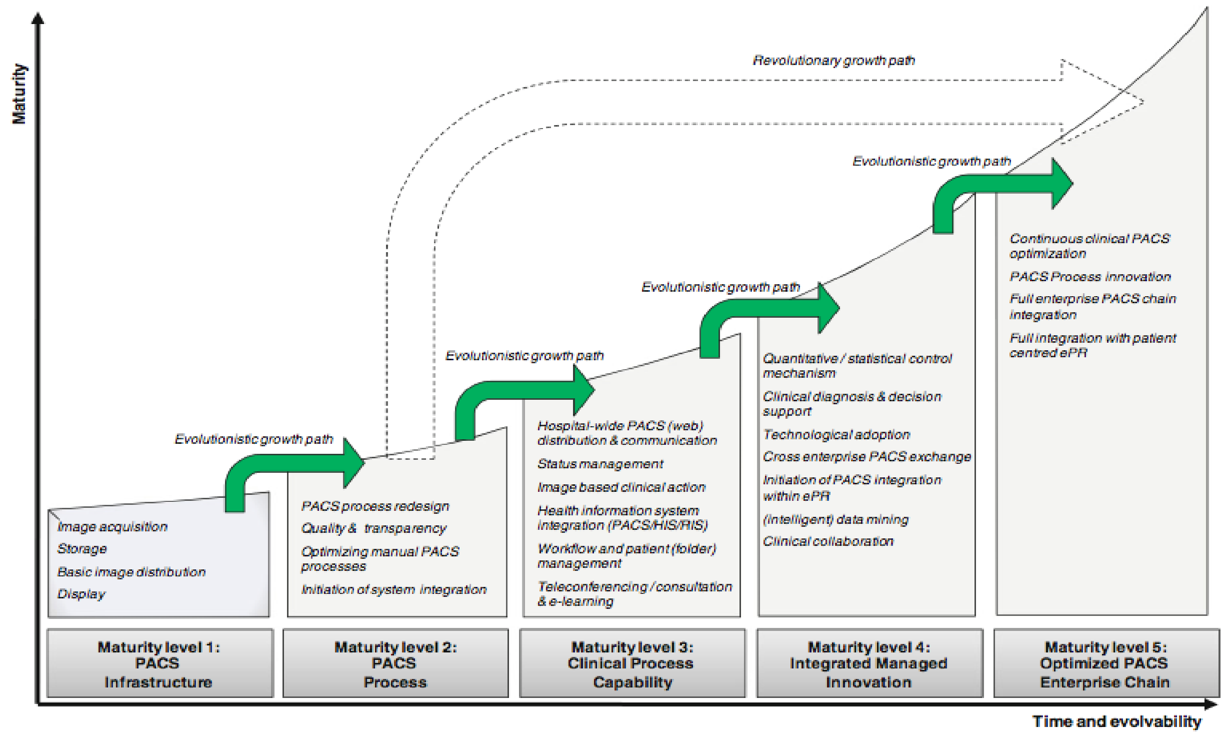


Figure 40: PACS MM developed by R van Wetering

8.2.2.1 The suitability of the PMM

The PMM was developed by van Wetering focusing on the European hospital environment and needs. The PACS process needs defined by van Wetering differs from that of the South African health context. In South Africa the goal of PACS is to allow more patients access the specialised healthcare, rather than optimizing the services for the patients. And the barriers faced by PACS projects in South Africa differ greatly from European barriers. SA is faced with a much greater percentage of users that are computer illiterate or refuse to use computers, funds are limited, necessary Internet availability is not a given and imaging machines are out of date (Department of Health, 2010) (Doubell P. A., 2011) (World Health Organisation, 2012). Europe focuses more on optimizing the PACS process where as SA is just trying to deploy and standardize the process (Van der Wetering, Batenburg, & Lederman, 2010). Therefore the PMM does not fully capture the need of PACS systems in SA and therefore is not a relevant model to facilitate management to optimise PACS in the South African hospital enterprise.

8.2.3 The telemedicine service maturity model (TMSMM)

The final TMSMM is a prescriptive maturity grid developed for all telemedicine services in South Africa, the telemedicine service maturity model. This model describes the levels of telemedicine service maturity and provides a framework to determine the position of maturity of any telemedicine process. This model was developed in parallel to this study.

The telemedicine service steps are listed as: capture data, transmit data, diagnose, transmit feedback and lastly react on feedback. The TMSMM divides every telemedicine process step into domains: Users and user community (*man*); ICT infrastructure, devices and software (*machine*); electronic health records (*material*); business process and policy and work protocols (*methods)*; cost and financial sustainability (*money)*. The TMSMM describes 5 maturity levels for each domain of each process step of the telemedicine service. The maturity levels are based on the stages of the CMM (Van Dyk & Schutte, 2012).

8.2.3.1 The suitability of the TMSMM

The TMSMM was developed for the SA health service environment as a broad model covering all telemedicine service processes. The domains as were defined by the TMSMM are appropriate for purposes of this study, with minor adaptations (Van Dyk, Schutte, & Fortuin, 2012). However, the process steps and maturity levels had to be adapted considerably for purposes of this study. The reasons for this are firstly that the TMSMM was developed in parallel to this study. A complete model was not available when this study commenced. Furthermore, the process and maturity levels are not specified for the PACS process and the technical requirements of the system.

Although the needs of the South African healthcare environment are relevant, the process steps do not capture the whole PACS process and its technical system specifications. The PACS process captures data, transfers data, stores and processes data, provides retrieval and analysis of the stored data where after it allows for compiling and transmission of feedback (Van Dyk, Schutte, & Fortuin, 2012). The TMSMM looks at the health service delivery from a treatment perspective in general, separate form a technical healthcare life-cycle, and therefore only has the steps: Capture, transmit, diagnose, transmit, feedback and react. Therefore even though the TMSMM has the correct needs for the SA healthcare delivery process it does not capture the exact PACS process in enough detail to assist with the deployment and development of the system.

8.3 Analysis of existing models

All three models discussed, individually define the maturity evolution of a given telemedicine process. They (the models) each provide a set of statements defining the different maturity levels. These can serve as yardsticks for assessment of the organisation's position and subsequently, where necessary, for suggesting an improvement path.

The above models are all relevant to their associated process and goal. However none of the above mentioned models take into account the correct steps of the process in combination with the correct needs of the PACS healthcare delivery environment in SA. Therefore none of them are adequate to foster PACS maturity in SA. Hence, to accomplish the purpose of this study a new maturity model is developed, adapting certain elements from the existing models to form the PACS Maturity Model (PMM). The PMM will be discussed in the next chapter

In this chapter MM's were discussed and current healthcare MM's were assessed for suitability. It was concluded that none of the existing MM's are sufficient in detail for the system's technical requirements or interrelated PACS healthcare delivery steps, needed within the public South African healthcare environment, as a developing country. Consequently, a new MM was developed. The following chapter will address the required characteristics (or criteria and dimensions as it is referred to in the PMM) of just such a model, with a dedicated focus on development of a PACS healthcare delivery system to serve the South African public healthcare environment.

9 The PACS MM structure

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. After concluding that existing models are not sufficient in detail for the system's technical and operational requirements for South Africa a new PACS Maturity Model (PACS MM) was developed, specifically for PACS in South Africa. In this chapter, as illustrated in Figure 41, the criteria and dimensions of the PACS MM will be discussed in more detail.

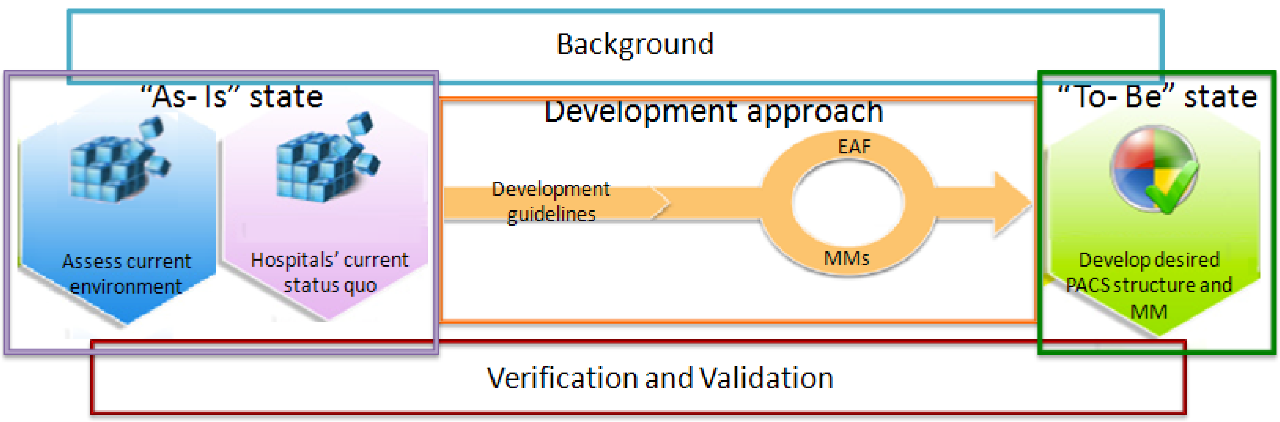


Figure 41: MM development structure methodology

The PACS maturity model was developed to take into account the different PACS healthcare delivery process steps, the different hospital domains from a PACS healthcare delivery perspective, and the evolutionary plateaus of the PACS healthcare delivery process deployment and maturation. This was established though the research that was completed by visiting different hospitals and investigating different stakeholders from a broad spectrum of the South African public medical sector, following an iterative process of empirical en literature research. The methodology in Figure 41 illustrates the process as in circular procedure, in conjunction with the PACS MM model, because the two happened concomitantly, through an iterative process. In the chapter the development of PACS MM is discussed with regard to each of the dimensions, the way they were determined and their relevance.

9.1 The dimensions of PACS MM for South Africa

The PACS MM was developed through literature research, combined with practical results found during hospital visits. The healthcare workers involved in the PACS healthcare delivery process were approached, to determine each step of their work process and the elements they came into contact with. The users included healthcare workers (e.g. specialists, clinicians, radiographers and nurses), hospital managerial figures, hospital information and communication technology (ICT) personnel, hospital finance and admin personnel, as well as PACS suppliers. The system role-players were questioned regarding PACS, their experience towards PACS, their needs, and what they like and dislike about the current system setup where determined. The role-players contributed their domain knowledge for solution creation and in doing so, contributed to the validity of the model. The role-player's feedback was considered; together with the thoughts of other researchers from literature; as well as PACS technical limitations; HL7 specifications; and DICOM requirements in order to revise key design features for the PACS MM. The hospitals were visited and the role-player of the PACS process's feedback was considered; together with the thoughts of other researchers from literature; as well as PACS technical limitations; HL7 specifications; and DICOM requirements in order to revise key design features for the PACS MM.

The two dimensions of importance were established, namely; the PACS process steps and the PACS process domains. Both the process steps and domains need to be aligned to support the process and are vital for process optimisation to reach the defined PACS structure. Due to the previous, both the process domains and steps are discussed as to their maturity, resulting in three PACS MM dimensions for the PACS MM: PACS process steps, PACS process domains and PACS process maturity levels.

9.1.1 The PACS process steps

PACS is a complex system dependent on a long range of steps in the healthcare delivery process. For the purpose of this thesis the PACS healthcare delivery system is broken into individual steps and simplified to make it more understandable and manageable in PACS MM. The need to focus on the individual PACS healthcare delivery steps separately are strengthened, due to the fact that while certain steps of the process function optimally others have problems and cause the whole PACS healthcare delivery process to fail. Therefore, it is necessary to break the process into its separate steps to determine exactly which step is the process barrier and thereby determine what the solution needs to be to optimise that specific step. For example, if the images are captured and transmitted, but not stored effectively, it cannot be accessed and the rest of the care delivery process collapses. The problem is not the way it is accessed but the way it is stored, even though the problem is experienced at accessing the image. Due to the previously stated phenomenon all the steps must be considered in accordance to their maturity in the PACS process to eventually achieve an optimal PACS healthcare delivery process.

The generalised process steps, as explained in Figure 7 of section 3.1 of the “As-Is” analysis and established again in Figure 25 of section 5.2 of the “To-Be” analysis, are applicable to the PACS healthcare delivery processes on any maturity level at any healthcare institution. As the system becomes more mature the process entailed changes and the steps become more automised. The PACS healthcare delivery process steps that were established are: (1) Patient data is captured, (2) transmitted to a where the (3) data is stored and backed-up until it is later (4) retrieved for (5) analysis, where after a (6) feedback is compiled and transmitted back. In Table 10 below each one of the PACS process steps are listed and described in general.

Table 10: PACS process steps' descriptions

PACS process steps	PACS process steps’ description
Capture patient image	Capture the patient image with digital imaging equipment
Log and Transmit patient data	Log patient image and link with patient
Store patient data	Store image on PACS and manage the stored patient data.
Retrieve patient data	Access and retrieve patient image and patient data for analysis
Analyse patient data	Analyse patient image and data to make diagnosis
Transmit patient feedback	Reconstruct image and compile feedback, transmit the diagnosis.

**The table is presented in orange, as will all the PACS process step illustrations in the PACS MM throughout the thesis.*

9.1.2 The PACS process domains

The PACS healthcare delivery process, being a long and complex process dependant on many factors, has numerous role-players and elements contributing to its successful operation, (as discussed in section 4.2) which highlights the numerous root causes for the PACS barriers. The root causes, grouped by the 6m's of the quality assurance principles of Dr Ishikawa were combined with the domains of the TMSMM, to result in the PACS healthcare delivery process domains, which are:

1. Man
2. Machine
3. Method
4. Material
5. Money

The domains are listed and described in Table 11.

Table 11: PACS process domains' description

PACS process domains	PACS process domains' description
Man	All the hospital users involved in the PACS healthcare delivery system
Machine	The hardware and software technology used to operate the PACS healthcare delivery system
Method	The work methods, operating procedures and protocols used in the PACS healthcare delivery system
Material	The data obtained, stored and transferred in the PACS healthcare delivery system. Material involves the file format and data format of images and patient files, as well as the transfer and compression format of such files.

Money	The financial resource used to fund the PACS healthcare delivery system and the contracts stipulating its use.

**The table is presented in green, as will all the PACS process domain illustrations in the PACS MM throughout the thesis.*

The successful operation of is dependent on all tasks performed by all of the domains. All the domains must be considered in accordance to their maturity in the PACS process to eventually achieve an optimal PACS process. For example, if funding is available but the hospital is not free to use it as they need, this can result in suboptimal system design due to certain necessary elements being underfunded. In such a case the money-domain is not mature in accordance to the PACS healthcare delivery process even though there is enough money available. If all the hardware is state of the art but is not setup in ergonomically positioning for personnel, it causes personnel to struggle with the use of the particular apparatus (as was found with some screens being too high for viewing). In such a case the machine-domain is not mature in accordance to the PACS healthcare delivery process even though all the machinery is available.

9.1.3 The PACS process maturity levels

A newly implemented system evolves through levels of development from the starting: impromptu, unorganized phase to the final: mature, structured, optimised phase. These evolutionary plateaus are referred to as maturity levels. Through the research done in this project, the suitable PACS healthcare delivery process has been determined. This section discussed the maturity levels of the PACS healthcare delivery process development necessary to reach the desired state. For the PACS MM to be applicable to all hospitals in South Africa, the model must consider the different maturity levels that various hospitals in South Africa are at. This will allow the model to consider all the relevant development phases of the PACS deployment process. The phases for the PACS healthcare delivery process start from obtaining PACS to deploying the process, standardising it in a single department and deploying it through the hospital and eventually to other hospitals. The initial phases focus on the infrastructure and PACS development within the hospital and the final phases are more oriented towards efficient PACS workflow, process integration and integrating the other hospitals hospital.

The different evolutionary plateaus for the PACS healthcare delivery process where developed by building on the plateaus of the exciting MMs (PMM of van Wetering and the TMSMM of van Dyk) and the development phases suggested in the South African telemedicine strategy. These phases were then adjusted to incorporate all the PACS development phases found in South African public healthcare environments. The established evolutionary plateaus or maturity levels of the PACS healthcare delivery process are as follows:

1. Ad hoc
2. Deployed
3. Standardised within the hospital
4. Controlled and optimised within the hospital:
5. Optimised, integrated enterprise:

Each of the maturity levels' concepts are described in Table 12.

Table 12: PACS process maturity levels' descriptions

PACS process maturity levels	PACS process maturity levels' description
(1) Ad hoc	A PACS system is just been obtained or is being obtained, but not installed yet.
(2) Deployed	A PACS is deployed, using the PACS archive and sharing only image data, patient data is still on hardcopy. This system is used separately for separate departments. (DICOM / vendor PACS)
(3) Standardised within the hospital	A hospital server is installed and the hospital PACS architect integrated with patient information with PACS images system. The system is deployed throughout the whole hospital (vendor / super PACS)
(4) Controlled and optimised within the hospital:	The system is managed, measured and optimised within the hospital. (hospital owned PACS)
(5) Optimised, integrated enterprise:	PACS is connected and integrated with other hospitals. The system in continually improved and updated. (integrated PACS enterprise)

**The table is presented in blue, as will all the PACS process maturity level illustrations in the PACS MM throughout the thesis.*

As the PACS healthcare delivery process matures so do the process steps and domains involved in the healthcare delivery process. Table 13 describes the process steps and Table 14 the process domains on each maturity level.

Each of the process steps mature on the following basis:

- The **capture process steps** becomes standardised to the level where a general practitioner can capture the bulk images for a specialist to later select the necessary images for diagnosis.
- The **transfer process step** becomes automated, eliminating the administrative and logistic tasks of printing and transferring the image to the storage room. The image file is linked with the patient data by a patient UID. Also the printing machine and x-ray files become obsolete, saving large amounts of money.
- The **storage process step** also becomes automated, eliminating the administrative task of filling and maintaining the patient images. The patient images are automatically linked with the patient information by patient UID. Also the need for large filling rooms is eliminated.
- The **retrieval process step,** like transfer, becomes automated, accessing the entire patient file from a computer with access to the server, eliminating the administrative and logistic tasks of printing and transferring the image to the storage room. Thus minimizing the possibility of lost patient files and redoing imaging examinations.
- The **analyse process step** becomes more effective and efficient as images are easily accessed, in a high quality, by specialists linked with the entire patient file and history. The amount of information available in combination with the post processing capabilities allows the specialist to more accurately make remote diagnosis.
- The **feedback process step** becomes more efficient as the entire patient file is accessible and editable from the personal computers of doctors and specialist.

Table 13 describes how each of the PACS healthcare delivery process development phases through the maturation process.

Table 13: The maturation of the PACS process steps

Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: QC	Level 5: Optimising

CAPTURE	Digital imaging equipment is not yet available or not yet y being used digitally	Digital imaging equipment being used digitally in certain departmental groups.	Digital imaging equipment being used digitally throughout the hospital. There is a standard determined for operation.	Digital image capture is being monitored and measured.	Lower level personnel are empowered for digital imaging capture.
TRANSMIT	Network points and software not yet available or not no used to logged or transmitted on IS.	Network is setup. Software is installed and operational. Data is logged/transmitted according to departmental IS and transmitted.	Hospital network is operational and data is logged according to Hospital IS and transmitted securely.	Network and transmission is managed and standardised. Data is transmitted in RAW format	Inter-hospital network is establish, for secure, automatic RAW data transmission
STORE	No formal storage. Images not stored on PACS archive	A local/ departmental IS, server and archive is setup	A central IS, server and archive for whole hospital and designated specialists is setup.	Data is stored in raw format and made interoperable on IS.	Hospital server and archive is interlinked with other hospitals.
RETRIEVE	Patient data is retrieved according to the storage method	Images are retrieved at the specialist WS from the departmental archive via the departmental IS, with the	Images are retrieved at any WS from the hospital archive via the HIS with the hospital patient ID	Data managed and secured. It is retrieved in raw format, allowing all post processing.	Images are retrieved at any WS from any hospital's archive via the inter – hospital IS

		departmental patient ID			with the universal patient ID
ANALYSE	Viewers and WS not yet available. Still images are analysed (JPEG, PDF)	Data in DICOM format can be analysed: allowing DICOM post processing	DICOM, patient data, files are analysed: allowing DICOM post processing and patient history access.	Raw data analysed: allowing all post processing and patient data access	Patient history from all hospitals can be accessed in all formats.
TRANSMIT FEEDBACK	Users preference is used for feedback	Feedback is uploaded to departmental IS as encapsulated pdf, non securely	Feedback is uploaded to hospital IS as encapsulated, non securely	Feedback is uploaded to hospital IS as text, securely	Feedback is uploaded to inter-hospital IS as text, securely

Each of the process domains mature on the following basis:

- The users become more trained, motivated, and the system becomes the norm. Lower level users are empowered to perform certain steps of the process to spare scarce specialists to perform more complex tasks only they are able to perform, such as die examination, diagnosis and treatment.
- Machines become standardised and interoperable and there setup ergonomically designed and adjusted to user specification.
- Material or patient data is stored on a patient database and images on an image database that are merged through the server on a patient centric information, allowing diagnosis from any computer with a web access to server and image viewing software with post processing capabilities.
- The work methods become standardised, and optimised to suit the hospital needs and the process workflow becomes efficient and transparent while quality of healthcare delivery is improved.

- The money is catered for in the hospital strategy for PACS healthcare delivery process and funds are available to sustain the process and its growth.

Table 14: The maturation of the PACS process domains

	Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
MAN	Users resist new system. Staff is untrained and unmotivated.	System becomes acceptable. A pilot team motivated, driven by champion.	New system becomes is norm. Trained and motivated.	Human resource management/ client management for new system.	New system brings a change to community. Continuous user empowerment
MACHINE	Some technology is obtained as experiments or pilots	Technology is available and effective and used by certain departmental groups.	Technology is standardized, forced to interoperate and used throughout the hospital and its specialists	Technology is managed, monitored and measured for reliability, availability usage and maintainability	Continuous R&D and technology is continuously improved and standardised for intra-hospital interoperable system - VNA
MATERIAL	Informal usage of electronic patient information. No IS or PACS setup	Localised departmental IS and PACS	Force integrated IS and PACS within the hospital (and designated specialists)	Patient information is managed in one patient centric information system.	Interoperable intra-hospital patient information system.

METHOD	Hospital protocols discourage telemedicine services	Hospital protocols allowing telemedicine services	Hospital policies and protocols catering for telemedicine services. Clearly outlined	Hospital policies and protocols manage and optimise telemedicine services	Hospital strategy catering for continuous improvement of telemedicine services
MONEY	Financed by a once of investment. Acquisition and maintenance is not in hospital budget.	The acquisition is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution.	Operation of PACS process and their users are included in hospitals budget from governmental institution	The acquisition and operating cost are effectively measures, reported and reviewed, together with the calculated ROI. There are funds for system management and improvement.	Funds are available for R&D and business model sustains growth of system and increasing cost.

9.1.4 PACS MM Capability Statements

Finally to conclude the PMM's structure, capability statements were defined for each domain at each process step. The capabilities describe what the the specific PACS healthcare delivery domain at the specific process step entails. For example, the Man-domain at capture: Clinician must take the digital patient image. The capability statements are described in Table 15.

Table 15: The PACS MM capabilities

MAN	MACHINE	MATERIAL	METHOD	MONEY

CAPTURE	Clinician taking digital patient image	Digital imaging machine	Image data	Work protocol to capture digital image	Funds for machinery, maintenance and personnel
TRANSMIT	Clinician/Admin personnel responsible for transmission and file linking	Local WS, PACS software, intranet	Patient UID, image data, image UID	Work protocols to log patient ID on IS and transmit patient data	Funds for network, software and personnel
STORE	Admin/ IT personnel	Central server, IS, Archive,	Patient Information system, backup data	Work protocols to securely store patient data	Funds for machinery, maintenance
RETRIEVE	Personnel responsible for data retrieval	Viewing station, software, internet	Patient image, patient information, with patient ID	Retrieve Patient image by tracking the patient file on RIS	Funds for network, software and personnel
ANALYSE	Specialist responsible for data analysis	Viewing station, Viewer software	Patient image, patient information	Work protocol to analyse patient data on viewer software	Funds for machinery, maintenance and personnel
RETRIEVE FEEDBACK	Personnel authorised to transmit feedback	Viewing station, text enabling software, internet	Text feedback data, patient ID	Work protocols to transmit text feedback to IS	Funds for software, personnel

In this chapter the criteria and dimensions of the MM for PACS system implementation and optimisation guidelines, suited for the South Africa public healthcare environment was established. The following chapter elaborates on the PACS MM for South Africa.

10 The PACS maturity model

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. After establishing the requirements for the improvement guidelines and the PACS MM structure, this chapter discusses the PACS MM for South Africa, in accordance to its structure, elements, and function. Figure 42

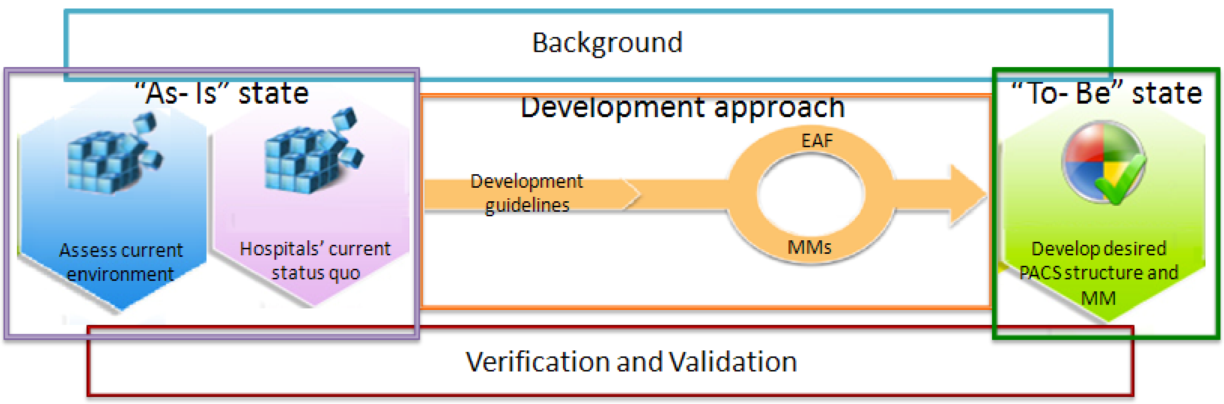


Figure 42: PACS MM methodology

A model that takes into account all three dimensions of the PACS healthcare process (steps, domains and maturity level) was constructed, as seen in

Figure 43: PACS MM

Each facet of the model represents a dimension of the PACS healthcare process: the width lists the PACS process maturity (*illustrated in blue*), the height indicates process steps (*illustrated in orange),* and the depth the process domains (*illustrated in green*). The colouring specifications are relevant to all the figures that follow. With the model constructed in this way, the process is broken up into its fundamental elements. The maturity of the process step and the process domain are considered, to give a combined maturity result. This makes it easier to find the exact position and barrier that needs attention to reach the next maturity level. Each element of the three dimensions is discussed in detail in the following section. The PACS MM is attached Addendum A

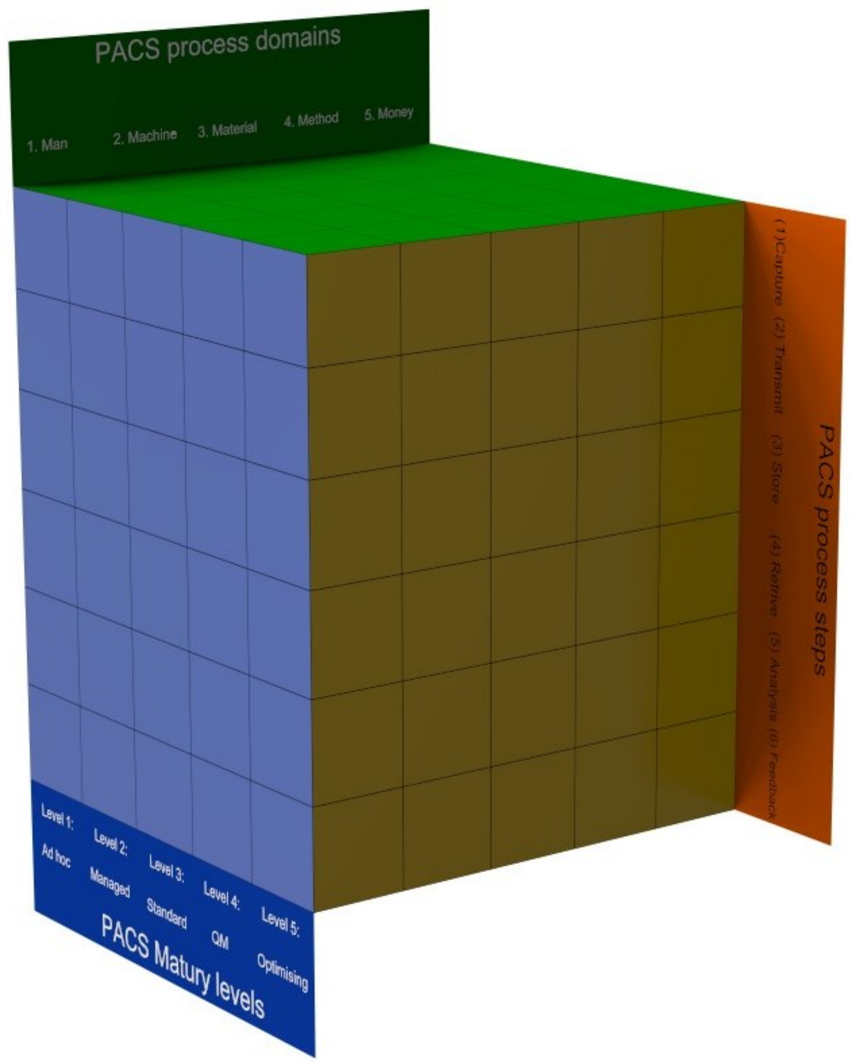


Figure 43: PACS MM

10.1 PMM: The Process steps

The six PACS healthcare delivery process steps, as illustrated in Figure 7, are described according to the different domains and maturity levels in the following section. In terms of the PACS MM in

Figure 43: PACS MM

, the process steps are represented by the yellow and orange planes.

10.1.1 Capture patient data

The first of the PACS healthcare delivery process steps is to capture the patient image data. Capturing patient images entails using the imaging machine in question, placing the patient in the correct position for the imaging procedure and recording the data by activating the imaging modality. Even though capturing patient data seems like a monotonous task, capturing the right quantity of the right data requires specialist knowledge. Specialists are a scarce resource. The suitable / mature state is to empower a lower level user to capture the patient data and send it to a specialist to diagnose, or have a remote specialist assisting the image capture. The whole capturing process thus moves from the ad hoc state, where the specific images are captured with digital machines by an on-site specialist for on-site diagnosis, to a mature state where general digital images are captured by a lower level user, such as a GP or a nurse, onto a digital system that integrates with patient data file. Both the files are accessible by a specialist who can manipulate and select the necessary images to perform the diagnosis remotely.

The user, in general for the capture step, changes from being untrained and unmotivated to use the digital capturing process, to using the process as standard practice. By managing, measuring and monitoring the user, self-empowerment can be continuously increased. The machines for capture process, in general, change from being unstandardised for the digital capturing process, to being standardised and needing less information input. This occurs as the patient file is accessed and automatically linked with the new patient image. The material changes from being a hardcopy image, to a DICOM file image with a study date, to a PACS file with a patient name, to eventually two separate patient data and image files linked with patient UID. The methods change from doing everything manually: selecting images, printing the images, filling the images; to entering the patient information in the file. Eventually the patient file with patient UID is accessed and the image automatically links with the patient file and a new, unique study UID. The expense starts as a once-off funding for machines, to eventually creating a budget for the hospital to manage, maintain and upgrade the digital image capturing machines.

Measuring the performance of the capturing process entails: the amount of patient images captured, the amount of images that need to be re-captured and the success rate of remote diagnosis from digital images. Worker performance metrics, for the digital imaging procedure, need to be effectively included in the performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with imaging procedure is recorded. The machines for capture process, in general, changes from being unstandardised, for digital capturing process, to being standardised and needing less information input. This occurs as the patient file is accessed and automatically linked with the new patient image. The material changes from being a hardcopy image, to a DICOM file image with a study date, to a PACS file with a patient name, to eventually two separate patient data and image files linked with patient UID. The methods change from doing everything manually: selecting images, printing the images, filling the images; to entering the patient information with the file and eventually accessing the patient file with patient UID and the image that automatically links with the patient file and a new, unique study UID. The expense starts as a once-off funding for machines, to eventually creating a budget for the hospital to manage, maintain and upgrade the digital image capturing machines.

The capture process step of the PACS MM can be viewed in Addendum B, Figure 2.

10.1.2 Transmit patient data

The second of the PACS healthcare delivery process steps is to transmit the patient image data. Transmitting the patient images entails logging the patient image with the correct patient file number and linking it with the patient file on the HIS for later retrieval. This task seems fairly simple, but correct logging becomes difficult when there is not a good patient referencing system in place and when different hospital information systems are not interoperable. The whole storing process therefore moves from the ad hoc state, where workstations (WS) and PACS software is not yet set up with the HIS, and there is no standard for logging patient data, to the mature state where there is a secure inter-hospital network and a standard to log patient data for secure storage on an patient centric information system.

The user, in general, changes from being untrained and unmotivated to log the digital patient data, to using a standardised process as standard practice. The machines for transmitting the patient changes from being non-existent, due to the DICOM patient image printed cannot be linked with patient data, to eventually automatically linking the new patient image with the patient file through patient UID. The material changes from being a hardcopy image that is filed in a hard copy patient file, to a DICOM file image with a study date and a duplicate hard copy patient file containing the study date, to a PACS file containing the patient name, to eventually two separate patient data and image files linked with patient UID. The methods change from doing everything manually: selecting images, printing the images, filling the images, to entering the patient information with the file, to eventually automatically linking the image with a new, unique study UID to the patient file through patient UID. The expense starts as a once-off funding for software, to eventually having a budget for the hospital to manage, maintain and upgrade the software with IT maintenance personnel.

Measuring the performance when storing, entails looking at: the number of images that are lost, the number of images with incomplete data, the number of images that need to be retaken, the time it takes a user to log or access a file, as well as the user satisfaction with the software and process.

The transmit process step of the PACS MM can be viewed in Addendum B, Figure 3.

10.1.3 Store patient data

The third of the PACS healthcare delivery process steps is to store the patient image data. Storing the patient images entails logging the patient images with the patient key to the given database. The stored data also needs to be managed for integrity, authentication and backup. Data ownership is also an important facet of the data storage process. When the PACS system is set up correctly, most of the data storage steps are automated, although the management of the stored data on the IS needs to be done by dedicated personnel. The whole storage process therefore moves from the ad hoc non-automated state, where the user stores the images by his own method on his own computer, to the mature state, where images are stored automatically in raw format on a patient centric hospital information system and backed. The users, in general, change from being involved in each step of storing the data, to not having to be involved in each step due to an automated system that only needs to be managed by one dedicated person.

The user involvement changes from high, when storing the hardcopy files, to none, when the server stores files. IT staff are, however, required to maintain and manage the server. The machines for storing change from none, to a vendor PACS archive, to eventually a hospital-owned server and separate archives that the hospital manages and maintains. The material changes from being hardcopy patient files in a storage room, to a DICOM file in a DICOM archive with a study date, to a PACS file containing some information and the patient name, to eventually being separate patient data and image files linked with patient ID. The methods change from doing everything manually; maintaining, sorting, filing and protecting files, to eventually automatically managing patient files and keeping the patient file integrity of the database. The expense starts as a once-off funding for a vendor solution, to eventually having a budget for the hospital to manage, maintain and upgrade the server and databases software, with IT maintenance personnel.

Measuring user performance when storing, entails measuring the data integrity, storage space and cost, as well as the data accessibility.

The store process step of the PACS MM can be viewed in Addendum B, Figure 4.

10.1.4 Retrieve patient data

The fourth of the PACS healthcare delivery process steps is retrieving the patient image data from the database. The retrieving step entails accessing the patient data and image file on the respective databases through the server, by entering the patient ID from a clinician's workstation. Basic retrieval in the ad hoc state entails opening a specific file, sent via email or CD, with DICOM viewer software. This file does not include all the patient data and history. On the other hand, in the mature state, the patient file is accessed by means of the patient UID, through the server, from the clinician's workstation (WS). The server accesses the patient data and patient image on the separate databases and integrates the data to send the whole file to the clinician's workstation. This file on the clinician's workstation then contains all the patient data, images and previous examinations in raw format.

Maturation of the retrieval process for the user domain regards the position of the user accessing the data. As the system matures, remote specialists can access the data without having any other communication with the on-site clinician. In the ad hoc state, if the specialist accesses the patient images, he has to be in contact with the on-site doctor to explain the patient condition. As the accessibility of data matures, the specialist can access complete history and examination records, and therefore the data does not have to be sent selectively to the specialist. This means that the specialist can examine image studies that have been captured by an amateur. The machines and material domains for retrieving the patient data changes from being very limited, due to the amount and type of data accessible, to accessing any amount and type of data, as well as the complete patient history. The methods change from retrieving patient files manually from a filling room, to eventually accessing the data by the press of a button with patient UID. The expense starts as a once-off funding for software, to eventually having a budget for the hospital to manage, maintain and upgrade the software and hospital network, with IT maintenance personnel.

Measuring user performance, when retrieving the patient data entails, determining the patient studies which are diagnosed on-site and remotely, the speed and accessibility of the patient files, as well as the amount of data being accessed.

The retrieve process step of the PACS MM can be viewed in Addendum B, Figure 5.

10.1.5 Analyse patient data

The fifth of the PACS healthcare delivery process steps is analysing the patient image data. Analysing patient images entails assessing the image with PACS viewer software on the clinician's WS. This task seems fairly simple, but the image needs to be accessible in a format that allows post-processing and the image quality must be high enough to allow for grey scale definition. Therefore, the whole analysis process moves from the ad hoc state, where the image is assessed on DICOM viewer software on a normal computer screen, to the mature state, where the image data is viewed in raw format, allowing all post-processing options on a work station with high quality and large analysis screens.

The user changes from being untrained and unmotivated to use the digital analysis process, to using the process as standard practice. The machines used to retrieve the patient data, change from being very limited, to having the viewing abilities to allow post-processing and manipulation of any image data for analysis. The material domain matures as the amount of data available to analyse increases. As the analysis process step matures, more data is available and the specialist can decide which data are necessary for diagnosis, instead of the on-site clinician. This describes the change in method: in an ad hoc analysis process, the on-site doctor decides which cases need to be sent for specialist examination. In a mature analysis state, the specialist receives all the patient data and makes the decision which of the data is vital for diagnosis. Again, the expense starts as once-off funding for software and analysis screens, to eventually having a budget for the hospital to manage, maintain and upgrade the software and hardware for analysis.

Measuring user performance when retrieving, entails determining: the amount of patient studies being diagnosed on-site and remotely, the specialist acceptance and satisfaction with the digital analysis, the speed and accessibility of the patient files, as well as the amount of data being accessed.

The analysis process step of the PACS MM can be viewed in Addendum B, Figure 2.

10.1.6 Transmit patient feedback

The final PACS healthcare delivery process step is to transmit the patient's diagnosis feedback. Transmitting the patient feedback entails compiling the feedback and transmitting it with patient UID to the patient data file. In the ad hoc state, feedback is communicated verbally between participants, because test data is not integrated into the patient image files but kept separate on hard-copy file. In the mature state, the analysis feedback is added to the accessed patient data file and saved to the patient information database automatically. Therefore, transmitting feedback matures as the material domain and server matures

The user changes from being untrained and unmotivated to use the digital feedback process, to using the process as standard practice, managing, measuring and monitoring the standard practice to lastly continuously increasing self-empowerment. The machine domain for transmitting the patient feedback, changes from being non-existent, to simply typing the text into the patient file on the specialist's workstation. The material changes from being hardcopy feedback in a patient file or telephonic communication, to eventually being an electronic patient file linked with the patient ID. The methods change from everything being done in hard copy, to doing it digitally from the clinician's workstation. The expense starts as a once-off funding for software, to eventually having a budget for the hospital to manage, maintain and upgrade the software with IT maintenance personnel.

Measuring user performance when storing, entails determining: the number of patients that get diagnosed and the number of unnecessary transfers that are avoided.

The transmit process step of the PACS MM can be viewed in Addendum B, Figure 7.

10.2 PMM: The PACS process domains

The PACS healthcare delivery process domains (the green plane of the PACS MM in figure

Figure 43: PACS MM

) are described in detail in the following section. Each domain of the process is described according to the different process steps and maturity levels.

10.2.1 Man

The first of the PACS healthcare delivery process domains is the "man" or users involved in the process. The users differ from patients to admin personnel, IT personnel, nurses, clinicians and specialists. The users are a very important element of the system because not only are they resources that can be barriers to the optimal functioning of the system, if they dislike, do not understand or disapprove of the system, they can resist its use completely. Due to this change management becomes important in assisting the deployment and maturation of the PACS systems. Change management entails, assisting users from an ad hoc, experimental phase, to a trained, motivated, standard phase. It also entails empowering users to save scarce resources and empowers lower level users to do monotonous tasks so that specialised users can concentrate on the important tasks, in this way more patients can be helped.

Employing a PACS system does not eliminate the role of humans, it just automates as much of the process as possible, so that humans can apply themselves to tasks that are necessary to help more patients. This leads to a mature process, where some of the process steps are automated, such as data transfer and storage. These, however, create new tasks, such as the IT personnel managing the system and the data backup. Worker performance metrics for the digital imaging procedure are effectively included in performance management and the work appraisal process, and thus need to be managed. In addition, IT staff response and error correction performance metrics need to be tested. Lastly, patient satisfaction with imaging procedure is recorded. To aid in the managing of these tasks, a champion who can manage the feedback and measurement needs to be appointed.

The man process domain of the PACS MM can be viewed in Addendum B, Figure 8.

10.2.2 Machine

The second PACS healthcare delivery process domain is the “machines” or technology involved in the process. The technology includes the software and hardware necessary to sustain the new system. The technology is firstly obtained as experiments and pilots, and then rolled out to departmental groups and thereafter to the whole hospital. Through this process of deployment, adjustments on a small scale can be made, before the system is introduced to the whole hospital. Users who resist the change can see the operation and benefits when used by others, before being urged to use the system themselves. After the technology is used throughout the whole hospital, it is extended to interoperate with other hospitals, in this way a big patient centric database is built.

Some could argue that obtaining and installing the correct technology is deploying a new system, but it is very important to remember that the users must accept the technology; the methods must support the use of the technology and the funds need to sustain the new technology. This means that it is important to assess technology by its usability in the system and the acceptance of the users, as well as its operating and maintenance cost.

The machine process domain of the PACS MM can be viewed in Addendum B, Figure 9.

10.2.3 Material

The third PACS healthcare delivery process domain is the "material" or data involved in the process. The material includes the patient data, history and images and patient UID used as keys to locate stored patient information and images. The material starts by being a single image study, sent via email between two participating users with no UID, and not being stored digitally, to a small departmental database, with a temporary departmental patient ID, containing all the patient information obtained in that department. Later, the database grows to include the whole hospital. All the patient information and history is in two separate files; one for patient data and the other for patient images. The two files are both stored under patient UID and integrated through a server. This allows clinicians to track patient history, information and images from previous studies. Eventually, the server connects different hospitals' databases, wherefrom clinicians can access information of a patient from previous studies done at other hospitals, or refer a study to a specialist at another hospital.

Issues with inter-hospital database access, in terms of patient confidentiality and specialist responsibility, could occur. . Patient confidentiality is jeopardised due to information being accessible to multiple clinicians from multiple institutions. Clinician responsibility becomes an issue since several clinicians collaborate to diagnose and treat the patient. Therefore, the database must be secure and allow only specified access to patient information. Database managers need to be appointed to keep information clean and organised and insure IS data integrity. A system needs to be appointed for determining when a study can be referred to, to ensure that doctors do not just refer the study without trying to examine the patient locally. It is thus important to monitor the system for data integrity, data backup, data usage, studies that are re-used, data accessibility and data security.

The material process domain of the PACS MM can be viewed in Addendum B, Figure 10.

10.2.4 Method

The fourth PACS healthcare delivery process domain is the "method" or procedure of the process. The method includes the work methods, procedures and protocols. The method starts off as an experiment, with no standard work procedure and protocols that discourage the use.

The new PACS process then becomes accepted and a best-practiced method is determined. Thereafter, protocols are changed to encourage the new process and a standard operating procedure (SOP) is determined and documented, including SOPs in case of system failure. Measurement techniques are finally included within the SOPs to monitor and manage the system. These are then used for continuous assessment and improvement.

The method process domain of the PACS MM can be viewed in Addendum B, Figure 11.

10.2.5 Money

The final PACS healthcare delivery process domain is the "money" or funds involved in the process. The money includes initial acquisition cost, as well as operating and maintenance cost. The money starts off as a once-off investment from the hospital or an external sponsor, for the acquisition. The money domain develops to funding for a project initiative by the hospital, thereafter operation and maintenance are included in the hospital budget. For the money domain at level 4, costs are being measured and return on investment is calculated as standard practise. Suitablely, a sustainable business model would exist that sustains the necessary growth, and funds are available for R&D.

As technology develops, and images are transferred to large data bundles, it is important to allow for the logarithmic growth of the system. There has to be funds for new positions, to sustain the system and technology, such as a server manager and IT personnel.

The money process domain of the PACS MM can be viewed in Addendum B, Figure 12.

10.3 PMM: The PACS process maturity levels

The goal of this research is to develop maturity levels for the PACS healthcare delivery process. These levels (the blue plane of the PACS MM in

Figure 43: PACS MM

) are described in detail in the following section. Each maturity level of the process is described according to the different domains and process steps.

10.3.1 Maturity level 1: The ad hoc phase

The first level of the PACS MM describes the basic and unstructured implementation and use of image acquisition, storage, distribution and display. At this level, the PACS system has been acquired and is in the process of being deployed, but not completely installed yet. This maturity level has many technical and organisational problems. This is due to the lack of implemented standards, the storage and transfer formats of digital images and the dramatic changes that result from PACS implementation.

The first maturity level of the PACS MM can be viewed in Addendum B, figure 13.

10.3.2 Maturity level 2: The deployment phase

At the second maturity level, the system is deployed and standardised in departments, with some early adopters using the digital system as standard practise. At this stage, most of the initial pitfalls have been covered by system standardisation within the department. Usually at this stage, the PACS system is vendor supplied, using the PACS archive and sharing only image data, while patient data is still on hardcopy. The level two PACS is still used as an isolated departmental systems, and is not integrated throughout the hospital. The focus of the deployment phase is on the first effective process flow, where the digital image is used from the initial process stage, to the final feedback stage by certain individuals.

The second maturity level of the PACS MM can be viewed in Addendum B, Figure 14.

10.3.3 Maturity level 3: The standardisation phase

The third maturity level of the PACS MM is represented by the hospital-wide deployment and standardisation of PACS. At this stage the system is operational throughout the hospital and all individuals are encouraged to use it. The system is standardised, but not yet effective and many problems are experienced with the new process of internal data management. Usually at this stage, the system is still a vendor supplied PACS, without patient data or the patient image database of the hospital's personal PACS. The focus of the deployment phase is on the first effective process redesign. The focus at this maturity level, however, is on medical images and is therefore restrictive in managing (hospital) workflow. The transition to filmless operation alone results in a relatively small gain in productivity, if it is not accompanied by a redesign of the basic departmental workflow.

The third maturity level of the PACS MM can be viewed in Addendum B, Figure 15.

10.3.4 Maturity level 4: The managed phase

The fourth level of maturity can be characterised by the initial integration of the patient image and information databases. A hospital server is installed and the hospital PACS architecture is integrated with the current patient information database and images. The data is owned by the hospital and managed to integrate the whole hospital. The evolution to this level requires important alterations in terms of PACS processes, extending the scope beyond imaging data and the level of integration of patient information databases. At this level, the clinical applicability of PACS begins to pay off. This is done by providing the imaging and associated (medical) documentation to clinicians, operating theatres, outpatient clinics and in some cases even outside the boundaries of the hospital. The fourth level is categorised by the evolution of PACS towards a system that can handle patient images and information, and therefore manage and optimise workflow to streamline the flow of data transfer and patient care delivery within the whole healthcare institute. The system is managed, measured and optimised within the hospital.

The fourth maturity level of the PACS MM can be viewed in Addendum B, Figure 16.

10.3.5 Maturity level 5: The optimizing phase

The fifth and final maturity level represents the system evolution beyond a single institutional system, to integrate with other healthcare enterprises. The system is made scalable and adjustable to integrate with other departments and is continually improved and updated. Key process characteristics at this development stage include the following: large system integrations of separate institutions' patient information and image databases through hospital operated servers. Moreover, at this level, the adoption within the wider patient information database and healthcare facility integration is continually optimised, and the operational improvements yield process innovations and overall efficiencies in the continuum of the patient-care delivery process, to reach an integrated healthcare enterprise.

The fifth maturity level of the PACS MM can be viewed in Addendum B, Figure 17.

The next step is to develop a system, which gives users feedback. After determining which level the hospital is at, users need to know what the next step is to optimise the process.

10.4 Management optimisation guidelines

Maturation guidelines were developed to accompany the maturity model and assist hospital decision makers in maturing the PACS healthcare delivery process. The guidelines are steps to improving each specific component or process steps to reach the next level of maturity. The guidelines are seen in Table 16 and Table 17. The improvement steps state the necessary steps that the hospital needs to take to reach the next maturity level and eventually optimise the entire system. The guidelines are of such a format that they draw attention to the lagging system steps or components, in order to get all of them to a certain maturity level, before developing other elements further. These underdeveloped elements keep the overall system from maturing further (Van der Wetering & Batenburg, 2009).

In this way, after analysing the system and determining where the barriers are, the prescriptive feedback is given to overcome those barriers. This allows the model to be applied to any system, no matter the maturity level, to determine the system condition and apply the relevant improvement steps suited for the specific system.

True to the principles of maturity models, the guidelines are universal, vendor–neutral, descriptive, improving steps. They are not specific, detailed steps. The system of each hospital is tweaked to suit its specific needs and technological requirements change continually.

Table 16: Process step feedback

	Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4*: QC*	Level 5: Optimising
CAPTURE	Obtain the necessary imaging equipment. Motivate departmental groups to capture digitally.	Obtain digital imaging equipment throughout hospital. Motivate and train all users to capture digitally. Standardise the imaging procedure.	Deploy managing, monitoring and measuring of digital imaging capture.	Empower lower level personnel to capture digital images.	Optimised
TRANSMIT	Obtain the necessary WS and intranet equipment. Set up network. Motivate departmental	Obtain WS and intranet throughout hospital. Set up hospital network. Ensure standard for logging and	Deploy managing, monitoring and measuring of patient data transfer to IS.	Establish inter-hospital network, with secure raw data transferal network.	Optimised

	groups to log and transmit digital patient data.	transmitting patient data. Motivate and train all users to log and transmit digital data.			
STORE	Obtain the necessary storage, server and IS. Motivate departmental groups to store digital data.	Obtain storage, server and IS throughout hospital. Motivate and train all users to store digital data. Standardise the storage format, and procedure.	Deploy managing monitoring and measuring of stored digital data. Store data in raw format and make system interoperable.	Interlink hospital server and archive with other hospitals	Optimised
RETRIEVE	Obtain the necessary WS, internet, and software and install it. Motivate departmental groups to retrieve digital data.	Obtain WS, internet and software and install throughout hospital. Motivate and train all users to retrieve digital data. Standardise the retrieval procedure.	Deploy managing monitoring and measuring of data retrieval.	Optimise access to raw patient data. Interlink with other hospitals' archives and specialists.	Optimised
ANALYSE	Obtain the necessary analysis screens and software. Motivate departmental	Obtain analysis screens and software throughout hospital. Motivate and train all users	Deploy managing monitoring and measuring of digital analysis.	Optimise the amount of raw data that is analysable and the post processing	Optimised

	groups to analyse digitally.	to analyse digitally. Standardise the analysis procedure.		capabilities of viewing software.	
TRANSMIT FEEDBACK	Obtain and install the necessary software that allows digital feedback. Motivate departmental groups to transmit digital feedback to IS.	Obtain and install software that allows digital feedback throughout hospital. Integrate with HIS and PACS. Motivate all users to transmit digital feedback to IS. Standardise the feedback procedure.	Deploy authentication, safety, managing monitoring and measuring of digital feedback procedure.	Empower lower level personnel to transmit digital feedback.	Optimised

Feedback is given for domain maturity, determined according to Table 17 below. It is important to determine which domains need attention and how they need this attention, as this is an easy way to focus funds, time and energy. In addition, the lowest domains are highlighted, to bring all domains on the same maturity level before proceeding further.

Table 17: Domain maturity feedback

Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised

MAN	Involve all users of the system in the planning of the new system. Find their opinions, eliminate fears and adjust to their needs where possible. Give necessary motivation and training.	Involve users in the new process team. Identify the users using the old method and find the exact reasons why they don't change over, try to solve.	Incorporate human resource management, client management. Use feedback to continuously optimise system.	Give more training to empower lower level users. Use feedback to continuously optimise system.	Congratulations, your users are optimised; Continuously involve users to constantly optimise system.
MACHINE	Obtain technology for whole hospital. (make sure when obtaining technology to choose interoperable solutions that satisfies user needs)	Obtain necessary technology to ensure interoperability. Standardise the technology.	Employ measures to record technology operation: reliability, availability, usage and maintainability.	Increase the size of system, interlink with more hospitals. Start technology R&D.	Congratulations your machinery is optimised. Continuously invest in R&D to improve system.
MATERIAL	Procreate a localized patient IS for designated departments. Decide on the	Procreate a patient IS for hospital and integrate with HIS and PACS. Decide on the	Gain ownership and manage patient data in raw format in patient centric integrated IS	Integrate hospital IS with other hospitals to for wide network of patients and	Optimise IS and patient data to manage patient information from patient centric integrated IS in

	data that will be transferred.	data for transferral and format thereof.		specialist.	raw format.
METHOD	Adjust work protocols, policies and procedures to allow PACS process.	Identify best practices for PACS process and formulate it to be standard procedure. Document the processes and teach all users. Use incentives if necessary.	Incorporate the measurement and quality control of PACS process in work protocol.	Regularly review and update work methods to optimally suit system.	The work methods are optimised, but do not cease to continuously assess and adjust the standard procedure and system needs change.
MONEY	Include funding for PACS in hospital budget from governmental institution.	Include funding for new positions, operations, management and maintenance of PACS in hospital budget from governmental institution.	Employ measures to record and review the acquisition and operating cost of new system.	Make provision to assure funds will be available to sustain growth of system and invest in necessary future R&D.	Continually ensure sustainability of business model.

10.4.1 Feedback application for improvement guidelines

To accompany the model and present the user with feedback, an Excel application was developed to process the data. This was done to determine the maturity ratings of each process step and component and to determine where the optimisation procedure must begin.

The PMM describes each maturity level, by process step and domain. After determining where a system is situated on the PMM, a score from 1 to 5 is given, according to the relevant maturity level:

- Ad hoc – 1
- Deployed - 2
- Standardised - 3
- Controlled – 4
- Optimised – 5

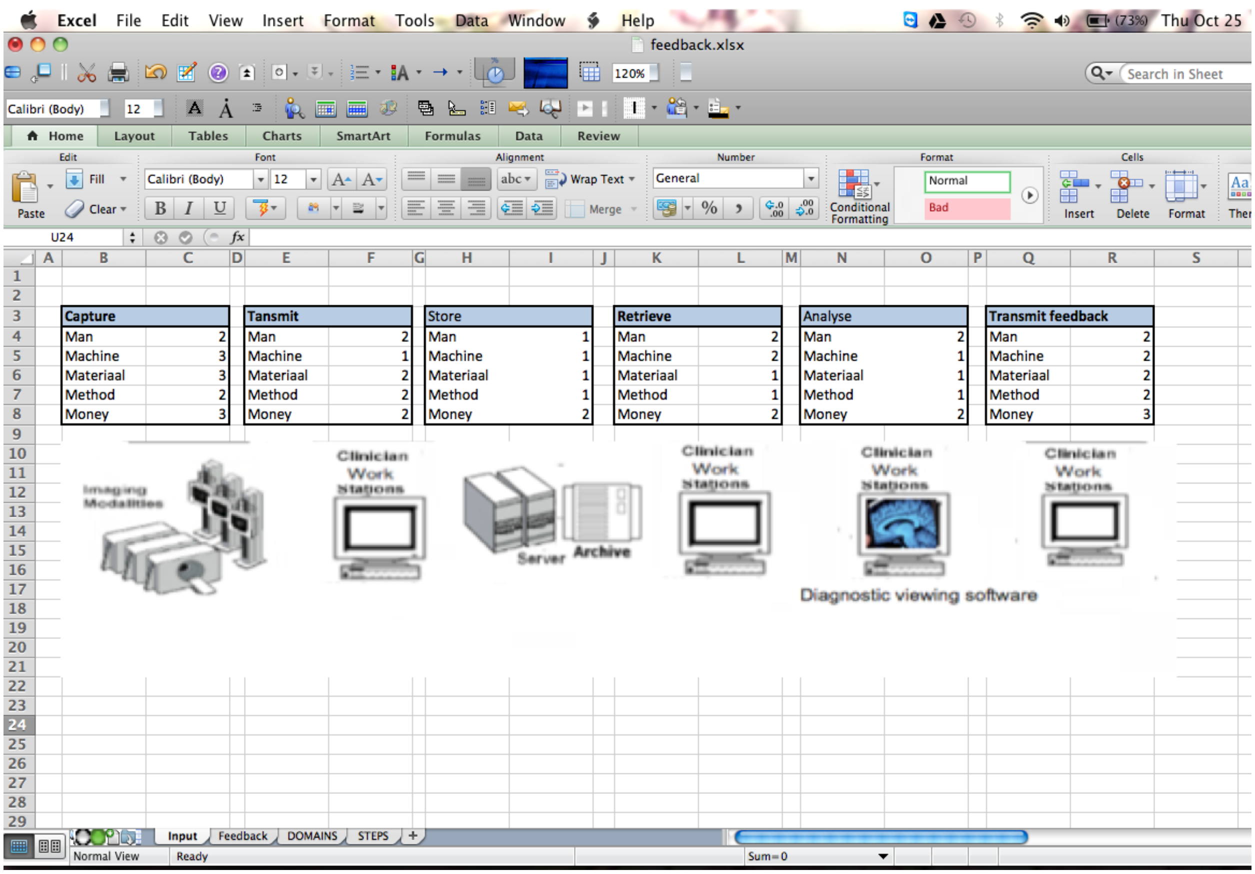


Figure 44: Excel score input

Figure 44: Excel score input shows the input data. The file receives scores of each domain in each process step. The file processes the data to determine the average score of each domain, as well as the average score for each process step. Using the Excel “SUM()” and “DIVIDE()” and “ROUND()” functions, the application determines the score out of 5 for each of the element.

There are 5 domains and 6 steps. The average of each steps is determined by adding the rating given to each domain in that step and dividing it by the number of domains (5). In the same manner, the average for each domain is determined by adding the rating given to it in each step of the system and dividing it by the number of steps(6), as seen in the formulas below.

$$Each\ domain's\ average = \left(\frac{The\ sum\ of\ the\ maturity\ of\ the\ spesific\ domain\ on\ each\ process\ step}{6}\right)$$

$$Each\ step's\ average = \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{5}\right)$$

The percentage to which the system is standardised and optimised is also determined. As a standardised system is on level 3 and an optimised system is on level 5, the scores are determined according to those ratings, as seen in the formulas below.

$$Each\ step's\ standardisation\ percentage = \left(\frac{The\ step's\ average}{3}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{5}\right) * \left(\frac{1}{3}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{15}\right) * 100\%$$

In the same manner the step is optimised:

$$Each\ step's\ optimised\ percentage = \left(\frac{The\ step's\ average}{5}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{25}\right) * 100\%$$

The domains:

$$Each\ domain's\ standardasation\ percentage = \left(\frac{The\ domain's\ average}{3}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{6}\right) * \left(\frac{1}{3}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{18}\right) * \ 100\%$$

And the optimised:

$$Each\ domains'\ optimised\ percentage = \left(\frac{The\ domain's\ average}{5}\right) * 100\%$$

$$= \left(\frac{The\ sum\ of\ the\ maturity\ of\ each\ domain\ in\ that\ process\ step}{30}\right) * \ 100\%$$

The excel formulas are shown in Figure 45 and the output in Figure 46

	MAN
tot	K2+K9+K16+K23+K30+K37
mark out 5	ROUND((N3/6); 0)
standardised	N3/18
optimised	N3/30

	CAPTURE
tot	SUM(K2:K6)
mark out 5	ROUND((N9/5); 0)
standardised	N9/15
optimised	N9/25

Figure 45: Excel formulas for average and percentage

	MAN	MACHINE	MATERIAL	METHOD	MONEY
tot	11	10	10	9	14
mark out 5	2	2	2	2	2
standardised	61%	56%	56%	50%	78%
optimised	37%	33%	33%	30%	47%

	CAPTURE	TRANSMIT	STORE	RETRIEVE	ANALYSE	TRANSMIT FEEDBACK
tot	13	9	6	8	7	11
mark out 5	3	2	1	2	1	2
standardised	87%	60%	40%	53%	47%	73%
optimised	52%	36%	24%	32%	28%	44%

Figure 46: The Excel score output

The application draws a graph of the different elements to allow clear visualisation as seen below.

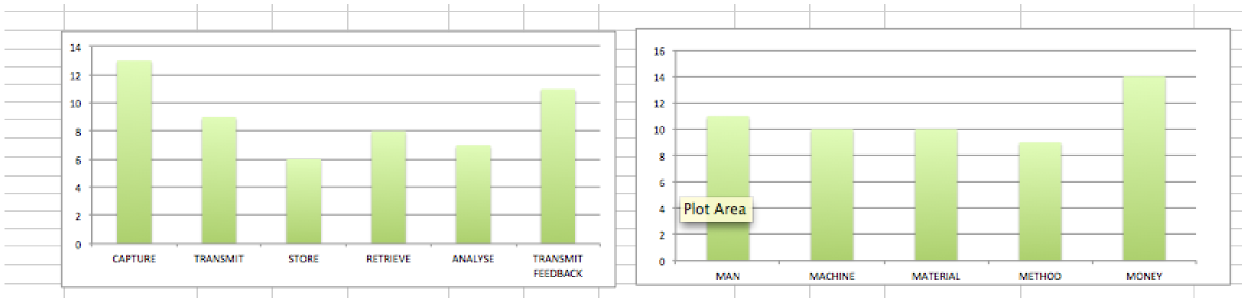


Figure 47: Element graphs

Lastly, the system as a whole's maturity standardisation and optimisation is determined. The system, consisting of 5 domains and 6 steps are rated on a scale of 1 to 5, resulting in a total of 30 elements. If each of the elements could be standardised (level 3) it would result in an overall maturity score of 90, and if they were optimised (level 5) it would result in an overall maturity score of 150. Therefore, the formulas for the system as a whole are as follows:

$$\text{The system standardisation percentage} = \left(\frac{\text{The sum of all the system domains and step maturities}}{90}\right) x100\%$$

$$\text{The system optimisation percentage} = \left(\frac{\text{The sum of all the system domains and step maturities}}{150}\right) x100\%$$

The Excell output and formulas can be seen in the screenshots in Figure 48 and Figure 49.

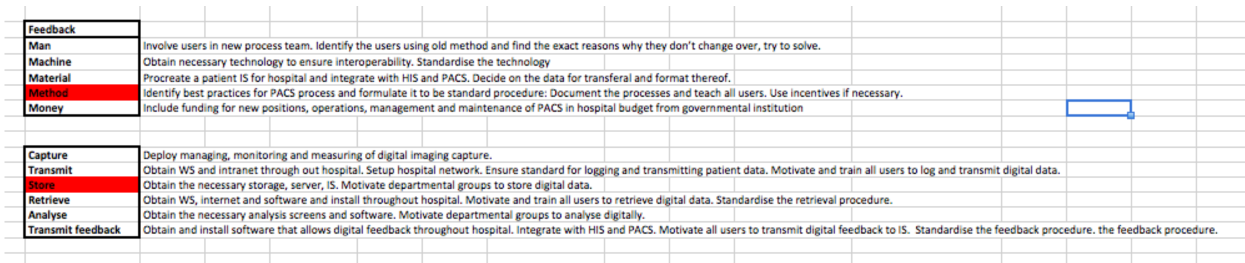
Process standardised	60%
Process optimised	36%

Figure 48: Total output

Process standard	(SUM(E2:E6)+SUM(E9:E13)+SUM(E16:E20)+SUM(E23:E27)+SUM(E30:E34)+SUM(E37:E41))/90
Process optimise	(SUM(E2:E6)+SUM(E9:E13)+SUM(E16:E20)+SUM(E23:E27)+SUM(E30:E34)+SUM(E37:E41))/150

Figure 49: the total formulas

According to the resulting average scores of the process steps and domains, the application will access and bring forth the relevant improvement guidelines for each of the elements. Depending on the average maturity level calculated for each process step, feedback is given accordingly, as seen in Table 16. Depending on what maturity level the process step is at, suitable steps to be taken are suggested. The process steps of the lowest maturity will be highlighted by the application. Thereby the steps that need the most attention are highlighted in an attempt to bring the whole process to the same level before proceeding to the next maturity level. In addition, the application will search for the lowest scoring element and highlight them to show that they are of most importance to be handled first, as seen in Figure 50.



Feedback	
Man	Involve users in new process team. Identify the users using old method and find the exact reasons why they don't change over, try to solve.
Machine	Obtain necessary technology to ensure interoperability. Standardise the technology
Material	Procreate a patient IS for hospital and integrate with HIS and PACS. Decide on the data for transferal and format thereof.
Method	Identify best practices for PACS process and formulate it to be standard procedure: Document the processes and teach all users. Use incentives if necessary.
Money	Include funding for new positions, operations, management and maintenance of PACS in hospital budget from governmental institution
Capture	Deploy managing, monitoring and measuring of digital imaging capture.
Transmit	Obtain WS and intranet through out hospital. Setup hospital network. Ensure standard for logging and transmitting patient data. Motivate and train all users to log and transmit digital data.
Store	Obtain the necessary storage, server, IS. Motivate departmental groups to store digital data.
Retrieve	Obtain WS, internet and software and install throughout hospital. Motivate and train all users to retrieve digital data. Standardise the retrieval procedure.
Analyse	Obtain the necessary analysis screens and software. Motivate departmental groups to analyse digitally.
Transmit feedback	Obtain and install software that allows digital feedback throughout hospital. Integrate with HIS and PACS. Motivate all users to transmit digital feedback to IS. Standardise the feedback procedure. the feedback procedure.

Figure 50: The guidelines given

Figure 51 shows a screen shot of the end result of the application's feedback given.

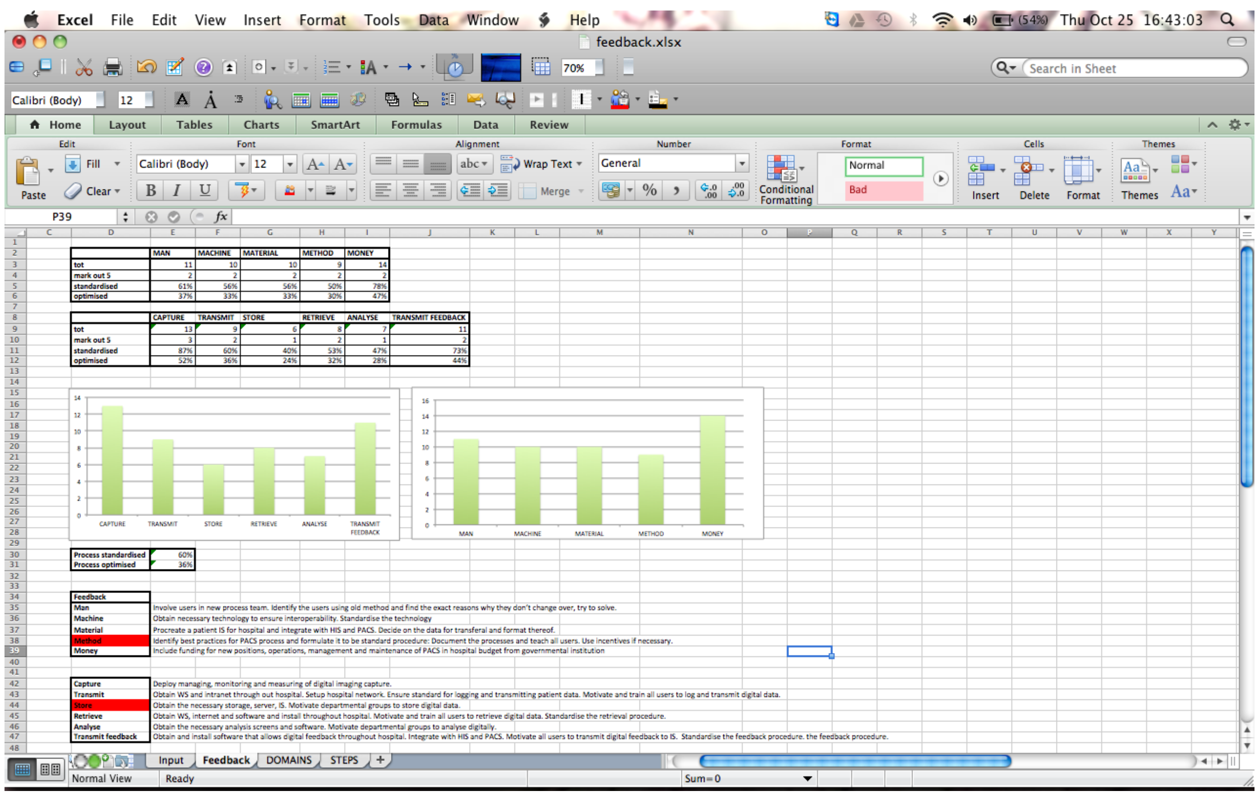


Figure 51: screenshot of the Excell feedback application

In this chapter, after developing the PACS MM and the optimisation guidelines, validation occurred through case studies, described in the next section.

11 Verification and validation

The purpose of this thesis was to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure. The goal of the thesis was reached by means of a scientific, iterative process, involving a literature study, as well as input from the current PACS users in a selection of hospitals. The required structure was developed and with that knowledge, the improvement guidelines were set and therewith a suitable PACS MM was developed. The purpose of this chapter is to verify and validate the PACS technical and operational structure and the PACS MM as guidelines for implementation and optimisation of PACS in the South African public healthcare environment.

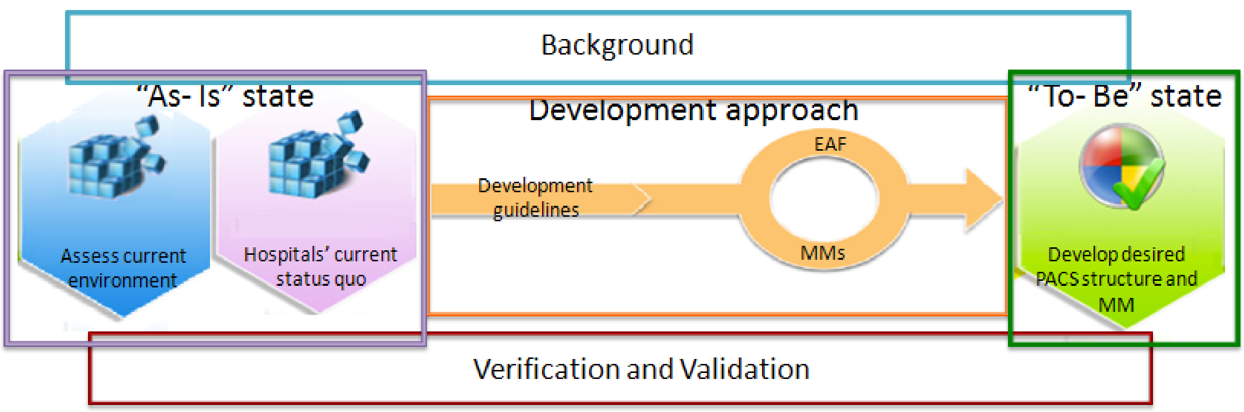


Figure 52: Verification and validation methodology

Validation and verification are both solution evolution methods that are closely related, but each addresses different aspects of the solution evaluation. Through validation it is examined whether a solution meets the customer's actual needs. Whereas, verification examines whether the solution is well engineered and faultless (Verification and validation of simulation models, 2005). Verification will help to determine whether the solution is of high quality, but it will not ensure that the solution is useful in addressing the original problem statement. The definition and procedure, as applied to the thesis, of validation and verification are discussed below.

11.1 Validation

Validation is described as the process of assessing whether the developed solution addresses the defined problem (Verification and validation of simulation models, 2005). In this thesis the problem was defined as PACS being unsuccessful due to a lack of specifications, guidelines and best practice operational methods for the appropriate PACS technical structure in South African literature and in governmental strategies. Another factor stated to contribute to the failure of PACS is the lack of PACS implementation and support guidelines for hospital decision makers to manage the system and enterprise change. In this thesis the goal of validation is to inspect the technical and operational PACS structure and PACS MM, in order to ascertain whether it solved the defined problem.

In order to ascertain whether the defined problem was solved user acceptance and usability tests, and goal analysis was performed for the PACS structure and MM. The user acceptance and usability test was done by means of focus group discussions - used to confirm whether the participants found the structure and model useful and appropriate. The goal analysis was achieved by presenting the PACS structure and MM to experts in the South African PACS healthcare environment. The experts had to confirm whether they were of the opinion that the model would assist the implementation and optimisation of PACS. Thereby, confirming that the solution obtained addresses the defined problem statement.

11.2 Verification

Verification is described as the process of assessing whether the solution was developed in a correct manner (Verification and validation of simulation models, 2005). In this thesis the goal of validation was to determine whether the PACS structure and PACS MM were developed correctly, in light of the design requirement and the implementation thereof.

In this thesis verification was achieved by way of consistency checking and design specification analysis and for proof of correctness. Consistency checking was done by analysing the results obtained from the focus group discussions to ensure the model correctly plots the PACS system and that it suggests the appropriate improvement step. Design specification analysis was achieved by inspecting the PACS structure and PACS MM against the defined design requirements established. This allowed for the suitable structure and the improvement guidelines to be tested, thereby, proving that the model was correctly developed.

11.3 Procedure

The validation and verification of this thesis was achieved by (a) user acceptance and usability tests by means of focus group discussions, (b) goal analysis by means of expert review, (c) consistency checking by means of focus group discussion result analysis, and (d) proof of correctness by means of design specification inspection. The following section defines and discusses the focus group discussions, expert reviews and the design specification analysis.

11.3.1 Focus group discussion

The purpose of the focus group discussions was twofold:

1. Firstly, for validation purposes, the goal of focus group discussions were to present the PACS structure and MM to PACS users within the hospital and assess whether they accept the solution and find it to be a usable option.

2. Secondly, for verification purposes, the results of the focus group discussions were analysed for the accuracy and the consistency of the scores allocated and results suggested by the MM. Thereby, assessing whether the PACS MM and structure is accurate and consistent in terms of the prescriptive process plotting and the descriptive guidelines suggested.

A focus group discussion is a form of qualitative research in which members of a small group is led by a moderator, who asks for their opinions, views, perceptions and attitudes regarding a concept. The moderator nurtures spontaneous disclosure in an open forum. The group needs to be large enough to generate rich discussion, but not too large, so that the opinions of some participants are left unheard (Eliot and Associates, 2005). Additionally, the participants of the focus group discussion must be selected from a range of users involved in the concept evaluated, to ensure more accurate feedback.

This approach, suggested by *Elliot and Associates* (Eliot and Associates, 2005), was selected as a research evaluation method for three reasons: (1) time-limit restrictions removed the possibility of implementation and evolution of the model over a case study of an extended of time. (2) Focus group discussions allows the immediate incorporation of the whole PACS process, involving stakeholders and process steps from different domains within a wide spectrum of the healthcare delivery system, this method is thus well suited to address the needs for comprehensive consultation across the spectrum; (3) the research model incorporates admin, ICT staff and clinicians physically working with the system, managing their methods and standards. It also requires hospital financial managers to deal with and distribute funding provided by governmental institutions. (4) By conducting focus group discussions, using all the stakeholders participated and giving feedback on their respective levels and domains of the system.

The two Western Cape hospitals analysed in 2010 and 2011, as reported in Section 4, were revisited, approximately 27 and 15 months after the first visit, respectively. Relevant PACS users took part in a focus group discussion, which offered an opportunity for them to give feedback, establish relevance and determine the usability of the model.

Tygerberg Hospital (in Bellville) and Eben Dönges Hospital (in Worcester) were selected for the study, based on proximity. The researcher approached each of the individual hospitals and invited them to participate in a study, which facilitated the validation and verification of the PACS structure and model. In return for their participation feedback was supplied to them as to their PACS process maturity and the improvement procedure. At both hospitals the personnel received the invitation with great enthusiasm and were willing to participate, to learn from the experience and to assist with PACS field research for to improve the use in South African hospitals.

The researcher led the discussions in such a way that the participants were facilitated and led through the process to understand the ideal PACS structure and the PACS MM. Consequently, the participants were led through the process to assess the PACS healthcare delivery system of their hospital and a conclusion of the PACS status quo was determined.

The focus group session was executed by the researcher who facilitated the assessment process to translate the participant's feedback of the system into scores (based on maturity levels assigned to the process steps and process domains). The process was plotted and the process scores determined.

For verification the individual and overall scores given was assessed for correctness, accurracy and consistency. This was done comparing the system state to the scores given. For validation the participants were asked to give their feedback orally regarding the PMM and the improvement guidelines presented to them. Feedback was assessed according to their acceptance of the PACS structure and MM as an implementation and optimisation tool. Participants were additionally asked: (1) whether they found the model user-friendly; (2) whether they understood its purpose and whether it fitted into the system; (3) whether the guidelines to improving the system was appropriate; and (4) whether using this model in the hospital to optimise PACS was purposeful to them; giving them a clear view of the road ahead and assisted with deployment, optimisation and strategic planning of the PACS healthcare delivery system. The questions, which were asked questions , are shown in Table 18.

Table 18: Questions to plot hospital process

Question	Information used
What type of PACS setup are you using?	
Where are your data stored?	
Who sorts stored files?	
How is the network set up?	
How are data accessed?	
Are your patient files integrated with image files?	
How do staff members feel about PACS?	
Do you have enough IT staff on hand?	
Who drives the project?	
Who funds the project?	
What software training did you receive?	
Who do you report your problems to?	
What are the problems experienced?	Clinicians:
	Management:
	IT staff:
	PACS administrator:
	Nurses:
	Admin personnel:

11.3.1.1 Participants

At each hospital users involved in the PACS healthcare delivery system from various domains of the hospital environment, were asked to participate. Nurses, clinicians, specialists, management, the PACS project champion, the PACS administrator, IT staff and admin staff were all asked to contribute. At Eben Dönges Hospital, all the required staff took part in the focus group discussion, which lead to rich and meaningful feedback. At Tygerberg, the managing representative could unfortunately not participate, but the discussion was still very meaningful as the PACS champion works closely with the hospital CEO and stood in for him in most cases.

The documents and procedures sent to the participants are attached in Addendum C.

11.3.1.2 Informed consent

Informed consent to participate was subject to an agreement that:

- No information pertaining to individual patients would be used;
- The opinions expressed by individuals would not be traceable to their origin; and
- No confidential, hospital-specific information would be published

11.3.2 Expert review

The purpose of obtaining reviews from experts was to assess whether the solution obtained in this thesis achieved its purpose, for validation. This was achieved by approaching a selection of experts and presenting them with the PACS structure and MM for evaluation.

Expert review is a form of qualitative research evaluation in which experienced members of the field of study assess the proposed solution and give their professional opinion, as to its suitability to achieve the desired purpose.

The thesis was handed to diverse experts in the South African PACS healthcare environment for evaluation. The experts were given two key areas of the thesis to assess. The first was to assess whether the defined structure would serve as an appropriate technical and operational solution for the South African public healthcare environment in order to overcome the barriers experienced. The second was to assess whether the PACS MM would serve as an appropriate tool for PACS implementation and optimisation guidelines, to reach the defined structure. Thereby, confirming that the solution that was obtained addresses the problem statement. The participants were selected due to their diverse experience and expertise in the field as well as their willingness to participate.

11.3.2.1 Participants

Three experts in the PACS healthcare environment were addressed to assess the PACS structure and MM: Ms JB Fortuin, Prof AF Doubell, and Mr B Lines. All three of the experts have had a considerable amount of exposure to PACS healthcare in South African environment, with expertise in different areas.

Ms JB Fortuin was selected as expert in the field on telemedicine and PACS project implementation and administration in South Africa. She was the previous telemedicine representative for the Medical Research Council of South Africa. She has been involved in numerous telemedicine projects across many South African public hospitals, and in some PACS projects implementation attempts. Additionally, she started that her career in the medical field, as a nurse. Therefore she has diverse knowledge to apply to medical project implementation. See correspondence in Addendum C, section 16.1.3.

Prof AF Doubell was selected as an expert in the field of PACS research and implementation in a South African hospital, as well as being a high end user of PACS. Prof Doubell is the current Head of the Division of Cardiology at Tygerberg Hospital and at the Faculty of Medicine and Health Sciences, Stellenbosch University. PACS is of special concern within the Division of Cardiology due to the complex nature of the images and the analysis techniques used. Doubell was part of a pioneer study that started in 2002 to implement PACS in Tygerberg Hospital. The Cardiology Division obtained its own vendor PACS, which they refer to as an 'in-house PACS' because it is only used and integrated within the department. Therefore, Prof Doubell has knowledge, experience and expertise as a high end PACS user and from a hospital management role. See correspondence in Addendum C, section 16.1.4.

Mr B Lines was selected for his expertise in the field of technical PACS and HIS healthcare systems knowledge. Mr Lines is the information technology manager for public hospitals in the Eastern Cape Province. He works together with his IT personnel to implement and maintain all the Eastern Cape hospital's hardware and software. As the Eastern Cape has an operational super PACS system, Mr Lines has had experience with the database and system storage and transfer protocols. Additionally Mr Lines is familiar with the technical system's possibilities and limitations. See correspondence in Addendum C, section 16.1.5.

11.3.3 Design specification analysis

The purpose of a design specification analysis was to assess whether the new system PACS healthcare delivery structure and PACS MM specifications overcome each of the system barriers - consequently, assessing whether the system structure and model was developed correctly.

Design specification analysis is a form of qualitative research, used to discover problems, incompleteness and inconsistencies in the fulfillment of design specifications in accordance to the developed model.

11.4 Execution

This section discusses the details of the execution of the hospital visitations and how validation and verification is established therewith.

11.4.1 Focused group discussions

This section discusses the execution of each hospital visitation.

11.4.1.1 Eben Dönges Hospital focus group discussion

The first hospital visited was Eben Dönges in Worcester, where strategic-focused group discussions were conducted with the PACS administrator, the clinician performing imaging exams, the radiology nurse and the hospital CEO. It took place on 30 July 2012, 14 months after the previous visit, which took place in May 2011. In May 2011 the hospital started the acquisition and deployment of PACS, in an attempt to connect to Tygerberg Hospital. After discussing the model with the representatives involved and assessing the specific PACS system, the PACS MM was completed for Eben Dönges Hospital. The results determined are mentioned in Section 11.4.1.2, below.

11.4.1.2 Eben Dönges Hospital PACS MM results

Eben Dönges Hospital is part of a Western Cape network waiting for a joint decision from the relevant governmental institutions on which particular PACS vendor to use. The hospital has already acquired the necessary digital imaging equipment, network points, minimum speed data line, workstations and viewing screens. Internally they are using CDs to write digital images and transfer them between specialists, as they do not have an archive or central server yet.

Accordingly, as a result of the present situation, Eben Dönges hospital scored 60% standardised, and only 36% optimised. This means that the process is at 60% on level 3, but at only 36% on level 5. These results were the output of Excel as seen in Table 19.

The process steps are indicated in the graph, which shows that the process step ratings and the process domains are visible in all the process domain ratings. These graphs can be seen in Figure 53 and Figure 54. Lastly, feedback supplied for each domain and relevant process steps are discussed below and shown in Table 20.

Table 19: The excel output scoring for Eben Dönges Hospital

DOMAINS	MAN	MACHINE	MATERIAL	METHOD	MONEY
Total	11	10	10	9	14
Mark out 5	2	2	2	2	2
Standardized	61%	56%	56%	50%	78%
Optimized	37%	33%	33%	30%	47%

STEPS	CAPTURE	TRANSMIT	STORE	RETRIEVE	ANALYSE	TRANSMIT FEEDBACK
Total	13	9	6	8	7	11
Mark out 5	3	2	1	2	1	2
Standardized	87%	60%	40%	53%	47%	73%
Optimized	52%	36%	24%	32%	28%	44%

TOTAL RATING	
Process standardized	60%
Process optimized	36%

The excel scores seen in Table 19 form the following column charts. The ratings of the process steps and domains are plotted, as seen below. The rating quantities in the chart represent the *Total* shown in Table 19.

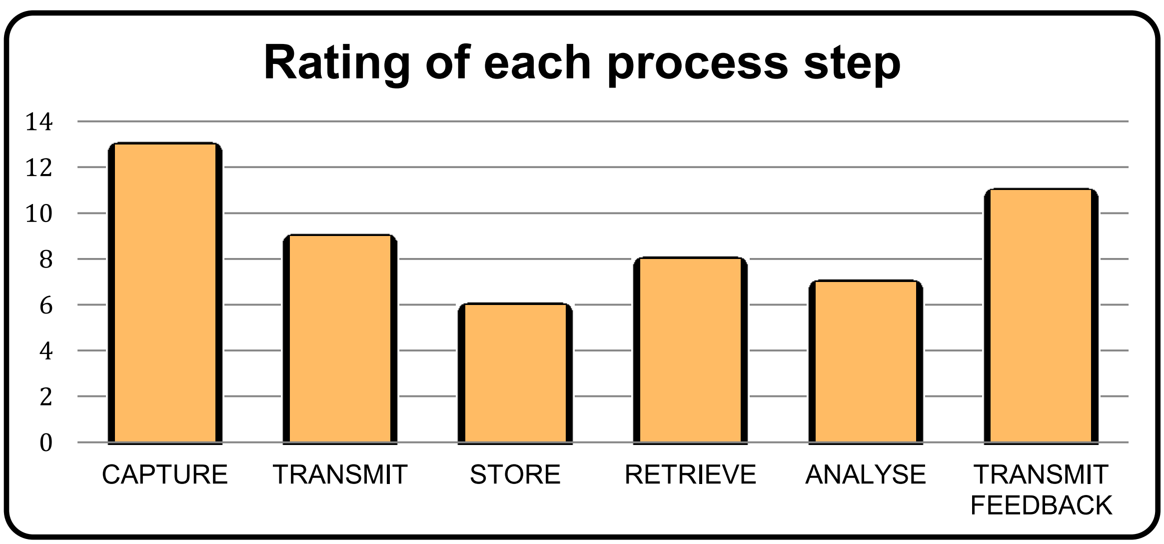


Figure 53: Eben Donges Hospital process step column graph

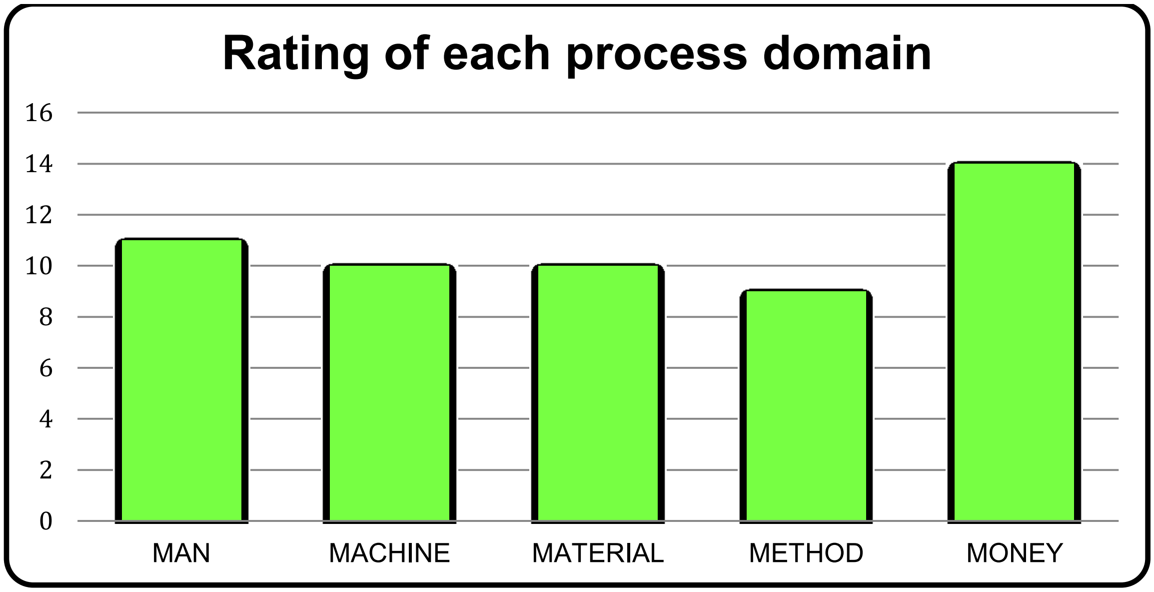


Figure 54: Eben Donges Hospital process domain column graph

As depicted in the *Ratings of each process domain* graph, above, the *methods* category scored the lowest and in the *Ratings of each process step* graph, above, and the *store* and *analyse* categories scored the lowest. Therefore, it is clear that these should be prioritised for the most immediate attention. The feedback given is broken down in the table below, to facilitate focus on the lowest scoring elements.

The lowest scoring categories were the Methods domain, the Storage step and the Analyse step. The feedback for these categories is as follows:

1. Methods domain: Methods need to be identified for best practices and formulated standard procedures. Standard procedures need to be put in place for when systems fail or power is down. The standard process needs to be documented and the procedure taught to relevant users.

2. Storage step: To get the storage process to the next level, it is necessary to acquire a server, archive and information system before any data can be stored effectively. Thereafter, departmental groups should store digitally.

3. Analyse step: To get the analysis process to the next level, it is necessary to acquire the necessary analysis screens and software. Departmental groups should be motivated to give preference to analysing digitally.

Table 20: Feedback for Eben Dönges Hospital

Feedback	
Man	Involve users in a new process team. Identify the users still using old methods and find the exact reasons why they do not change. Trial and solve.
Machine	Obtain necessary technology to ensure interoperability. Standardise the technology.
Material	Procreate a patient IS for the hospital and integrate it with HIS and PACS. Decide on the data for the transferral and format thereof.
Method	Identify best practices for the PACS process and formulate them to be standard procedure: Document the processes and inform all users. Use incentives if necessary.
Money	Include funding for new positions, operations, management and maintenance of PACS in the hospital budget set out by the governmental institution.

Capture	Deploy the managing, monitoring and measuring of digital imaging capture.
Transmit	Obtain WS and intranet throughout the hospital. Setup a hospital network. Ensure a standard for logging and transmitting patient data. Motivate and train all users to log and transmit digital data.
Store	Obtain the necessary storage, server and IS. Motivate departmental groups to store digital data.
Retrieve	Obtain WS, internet and software and install throughout the hospital. Motivate and train all users to retrieve digital data. Standardise the retrieval procedure.
Analyse	Obtain the necessary analysis screens and software. Motivate departmental groups to analyse digitally.
Transmit feedback	Obtain and install software that allows digital feedback throughout the hospital. Integrate with HIS and PACS. Motivate all users to transmit digital feedback to IS. Standardise the feedback procedure.

11.4.1.2.1 Eben Dönges Hospital users acceptance and usability

After the PACS MM was explained to the participants at Eben Dönges Hospital, the participants said that they understood the model, and the necessity for its use. They identified that they would still require systematic measurement techniques to help them monitor the system, rate and evaluate the operation of their healthcare delivery system. Unfortunately, deployment of the PACS for the hospital has been in the pipeline for more than two years and they continue to wait on decisions that are out of their hands. As a result, some PACS users are becoming hostile towards PACS. The hospital's personnel have done what they can to optimise the system, while the Government makes its decision.

Even though the participants for Eben Dönges understood and agreed with the suggested plotting of their processes and the improvements, the model did not present a solution to accelerate the governmental decision-making process. They are positive about the model and its abilities, and would like to use and deploy the system.

11.4.1.2.2 Eben Dönges Hospital result's consistency checking

The PACS healthcare delivery process at Eben Dönges Hospital rated 36% (1,8 out of 5, which resembles a score between the first and second maturity level; in other words, between ad-hoc and the deployed stage). The state between ad-hoc and deployed resembled their situation. Much of the technology has been obtained and most users are on-board with the transition to PACS (some using it internally for certain parts of the process). The system is, however, not in full operation yet. The process steps *store* and *analyse*, scored very low, which were expected, because the hospital does not have an operational PACS archive, where data can be stored or retrieved. The *capture* process step scored the highest, which was expected, because the hospital has a digital imaging machine and viewing stations for data capturing. The *methods* category scored the lowest, because adequate methods have not been established, due to the long process for Governmental decision-making on the installation of a central archive.

Feedback obtained is relevant. However, in this case the feedback was not sufficient, despite the suggestion that the best-practice methods need to be implemented, in order to formulate a standard. There was no suggestion to accelerate the Government's decision, or which method should be used to store central data. It was suggested that a server be obtained, and that an IS and archive is not a sufficient guideline to assist the hospital while they are waiting for a decision to be made the Government. The analysis screens have been obtained but users cannot analyse them before they can retrieve the images digitally; another process delayed by the Government's impending decision.

As is discussed under user feedback (Section 11.4.1.2.1), the users regarded the model as useful, relevant and applicable. They understood the model and agreed that its outcomes offered value. They stated that their attitudes were positive, mainly because the presenter guided them. They suggested that a simplified model could improve the user-friendliness and assist the monitoring of day-to-day operations.

11.4.1.3 Tygerberg Hospital focus group discussion

The second hospital visited, was Tygerberg Hospital, near Cape Town. The following representatives took part in the focus group discussion on 8 August 2012: The clinician appointed as Head of Cardiology, the newly appointed PACS champion, the PACS administrator, the nurses and admin personnel. The validation visitation to Tygerberg took place 21 months after the first exploration visit in June 2010, during which time Tygerberg had appointed a PACS administrator to deploy and integrate the PACS system with the surrounding rural hospitals. After discussing the model with the representatives involved, and investigating their current PACS system, the PMM was completed for Tygerberg Hospital. The results have been set out in section 11.4.1.4

11.4.1.4 Tygerberg Hospital PACS MM results

At Tygerberg Hospital a great deal of PACS research has been done and the hospital has acquired excellent state-of-the-art equipment. They have a PACS vendor and employed a PACS champion to drive the project and integrate it with the relevant second-tier hospitals. It was, however, alarming to notice that, despite the immense research completed, they were relatively ignorant regarding a vendor-neutral system and the value of integration standards. Most of the research completed dealt with the internal PACS at Tygerberg, which resulted in the relevantly high rates. However, it had not been integrated with HIS yet and therefore it was not connected to any rural hospitals.

Users were becoming negative towards PACS because of failed promises from vendors and their struggles with sub-optimal system set-up. After discussing the model with the candidates involved and finding out more about their PACS system, the Tygerberg Hospital PACS MM was completed.

Table 21: The excel output scoring for Tygerberg Hospital

	MAN	MACHINE	MATERIAL	METHOD	MONEY
Total	16	19	10	12	17
Mark out 5	3	3	2	2	3
Standardized	89%	106%	56%	67%	94%
Optimized	53%	63%	33%	40%	57%

	CAPTURE	TRANSMIT	STORE	RETRIEVE	ANALYSE	TRANSMIT FEEDBACK
Total	18	9	8	8	18	13
Mark out 5	4	2	2	2	4	3
Standardized	120%	60%	53%	53%	120%	87%
Optimized	72%	36%	32%	32%	72%	52%

Process standardized	82%
Process optimized	49%

The excel scores seen in Table 21 are graphically depicted in the column charts, Figure 55 and Figure 56, below. The charts plot the ratings of the process steps and domains.

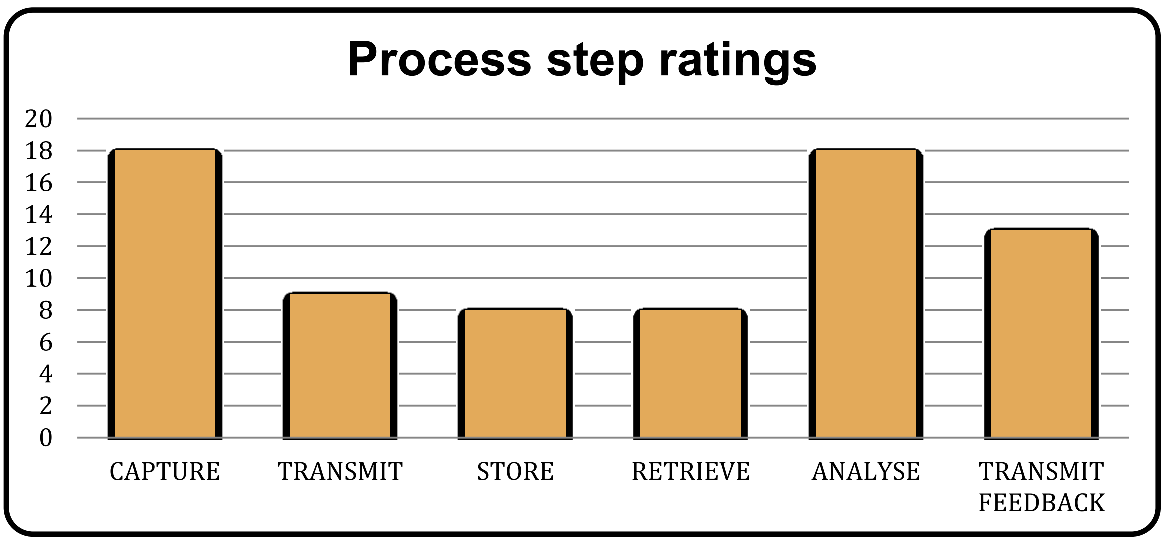


Figure 55: Tygerberg Hospital process step column graph

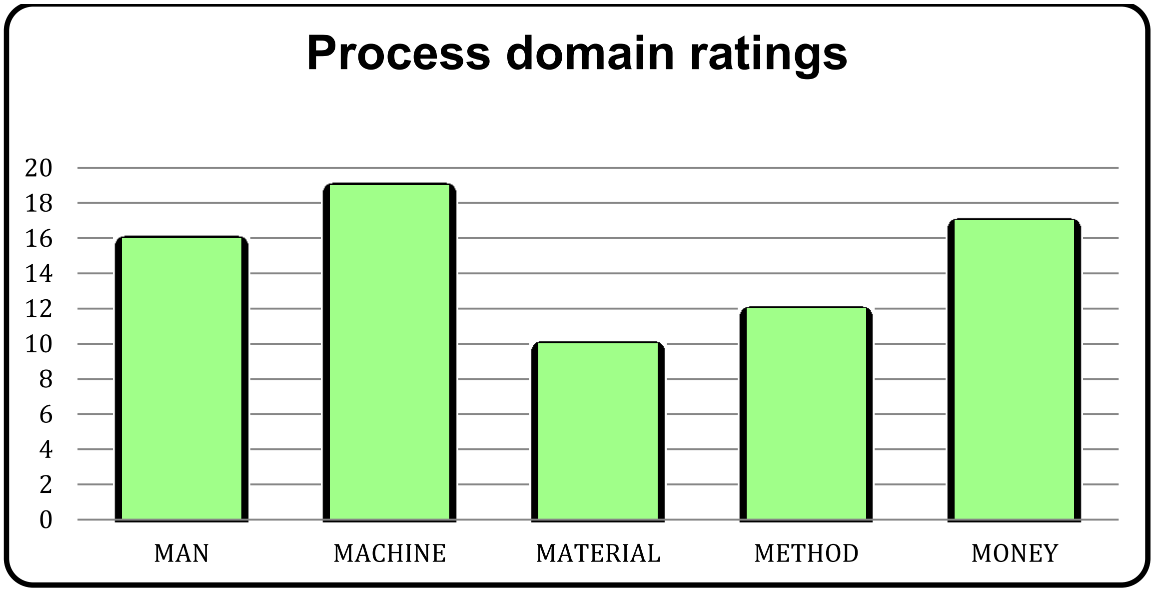


Figure 56: Tygerberg Hospital process domain column graph

As seen in the domains graph, the *material* category scored the lowest and in the process steps graph, the *store* and *retrieve* categories scored the lowest. It is, therefore, clear that these elements need the immediate attention. The feedback given is illustrated in the Table 22 below, focusing on the lowest scoring elements.

Table 22:Tygerberg PACS domain feedback

Feedback	
Man	Incorporate Human Resource Management and Client Management. Use feedback to optimise system continuously.
Machine	Employ measures to record technology operation: reliability, availability, usage and maintainability
Material	Procreate a patient IS for the hospital and integrate with HIS and PACS. Decide on the data for transferral and format thereof.
Method	Identify best practices for the PACS process and formulate them to be standard procedures. Document the processes and inform all users. Use incentives if necessary.
Money	Employ measures to record and review the acquisition and operating cost of new system.

Table 23: Tygerberg PACS process step feedback

Capture	Empower lower-level personnel to capture digital images.
Transmit	Obtain WS and intranet throughout the hospital. Set up the hospital's PACS network. Ensure standard for logging and transmitting patient data. Motivate and train all users to log and transmit digital data.
Store	Obtain storage, server and IS throughout the hospital. Motivate and train all users to store digital data. Standardise the storage format, and procedure.
Retrieve	Obtain WS, internet and software and install throughout the hospital. Motivate and train all users to retrieve digital data. Standardise the retrieval procedure.
Analyse	Optimise the amount of raw data that is analysable and the post- processing capabilities of viewing software.
Transmit feedback	Deploy authentication, safety, managing monitoring and measuring of digital feedback procedure.

11.4.1.4.1 Tygerberg Hospital user acceptance and usability

Users, especially the new PACS champion, valued the PMM and its relevance. He agreed with the best-practiced methods given. The PACS champion at Tygerberg worked in the UK with PACS deployment prior to this project. He agreed with the basic structure and deployment methods (and improvements) suggested. He saw the relevance of the model and appreciated the South African research and specification. He suggested that it would be of great value to give the model to governing institutions, where standards and deployment decisions would be decided. The participants, however, expressed the need for a more simplified model, so that they can use the model for periodical evaluation. The PACS champion wishes to use the model to assist the deployment and decision-making process in the future and to also assist with strategic decision making.

11.4.1.4.2 Tygerberg Hospital results' consistency checking

The PACS healthcare delivery process at Tygerberg Hospital rated 49% (2,4 out of 5, or between the second and third stage, in other words in the deployed stage on the way to being standardised). The state between deployed and standardised resembles the PACS healthcare delivery process at Tygerberg Hospital. The PACS health care delivery process at Tygerberg Hospital is deployed but not integrated with the HIS nor extended and standardised throughout the whole hospital. The process steps*, store* and *retrieve* scored low. This is to be expected, because they do not have an installed central archive where they can access the images sent to them from other departments or from other hospitals.

The feedback given is relevant. They need to standardise the storage format of data and integrate it with their HIS to deploy throughout the entire hospital. In addition, they must insist that the process is extended to other relevant hospitals. This will enable digital retrieval and motivate all users to retrieve images digitally.

As discussed under user feedback (Section 11.4.1.4.1), the participants regarded the model as useful, relevant and applicable, especially the PACS champion who had experience of the deployment life cycle. Again, they understood and agreed with the model. Tygerberg Hospital participants suggested that the model should be supplied to the relevant governmental institutions for assessment, so that important deployment decisions can be made.

11.4.2 Expert review

The thesis was submitted to experts in the field of PACS systems implementation in the South African telemedicine, PACS, and healthcare enterprise management environment; Ms JB Fortuin, Prof AF Doubell and Mr B Lines

Ms Fortuin was of the opinion that the model succeeds with an overall look of PACS in South African hospitals. She stated that PACS and telemedicine implementation is a complex process in South African hospitals, with very little governance standards. The model gives a good overview of the desired structure and technical requirement of the PACS system and the reasons for its choice. She stated that it would be suitable for hospitals in South Africa and it would function in a PACS healthcare delivery process. She did, however, raise concern that the model needs to be implemented on a higher level. If the DoH could use the model as a basis for compliance standard for national PACS systems, it would help ensure hospital integration and co-operation. However, without forced compliance and integration standards from the DoH, each hospital would still implement the system as they see fit – barring its full potential. She raised concern that the model was too complex for users, who have not had adequate training.

Prof Doubell stated that after the perusal of this thesis he believes that the medical field was thoroughly studied, and the barriers encountered by hospitals were valid. The technical solutions that were developed appeared to be accurate according to him. He stated that they are busy with a similar research project at Tygerberg Hospital that separates the patient information and patient images on two different databases. According to Prof Doubell, the MM and the structure that was developed are relevant, especially, on a higher level in order to form a basis for hospital standards and software proposal requirements in the future. The proposed solution would ensure that integration is realised within and between healthcare institutions.

Mr Lines was positive about the solution offered by the model. He agreed that it would be a much better option for hospitals to manage their own PACS database and integrate it with their patient information database. It would ease his work process, as it would not be necessary for him to dispute over file formats and location with an external vendor. He was familiar with the HL7 standards and its international acceptance.

11.4.3 Design specification analysis

This chapter examines the design specifications and system barriers, developed in Chapter 5. The purpose is to ensure that all system barriers are overcome and that the final model fulfils all design specifications, for validation and proof of correctness.

Table 24 lists the barriers found with the current PACS operational and technical structure. Section 5.1 establishes the collective barriers, grouping all the hospitals' barriers to find the generalised system barriers. Each of the barriers is accompanied by the design specification. Table 24, below, assesses each of the design specifications, to ensure that the PACS technical and operational structure is developed correctly. The last column describes the means whereby the proposed solution satisfies the design specification and overcomes the system barrier.

Table 24: PACS structure design specification analysis

System barrier	Design specification	Specification met by
All patient information is not available	Allow all data fields	Vendor-neutral archiving format, allow all patient fields
Non-image data is not interoperable	Standard vendor neutral archive for all non-image data	Use HL7 for standard non-image data sharing
Not all viewing functionalities are available	Allow any viewing software	Vendor neutral storage format interoperate any

		viewing software
Patient information not easily accessible	Easy access for all patient images	Archive images (DICOM) and archive non-image data (HL7) & integrate server (HL7)
Hospital cannot access own patient information system	Hospital must be able to access own patient database	Hospital owns their own data system and appoint database manager
No Patient UID to access patient files	Store image & non-image data under patient UID	Use HL7 format to store each separate file under patient UID and integrate files.
No national patient UID	File all patients and a unique national patient number on arrival	Introduce national patient UID
No Standard best-practiced work methods	Define standard best practiced methods	Define the suited PACS patient healthcare delivery workflow
Database not managed between departments	Appoint manager to interact with other departments / institutions	Hospital owns their own data system and appoint database manager
No database control	Clear database management guidelines	Use HL7 standards
No standard implementation methods to assure integration	Standard implementation methods	Assist long term planning

In Table 24 it is indicated that each of the design specifications has been met and the barrier overcome by the technical and operational structure proposed.

Table 25 lists the barriers and design specifications developed for the PACS implementation and optimisation guidelines in chapter 6. In the Table 25, below, each of the design specifications is assessed for correctness of the developed PACS MM. The last column describes the means whereby the proposed model satisfies the design specification and overcomes the system barrier for implementation and optimisation guidelines.

Table 25: PACS implementation and optimisation guideline design specifications

System barrier	Design specification	Specification met by
Critical system, cannot afford error	Avoid implementation errors	MM Clearly defines implementation steps and guidelines
Data is subject to patient privacy rights	Ensure data privacy and responsibility	MM states to use HL7 standards which contain the correct data security protocols
No co-operation and integration between separate institutions	Ensure governance between separate institutions	MM states to appoint a national head of telemedicine
Technology changes continually	Make provision for technological changes	MM is generic enough to be scalable.
All hospitals are on different PACS levels and structures	Must be suitable for any of the South African public Hospitals	MM contains all the SA PACS system states and appropriate improvement guidelines
Users are opposed to use complex implementation and optimisation guidelines	MM must be user friendly	Assessment and improvement guidelines are general enough for users to understand after explanation and guidance given
All hospitals are on different PACS levels and structures and cannot integrate	Must offer governance and integration between hospitals	Is specific enough to describe the appropriate improvement steps to be followed throughout and across hospitals

Table 25 indicates that each of the design specifications has been theoretically met and that the barriers are overcome by the proposed PACS MM for South Africa. The design specifications are met, assuming that the model is followed and used as the system proposes; at a national South African standard. However, if the model is only used by one institution it will only meet specifications and overcome the barriers within that institution.

11.5 Results

The validation was performed. Validation entailed user acceptance, usability and goal analysis, while verification entailed consistency checking and proof of correctness assessment. The results of the validation and verification are discussed below.

11.5.1 Validation

The goal of validation was to assess the technical and operational PACS structure and PACS MM, in order to ascertain whether it offered a suitable structure, implementation guidelines and best practiced methods and as well as support for hospital decision makers to manage the system and enterprise change. The validation was executed by means of user acceptance and usability, implemented through focus group discussions (in section 11.4.1), as well as goal analysis, implemented through expert reviews (in section 11.4.2).

Participants from both the focus group discussions and the expert reviews confirmed that the proposed PACS technical and operational structure is a suitable structure for the South African public healthcare environment to ensure an integrated and optimised PACS healthcare delivery process. However, concerns were raised that the MM should be enforced by higher lever decision makers, from the DoH, to ensure the compliance of all hospitals as integration standards for implementation throughout all SA hospitals. All the participants understood the model after explanation and agreed with the guidelines suggested by the model. They felt that it offered sufficient guidelines and support to make informed decisions, regarding PACS deployment and process improvement.

Thus, it was concluded that the PACS technical and operational structure is valid and would ensure a standard for implementation and operation of PACS systems within the South African public healthcare environment.

The PACS MM proposed was partially validated. The MM suggests the correct implementation and optimisation steps for PACS systems in South Africa. However, this cannot ensure the systems will be operational and integrated, unless all South African hospitals use it, and the DoH enforce patient UID use.

11.5.2 Verification

The goal of verification was to determine whether the PACS structure and PACS MM were developed correctly, in light of the consistency and design requirement. Thereby, assessing whether the design requirements addressed the proposed problem statement and whether the model was designed correctly to address the problem statement. The PACS technical and operational structure and MM was verified through consistency checking using focus group discussions (in section 11.4.1) and a proof of correctness study using design specification analysis (in section 0).

The results of the focus group discussions were analysed for correctness and consistency (in section 11.4.1.2 and 11.4.1.4, of the two healthcare institutions). The results obtained illustrated that the PACS MM (under study) has have all the PACS states in SA. Additionally, The PACS MM plots the hospital's PACS healthcare delivery process correctly and gives the correct improvement guidelines. The improvement guidelines given by the model were consistent to that of the hospital needs to improve their PACS system. Consequently, the scores given, represents the hospital's actual PACS healthcare delivery state and are the correct guidelines to achieve the final optimise PACS structure.

Each of the barriers stated was assessed in accordance to the design specification to see whether the barrier was overcome and the design specification met. Consequently, the PACS structure and MM was found to address all the requirements stated in the thesis, except governance. Governance can only be offered when the model is in compliance and enforced by authority in South Africa.

Thereby, it was concluded that the model is practically verified: designed correctly, all the design requirements were met and the output of the model is correct and consistent.

12 Conclusion

The purpose of this thesis was to address the success of PACS healthcare delivery in the South African public healthcare environment by establishing a suited PACS technical and operational structure, together with a Maturity Model to guide the implementation and optimisation thereof. Thereby, the thesis provides a means to assist decision makers in South African hospitals to manage their PACS projects and enterprise change when implementing and managing PACS. It was found that the absence of an appropriate PACS technical and operational structure, along with proficient project and change management is what causes PACS to fail in South African public healthcare environment.

By addressing the success of PACS in South Africa this thesis provides a means to increase rural patients' access to specialised medical care and so improve the South African healthcare environment by streamlining patient care delivery.

The thesis was executed by firstly, assessing the current PACS healthcare delivery system in South Africa was assessed, defining the three PACS structures currently available. The barriers of each structure were highlighted, where after the design specification, to overcome the barriers, was established through literature research. Secondly, the desired PACS technical and operational structure was developed, building on the design specifications. A gap analysis led to the establishment of requirements for the implementation and optimisation guidelines. Thirdly, five common enterprise architecture frameworks (ZEF, TOGAF, FEA, GM, MM) were investigated and evaluated for suitability in the improvement guidelines for the public PACS healthcare delivery system in South Africa. The MM was deemed the most appropriate of the five models. Current MMs were investigated, deficiencies were identified and a new, PACS MM was designed and constructed. The PACS MM encompassed the PACS process domains and steps, each as a dimension, relative to the PACS system maturity. Lastly, prescriptive improvement guidelines were developed to direct the hospital once its PACS process state was determined.

The PACS technical and operational structure and PACS MM were validated and verified. Validation was achieved by means of usability study, user acceptance and goal checking, through focus group discussion and expert review. Users found the model to be a suitable implementation and optimisation guide, as well as a proficient strategic planning tool. Verification was achieved by means of proof of correctness and consistency checking through the use of focus group discussions and requirement analysis. The PACS technical and operational structure and MM was found to be consistent and accurate with the output scores and guidelines suggested. The requirement analysis showed that the PACS structure and MM was found to address all the barriers, except governance. Governance can only be offered when the model is used as a compliance model, enforced by authority in South Africa. Thereby, it was concluded that the model is practically verified.

Consequently, the PACS structure and MM is a valid descriptive and prescriptive tool, providing the hospital management with sufficient literature and guidelines to make informed decisions to manage PACS systems and the associated enterprise change.

12.1 Future work and recommendations

After validating and concluding the thesis this section addresses the future work that became relevant through the thesis.

It was found that, even though the model supplied sufficient information for hospital management to make decisions regarding the implementation and improvement of PACS, the study exposes the need for governance for the South African DoH. If the DoH enforces the use of the PACS structure and model, it will ensure integration and co-operation between healthcare enterprises.

This thesis is a pioneering study for the integration of healthcare IT systems, the transferral of specialised medical data and the dispersal of expert knowledge within South African public healthcare environment. The study has a clear possibility of extending to within the field and into other fields of practice (Fortuin, 2013. Expert review). It can, for example, be extended the South African private healthcare sector or the rest of Africa.

It would be of value if a PACS MM case study is set into motion. The proposed case study process should be monitored during the deployment and maturation process, obtaining scientific proof of the model's impact. Scientific proof could be presented to any governing institution as persuasion for implementation and financial justification. It would open the door for PACS MM to be deployed in all healthcare institutions and, therefore, serve as a compliance model. The previously stated would also ensure a national standard for interoperation.

12.2 Significance

To conclude the thesis a last section was dedicated to the significance of the work completed. The study contributes on different levels depending on the way it is used. It can be used as (a) a model in a single hospital enterprise, (b) a compliance model throughout South Africa, (c) literature research to assist informed decision making.

In the case where a single healthcare enterprise uses this model, it proves sufficient to guide the PACS system to be managed and become an optimised system within a single institution. Optimised meaning: to ensure increased patient healthcare delivery by streamlining the system. If multiple healthcare enterprises use the model, it proves sufficient to ensure integration and become an optimised system between separate institutions. There should also be a noticeable decrease in medical errors, particularly faulty diagnoses. Thereby, it would result in a system that allows more rural patients access to specialised healthcare and increase patient throughput and treatment between hospitals. Thus, addressing the healthcare needs to a greater part of the South African population. In this way, it will contribute to the aim of the South African DoH's goal to improve the healthcare system and, specifically, increase rural patients' access to specialised healthcare services.

If the structure and PACS MM are put into action as a compliance model by the South African DoH, the effects of its success will expand, resulting in an integrated national healthcare system that offers access to patients throughout South Africa, while streamlining their healthcare delivery process. Additionally, the integration standards and methods offered by the PACS structure and model can serve to ease the union between public and private healthcare sectors in South Africa. Thereby, the thesis addresses the National Health Service's aim to facilitate integrated nutritional patient health record sharing in South Africa.

IF the research done is used as scientific grounds to base PACS deployment decisions on, it will ensure better PACS implementation and vendor contracts. The information provided in the thesis, regarding the desired PACS structure and domains, provided sufficient information for hospitals to setup standards for future proposals for PACS equipment, operational staff and funding. It will allow the hospital decision makes to make informed choices when deploying new PACS resources. Additionally, it will serve as a base for the minimum requirements for integration and optimal operation. Thereby, assisting planning and ensuring the optimal choices of resources for the hospital.

The most important point in the development of this PACS structure and MM is that when implementing this system, improvement to healthcare delivery and the welfare of South African citizens are made.

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14 Addendum A

14.1 List of terminology

Picture archiving and communication system (PACS)	PACS is a medical-image management system, developed to allow secure inter-operable storage and transfer of medical images within and between healthcare enterprises. It consists of hardware for storage and transfer, and software for data storage formats and transfer protocols.
Healthcare delivery process	The process of treating the patient, from receiving, examining and diagnosing to treating the patient.
PACS healthcare delivery process	The healthcare delivery process that involves PACS and digital clinical images.
Healthcare system	The system in place to treat patients. In South Africa it consists of three levels: district, provincial, national hospitals.
System maturation	A system that develops from the initial ad hoc state to a standardised and eventually optimised state where it is streamlined and operates effectively
System maturity level	Descriptive development plateaus of the a systems maturation process
Mature system	An optimised, streamlined system that operates effectively
"As-Is" state	The current state of a system that is unorganised and ineffective.
“To-Be” state	The desired mature sate.
Telemedicine	Telemedicine is the exchange of medical information from one site to another via ICT to improve access to medical services
DICOM	DICOM is an industry standard format for the storage and transfer digital medical images, which contains network communications protocol and file-format definition
DICOM-only, image-	A DICOM archive that stores only imaging data and meta data about

management system	the imaging modality, automatically generated during the examination.
Vendor-provided PACS	A proprietary extension of a DICOM archive, designed by a PACS vendor to incorporate study and patient demographic data in one file.
Super PACS	A super PACS is a vendor PACS that is forced to integrate with patient information database and accepts data from all imaging modalities. A super PACS vendor owns the data on the database.
Data integrity	Clear, organised electronic files in a database with unduplicated data and data keys.
System transparency	Having a clear system that's flow is easily understood and monitored.
eHealth	Electronic health
mHealth	Mobile health
teleHealth	Health over a distance.
PACS hardware devices	Imaging modalities, as well as archive and viewing stations;
PACS network	The connective system operating between these devices to communicate the digital clinical images.
PACS software	Each device on the PACS network has software controlling its operations. Each application is geared to produce, transfer, save and request the digital clinical images.
Health level 7 (HL7)	HL7 is an international standard has been created for the integration of PACS and patient electronic information.
Patient centric database	An database containing clinical information stored and accessed by patient UIDs
Early adopters	The visionary and experimental users that are open to acceptance of new technology.

15 Addendum B

15.1 PACS Maturity Model

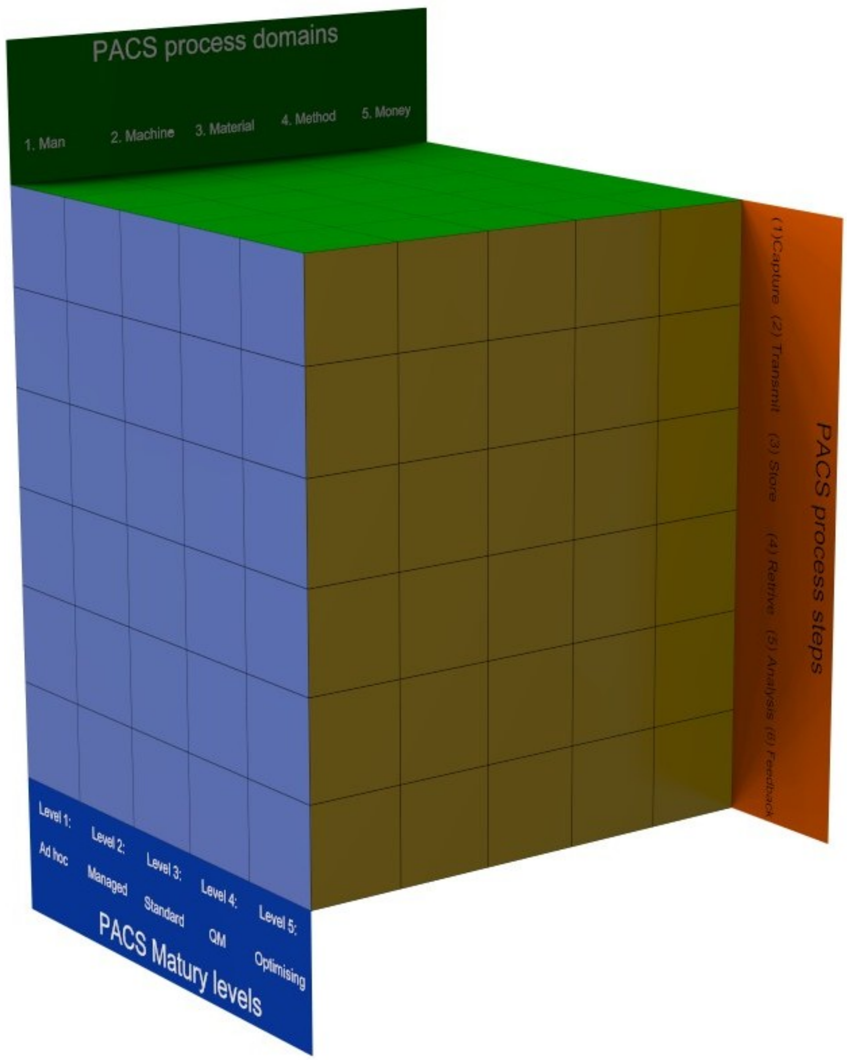


Figure 57: PACS MM

15.2 PACS MM Process steps

Table 26: PACS MM- Process Step: Capture patient data

Capture		Man	Machine	Material	Method	Money
		Clinician taking digital patient image	Digital imaging machine	Image data	Work protocol to capture digital image	Funds for machinery, maintenance and personnel
Level 1: Ad hoc	Digital equipment is not yet available or not yet being used digitally	There are some user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging equipment	Digital imaging machines are not yet acquired or not necessarily being used digitally.	No set image data or data format captured. Data is captured in DICOM or pdf format.	No standard, protocol/work procedure exists to capturing of digital patient images. This procedure is executed according to each individual's discretion and preference.	The digital imaging machines are financed by a once of investment. Acquisition and maintenance is not in hospital budget.
Level 2: Deployed	Equipment being used digitally in certain departmental groups.	There is a departmental champion driving/ motivating the users to receive training, be able, capable and willing to use the digital imaging equipment. Departmental groups of users receive basic training to use digital imaging equipment	DICOM compatible digital imaging machines are available and connected to departmental intra-net network.	Patient images are consistently and repeatably captured digitally in certain departments.	The capturing of digital patient images is done consistently by certain departmental groups. However, the procedure is not documented, approved and formalised throughout the hospital.	The acquisition of the digital imaging machines is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution.
Level 3: Standard	Equipment being used digitally throughout the hospital. There is a standard determined for operation.	All users are able, capable and willing to use the digital imaging equipment and accept it as the standard procedure. There are dedicated IT staffs on hand to assist with problems.	DICOM compatible digital imaging machines are available throughout the hospital and connected to hospital intra-net network.	Patient images are consistently and repeatably captured digitally and packaged together with meta-data about time, place and user throughout the hospital.	The capturing of digital patient images is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (transmission).	The digital imaging machines and their users are included in hospitals budget from governmental institution
Level 4: Quality controlled	Digital image capture is being monitored and measured.	procedure are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with imaging procedure is recorded. There is a	*RAW data. The use, availability, reliability and maintainability of the digital imaging machines to capture and digitise medical images are effectively measured, reported and reviewed.	Captured data are tracked, and integrity of meta-data checked, to ensure that all diagnosis are executed according to service level agreement.	incorporates the quality control of the digital patient image capturing process by medical imaging machine. Quality metrics are defined and captured with respect to the capturing and digitizing	The acquisition and operating cost of digital imaging machines versus analog machines are effectively measures, reported and reviewed, together with the calculated ROI.
Level 5: Optimised	Lower level personnel are empowered for digital imaging capture.	Continuous process improvement includes deliberate professional development/empowerment of lower level user to captures the image.	Appropriate, useful and interoperable new technology for digital image capture and digital imaging machines' upgrades and scalability are continually and efficiently researched, acquired and implemented	Patient images are consistently and repeatably captured digitally and packaged together with meta-data about time, place and user throughout all hospitals.	Protocols are easily updated and operationalized to incorporate improved methods and digital imaging machinery.	Funds are available for R&D and business model sustains growth of system and increasing cost of digital imaging machines.

Table 27: PACS MM- Process step: Transmit patient data

Transmit		Money	Method	Material	Machine	Man
		Funds for network, software and personnel	Work protocols to log patient ID on IS and transmit patient data	Patient ID, image data	Local WS, PACS software, intranet	Clinician/Admin personnel responsible for transmission
Level 1: Ad hoc	Network points and software available. Data not transmitted on IS.	The WS, software and intra-net is financed by a once of investment. Acquisition and maintenance is not in hospital budget.	No standard, protocol/work procedure exists to log and transmit the patient image. This procedure is executed according to each individual's discretion and preference.	No set patient ID'ing system is used, and no transfer security. User decides which is the best method to transfer the required data and how to label the data.	WS and PACS software and intra-net are not yet acquired, set-up or not necessarily being used.	There are some user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to log and transmit the data to the required standard.
Level 2: Deployed	Data is logged / transmitted according to departmental IS	WS, software and intra-net is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental	image to the IS is done consistently by certain departmental groups. However, the procedure is not documented, approved and formalized	ID used to log image data for transferal. Transferal is not necessarily according to the encryption and decryption standards of the governing	WS and PACS software and intra-net are available and connected in some departments to the departmental IS	capable and willing to log a patient on IS and thereby transmitting the digital image data to PACS. Departmental groups become able,
Level 3: Standard	Data is logged / transmitted securely according to hospital IS	The WS, software and intra-net and their users are included in hospitals budget from governmental institution	IS is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which link. Hospital network is	Patient ID used to log image data for transferal. Transferal is according to the encryption and decryption standards of the governing institution.	WS and PACS software and intra-net (with constant minimum line speed) are available throughout the hospital and connected to the hospital IS	a patient on IS and thereby transmitting the digital image data to PACS. Users except it as standard procedure to log and transmit the data to the required standard. There is dedicated IT
Level 4: Quality controlled	Network and transmission is managed and standardised. Data is transmitted in RAW format	The acquisition and operating cost of WS, software and intra-net versus hard copy image transfer are effectively measures, reported and reviewed, together with the calculated ROI.	The work protocol incorporates the quality control of naming and transmitting the patient image. Quality metrics are defined and captured with respect to the transmission.	Encryption and decryption of data are checked, to ensure that all diagnosis is executed according to service level agreement.	The use, availability, reliability and maintainability of the intra-net to transmit image data is effectively measured, reported and reviewed. Measure data-line connection speed and line use.	labeling and transmission of images to PACS and linking RIS files are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage
Level 5: Optimised	Secure inter-hospital network	Funds are available for R&D and business model sustains growth of system and increasing cost of WS, software and intra-net.	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (intranet needs).	Universal patient ID used to log image data for transferal. Transferal is according to the internationally accepted encryption and decryption standards.	Appropriate, useful and interoperable new technology for intra-net. HIS and patient data transfer's upgrades and scalability are continually and efficiently researched, acquired and implemented	Continuous process improvement includes deliberate professional development/empowerment of lower level user to log and transmit patient image.

Table 28: PACS MM- Process step: Store patient data

Store		Money	Method	Material	Machine	Man
		Funds for machinery, maintenance	Work protocols to securely store patient data	Patient Information system, backup data	Central server, IS, Archive,	Admin/ IT personnel
Level 1: Ad hoc	No formal storage or IS. Some images on PACS archive	The acquisition of the HIS, central server and storage unit is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution.	No standard protocol/work procedure exists manage the IS, server and stored data. This procedure is executed according to each individual's discretion and preference.	No formal IS, server or storage. Data is stored by user personally.	and storage unit are not yet acquired, set-up or not necessarily being used. .No back-up storage	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging
Level 2: Deployed	A local/ departmental server, IS and archive is setup	The acquisition of the HIS, central server and storage unit is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution	Managing the IS, server and stored data is done consistently by certain departmental groups. However, the procedure is not documented, approved and formalized throughout the hospital	Server or storage unit securely stores DICOM and encapsulated pdf under patient ID in departmental IS.	available and connected for some departments to the departmental IS. On-site back-up storage	motivating the users to receive training, be able, capable and willing to store digital images on server. Someone in the department becomes able, qualified, capable and willing to manage the stored images and
Level 3: Standard	A central IS, server and archive for whole hospital and designated specialists	The HIS, central server and storage unit and their users are included in hospitals budget from governmental institution	Managing the IS, server and stored data is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (retrieval).	Server and storage unit securely stores all formats of data under patient ID in hospital IS.	storage unit are available throughout the hospital and connected to the hospital IS. Off-site	There are assigned users to store digital images on server. They are willing, qualified and capable to manage the stored images and the patient data on IS archive and securely backup the data.
Level 4: Quality controlled	Data is stored in raw format and made interoperable on IS.	The acquisition and operating cost of HIS, central server and storage unit versus hard copy storage is effectively measures, reported and reviewed, together with the calculated ROI.	The work protocol incorporates the quality control of saving the patient image and the format there of. Quality metrics are defined and captured with respect to the storage process.	Stored data is tracked, checked and managed.	date is effectively measured, reported and reviewed. (Measure data growth. VNA data manager enable data	storage management of images on PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a
Level 5: Optimised	Hospital server and archive interlinked with other hospitals	Funds are available for R&D and business model sustains growth of system and increasing cost of HIS, central server and storage unit.	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (archiving needs, patient central archiving system)	Central server and storage unit securely stores all formats of data under universal patient ID inter-hospital IS.	for storage, backup and data management's upgrades and scalability are continually	Continuous process improvement includes deliberate professional development/empowerment of designated user to manage, backup, secure and ensure interoperability of stored patient data.

Table 29: PACS MM- Process step: Retrieve patient data

Retrieve		Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
		Retrieval according to storage method	Retrieved from departmental archive by means of departmental patient ID	Retrieved from hospital archive by means of hospital patient ID	Data managed and secured. Managed RAW format	Retrieved from any hospital archive by means of universal patient ID
Man	Personnel responsible for data retrieval	using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and	willing to retrieve digital images from central server. Departmental groups	central server. Users accept it as standard procedure to access the image with the patient	appraisal process. IT staff response and error correction performance metrics are tested. Patient	development/empowerment of lower level user to access the image with the patient ID from the IS and broadening
Machine	Viewing station, software, internet	WS and internet (with minimum line speed) are not yet acquired, set-up or not necessarily being used.	WS and internet (with minimum line speed) available and connected for some departments to the departmental IS	WS and internet (with minimum line speed) are available throughout the hospital and connected to the hospital IS.	The use, availability, reliability and maintainability of the internet to transmit image data fast and securely is effectively measured, reported and reviewed.	Appropriate, useful and interoperable new technology for internet and data transfer's upgrades scalability are continually and efficiently researched, acquired and implemented
Material	Patient image, patient information, with patient ID	DICOM / still images are retrieved by the method agreed between two users without encryption/ decryption.	DICOM image data / encapsulated pdf are retrieved securely with departmental ID but not necessarily according to the encryption and decryption standards of the governing institution	All patient image data is retrieved securely in native format with patient ID by means and encryption and decryption standards of the governing institution from the hospitals storage archive.	Encryption and decryption of data are checked, to ensure that all diagnosis are executed according to service level agreement.	All patient image data is retrieved securely in native format with patient ID by means and internationally accepted encryption and decryption standards from the central storage archive
Method	Retrieve Patient image by tracking the patient file on RIS	No protocol/work procedure exists to retrieving the patient information from IS. This procedure is executed according to instructions given by the individual saving the image.	information from IS is done consistently by certain departmental groups from the departmental IS. However, the procedure is is not documented, approved and formalized throughout the	Images are retrieved throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (diagnosis).	The work protocol incorporates the quality control of images are retrieval and patient privacy. Quality metrics are defined and captured with respect to the retrieval process.	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (internet needs).
Money	Funds for network, software and personnel	WS and constant minimum lines peed internet is financed by a once of investment. Acquisition and maintenance is not in hospital budget.	The acquisition of the WS and constant minimum lines peed internet is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution.	The WS and constant minimum lines peed internet and their users are included in hospitals budget from governmental institution	The acquisition and operating cost of WS and constant minimum lines peed internet versus hard copy image and patient transfer are effectively measures, reported and reviewed, together with the calculated ROI	Funds are available for R&D and business model sustains growth of system and increasing cost of the WS and constant minimum line-speed internet.

Table 30: PACS MM- Process step: Analyse patient data

Analyse	Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
	Viewers not available. Still images are analysed (JPEG, PDF)	DICOM image data, post processing	DICOM image data, PP, patient information access.	Raw data analysed (allowing all post processing)	Patient history from all hospitals can be access in all formats.

Money	Method	Material	Machine	Man
Funds for machinery, maintenance and personnel	Work protocol to analyze patient data on viewer software	Patient image, patient information	Viewing station, Viewer software	Specialist
The viewer software and viewing WS are financed by a once of investment. Acquisition and maintenance is not in hospital budget.	procedure exists to use the viewer software to analyse the digital image. There is no digital signature to assign authentication for diagnosis. This procedure is executed according to each individual's discretion	Only DICOM / still patient image can be viewed, no post processing and no patient information	Viewing software and viewing WS are not yet acquired, set-up or not necessarily being used.	There are some user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging equipment
The acquisition of the viewer software and viewing WSS are financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution	software to analyse the digital image is done consistently by certain departmental groups. However, the procedure is not documented, approved and formalized throughout the	DICOM images are analysed on DICOM viewer for some post processing. Patient data is viewed in pdf format.	Viewing software and viewing WS are available and installed in some departments	[illegible] driving all users to be able, capable and motivated to use digital images for diagnosis. Departmental groups become able, qualified, capable and willing to view, process and interpret a digital
The viewer software and viewing WS and their users are included in hospitals budget from governmental institution	software to analyse the digital image is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process	Images are analysed on viewer software in raw format and all post processing is enabled. Patient data is viewed in text format in hospital IS.	Viewing software and viewing WS are available and installed in throughout the hospital.	All users are capable to use the web viewer and digital images for diagnosis and accept it as standard procedure. There is dedicated IT staff on hand to assist with problems.
The acquisition and operating cost of viewer software and viewing WSs versus hard copy image diagnosis are effectively measures, reported and reviewed, together with the calculated ROI.	The work protocol incorporates the quality control of diagnosis of the digital image and its authentication. Quality metrics are defined and captured with respect to the diagnosis process.	Records are tracked, and integrity of meta-data checked, to ensure that all diagnosis are executed according to service level agreement.	The use, availability, reliability and maintainability of viewing stations or web viewer and viewing computers to allow appropriate quality, tools and views for diagnosis are effectively measured,	is effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image procedure is recorded. There is a champion to
Funds are available for R&D and business model sustains growth of system and increasing cost of viewer software and viewing WS.	Protocols are easily updated and operationalized to incorporate improved methods and technology (diagnosis needs)	Images are analysed on viewer software in raw format and all post processing is enabled. Patient data is viewed in text format in hospital IS.	technology for viewing and manipulating image data, upgrades and scalability are continually and efficiently researched, acquired and implemented. Images are viewed on a single interface capable of	Continuous process improvement includes deliberate professional development and dedicated specialised staff access.

Table 31: PACS MM- Process step: Transmit patient feedback

Transmit feedback	Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
	Users preference used for feedback	Uploaded to departmental IS	Uploaded to hospital IS	Secure, raw data	Uploaded to inter-hospital IS

Money	Method	Material	Machine	Man
Funds for software, personnel	Work protocols to transmit text feedback to IS	Text feedback data, patient ID	Viewing station, text enabling software, internet	Personnel authorised to transmit feedback
Software and IS that allows for diagnostic data and is financed by a once of investment. Acquisition and maintenance is not in hospital budget.	procedure exists to compile, authenticate and transmit patient feedback. There is no digital signature to assign authentication for diagnosis. Diagnosis feedback transmitted according to the instructions of	Feedback is done separately form patient imaged and transmitted non-securely my email or telephone.	Software for compiling, authenticating and transmitting patient analysis are not yet acquired, set-up or not necessarily being used.	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging
The acquisition of the software and IS that allows for diagnostic data is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental institution.	authenticating and transmitting patient feedback is done consistently by certain departmental groups. However, the procedure is not documented, approved and formalized throughout the	results are transmitted securely as encapsulated PDF under the patient ID on the departmental IS, but not necessarily according to the encryption and decryption standards of the governing	Software for compiling, authenticating and transmitting patient analysis are available and installed in some departments	departmental champion driving all users to be able, capable and motivated to load the diagnosis on IS. Departmental groups become able, qualified, capable and willing to compile digital diagnosis at the
The software and IS that allows for diagnostic data and their users are included in hospitals budget from governmental institution	authenticating and transmitting patient feedback is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of	The analysis is compiled in native format under patient ID according to common hospital protocol, so it is interpretable in the execution of the entire patient care delivery process.	Software for compiling, authenticating and transmitting patient analysis are available and installed in throughout the hospital.	to load the diagnosis on IS and authenticate it. Users except it as standard procedure to compile digital diagnosis at the WS log it to IS. There is dedicated IT staff on hand to assist with
The acquisition and operating cost of the software and IS that allows for diagnostic data versus hard copy patient file transfer is effectively measures, reported and reviewed, together with the calculated ROI.	The work protocol incorporates the quality control of the diagnosis saving and transmission. Quality metrics are defined and captured with respect to the transmission of feedback.	Encryption and decryption of data are checked, to ensure that all diagnosis are executed according to service level agreement.	The use, availability, reliability and maintainability of the internet to transmit diagnostic data is effectively measured, reported and reviewed.	effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with diagnosis is recorded.
Funds are available for R&D and business model sustains growth of system and increasing cost of the software and IS that allows for diagnostic data.	Protocols are easily updated and operationalized to incorporate improved methods and technology (need of system to save diagnosis data in PACS)	The analysis is compiled in native format under patient ID according to internationally accepted protocol, so it is interpretable in the execution of the entire patient care delivery process.	Appropriate, useful and interoperable new technology for diagnostic data transfer's upgrades and scalability are continually and efficiently researched, acquired and implemented	Continuous process improvement includes deliberate professional development/empowerment of lower level user to compile digital diagnosis at the WS log it to IS and authenticate it.

15.3 PACS MM: Process domains

Table 32: PACS MM- Process domains: Man

MAN	Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
	Resist, untrained and unmotivated.	Accept system, pilot team and champion, motivated	Norm, everyone trained and motivated	Human resource management/ client management	Community change, continuous user empowerment

TRANSMIT FEEDBACK	ANALYSE	RETRIEVE	STORE	TRANSMIT	CAPTURE
Personnel authorised to transmit feedback	Specialist	Personnel responsible for data retrieval	Admin/ IT personnel	Clinician/Admin personnel responsible for transmission	Clinician taking digital patient image
user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging	user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging
departmental champion driving all users to be able, capable and motivated to load the diagnosis on IS. Departmental groups become able, qualified, capable and willing to compile digital diagnosis at the	champion driving all users to be able, capable and motivated to use digital images for diagnosis. Departmental groups become able, qualified, capable and willing to view, process and interpret a digital	motivating the users to receive training, be able, capable and willing to retrieve digital images from central server. Departmental groups become able, qualified, capable and willing to	receive training, be able, capable and willing to store digital images on server. Someone in the department becomes able, qualified, capable and willing to manage the stored images is able qualified capable	motivating the users to receive training, be able, capable and willing to log a patient on IS and thereby transmitting the digital image data to PACS. Departmental groups become able, qualified, capable and willing to	departmental champion driving/ motivating the users to receive training, be able, capable and willing to use the digital imaging equipment. Departmental groups of users receive basic training to use digital
to load the diagnosis on IS and authenticate it. Users except it as standard procedure to compile digital diagnosis at the WS log it to IS. There are dedicated IT staff on	All users are capable to use the web viewer and digital images for diagnosis and accept it as standard procedure. There are dedicated IT staff on hand to assist with problems.	capable and willing to retrieve digital images from central server. Users accept it as standard procedure to access the image with the patient ID from the IS. There is dedicated	images on server. They are willing, qualified and capable to manage the stored images is able, qualified, capable and willing to manage the patient data on IS	capable and willing to thereby transmitting the digital image data to PACS. Users except it as standard procedure to log and transmit the data to the required standard.	capable and willing to use the digital imaging equipment and accept it as the standard procedure. There are dedicated IT staffs on hand to assist with
effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with diagnosis is recorded.	are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image procedure is recorded. There is a champion to	effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image diagnosing procedure.	storage/ management of images on PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage	Transmission of images to PACS and linking RIS files are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a	effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with imaging procedure is recorded. There is a
Continuous process improvement includes deliberate professional development/empowerment of lower level user to compile digital diagnosis at the WS log it to IS and authenticate it.	Continuous process improvement includes deliberate professional development and dedicated specialised staff access.	improvement includes deliberate professional development/empowerment of lower level user to access the image with the patient ID from the IS and broadening the network of specialists to access and analyse	Continuous process improvement includes deliberate professional development/empowerment of designated user to manage, backup, secure and ensure interoperability of stored patient data.	Continuous process improvement includes deliberate professional development/empowerment of lower level user to log and transmit patient image.	Continuous process improvement includes deliberate professional development/empowerment of lower level user to captures the image.

Table 33: PACS MM- Process domains: Machine

MACHINE		Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
		Some technology is obtained as experiments or pilots	Technology available, effective, supported by departmental groups	Technology standardised, forced to interoperate and used throughout hospital	Measurement and monitoring of reliability, availability and maintainability of system. Connect with other hospitals.	Continuous R&D and technological improvement.
CAPTURE	Digital imaging machine	Digital imaging machines are not yet acquired or not necessarily being used digitally.	DICOM compatible digital imaging machines are available and connected to departmental intra-net network.	DICOM compatible digital imaging machines are available throughout the hospital and connected to hospital intra-net network.	use, availability, reliability and maintainability of the digital imaging machines to capture and digitise medical images are effectively measured, reported and	technology for digital image capture and digital imaging machines' upgrades and scalability are continually and efficiently
TRANSMIT	Local WS, PACS software, intranet	WS and PACS software and intra-net are not yet acquired, set-up or not necessarily being used.	WS and PACS software and intra-net are available and connected in some departments to the departmental IS	WS and PACS software and intra-net (with constant minimum line speed) are available throughout the hospital and connected to the hospital IS	availability, reliability and maintainability of the intra-net to transmit image data is effectively measured, reported and reviewed. Measure data-line connection speed	technology for intra-net. HIS and patient data transfer's upgrades and scalability are continually and efficiently
STORE	Central server, IS, Archive,	Server, IS and storage unit are not yet acquired, set-up or not necessarily being used. .No back-up storage archives.	storage unit available and connected for some departments to the departmental IS. On-site back-up storage archive, but no	Server, IS and storage unit are available throughout the hospital and connected to the hospital IS. Off-site back-up available.	patient data accurately and up to date is effectively measured, reported and reviewed. (Measure data growth. VNA data manager enable data queries. Measure server	New/upgraded technology for storage, backup and data management's upgrades and scalability are continually and efficiently
RETRIEVE	Viewing station, software, internet	WS and internet (with minimum line speed) are not yet acquired, set-up or not necessarily being used.	WS and internet (with minimum line speed) available and connected for some departments to the departmental IS	WS and internet (with minimum line speed) are available throughout the hospital and connected to the hospital IS.	The use, availability, reliability and maintainability of the internet to transmit image data fast and securely is effectively measured, reported and reviewed.	interoperable new technology for internet and data transfer's upgrades scalability are continually and efficiently researched
ANALYSE	Viewing station, Viewer software	Viewing software and viewing WS are not yet acquired, set-up or not necessarily being used.	Viewing software and viewing WS are available and installed in some departments	Viewing software and viewing WS are available and installed in throughout the hospital.	reliability and maintainability of viewing stations or web viewer and viewing computers to allow appropriate quality, tools and views for diagnosis are effectively measured.	image data U's upgrades and scalability are continually and efficiently researched, acquired and implemented. Images are
TRANSMIT FEEDBACK	Viewing station, text enabling software, internet	software for compiling, authenticating and transmitting patient analysis are not yet acquired, set-up or not necessarily being used.	Software for compiling, authenticating and transmitting patient analysis are available and installed in some departments	Software for compiling, authenticating and transmitting patient analysis are available and installed in throughout the hospital.	The use, availability, reliability and maintainability of the internet to transmit diagnostic data is effectively measured, reported and reviewed.	interoperable new technology for diagnostic data transfer's upgrades and scalability are continually and efficiently researched

Table 34: PACS MM- Process domain: Material

MATERIAL		Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
		Informal EPI, no IS or PACS setup.	Localised departmental IS and PACS	Force integrated IS and PACS within the hospital (and designated specialists)	Managed patient centric information system	Interoperable intra-hospital patient information system.
CAPTURE	Image data	No set image data or data format captured. Data is captured in DICOM or pdf format.	Patient images are consistently and repeatably captured digitally in certain departments.	are consistently and repeatably captured digitally and packaged together with meta-data about time, place and user throughout	are tracked, and integrity of meta-data checked, to ensure that all diagnosis are executed according to service level	are consistently and repeatably captured digitally and packaged together with meta-data about time, place and user throughout
TRANSMIT	Patient ID, image data	transfer security. User decides which is the best method to transfer the	to log image data for transferal. Transferal is not necessarily according to the encryption and decryption standards of the	to log image data for transferal. Transferal is according to the encryption and decryption standards of the governing	decryption of data are checked, to ensure that all diagnosis is executed according to service level	patient ID used to log image data for transferal. Transferal is according to the internationally accepted encryption and decryption
STORE	Patient Information system, backup data	No formal IS, server or storage. Data is stored by user personally.	Server or storage unit securely stores DICOM and encapsulated pdf under patient ID in departmental IS.	Server and storage unit securely stores all formats of data under patient ID in hospital IS.	Stored data is tracked, checked and managed.	Central server and storage unit securely stores all formats of data under universal patient ID inter-hospital IS.
RETRIEVE	Patient image, patient information, with patient ID	images are retrieved by the method agreed between two users without encryption/	encapsulated pdf are retrieved securely with departmental ID but not necessarily according to the encryption and decryption standards of the	securely in native format with patient ID by means and encryption and decryption standards of the governing	decryption of data are checked, to ensure that all diagnosis are executed according to service level	retrieved securely in native format with patient ID by means and internationally accepted encryption and decryption standards from
ANALYSE	Patient image, patient information	still patient image can be viewed, no post processing and no patient	DICOM images are analysed on DICOM viewer for some post processing. Patient data is viewed in pdf format.	analysed on viewer software in raw format and all post processing is enabled. Patient data is viewed in text format in	integrity of meta-data checked, to ensure that all diagnosis are executed according to	Images are analysed on viewer software in raw format and all post processing is enabled. Patient data is viewed in text format in hospital IS.
TRANSMIT FEEDBACK	Text feedback data, patient ID	done separately form patient imaged and transmitted non-securely my email or	securely as encapsulated PDF under the patient ID on the departmental IS, but not necessarily according to the encryption and	under patient ID according to common hospital protocol, so it is interpretable in the execution of the entire	decryption of data are checked, to ensure that all diagnosis are executed according to service level	native format under patient ID according to internationally accepted protocol, so it is interpretable in the execution of the entire patient care

Table 35: PACS MM- Process domain: Method

Method		Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
		Protocols discourage telemedicine services	Protocols allowing telemedicine services	Policies and protocols catering for telemedicine services. Clearly outlined	Policies and protocols manage and optimise telemedicine services	Strategy catering for continuous improvement of telemedicine services
CAPTURE	Work protocol to capture digital image	procedure exists to capturing of digital patient images. This procedure is executed according to each individual's	consistently by certain departmental groups. However, the procedure is not documented, approved and	throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next	quality control of the digital patient image capturing process by medical imaging machine. Quality metrics are defined and captured with respect to the	Protocols are easily updated and operationalized to incorporate improved methods and digital imaging machinery.
TRANSMIT	work protocols to log patient ID on IS and transmit patient data	procedure exists to log and transmit the patient image. This procedure is executed according to each individual's	the IS is done consistently by certain departmental groups. However, the procedure is not documented, approved and	done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which link. Hospital	incorporates the quality control of naming and transmitting the patient image. Quality metrics are defined and captured with respect to the	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (intranet needs).
STORE	Work protocols to securely store patient data	procedure exists manage the IS, server and stored data. This procedure is executed according to each individual's	consistently by certain departmental groups. However, the procedure is not documented, approved and	throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next	incorporates the quality control of saving the patient image and the format there of. Quality metrics are defined and captured with respect to the	easily updated and operationalized to incorporate improved methods and transmission technology (archiving needs, patient central
RETRIEVE	Retrieve data	to retrieving the patient information from IS. This procedure is executed according to instructions given	consistently by certain departmental groups from the departmental IS. However, the procedure is is not documented,	throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next step of the	incorporates the quality control of images are retrieval and patient privacy. Quality metrics are defined and captured with respect to the	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (internet needs).
ANALYSE	Work protocol to analsze patient data on viewer software	digital image. There is no digital signature to assign authentication for diagnosis. This procedure is	digital image is done consistently by certain departmental groups. However, the procedure is not documented, approved and	digital image is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which links with the next	incorporates the quality control of diagnosis of the digital image and its authentication. Quality metrics are defined and captured with respect to the diagnosis	Protocols are easily updated and operationalized to incorporate improved methods and technology (diagnosis needs)
TRANSMIT FEEDBACK	Work protocols to transmit text feedback to IS	feedback. There is no digital signature to assign authentication for diagnosis. Diagnosis feedback	is done consistently by certain departmental groups. However, the procedure is is not documented,	is done throughout the hospital according to a standard, formalized and documented protocol/work procedure, which	incorporates the quality control of the diagnosis saving and transmission. Quality metrics are defined and captured with respect to the transmission of	easily updated and operationalized to incorporate improved methods and technology (need of system to save diagnosis data in

Table 36: PACS MM- Process domain: Money

Money		Level 1: Ad hoc	Level 2: Deployed	Level 3: Standard	Level 4: Quality controlled	Level 5: Optimised
		Project financed by a once of investment.	Project initiative financed by the hospital	System operation included in hospitals budget	Cost are effectively measures, reported and reviewed	Sustainable business model, with funds for R&D
CAPTURE	Funds for machinery, maintenance and personnel	The digital imaging machines are financed by a once of investment. Acquisition and maintenance is not in hospital budget.	the digital imaging machines is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental	The digital imaging machines and their users are included in hospitals budget from governmental institution	acquisition and operating cost of digital imaging machines versus analog machines are effectively measures, reported and reviewed, together with the calculated ROI	Funds are available for R&D and business model sustains growth of system and increasing cost of digital imaging machines.
TRANSMIT	Funds for network, software and personnel	The WS, software and intra-net is financed by a once of investment. Acquisition and maintenance is not in hospital budget.	the WS, software and intra-net is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental	The WS, software and intra-net and their users are included in hospitals budget from governmental institution	cost of WS, software and intra-net versus hard copy image transfer are effectively measures, reported and reviewed,	Funds are available for R&D and business model sustains growth of system and increasing cost of WS, software and intra-net.
STORE	Funds for machinery, maintenance	server and storage unit is financed by the hospital enterprise as an initiative but not included in hospital budget from the governmental	server and storage unit is financed by the hospital enterprise as an initiative but not included in hospital budget from the	server and storage unit and their users are included in hospitals budget from governmental institution	cost of HIS, central server and storage unit versus hard copy storage is effectively measures, reported and reviewed,	Funds are available for R&D and business model sustains growth of system and increasing cost of HIS, central server and storage unit.
RETRIEVE	Funds for network, software and personnel	minimum lines peed internet is financed by a once of investment. Acquisition and maintenance is not in hospital budget	constant minimum lines peed internet is financed by the hospital enterprise as an initiative but not included in hospital budget from the	constant minimum lines peed internet and their users are included in hospitals budget from governmental institution	constant minimum lines peed internet versus hard copy image and patient transfer are effectively measures, reported and	available for R&D and business model sustains growth of system and increasing cost of the WS and constant minimum line-
ANALYSE	Funds for machinery, maintenance and personnel	software and viewing WS are financed by a once of investment. Acquisition and maintenance is not in hospital budget	software and viewing WSS are financed by the hospital enterprise as an initiative but not included in hospital budget from the	software and viewing WS and their users are included in hospitals budget from governmental	cost of viewer software and viewing WSs versus hard copy image diagnosis are effectively measures, reported and reviewed,	Funds are available for R&D and business model sustains growth of system and increasing cost of viewer software and viewing WS.
TRANSMIT FEEDBACK	Funds for software, personnel	that allows for diagnostic data and is financed by a once of investment. Acquisition and maintenance is not in hospital	IS that allows for diagnostic data is financed by the hospital enterprise as an initiative but not included in hospital budget from the	IS that allows for diagnostic data and their users are included in hospitals budget from governmental	software and IS that allows for diagnostic data versus hard copy patient file transfer is effectively measures, reported and	available for R&D and business model sustains growth of system and increasing cost of the software and IS that allows for

15.4 PACS MM: The process maturity levels

Table 37: PACS MM- Maturity level: Ad hoc

Level 1		man	Machine	Material	Method	Money
		Users: Patients and personal	Technology: Hardware and software	Data transferred	Protocol and Policies	Project funding and salaries
Capture	capture the patient image with digital imaging equipment	There are some user(s) positive towards using digital imaging equipment but it is merely a coincidence if the user that is taking the image is qualified, capable and willing to use the digital imaging equipment	Digital imaging machines are not yet acquired or not being used digitally.	No set patient ID. Captured data are not intentionally kept on record, no set way to ID patients for filling system. Each user IDs patient images to his/ her own discretion. No patient information (PDF data) is transmitted	No standard, protocol/work procedure exists to use digital imaging machines and digital medical image. This procedure is executed according to each individual's discretion and preference.	The digital imaging machines are financed by a once of investment. Acquisition and maintenance is not in hospital budget.
Transmit	transmit data- log patient image on PACS and link with RIS patient file	There are some user(s) positive towards the transmission of digital images to PACS but it is merely a coincidence if the user transmitting the data is able, qualified, capable and willing to log the image on PACS and link it with the patient files on RIS. *If system is setup correctly (patient centric data base) this happens automatically with patient ID, but user still needs to check and make corrections where necessary	Intra-net not yet acquired or not connected to digital imaging machines, on-site computer and PACS server and central storage unit. PACS software not yet acquired or installed on on-site viewing computer.	DICOM image data is transmitted with ID (agreed between two users) and without consideration encryption/ decryption or other EHR standards to the PACS storage archive	Worker performance metrics for the correct labelling and transition of images to PACS and linking RIS files are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage feedback and measurement.	Continuous process improvement includes deliberate professional development/patient empowerment of the person who transmits the data.

Diagnose	Retrieve	Store
Diagnose/ analyse digital patient image on PACS viewer	Retrieve Patient image by tracking the patient file on RIS	Store data- save image on PACS and managing patient storage files
There are some user(s) positive towards diagnosing a digital image but it is merely a coincidence if the user is able, qualified, capable and willing to view, process and interpret a digital image using web viewer and viewer functions.	There is some user(s) positive towards retrieving digital images from PACS but it is merely a coincidence if the user retrieving the image is able, qualified, capable and willing to track the image with the patient file from RIS *It the system is setup correctly this is a simple task done by only entering a patient ID but errors can occur such as duplicate IDs or lost images whereby the users needs to be able to make use of alternative searches	There are some user(s) positive towards the storage of digital images in PACS archive but it is merely a coincidence if the user storing the image is able, qualified, capable and willing to storage the file and how the user storages and mange's the stored file *If system is setup correctly (patient centric data base) this happens automatically with patient ID, but user still needs to check for correctness and make adjustments where necessary
There are no viewing stations or web viewer and viewing computers or it is not connected to internet.	Internet not yet acquired or not connected to PACS SS and viewing station.	PACS server and central storage unit with PACS software (PACS SS) not yet acquired or not installed and connected to hospital intra-net. No back-up storage archives.
Only patient image can be viewed, no patient information	DICOM image data is retrieved with ID (agreed between two users) and without encryption/ decryption or other EHR standards from the PACS storage archive	PACS archive stores only DICOM image data, with Radom patient ID. No set ID for EHR
Analyser satiation with the digital image is effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image procedure is recorded. There is a champion to manage feedback and measurement	Worker satisfaction metrics for the retrieval of images to PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image diagnosing procedure. There is a champion to manage feedback and measurement	Worker performance metrics for the correct storage/ management of images on PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage feedback and measurement
Continuous process improvement includes deliberate professional development/patient empowerment of the person who diagnose/ analyse.	Continuous process improvement includes deliberate professional development/patient empowerment by patient centric storage archive	Continuous process improvement includes deliberate professional development/patient empowerment by patient centric storage archive

Transmit feedback
Transmit feedback on patient file in PACS-RIS system
There are some user(s) positive towards the transition of digital diagnosis to the PACS-RIS but it is merely a coincidence if the user transmitting the diagnosis is able, qualified, capable and willing to do so on the PACS-RIS and authenticate it.
PACS software does not yet allow for diagnostic data
PACS archive cannot handle diagnosis data (PDF data)
User performance metrics for loading diagnosis to PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with diagnosis is recorded. There is a champion to manage feedback and measurement.
Continuous process improvement includes deliberate professional development/patient empowerment of the person who transmits feedback.

Table 38: PACS MM- Maturity level: Deployed

Level 2		Man	Machine	Material	Method	Money
		Users: Patients and personal	Technology: Hardware and software	Data transferred	Protocol and Policies	Project funding and salaries
Capture	Capture the patient image with digital imaging equipment	There is a champion driving/ motivating the users to receive training, be able, capable and willing to use the digital imaging equipment. Users receive basic training to use digital imaging equipment	Digital imaging machines are DICOM compatible, available and connected to hospital intra-net network	Local set patient ID in dement. Patient information and image are consistently and repeatable captured and kept on record with a set patient ID.	Digital imaging machines and digital medical image uses consistent However, this work protocol is not formalized and documented.	The acquisition of the digital imaging machines is financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.
Transmit	Transmit data- log patient image on PACS and link with RIS patient file	There is a champion driving/ motivating the users to receive training and become able, capable and willing to log the digital image directly to PACS and link it with the patient file on RIS. Users receive basic training to name and transmit digital images to PACS and link it with RIS patient file. *If system is setup correctly (patient centric data base) this happens automatically with patient ID, but user still needs to check and make corrections where necessary	Intra-net available and connected to digital imaging machines, on-site computer and PACS server and central storage unit. PACS software acquired and installed on on-site viewing computer and DICOM images are transferred.	DICOM image data and encapsulated PDF data is securely transmitted with patient ID, but not necessarily according to the encryption and decryption standards of the governing institution.	Naming and transmitting the image is done consistently by all hospital personal, bit this work protocol is not formalized and documented.	The acquisition of the intra-net is is financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.

Diagnose	Retrieve	Store
Diagnose/ analyse digital patient image on PACS viewer	Retrieve Patient image by tracking the patient file on RIS	Store data- save image on PACS and managing patient storage files
There is a champion driving all users to be able, capable and motivated to use digital images for diagnosis. Users receive basic training to view, process and interpret a digital image using a web viewer.	There is a champion driving/ motivating all users to be able, capable and willing to retrieve the digital image from the PACS archive. Users receive basic training to retrieve digital images from PACS. *It the system is setup correctly this is a simple task done by only entering a patient ID but errors can occur such as duplicate IDs or lost images whereby the users needs to be able to make use of alternative searches	There is a champion driving/ motivating the users to be able, capable and willing to storage the file and how the user storages and mange's the stored file. *If system is setup correctly (patient centric data base) this happens automatically with patient ID, but user still needs to check for correctness and make adjustments where necessary
Viewing stations or web viewer and viewing computers are available and connected to internet. Images are still viewed with vendor viewer	Internet is available and connected to PACS SS and viewing station.	PACS SS available and connected to hospital intra-net. Data stored in DICOM/ encapsulated PDF format. On-site back-up storage archive, but no off-site back up.
The result of diagnosis/analysis compiled in PDF document	DICOM image data is retrieved securely with ID and but not necessarily according to the encryption and decryption standards of the governing institution from the PACS-RIS storage archive	PACS-RIS archive stores only DICOM/ encapsulated PDF data, with set patient ID on HER
Diagnosis of the transmitted digital image is done and "singed" in a consistent manner by all hospital personal, but this work protocol is not formalized, approved and documented.	Images are retrieved by consistent means by all hospital personal, but this work protocol is not formalized and documented.	Save the patient image and the format there of is consistently done by all hospital personal, but this work protocol is not formalized and documented.
The acquisition of the viewing stations, web viewer and viewing computers are financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.	The acquisition of the internet is financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.	The acquisition of the PACS software and central storage unit is financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.

Transmit feedback	Transmit feedback on patient file in PACS-RIS system	There is a champion driving all users to be able, capable and motivated to load the diagnosis on PACS. Users receive basic training to compile digital diagnosis and send it.	PACS software does allow encapsulated pdf data	The transmission of results are transmitted securely as encapsulated PDF under the patient ID on the RIS, but not necessarily according to the encryption and decryption standards of the governing institution.	Transmitting and saving the diagnosis is done consistently by all hospital personal, but this work protocol is not formalized and documented. Digital signature is accepted but not yet formally approved.	The acquisition of the PACS software that allows for diagnostic data is financed by the hospital enterprise as an initiative but not included in hospital budget from the governable institution.

Table 39: PACS MM- Maturity level: Standardised

Level 3		Man	Machine	Material	Method	Money
		Users: Patients and personal	Technology: Hardware and software	Data transferred	Protocol and Policies	Project funding and salaries
Capture	Capture the patient image with digital imaging equipment	All users are capable to use the digital imaging equipment and accept it as the standard procedure. There is a dedicated IT staff on hand to assist with problems.	Digital imaging machines all operate with DICOM and are connected to a hospital intra-net network. Clear system working standards are outlined.	Intra-hospital set patient ID. Patient information and image are consistently and repeatable captured and packaged together with meta-data about time, place and user, according to a standard data format and common protocol, so it is interpretable in the execution of the entire patient care delivery process.	Patient images are captured and digitized according to a standard, formalized and documented protocol/work procedure by the medical imaging machine, which links with the next step of the process (transmission).	The digital imaging machines and their users are included in hospitals budget from governmental institution
Transmit	Transmit data- log patient image on PACS and link with RIS patient file	All users are capable to correctly name and transmit the digital image directly to PACS and link it with RIS patient file and accept it as the standard procedure. There are dedicated IT staffs on hand to asset with problems. *If system is setup correctly (patient centric data base) this happens automatically with patient ID, but user still needs to check and make corrections where necessary	Intra-net (with constant *minimum line speed) available in hospital and connected to all digital imaging machines, on-site computers and PACS server and central storage unit. PACS software operating seamlessly to transfer patient images to on-site viewing computer and archiving system. (Intra-net connection plan clearly outlined *IP database, with failure procured)	The image and patient data in native format is transmitted with patient ID securely by means and encryption and decryption standards of the governing institution.	Naming and transmitting the image is done according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (storage).	The intra-neater and their users are included in hospitals budget from governmental institution

Transmit feedback	Diagnose	Retrieve	Store
Transmit feedback on patient file in PACS-RIS system	analyse digital patient image on PACS	Retrieve Patient image by tracking the patient file on RIS	Store data- save image on PACS and managing patient storage files
All users to be capable to correctly file and load the diagnosis on PACS and accept it as the standard procedure. There is dedicated IT staff on hand to assist with problems.	digital images for diagnosis and accept it as standard procedure. There is dedicated IT	All users are capable to retrieve the digital image from the PACS archive and accept it as the standard procedure by only entering a patient ID but errors can occur such as duplicate IDs or lost images whereby the users needs to be able to make use of alternative searches. . There is dedicated IT staff on hand to asset with problems	Images are stored automatically and the system manages the stored patient files, but users are trained to check for correctness and make adjustments where necessary. There are dedicated staffs on hand to assist with IT problems and also staff that are responsible for correctness of storage of patient data (manage the patient archive) and back-up archive.
Communication of different data types are forced, therefore PDF and Word patient files can be sent (HIS and PACS are forced to communicate)	to internet. Multiple vendor viewers installed to view all data in RAW format. Clear	Internet is available and connected to PACS SS and viewing station and off-site specialist or referral hospitals. (Internet connection plan clearly outlined *IP database, with failure procedure)	PACS archive operating constantly, seamlessly to store patient images in native formats. And manage stored images for the required number of years before deletion. Off-site back-up storage archives available and connected to network for backup. Clear system working standards are outlined (Serves agreements in place in case of system failure).
The result of diagnosis/analysis transmitted together with meta-data about time, place and user, in native format under patient ID according to common intra hospital protocol, so it is interpretable in the execution of the entire patient care delivery process.	with meta-data about time, place and user, in native format according to common protocol, so it is	All patient data is retrieved securely in native format with patient ID by means and encryption and decryption standards of the governing institution from the PACS-RIS storage archive.	PACS-RIS-HIS archive operates as a patient centric database that stores all data formats with set intra-hospital patient ID.
Transmitting and saving the diagnosis is done consistently done according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (retrieve).	done according to a standard, formalized and documented protocol/work procedure,	Images are retrieved by consistent means according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (diagnosis).	Save the patient image and the format there of is done according to a standard, formalized and documented protocol/work procedure, which links with the next step of the process (retrieval).
The PACS software and their users are included in hospitals budget from governmental institution	The viewing stations, web viewer and viewing computers and their users are included in hospitals budget from governmental institution	The internet and their users are included in hospitals budget from governmental institution	The PACS software and central storage unit and their users are included in hospitals budget from governmental institution

Table 40: PACS MM- Maturity level: Quality controlled

Level 4		Man	Machine	Material	Method	Money
		Users: Patients and personal	Technology: Hardware and software	Data transferred	Protocol and Policies	Project funding and salaries
Capture	Capture the patient image with digital imaging equipment	Worker performance metrics for the digital imaging procedure are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with imaging procedure is recorded. There is a champion to manage feedback and measurement	The use, availability, reliability and maintainability of the digital imaging machines to capture and digitise medical images are effectively measured, reported and reviewed.	Captured data are tracked, and integrity of meta-data checked, to ensure that all diagnosis is executed according to service level agreement.	The work protocol incorporates the quality control of the digital patient image capturing process by medical imaging machine. Quality metrics are defined and captured with respect to the capturing and digitizing of data.	The acquisition and operating cost of digital imaging machines versus analogy machines are effectively measures, reported and reviewed, together with the calculated ROI.
Transmit	Transmit data- log patient image on PACS and link with RIS patient file	Worker performance metrics for the correct labelling and transition of images to PACS and linking RIS files are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage feedback and measurement.	The use, availability, reliability and maintainability of the intra-net to transmit image data is effectively measured, reported and reviewed. Measure data-line connection speed and line use.	Encryption and decryption of data are checked, to ensure that all diagnosis is executed according to service level agreement.	The work protocol incorporates the quality control of naming and transmitting the patient image. Quality metrics are defined and captured with respect to the transmission.	The acquisition and operating cost of intra-net versus hard copy image transfer are effectively measures, reported and reviewed, together with the calculated ROI.

Diagnose	Retrieve	Store
Diagnose/ analyse digital patient image on PACS viewer	Retrieve Patient image by tracking the patient file on RIS	Store data- save image on PACS and managing patient storage files
Analyser satiation with the digital image is effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image procedure is recorded. There is a champion to manage feedback and measurement	Worker satisfaction metrics for the retrieval of images to PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with image diagnosing procedure. There is a champion to manage feedback and measurement	Worker performance metrics for the correct storage/ management of images on PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. There is a champion to manage feedback and measurement
The use, availability, reliability and maintainability of viewing stations or web viewer and viewing computers to allow appropriate quality, tools and views for diagnosis are effectively measured, reported and reviewed.	The use, availability, reliability and maintainability of the internet to transmit image data fast and securely is effectively measured, reported and reviewed.	The use, availability, reliability and maintainability of the PACS software and central-storage unite to store patient data accurately and up to date is effectively measured, reported and reviewed. (Measure data growth. VNA data manager enable data queries. Measure server downtime and usage. Measure stored data size and track data growth to ensure enough storage and server space.)
Records are tracked, and integrity of meta-data checked, to ensure that all diagnosis is executed according to service level agreement.	Encryption and decryption of data are checked, to ensure that all diagnosis is executed according to service level agreement.	Stored data is tracked, checked and managed.
The work protocol incorporates the quality control of diagnosis of the digital image and its authentication. Quality metrics are defined and captured with respect to the diagnosis process.	The work protocol incorporates the quality control of images are retrieval and patient privacy. Quality metrics are defined and captured with respect to the retrieval process.	The work protocol incorporates the quality control of saving the patient image and the format there of. Quality metrics are defined and captured with respect to the storage process.
The acquisition and operating cost of viewing stations, web viewer and viewing computers versus hard copy image diagnosis are effectively measures, reported and reviewed, together with the calculated ROI.	The acquisition and operating cost of internet versus hard copy image and patient transfer are effectively measures, reported and reviewed, together with the calculated ROI	The acquisition and operating cost of PACS software and central storage unit versus hard copy storage is effectively measures, reported and reviewed, together with the calculated ROI.

	Transmit feedback
	Transmit feedback on patient file in PACS-RIS system
Man	User performance metrics for loading diagnosis to PACS are effectively included in performance management and work appraisal process. IT staff response and error correction performance metrics are tested. Patient satisfaction with diagnosis is recorded. There is a champion to manage feedback and measurement
Machine	The use, availability, reliability and maintainability of the internet to transmit diagnostic data is effectively measured, reported and reviewed.
Material	Encryption and decryption of data are checked, to ensure that all diagnosis is executed according to service level agreement.
Method	The work protocol incorporates the quality control of the diagnosis saving and transmission. Quality metrics are defined and captured with respect to the transmission of feedback.
Money	The acquisition and operating cost of the internet and PACS versus hard copy patient file transfer is effectively measures, reported and reviewed, together with the calculated ROI.

Table 41: PACS MM- Maturity level: Optimised

Level 5		Capture	Transmit
		Capture the patient image with digital imaging equipment	Transmit data- log patient image on PACS and link with RIS patient file
Man	Users: Patients and personal	Continuous process improvement includes deliberate professional development/patient empowerment of the person who captures the data.	Continuous process improvement includes deliberate professional development/patient empowerment of the person who transmits the data.
Machine	Technology: Hardware and software	Appropriate, useful and interoperable new technology for digital image capture and digital imaging machines' upgrades and scalability are continually and efficiently researched, acquired and implemented	Appropriate, useful and interoperable new technology for intra-net and data transfer's upgrades and scalability are continually and efficiently researched, acquired and implemented
Material	Data transferred	Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.	Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.
Method	Protocol and Policies	Protocols are easily updated and operationalized to incorporate improved methods and digital imaging machinery.	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (intranet needs).
Money	Project funding and salaries	Funds are available for R&D and business model sustains growth of system and increasing cost of digital imaging machines.	Funds are available for R&D and business model sustains growth of system and increasing cost of intra-net.

Diagnose	Retrieve	Store
Diagnose/ analyse digital patient image on PACS viewer	Retrieve Patient image by tracking the patient file on RIS	Store data- save image on PACS and managing patient storage files
Continuous process improvement includes deliberate professional development/patient empowerment of the person who diagnose/ analyse.	Continuous process improvement includes deliberate professional development/patient empowerment by patient centric storage archive	Continuous process improvement includes deliberate professional development/patient empowerment by patient centric storage archive
Appropriate, useful and interoperable new technology for viewing and manipulating image data o's upgrades and scalability are continually and efficiently researched, acquired and implemented. Images are viewed on a single interface capable of viewing all data types in raw format (plug-in)	Appropriate, useful and interoperable new technology for internet and data transfer's upgrades scalability are continually and efficiently researched, acquired and implemented	Appropriate, useful and interoperable new/upgraded technology for storage, backup and data management's upgrades and scalability are continually and efficiently researched, acquired and implemented.
Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.	Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.	Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.
Protocols are easily updated and operationalized to incorporate improved methods and technology (diagnosis needs)	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (internet needs).	Protocols are easily updated and operationalized to incorporate improved methods and transmission technology (archiving needs).
Funds are available for R&D and business model sustains growth of system and increasing cost of viewing stations, web viewer and viewing computers.	Funds are available for R&D and business model sustains growth of system and increasing cost of the internet.	Funds are available for R&D and business model sustains growth of system and increasing cost of PACS software and central storage unit.

Transmit feedback
Transmit feedback on patient file in PACS-RIS system
Continuous process improvement includes deliberate professional development/patient empowerment of the person who transmits feedback.
Appropriate, useful and interoperable new technology for diagnostic data transfer's upgrades and scalability are continually and efficiently researched, acquired and implemented
Deliberate efforts are in place identify causes for insufficiently captured EHR and to address these causes.
Protocols are easily updated and operationalized to incorporate improved methods and technology (need of system to save diagnosis data in PACS)
Funds are available for R&D and business model sustains growth of system and increasing cost of the internet and PACS software.

16 Addendum C

16.1 Correspondence

16.1.1 Correspondence with Tygerberg hospital

RE: Visit by engineering student Ms Myra Triegaardt (role of IT in the health care sector) Inbox x

Doubell, AF, Prof <afd@sun.ac.za> <afd@sun.ac.za> 03/09/2010
to Revere, Shareen, me

Hi Shareen

Thursday the 9th at 14h00 is fine.

Regards

Prof D.

-----Original Message-----
From: Shareen Ely [mailto:Sely@pgwc.gov.za]
Sent: 03 September 2010 15:31
To: Doubell, AF, Prof <afd@sun.ac.za>
Subject: RE: Visit by engineering student Ms Myra Triegaardt (role of IT in the health care sector)

Good Afternoon Prof

The 9 September @ 14:00 is the only date Dr has available in next week. Is this date and time fine?

Regards
Shareen

>>> "Doubell, AF, Prof <afd@sun.ac.za>" <afd@sun.ac.za> 03/09/2010 15:28 >>>
Dear Revere

I note that the date you have given to meet with Ms Triegaardt is the 15th of September. As indicated in my previous e-mail attached below she is hoping to do this visit during her vacation which is next week. Will you not be able see her between the 6th and the 10th?

Regards

Anton

Copy of previous e-mail:
Dear Revere

I have been approached by an engineering student, Ms Myra Triegaardt, doing a project on the role of information technology in the health care sector. She has requested to visit Tygerberg Hospital to assess the flow of information during the management of a patient from arrival until completion of treatment. I think you are a good person for her to talk to in order to get a good overall view of the flow of information. She is particularly interested in the manner and format in which data is captured. She would like to co-ordinate her visit to coincide with her leave (6-12 September 2010). Could you please let me know if you would be able to meet with her and what day and time would suit you (I will arrange her site visit for the same day using the Cardiology Division as her study area).

Regards

Anton Doubell
Head: Division of Cardiology

-----Original Appointment-----
From: Shareen Ely [mailto:Sely@pgwc.gov.za]
Sent: 02 September 2010 10:35
To: Adam Loff; Jennefer Jooste; Revere Thomson; Doubell, AF, Prof <afd@sun.ac.za>
Cc: Waller, MY, Mrs <myw@sun.ac.za>
Subject: Visit by engineering student Ms Myra Triegaardt (role of IT in the health care sector)
When: 15 September 2010 10:00-11:00 (GMT+02:00) Harare, Pretoria.
Where: Meet at Dr Thomson's office

Item Type: Appointment
Start Date: Wednesday, 15 Sep 2010, 10:00:00am (South Africa Standard Time)
Duration: 1 Hour
Place: Meet at Dr Thomson's office

myra triegaardt <triegaardtm@gmail.com> 01/09/2010

to afd

Hello Prof Anton Doubell

Ek wil graag 'n afspraak maak om Tygerberg hosiptaal te kom besoek.

Ons het volgende week (6 -12 September) vakansie en ek wil graag die hospitaal kom besoek om te sien hoe die vloei van informasie plaasvind vandat die pasiente arriveer tot na die behandeling. Ek wil ook graag uitvind oor die manier en formaat waarin data vasgele word.

Baie dankie

16.1.2 Correspondence with Worcester hospital

Karl Klusmann <Kklusman@pgwc.gov.za>
to me

Afrikaans › English · Translate message

Beste Myra,

Ek is nie seker of die epos aan my ge-adresseer is nie, maar ons by Worcester Hospitaal sal graag die uitslag van jou navorsing wil aanhoor.

Ek probeer n geskikte datum gou reel.

Hoe sou Maandagoggend van 30 Julie, 9H-11H00, vir jou pas?

Karl Klusmann

Dr Karl Klusmann

Head of Department
Internal Medicine
Worcester Hospital
P/B X3058
Worcester
South Africa
6849

Tel: +27 23 3481100
Fax: +27 86 514 9694
Mobile: +27 72 8233304

>>> myra triegaardt <triegaardtm@gmail.com> 6/22/2012 10:24 AM >>>
Goeie môre Lesley

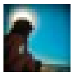
Hoe gaan dit by julle in Worcester?
My navorsing het nou tot op 'n punt gekom, en ek het PACS implimenterings
modelle geformuleer. Ek is jammer dit het so lank geneem, maar die probleem
het baie meer lyf gehad as wat ek verwag het. Ek wil hoor of dit moontlik
vir my sal wees om julle weer te kom besoek en my modelle te wys en vergelyk met julle stelsel.

Enige tyd van Julie af pas my. Sal baie bly wees as ek kan kom en ek hoop
my navorsing kan nou vir julle ook iets bied.

Groete,
Myra Triegaardt

Universiteit van Stellenbosch
Departement van "Bedryfsingenieurswese"
+27 (21) 808 4234

PACS process



myra triegaardt <triegaardtm@gmail.com>
to Patrick

Hi Patrick

Baie dankie vir jou moeite, ek sal definitief groep bywoon by TBH volgende week .

Ek het die vrou by PS geemail wat die kurses gedoen het, wag vir haar terugvoer.

Hier is my terugvoer en tabelle oor julle PACS proses.

Groete,

...

7 attachments — Download all attachments

Terugvoer.docx
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42K View Download

Oordra.pdf
42K View Download

Oproep.pdf
41K View Download

Stoor.pdf
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Terugvoer.pdf
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Vasvang.pdf
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16.1.3 Correspondence with Ms JB Fortuin

Re: PACS Maturity Model Inbox x Telemedicine

Jill <jbfortuin@gmail.com> 13 May
to me

Dear Myra

Certainly I will do all that I can to assist, Send me a copy of your thesis I will work through it this evening and I will call you tomorrow morning to arrange an appointment for either tommorrow afternoon or Wednesday morning.

Kind regards

Jill

Sent from my iPad

On 13 May 2013, at 3:51 PM, Myra Triegaardt <triegaardtm@gmail.com> wrote:

> Hi Jill
>
>
> How are you doing?
>
>
> I want to ask you a big favour. I just got feedback that my thesis verification is complete but it is lacking in a strong validation. I was wondering whether I could meet with you and discuss it or send an electronic summary for further validation. The problem is that my oral presentation is on Thursday and this would be very short notice. I am sure the examiner does not expect of me to perform validation in such a short time, but as any student would, I would like to make my argument as solid as possible.
>
>
> Kind regards,
> Myra

Click here to Reply or Forward

16.1.4 Correspondence with Prof AF Doubell

Re: Thesis validation

myra triegaardt <triegaardtm@gmail.com>
to AF,

Hi Prof Doubel

Aangeheg is my tesis in 'Adobe reader'- formaat.

Die doel van my tesis was om twee goed te ontwikkel:
1 - Die ideale PACS struktuur vir SA
2 - Die Maturity Model (MM) vir die instelling en verbetering van PACS.

As jy na die tesis kyk:
Die ideale struktuur is in hoofstuk 5
Die MM is in hoofstuk 10 en Addendum B (Hoofstuk 109 verduidelik die basiese konsepte van die model en die hele model is aangeheg as add B)

Baie daie vir jou gewilligheid om daarna te kyk.

Baie groete,

16.1.5 Correspondence with Mr B Lines

Move to Inbox | More

Communication Skills - CorporateTrainingMaterials.com - Workshop training materials to teach communication skills.

PACS evalution

myra triegaardt <triegaardtm@gmail.com>
to brendonlines322

Hi Brendon

Attached is the PACS system for evaluation, as discussed.

If you could give me feedback as to whether it will work in the hospital and whether it will address the issues you experience.
Take a special look at chapter 5, which contains the suited PACS structure.

Appreciate your willingness, thank you. Hope the solution can help you in the future.

Kind regards,

...

Myra Triegaardt Thesis.pdf
5542K View Download

17 Addendum D: Thesis Amendments

Document structure

1. Introduction

After the thesis was reviewed, changes were made in light of the feedback. This report refers to all the corrections and amendments made to the thesis.

The following areas were addressed:

- the thesis problem, purpose and objectives were restructured;
- the methodology was scientifically defined;
- the use of a maturity model (MM) was justified;
- the validation and verification of the research was completed;
- the conclusion was restructured;
- corrected spelling and grammatical errors.

2. Thesis problem purpose and objectives

<u>Comment from the examiners:</u>

The problem statement doesn't seamlessly relate to the problem addressed in the thesis, although the research and study done did address a relevant problem and the model developed was of good quality.

<u>Amendments:</u>

Amended area: The Background (p.1), Problem statement (p.2), Purpose (p.3), and Research objectives (p.3) were restructured.

The background was elaborated upon to include the following. "It is commonly found, across different fields, that the IT system implementation is a problem due to these four issues (p.2):

a) vague enterprise vision and undefined goals;
b) lack of commitment by top management;
c) inappropriate technical and operational IT solutions;
d) incompetent project and change management.

It was established that in the South African healthcare environment the Department of Health (DoH) has a clear vision and set goals. They are commitment to implement PACS throughout SA to improve healthcare services. "

In light of the amended background the following changes were made to the problem statement. The problem statement no longer solely states that PACS systems in SA are unsuccessful. It now focuses on the reasons for such a conclusion, in terms of issues (c) and (d). The new thesis problem states that specifications, guidelines and best practice operational methods, for the appropriate PACS technical structure, are lacking in South African literature and in governmental strategies *(*Refer to section: Problem statement*).* Additionally, there are no implementation guidelines or support for hospital decision makers to manage the project and enterprise change.

The purpose of the thesis was subsequently changed from *'A model to assist the implementation and deployment of PACS in SA'* to suit the new problem statement. The purpose of the thesis is currently "firstly to define a PACS technical and operational structure suited for the South African public healthcare environment and secondly, to develop guidelines for its implementation and optimisation. Thereby, equipping hospital decision makers to progressively reach the defined PACS structure" *(*Refer to section: Problem statement*)*.

The objectives were also adjusted to suit the new purpose and guide problem development more seamlessly *(*Refer to section: Research objectives*)*. The first two objectives remained as identifying the current PACS situation barriers, and defining a suited PACS technical and operational structure for the SA public healthcare environment. Objective 3 assessed the MM's appropriateness for the solution. This objective is now split into two objectives. Firstly, to define the requirements for implementation and optimisation guidelines that will equip hospital decision makers to progressively reach the defined structure (Objective 3). Secondly, to assess five common enterprise architecture models for suitability to the requirements defined (Objective 4).

3. Thesis methodology

Comment from the examiners:

The methodology lacks scientific support and structure.

Response:

Amended area: The Research methodology (p.6) and Document structure (p.7)

The Methodology was amended as follows.

The methodology was defined as a problem-oriented approach in an iterative process to finally reach a desired outcome. Literature regarding methodologies for system development and improvement process was considered and the methodology was elaborated upon, which adds Mouton's definition. Mouton (2001) defines the problem-oriented approach as problem focused continual research, used to iteratively build and evaluate intermediate solutions, in order to extend existing capability limitations until the desired model is reached. The final model is then verified against the defined design specifications established, and validated against the initial problem. *(*Refer to section: Research methodology*)*

The methodology was elaborated upon in section 1.3.2.1, addressing the document structure. The document structure explains the method used to attend to each of the objectives in the thesis and stipulates in what section these were attended to.

4. Maturity model justification

Comment from the examiners:

No other enterprise engineer models were considered. MM's were selected as the most suitable solution without supporting scientific literature.

Response:

Amended area: The two sections: chapter 'Develop guidelines for implementation and optimisation of PACS' (p.59) and the chapter 'Enterprise Architecture' (p.62)

In light of the new problem statement and purpose, the argument of the thesis changed. In the amended version the problem states that improvement guidelines are necessary for successful operation of PACS in SA public hospitals. Therefore the only of concern was to stipulate what the improvement guidelines should entail and to find a suitable model. Two objectives were adjusted to develop requirement for implementation and optimization guideline (objective 3), and to compare different improvement guideline structures (objective 4)

The two objectives were added in two separate chapters of the thesis:

Objective 3: Development guideline requirement (Chapter 6)
Objective 4: Enterprise architecture model comparison (Chapter 7)

Both sections are discussed in more detail below.

4.1 Implementation and optimization guideline requirements

This section defines the requirements for the PACS implementation and optimisation guidelines (Refer to Chapter 6: Develop guidelines for implementation and optimisation of PACS)

After the suited PACS technical and operational structure was developed. A gap analysis was done that focused on the management and deployment of PACS. The barriers to the implementation and optimisation of PACS were highlighted and the following was concluded:

PACS is no longer introduced into hospital enterprises solely to reduce the reliance on film-based radiology departments. The PACS system has become an integrated component of the healthcare delivery system. Consequently, the PACS healthcare delivery process consists of interrelated steps and influences various domains within the hospital. When implementing such an interrelated, comprehensive IT system in a critical environment, such as healthcare, it is important to align all the components of the system and manage the system change to reach to desired goal and minimise implementation errors. Key decision makers lack the expert knowledge necessary to make informed decisions to align all the process steps and domains for PACS.

In reengineering the enterprise, an approach to structure, manage and guide the system during IT implementation is called Enterprise Architecture (EA).

4.2 Enterprise architecture framework

This section compares enterprise architecture models for suitability to the guidelines developed. *(*Refer to chapter 7: Enterprise Architecture*)*

There are numerous definitions and approaches to EA as discussed below.

- 1994 IEEE conference on enabling technologies stated: EAs are methods to support information system development and enterprise reengineering.
- IEEE: Enterprise Architecture is a coherent whole of principles, methods and models that are used in the design and realization of an enterprise's organizational structure, business process, information system and infrastructure (Lankhorst, 2013)
- Harvard business school: The EA is an organizing logic for business process and IT infrastructure, reflecting the integration and standardization requirements of a company's operational model. The EA provides a long- term view of a company's process, system

and technologies so that individual's projects can build capabilities – not just fulfil immediate needs. (Ross, et al., 2006)

Enterprise reengineering is similar to a building process where an architect is required to layout the structure. However, enterprise architecture lays out the structure that guides the reengineering. Sources agree that EA used to focus on IT system integration but current IT systems cannot be viewed in isolation, it needs to be aligned with the whole enterprise strategy and capabilities. (Ross, et al., 2006)(Lankhorst, 2013). For the purpose of this thesis EA will be defined as the enterprise reengineering approach when implementing an IT system to structure, manage and guide the enterprise to reach its suitable state.

Enterprise Architecture provides a design and roadmap for managing business components with an IT system. The Enterprise Architecture Framework (EAF) is a framework that models the EA (The Third Workshop on Enablign techologies: Enterprise architecture: definition, content, and utility, 1994). Consequently, five common EAFs were considered to find the most suitable framework to assist the implementation and optimisation of PACS in the SA public healthcare environment.

The EAFs compared the separate frameworks against the previously defined requirements:

Criteria	ZEF	TOGAF	GF	FEA	MM
Descriptive completeness	4	2	1	2	4
Best practiced methods	1	4	2	3	3
Development guidelines	1	4	2	4	4
Applicable/ adaptable to healthcare environment	2	2	2	1	4
Applicable PACS process	1	2	1	1	4
Applicable to the public SA environment	1	2	1	1	1
Vendor neutrality	2	4	1	2	4
Governance offered	1	2	3	3	2
User friendliness	2	1	2	1	2
TOTAL	**17**	**23**	**16**	**18**	**26**

MMs were found to be the most suitable of the common EAF. Therefore, MMs are considered an appropriate vehicle to assist hospital decision makers through the PACS development phases, from implementation to the optimised structure, in the South African public healthcare environment.

5. Thesis validation and verification

Comment from the examiners:

The validation and verification was vague and these terms were not adequately distinguished from each other.

Response:

Amended area: The chapter Verification and validation (p.110)

A definition from scientific literature was given for validation and verification. These definitions were theoretically and practically applied to the thesis. (Refer to sections Validation and Verification)

5.1 Validation

Validation is described as the process of inspecting whether the developed solution is correct in order to address the defined problem (Verification and validation of simulation models, 2005). In this thesis the problem was defined as a lack of specifications, guidelines and best practice operational methods for the appropriate PACS technical structure in South African literature and in governmental strategies. Additionally, there are no guidelines for implementation or support for hospital decision makers to manage the system and enterprise change. In this thesis the technical and operational PACS structure and PACS MM is assessed to ascertain whether it solves the defined problem.

In this thesis validation was achieved by user acceptance tests and usability as well as goal analysis. The user acceptance and usability test was done by means of case study and focused group discussion to confirm whether the users found the model useful and appropriate. (Refer to sections 11.3.1, where the procedure is discussed, and 11.4.1 where the execution is discussed and, 11.4.1.2.1 & 11.4.1.4.1, where the two hospital's results are discussed) The goal analysis was done by presenting the PACS structure and PACS MM to three divers experts in the South African PACS healthcare environment to confirm whether they were of the opinion that the model would assist the implementation and optimization of PACS. (Refer to sections 11.3.2, where the procedure discussed, and 11.4.2, where the execution is discussed).

The experts were selected due to their divers experience and expertise in the field:

- Ms JB Fortuin, as a telemedicine and PACS specialist from the Medical Research Council of South Africa (until March 2013),
- Prof AF Doubell, as the Head of Cardiology for the Tygerberg hospital and the Medical Faculty of Stellenbosch University, and lastly,
- Mr B Lines, as the Information Technology manager for the public healthcare enterprises of the Eastern Cape province.

The experts were each given two key areas of the thesis to assess. The first was to assess whether the defined structure would serve as an appropriate technical and operational solution for the SA public healthcare environment to overcome the barriers defined. The second was to assess whether the PACS MM would serve as appropriate guidelines to implementation and optimisation PACS to reach the defined structure. Thereby, confirming that the solution obtained addresses the problem statement. (Refer to section 11.5.1 for the results of the validation).

5.2 Verification

Verification is described as the process of inspecting whether the solution was developed in a correct manner (Verification and validation of simulation models, 2005). In this thesis the PACS structure and PACS MM were inspected to ascertain whether they were developed correctly. This is considered in light of the design requirement and implementation.

In this thesis verification was achieved by requirement analysis and consistency checking for proof of correctness. Consistency checking was done by analysing the results obtained from the focus group discussions to ensure the model does plot the PACS system correctly and does suggests the appropriate improvement step (Refer to sections 11.3.1, where the procedure is discussed, and 11.4.1 where the execution is discussed and, 11.4.1.2.2, 11.4.1.4.2, where the two hospitals' results are discussed). Proof of correctness was achieved by inspecting the PACS structure and PACS MM against the defined design specifications established for the suitable structure and the management improvement guidelines (Refer to section 11.3.3, where the procedure is discussed and 0, where the execution is discussed). Thereby, proving that the model was correctly developed. (Refer to section 11.5.2 for the verification results)

6. Thesis conclusion

Comment from the examiners:

The conclusion doesn't seamlessly summaries the thesis argument and draw valid conclusions.

Response:

Amended area: The chapter Conclusion (p.110)

The conclusion was restructured to suit the newly defined problem statement and purpose and the results obtained in the verification and validation of the thesis. (Refer to chapter 7: Conclusion)

7. Language corrections

Comment from the examiners:

A list of spelling and grammatical errors was given. The language usage was inadequate and terminology was not used consistently.

Response:

Amended area: The whole thesis

The spelling and grammatical errors highlighted was corrected. Terminology used was reviewed. Lastly, the thesis was submitted for editing.