A Comparative Cost Analysis of Picture Archiving and Communications Systems (PACS) with Conventional Radiology in the Private Sector

Submitted to:

NELSON R. MANDELA SCHOOL OF MEDICINE

UNIVERSITY OF KWAZULU-NATAL DURBAN

SOUTH AFRICA

For:

Submission in partial fulfilment of the academic requirements for the degree:
Master of Public Health in the School of Family and Public Health Medicine

BY

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10 September 2012

As the candidate's supervisor I have approved this dissertation for submission.

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Name: Professor Indres Moodley

Date: September 10, 2012

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I, Sivani Moodley, declare that

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ii. ACKNOWLEDGEMENTS

I would like to thank everyone who has played a crucial part in assisting me with the completion of this dissertation.

My deepest gratitude goes to my supervisor, Prof Indres Moodley for his patience, guidance and motivation during the most trying times of my dissertation. I appreciated your advice and your willingness to assist me whenever was needed.

Thank you to all Lake, Smit and partners accounts and IT staff who had so graciously assisted me during my data collection. Thank you for taking the time out to assist.

I am deeply grateful to all participants of the study for their willingness and interest to participate in this study. Your input has been beneficial to this study.

Clive Katz, Thank you for your words of encouragement and support when I needed it the most. Your guidance throughout this dissertation has played an important role in the completion of my study.

I must acknowledge friends and family who so willingly assisted in giving advice and supported my research writing efforts. Your input has been so valuable to me.

To my loving parents and family, you have always been my support pillars during this journey. Every word of encouragement has always boosted me when my goal seemed so far away. Thank you for being there and believing in me.

To my husband, thank you for being so patient and understanding during this study. You helped me keep perspective on what is important in life and showed me how to deal with reality.

THIS DISSERTATION IS DEDICATED TO LAKSHANA and DERVINA MOODLIAR, my sweet daughters.

iii. TABLE OF CONTENTS

i. LIST OF TABLES

ii. LIST OF FIGURES

iii. ACRONYMS AND ABBREVIATIONS

ABC - Activity based costing is a method of allocating costs to products and services. It is generally used as a tool for planning and control. This is a necessary tool for doing value chain analysis.

CD – Compact Disc is a small, portable, round medium made of molded polymer for electronically recording, storing, and playing back audio, video, text, and other information in digital form.

CR – (Computed radiography) In this modality there is an extra sensitive plate within a cassette, which captures the X-rays. After being exposed the cassette can then be fed into a cassette reader, which extracts the X-ray image from the plate and erases the plate for re-use. This is a low cost solution.

CT – Pictures of structures within the body created by a computer that takes the data from multiple X-ray images and turns them into pictures on a screen. The CAT (computerized axial tomography) scan can reveal some soft-tissue and other structures that cannot even be seen in conventional X-rays.

DR – Digital radiography. In this modality there is no cassette, the patient is positioned against an X-ray sensitive panel and the X-ray image is captured directly. This is a high cost solution with the advantage of having better image quality

DICOM – Digital imaging and communication is a set of standards that allow systems to interface. Specifies how devices are built in conformance with the standards, react to commands and data being exchanged.

EMR – Electronic medical record is a computerised medical record created in an organisation to deliver care in a hospital. It is a health information system that allows for storage, retrieval and modification of records

HIS – Health information systems is a system used in hospitals to enter details of the patients and to link the patients data to a unique number which is then used to identify the patient throughout the hospital.

MRI – Magnetic resonance imaging uses magnetic signals to create image "slices" of the human body. Like all imaging techniques, an MRI scan creates images based on differences between types of tissues. MRI shows us the different tissues, and thus creates an image inside the body.

PACS – Picture archiving and communications systems is a computerized system used in radiology to transfer, archive, store and retrieve images.

NPV – Net present value is a time series of cash flows, both incoming and outgoing. It is defined as the sum of the present values (PVs) of the individual cash flows. In the case when all future cash flows are incoming (such as coupons and principal of a bond) and the only outflow of cash is the purchase price, the NPV is simply the PV of future cash flows minus the purchase price (which is its own PV). NPV is a central tool in discounted cash flow (DCF) analysis, and is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting.

Incremental cost analysis – Partial analysis of an incomplete product to allow early feedback on its development.

Micro costing – Used to establish cost estimates for the services provided. Included are data reflective of both costs and overheads. The analysis generates

information concerning the relative amount of labour used, projected annual volumes, costs for direct and indirect labour, overtime, direct and indirect supplies, allocated cost, and cost for each identified evaluation and/or treatment.

TELERADIOLOGY -radiology concerned with the transmission of digitized medical images (as X-rays, CAT scans, and sonograms) over electronic networks and with the interpretation of the transmitted images for diagnostic purposes

UPS – Universal Power supply

WORKLIST –A worklist is the structure to present information related to a particular set of tasks. One example is the worklist used to present information about scheduled imaging procedures at an imaging modality and to the operator of that modality. Another example is the worklist presented at a radiological reporting station to indicate which studies have been performed and are waiting to be reported.

iv. ABSTRACT

Radiology is rapidly changing in the 21st century and globally there is a transition of radiology departments to digital imaging technology. The major challenge confronting radiology practices is to obtain cost savings and productivity gains once PACS is established. The purpose of the study is to undertake an incremental cost analysis of PACS compared to a conventional radiology department. Cost savings of the system was also determined in terms of productivity gains.

An incremental cost analysis for Chest X-rays, CT Brain scans with and without contrast, MRI Brain scans with and without contrast was performed. The overall incremental cost between a PACS site and a conventional radiography site was determined in the study. The net present value technique was also determined to evaluate the capital budgeting requirements for both systems. The incremental costs for capital, RIS and image production for the PACS as well as the conventional system were performed. The incremental costs for both capital and RIS show an increase. In contrast, the incremental PACS image cost shows a reduction.

This study provides a number of South African Radiology Departments which plan to introduce PACS in the near future with a bench mark for the financial implications incurred during the implementation phase. It assists other facilities in deciding on implementing PACS and contributes to the development of methodologies within the South African context.

1. CHAPTER ONE - ORIENTATION

The outline of this dissertation is structured as follows:-

Chapter One gives an overview of the study with a brief outline of the relevant background. Also discussed within this chapter is the purpose and objectives of the study.

Chapter Two is a review of the previous literature, identifying the similarities and disparities within these studies. A summary of the different methodologies used in the literature is conducted in correlation to the objectives set out in the study.

Chapter Three describes how the incremental cost analysis was performed. Included in this chapter are the study design, data collection and data analysis.

Chapter Four presents the results obtained from this study in the form of tables and figures.

Chapter Five summarises the study with the discussion, conclusion and recommendations for further studies.

1.1 BACKGROUND

Previously, typical radiology departments used film-based management systems. The process for film based methods starts with the referring doctor requesting an X-ray (request form) which is handed over to the reception in the X-ray Department. The patient's details are entered into a computerized patient record system. The radiographer thereafter takes the request form and performs the necessary radiography procedures that have been requested. The radiographer processes and performs the quality assurance of the films before taking the request form and films to the radiologist for reporting. A report is compiled and linked to the radiographs. It is then given to the patient. However, if the patient is unable to wait he or she goes home, returning later to collect the results.
With the use of PACS and digital radiography the workflow in radiology is now changed. The patient's details are entered into to the radiographic information system (RIS). The information is transferred via Dicom (digital imaging and communications) to the digital equipment and computed radiography. The radiographer uses the electronic job card to obtain the patients information and history. Once the X-ray is performed it is sent to the archive where it is stored and distributed to the referring doctors. The radiologist only has access of these films once the radiographer completes the case. The case is reported on the system and the report is then sent to the archive and linked to the patient's unique identification. The referring doctor can thus access this report as well. The patient can obtain a CD of their procedure as soon as the X-rays are sent to the archive.

Picture archiving and communication system (PACS) installations in the United States and Europe have been flourishing from the 1980's. It was found that South Africa lagged behind Europe when it came to the number of PACS sites. However studies from the Netherlands CAPACITY program had shown that 13 countries had drawn conclusions that PACS was not able to provide a substantial financial return. It was however, expected that the future cost returns would be improved if the purchasing costs were decreased (Lemke, 2003).

In South Africa a few radiology departments had started using teleradiology in the 1990's. This was mostly used in the private sector. The move to PACS in the early

2000's is mainly due to the increase in costs of human resources as well as increasing productivity in the department. The introduction of PACS in the South African health sector was later than the United States and European countries however, over the last 5 years there has been a rapid increase in the implementation of full PACS sites in South Africa. One of the contributing factors to the increase could in fact be the recession throughout the world causing many private radiology practices to look for more cost-effective methods of running their practices. The public sector is still however far behind in introducing PACS functionality due to the lack of funding required in initiating PACS implementations in South Africa.

1.1.1 What is known so far?

Orand (2004) has developed a methodological framework to undertake a comparative cost analysis of PACS against conventional radiology and suggested that such an analysis will show that PACS reduces costs over a long period of time.

However, it was noted that an analysis of incremental costs of the PACS and computed radiography are only part of a cost effectiveness analysis which ideally should be undertaken provided all relevant data is available (Duerinchkx, et al., 2006).

In another analysis of the cost-effectiveness of PACS by Hilsenrath, et al. (1990) discussed how cost-effectiveness studies can assist in decision making when evaluating the viability of PACS. It was pointed out that guidelines for new technologies should be established in order to assist in the distribution of cost effective methods in radiology departments.

Reiner, et al. (2005) conducted a multi-institutional analysis of computed and direct radiography to determine the productivity levels and patient waiting time. This study did not include the use of the PACS system. The findings in this study suggest that the cost

effectiveness of the Digital equipment can only be achieved with usage of equipment of about 80%.

Various studies have been undertaken in the United States (Samuel, 1990, Schomer, et al., 2001, Hilsenrath, et al., 1990, Orand, 2004 and Reiner, et al., 2005) and one in Taipai (Fang, et al., 2006) to determine the cost effectiveness of digital radiography. South Africa has started to move in the direction of digital radiography and PACS; however, to date similar studies have not been undertaken in South Africa to research the principle cost effects of introducing such a system.

1.1.2 What needs to be known?

Within the South African context we need to know the incremental costs and benefits of PACS vs. conventional radiology as this will impact on the overall increase in healthcare costs.

In addition such a study will provide information on reduction in waiting times for patients.

1.1.3 What is the importance of this study?

It is important that decision makers have information regarding the financial impacts of a PACS system, to allow for appropriate planning of budgets for radiology departments within hospitals. An in-depth understanding of the issues of the cost of PACS can also assist in improving resource allocation in healthcare and its impact on overall costs in healthcare.

A number of South African Private Hospitals are in the process of introducing PACS or planning to introduce PACS in the near future. This study may contribute to the development of methodologies within the South African context that will assist other facilities in deciding on implementation of PACS.

1.1.4 How the study will solve the problem?

This study will focus on:

a.) An incremental cost analysis of conventional X-rays versus PACS

b.) An analysis of waiting time for patients

c.) An analysis of the speed of access of radiographs for referring doctors

1.2 STATEMENT OF THE PROBLEM

1.2.1 Research Hypothesis

U = There is no substantial differences in the cost of picture archiving and communication systems compared to conventional radiology systems.

1.2.2 Research Questions

- To determine the incremental cost of conventional printing of films against filmless system using computed tomography.
- To determine the incremental cost of conventional printing of films against filmless system in chest X-rays.
- To determine the incremental cost of conventional printing of films against filmless system in magnetic resonance imaging.
- To determine the time saving clinical benefit of this system

1.3 PURPOSE OF THE RESEARCH

The purpose of the study is to undertake a cost analysis of the PACS system compared to conventional radiography in a private radiology department

1.4SPECIFIC OBJECTIVES OF THE RESEARCH

- Describe current conventional radiography and the PACS system
- To determine the cost of conventional printing of films and the cost of the digital chest X-rays.
- To determine the cost of conventional printing of films and the cost of digital computed tomography.
- To determine the cost of conventional printing of films and the cost of digital magnetic resonance imaging.
- To determine the whether there is a reduction in patient waiting times by using PACS.

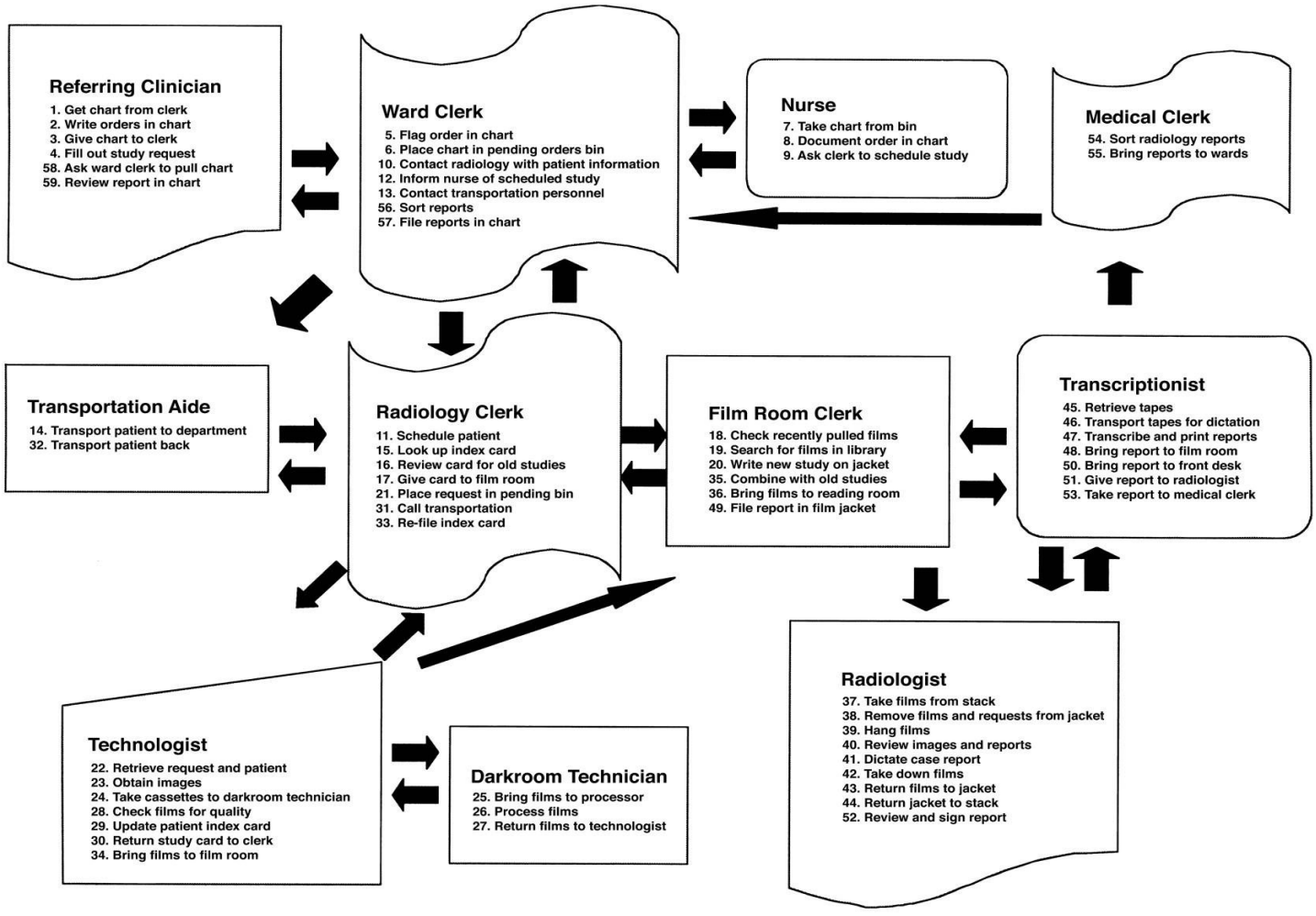
CHAPTER TWO - LITERATURE REVIEW

Chapter 2 discusses the PACS workflow in a radiology department. The theoretical and empirical literature is presented with respect to the objectives set in this study. A discussion of the previous literature is critically analysed. The strengths and weaknesses in the literature are identified.

2.1 Concepts

The conventional workflow in a PACS department is represented into a diagrammatic representation shown in Figure 1. This diagram was cited in the American Journal of Roentgenology by Siegel, E and Reiner, B (March 2002).

Figure 1 [1]displays a diagrammatic representation of workflow in a Conventional radiology department



[1] Work flow redesign-the key to success when using PACS cited in the American Journal of Roentgenology, March 2002, pg564

The steps for a conventional x-ray department to produce x-rays are as follows:-

Steps 1 – 10 – Shows the steps taken by the referring clinician, ward clerk and nurse to order the x-ray

Steps 11 – 14 – Booking patient and transporting patient to x-ray department if patient is from the ward

Steps 14- 32 – Involves the acquisition of the x-ray film by the radiographer and return of the patient

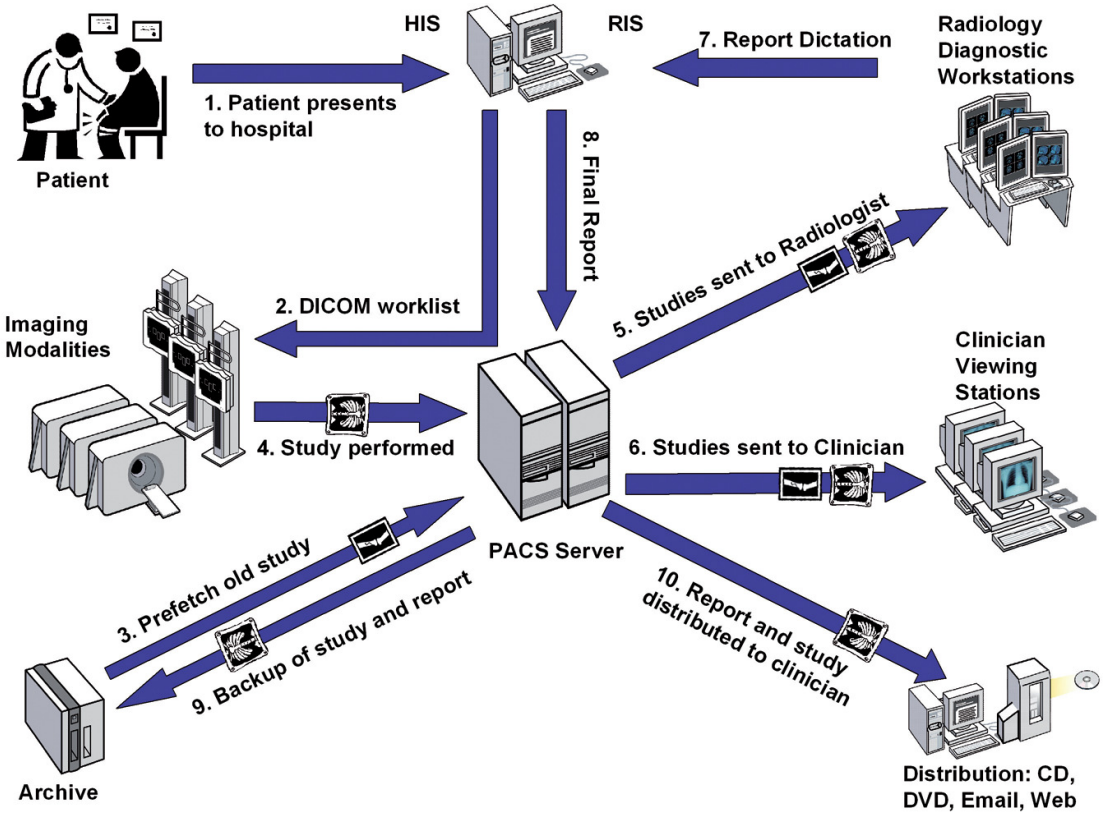
Steps 33 – 44 – Collating the x-rays and reporting the x-ray

Steps 45 – 55 – Transcribing report, verifying the report and sending to ward

Steps 56 – 59 – Filing report in ward and retrieving report for referring clinician

The workflow image in a PACS department is shown in Figure two. This was extracted from Schulze, et al. (2007) and published in the SA Journal of Radiology.

Figure 2 [2]Displays a diagrammatic representation of workflow in a PACS radiology department



The steps in image workflow of a PACS radiology department are as follows:-

Steps 1 – Patient enters the radiology department and the patients demographics are captured on the Radiology information system (RIS).

Step 2 – A Dicom worklist is generated and distributed to the PACS server and the image modality.

Step 3 – Previous studies are pre-fetched from the modality with the use of a unique patient id.

Step 4 – The patient is X-rayed and the images are sent to the PACS server.

Step 5 – The previous study and the current study is sent to the radiologist for reporting.

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[2] Talking PACS: Part 1-What is PACS? cited in the SA Journal of radiology, Sep 2007, pg50

Step 6 – At the same time the clinician/referring doctor has access to the images for viewing.

Step 7 – The exam is dictated and sent to the RIS.

Step 8 – The report is sent to the PACS server.

Step 9 – The current study and report is sent to the archive.

Step 10 – The report and images are distributed to the clinician/referring doctor.

2.2 LITERATURE REVIEWED

2.2.1 Introduction

With the growth of PACS, hospitals are beginning to move away from conventional radiography. Computers now allow for faster archiving, easy storage, quick transfer and easy viewing of medical images in a digital format. The HIS (Health Information system) allows for direct access to digital radiographs and patients medical records however, if such medical information systems are not available patient records can be electronically scanned and stored with digital radiographs. That is, the patient's images are linked to the radiological information system (RIS) and can be sent online to the radiologist. The radiologist therefore has immediate access to the images as well as any previous images to compile the report. Many radiology departments have a voice recognition system that transcribes the report onto the system, eliminating the need for manual entry. Once the report is done, it is sent via the web throughout the hospital or to the relevant referring doctors. The PACS process varies from practice to practice since PACS can be tailor made for each department(Dwyer and Jost, 1990).

2.2.2 Theoretical literature resources

An economic analysis consists of comparative costs and consequences of two competing alternatives. For such an analysis to be undertaken it is important to have all costs including direct and indirect costs credibly determined and compared with an outcome that is similar as in the case of a cost effective analysis.

There have been a number of studies evaluating the cost-benefit of PACS (Dwyer and Jost, 1990; Samuel, et al., 1990; Duerinchkx, et al., 2006). An early study (Dwyer, et al., 1990) compared the costs of four different PACS systems. This study showed that the speed of the digital communication network influenced the cost of PACS. It was found that a high speed network is less costly than low speed networks. However, all possible PACS cost savings were not taken into account (Dwyer and Jost, 1990).

Schuster, et al. (2003) suggested that PACS makes it possible to produce significant savings. However, the author cautions that in undertaking a cost effectiveness analyses consideration should be given to hiring of IT staff as well as monitoring the temporary productivity plateaus that occurs in the implementation. Since the cost of PACS is decreasing over time the cost/benefits equation will always be changing (Schuster, et al., 2003). Margulis and Sunshine (2000) believe that there is no easy manner to reduce cost of healthcare and it would be useful to train radiologists to conduct cost effectiveness and outcome studies that are well planned. Orand (2000) showed that with the introduction of PACS, the workflow will have to be redesigned and based on this, cost effectiveness studies should be undertaken.

Cost effectiveness studies undertaken by Samuel, et al.(1990) and Fang, et al.(2006) suggested that there is variability in the assumptions made by vendors with regard to personnel, supplies and other parameters. The vendor models seem to show that savings are achieved as a result of reduced usage of conventional films. However, this was not true for all sites. Whilst the reduced use of film results in savings, the overall cost

savings in radiologist and staff productivity is equivocal (Siegel and Reiner, 2002). It has been suggested that cost effectiveness should be performed together with the clinical impact of PACS(Hilsenrath, et al., 1990). These clinical effects should include diagnostic accuracy, more timely treatment and improved outcomes for patients to enable medical decision makers to make recommendations about the economic benefits of PACS. The importance of a sensitivity analyses to address uncertainty and to improve on understanding of how single variables affect viability was emphasized (Hilsenrath, et al., 1990).

2.2.3 Empirical studies

Various cost methods has been established in order to evaluate PACS and the costs incurred to implement the PACS system. Bryan, et al. (1995) discusses the two different aspects of evaluation and patient focused evaluation. The study uses key questions determined by PACS benefits to acquire evaluation questions. Randomised control trials were selected to compare hospitals with PACS and with conventional film technology. The author re-iterates that evaluation evidence for PACS is scarce although various hospitals have been undergoing evaluation at the time the article was written. The conclusion by the author advocates that all future PACS implementations should continue only if good evaluation evidence is obtained (Bryan, et al., 1995). A similar evaluation approach was used by Van Gennip, et al. (1996) however, a software package (PAGER) was used which reinforces the financial impact of PACS. Three clinical environments in Europe were taken into account. The researcher had considered the workflow changes and benefits as well as cost savings of film usage. It was assumed that if expected costs of film and personnel increases by 2% and PACS were assumed to decrease by 10% per year a breakeven point would be reached after 6 years (Van Gennip, et al., 1996).

Numerous cost models have also been created to evaluate the cost of PACS. Langer, et al. (1996) created a spreadsheet model accounting for differential costs of equipment and staff reductions only. The downfall of the model would be its relevance to the South African radiology practices since most of the PACS sites have Radiology information

systems (RIS) only and not Electronic Medical record systems (EMR). The researcher states that the break-even point for the cost of film and digital radiography is close to 50,000 cases per year. A similar study conducted by Reiner, et al. (2000) also created an economic model to draw conclusions for cost efficacy in radiology departments. This model was a more comprehensive and generalized costing, taking into account examination volume, lost billings, retake rates and archival cost disparate to Langer, et al. (1996). Both studies mention the need to evaluate the cost efficacy and justification for potential PACS customers.

Beard, et al., (1990) formed a static differential cost model which only included acquisition costs. This limited the cost model since no other variables such as radiologist productivity, radiologist salaries and time spent reporting were taken into account. The only variable that changed in this cost analysis was the network speeds, thus this model cannot be generalised to all radiology departments. However, a Pro-forma economic model was formulated in 2000 with the use of prospective data collected over a 6 year period in Balitomore VA Medical. The author makes a good point of saying that there are various variables to be considered when it comes to justifying PACS, however, to justify PACS the most important justification is cost efficacy. The variables important to take note of is the modality mix for the average number of films printed as well as the type of film used(laser film versus plain film), lost examinations, retake rates, duplication costs and delays related to film retrieval. The author recommends that as more data is obtained from filmless institutions it should be incorporated into the economic model in order to increase the generalisablity of the model (Reiner, et al., 2000).

Charvet-Protat and Thoral (1998) took a different approach to conducting an economic evaluation of PACS. The study methodology varied from the previous studies since a review of published literature was used to evaluate the financial impact of PACS. The researcher claims that the costs incurred by PACS far outweigh the savings of film, storage space and radiographic staff. The studies explored in the evaluation had only covered the cost aspect of PACS however, did not consider the efficacy of the system. The author criticises the methodologies used in previous studies since comparisons were

conducted but the sites were not similar in systems. On the whole it was found that PACS implementation is costly however, to conduct a full evaluation PACS must be amortized over a few years (Charvet-Protat and Thoral, 1998).

Terae, et al. (1998) compared costs of conventional radiography in 1988 with costs of PACS in 1992, showing remarkable reductions in film costs. Savings of $607 700 various other costs was cut over a 7 year period bringing the total savings of $ 607 700 however, in a later publication from the department of Radiology of Siena University it was stated that the advantage of PACS was not the reduction in films and chemicals but rather the digital equipment which caused the offset of increased costs (Terae, et al., 1998, Stefani, et al., 2001). A cost analysis conducted in 1998 in Turku University Central Hospital only took direct costs into account. It was suggested that to gain the full benefit of an economic analysis the clinical impact and overall impact should be included. The results derived showed a 50% reduction in film usage and processing chemicals as well as cuts in darkroom staff however, this study applies to a semi-PACS site (Maas, et al., 2001).

Cost analysis studies have been performed with various methodologies throughout the world. A study performed in 1997 to 2002 in Taipai, in a government run hospital used a differential cost analysis between film-based radiology and a hospital wide picture archiving and communication system implemented all at once. Cost savings were seen with a PACS implementation all at once. The incremental cost analysis did not consider the human resources aspect of the radiology department (Reception and radiology) as well as the overhead costs incurred. It was seen that the reduction of a full time employee aided in increasing the actual cost savings incurred by PACS. The assumption that CR and conventional cassettes are replaced at the same rate and the same price is misleading since CR cassettes are more expensive than conventional cassettes (Fang, et al., 2006).

Unit cost analysis for filmless ultrasound was conducted by Chan, et al. (1998) in Baltimore. Break even points was used to demonstrate the cost effectiveness of the study. The results showed film based operations compared to filmless operation was more expensive. The study is limiting in that it only assesses one modality. A Boston study took a different approach were the costing of a department-wide implementation of PACS was compared to a projected budget of the project. The results for the first year showed a cost savings, followed by over expenditures for 3 years, thereafter a plateau was reached. The limitations in this study were the inaccurate budget estimates and the multi site complications were not taken into account for the budget adjustments. The study showed a savings on supplies and salaries. The author concludes that planning, budgeting and variance analysis are crucial to managing the costing of complicated PACS projects (Chan, et al., 1998, Reddy, et al., 2006).

A technical costing of General diagnostic radiography, ultrasonography(US), Computed tomography(CT), Magnetic resonance imaging(MRI), Scintigraphic examinations and interventional radiology was conducted in a tertiary institution to determine the most cost efficient modality. The authors divided the costs into labour and non-labour costs however the downfall of this study was that the overhead costs were not taken into account. The aim of the study was to create a benchmark in order to decide the best possible modality with the lowest cost or highest productivity. The study has not taken into account that different procedures vary in cost and average costs will not give a true reflection. In a cost analysis study by Beard, et al. (1990) a static differential cost model was designed to take into account non-differential costs, film differential costs and PACS differential costs. The study does not take into account radiologist productivity, radiologist salaries and time. However, the model for PACS and film was created when the both systems were fully functional and working and not when it was in transition phase from film to PACS (Beard, et al., 1990, Saini, et al., 2000).

2.2.4 Recent studies

Duerinckx, et al. (2006) analyzed the incremental costs of PACS and computed radiography (CR). An evaluation was undertaken to assess factors that affect cost analysis for PACS. Certain areas of the PACS implementation and purchase were targeted in order to show a zero cost after 9 to 10 years of semi-filmless operation. However, it was concluded that the benefit of PACS technology cannot be accounted for by such cost models (Duerinchkx, et al., 2006). An activity based costing was used to evaluate the PACS system compared to the conventional film process and showed that the PACS system was more cost-effective (Schomer, et al., 2001).

Fang, et al. (2006) performed a financial assessment of a completely installed PACS system as opposed to a step wise installation. The purpose was to obtain the differential cost between film based radiology department and a hospital PACS implemented all at once. The author compared the costs of PACS and the annual cost of film, chemicals used for film processing, film jacket, and film library clerk. The payback period was defined as the period when the cost of conventional radiology was more than the cost of PACS, including costs of maintenance. The deduction made by the author is that a hospital wide PACS implemented all at once will prove to be cost saving(Fang, et al., 2006).

Mweli, T. (2010) conducted an exploratory business case for (RIS) in a South African setting. The study shows the pertinent need for financial assessments of Information technology (IT) in Radiology departments. Gaps in the information technology financial evaluations are apparent, due to conflicting results for cost savings and expenditures. Suggestions are made to evaluate before and after information technology initial investments. This cost-benefit analysis is recommended for “ex ante” and “ex post” financial costs in radiology departments in South Africa (Mweli, 2010).

Various studies have been undertaken in the United States (Samuel, et al., 1990, Schomer, et al., 2001, Hilsenrath, et al., 1990, Orand, 2004 and Reiner, et al., 2005) and one in Taipai (Fang, et al., 2006) to determine the cost effectiveness of digital

radiography. South Africa has started to move in the direction of digital radiography and PACS. However, to date similar studies have not been undertaken in South Africa to research the principle cost effects of introducing PACS.

CHAPTER THREE - METHODS

This Chapter discusses the study population, data sampling, data collection and data analysis. The data collection tools and data collection management is also included. The data analysis discusses how the costs were derived for the study.

3.1 STUDY DESIGN

This study is a prospective cross-sectional study which uses both descriptive and analytical methods.

3.2 STUDY LOCATION

This study was conducted in St Augustine's Hospital located in the Southern, Eastern suburbs and Westville Hospital located in the Western suburbs of Durban in Kwa-Zulu Natal of the Republic of South Africa.

3.3 STUDY POPULATION

Included in this study over its duration were the following:-

- All walk in patients requiring any of the following: - Chest X-rays, CT Brain scans and MRI Brain scans at both St Augustine's and Westville hospital.
- All radiographers, radiologists, receptionist, PACS administrator and darkroom assistants working in St Augustine's and Westville hospital.

3.4TARGET POPULATION

The target population used for the purposes of analysing the time benefits comprises of:

Patients: All patients attending the X-ray department in St. Augustine's and Westville hospital for the period under study.

Radiographers: All radiographers working in the X-ray department in St. Augustine's and Westville hospital for the period under study.

3.4.1 Selection of study population

The study population was selected by the following criteria:-

- All walk in patients for Chest X-rays, MRI Brain scans and CT Brain scans for both St Augustine's and Westville hospital from the 1st August 2009 to the 31st August 2009.

3.5 SAMPLING STRATEGY

Consecutive samples will be taken within a one month period.

3.6 DATA SOURCES

The questionnaires will be self administered by all radiographers who work in the PACS practice.

Primary data sources

- X-ray department -The costs for the equipment will be obtained from the appropriate vendors
- All radiographers- working in St Augustine's and Westville X-ray departments.
- Patients in St Augustine's and Westville- will need to fill in time sheets.
- Picture archiving and communication system (PACS) in the hospital.

3.7 DATA COLLECTION

Before beginning the data collection the Radiology practice and both the hospitals had given approval to conduct the study (APPENDICES M, N, and O).Thereafter the data collection was carried over 4 weeks in August. The data for the costing analysis was obtained by drawing up data collection sheets which was submitted to the Practice. The practice thereafter submitted the costing used for the time period of August 2009.

The questionnaires that were used for the radiographers were piloted on 10 people to ensure there was no ambiguity with the questions before it was administered. Thereafter the piloted questionnaire was given to all radiographers who work in both Westville and

St. Augustine's hospital. This questionnaire was self administered. The radiographers were required to read an information sheet as well as sign consent to participate in the study.

Patients waiting time sheets were self administered by all walk in Chest, CT Brain and MRI Brain patients. The patients were also given an information sheet (APPENDIX K) that explained their role in the study and what the study entailed. The patients were requested to sign the consent to participate in the study (APPENDIX J).

The procedures chosen for this data collection were Chest X-rays, CT Brain scans and MRI Brain scans. Mobile patients who presented to the X-ray departments were chosen for the study. The data obtained from the time sheets was correlated with the data from the PACS system in order to verify times for the different studies. The data was extracted using a stats program as well as running scripts of the SQL server.

3.7.1 Data collection instruments

Qualitative Data

The self administered questionnaires that were given to the radiographers. This provided the necessary information for the PACS system and any limitations that may exist.

Quantitative Data

Patient time sheets assisted in providing waiting times from the entry of the patient to the department, the time the X-ray was performed till the time the report was given to the patient.

The St Augustine's PACS system and the Westville database provided examination times and the report times. This was verified by the patient time sheets.

Data collection forms for the costing were given to the Accounts Department of the Practice for both Westville and St Augustine's Hospital. The radiology costs requested was as follows: - personnel, equipment, consumable, utility and maintenance costs.

3.7.2 Data collection management

Qualitative Data

The questionnaires was designed by the researcher and given individually to each radiographer to complete (APPENDIX H)

The questionnaire obtained the following information: -

- Work experience
- Actual X-ray times with PACS and conventional methods
- PACS problems experienced
- Suggestions for future PACS sites.

From the answers of the questionnaire feedback was captured on Microsoft Excel 2007.

Quantitative Data

The time sheets were designed around monitoring the times the patient entered the department till the time the report was distributed to the patient. Times were extracted from St Augustine's database and Westville database by the Medical Software Company. These times verified the quality of the data obtained with the patient's average times. All data was then captured on Microsoft Excel 2007(APPENDIX I)

The costing data was entered onto summary sheets created by the researcher. The data was entered onto Microsoft Excel

3.7.3 Data analysis

3.7.3.1 Cost calculation

All data obtained was entered into Excel sheets for analysis.

INPUT

PERSONNEL- The costs per minute for radiographic staff, medical receptionists, darkroom staff, PACS administrators and related medical staff were calculated by taking the total annual salary and dividing it by 365 days. The x-ray department is open 24 hours a day and there is always a radiographer working throughout the year, thus 365 days was used. The salary for a day was brought down to an hour by dividing it by the radiographers working hours. Thereafter that cost was divided by 60 minutes to obtain the costs per minute. The salaries given from the practice was cost to company thus including other benefits such as medical aid and provident fund. The cost for labour will be calculated as a cost per minute. A weighted staff distribution was performed. The average time a radiographer, radiologist, medical receptionists, darkroom staff and PACS administrator will spend at the different modalities performing a procedure was accounted for. The staff weighting in each department was obtained from the head of departments at both sites. The radiologist costs were obtained by determining the total minutes of interpretation and reporting of Chest X-rays, CT Brain scans and MRI Brain scans. A telephonic interview was performed to obtain this information from radiologists. The medical receptionist's average times to capture a patient was also noted and the total time the patient was in the department was taken for the weighting of the PACS administrator since he needs to be available at any stage of the workflow.

CONSUMABLES AND MATERIALS – The practice provided unit costs for most of the consumables. The cost for a single image was obtained by dividing the unit cost by the total number of patients examined in a month. In the case of Developer, Fixer and printer ink the amount used in a month was given and a similar calculation was performed.

UTILITIES, MAINTENANCE AND SERVICES

-Maintenance of X-ray equipment was given for the year 2008 since 2009 was not available. There are no scheduled services. The practice decides when they require services to be performed or when there are any queries on the system.

-The water bill is included in the rent for both sites. Westville pays a single amount for rent, electricity and water whereas the electricity for the San is a separate monthly amount. For purposes of this study the San rent and electricity was added to make the both sites comparable.

-Maintenance of the building is included in the monthly rent for both sites.

-Maintenance of the PACS system comes with a set price for all the practice sites thus it is divided between the total number of sites the practice has, to obtain the maintenance for only one particular site.

-Cleaning services and security is included in the rental payments.

X-RAY PROCEDURES

-The total number of waiting Chest, CT Brain and MRI Brain patients was extracted from the RIS server at both sites.

-The monthly expense of each examination was calculated by multiplying the monthly volume of patients by the unit cost of the examination.

-The monthly income for each examination was calculated by multiplying the cost for a single X-ray or Scan to the monthly volume of patients seen in the department.

CAPITAL COSTS

BUILDINGS

The building cost is included in the rental expenditure.

EQUIPMENT

The equipment and furniture was calculated using the replacement values as well as the life span. For computers and furniture the average life span is 3 to 5 years depending on its usage. The X-ray equipment life span is +- 10 years according to the practice however in the Net Present value of this study the South African Revenue service's depreciation allowance was used i.e. 5 years. The software depreciation allowance was 2 years and mainframe computers were 5 years.

TOTAL COST

A costing for each procedure will be done to deduce the image cost for PACS and conventional radiography. The total cost will be the sum of the overhead costs, operating costs and capital costs.

3.7.3.2 Net present value

Net present value (NPV) is used in businesses to analyse future values and capital budgeting. It is a financial tool which includes three factors of any financial project. NPV takes into account cash flows, discount rates and the lifetime of the project.

The mathematical formula is as follows:

$$NPV = \sum_{t=0}^{N} \frac{CF\,t}{(1+r)^t}$$

Where,

NPV = Net Present Value

CF_t = the cash flow in period t

r = the discount rate

n = the number of periods

The positive NPV indicates that the project is profitable. A negative NPV value shows that the project will decrease the practices profits. A NPV which is equal to 0 shows there is no economic difference between the two systems.

The income after tax was calculated by taking the Gross Income and subtracting the wear and tear for the Capital and Software. The net income was then multiplied by 28 % to derive the income after tax.

The productivity gains were added from the PACS NPV values to show the NPV with the total cost savings for Chest X-rays, CT Brain scans and MRI Brain scans.

3.7.4 Assumptions made in this study

- Radiology equipment vendors were approached for costing information. Obtaining prices was difficult since the vendors did not want to divulge their sales prices and discounts to outside parties. The final pricing obtained is from internet sites that showed online prices. These prices were in US Dollars at the current exchange rate. It should be noted that the true costs were used in this study and not estimates. This would provide the most accurate findings.

- This study considered 3 out of at least 3500 procedures that are conducted monthly in a practice. Of the many procedures e.g. Pelvis X-rays, MRI chest scans, Angiograms etc. this study focused on Chest X-rays, CT Brain scans and MRI brain scans. The selection of the studies was based on the volume of examinations performed in the X-ray department as well as the varying price ranges of X-rays in radiology departments. In general Chest X-rays are not as expensive as compared to CT brain scans and MRI brain scans.

- The study was conducted in a private practice and thus if it were to be adapted to a public sector careful consideration should be made to the work processes used in each radiology department. These workflow processes determines the costs for performing a procedure and examination in radiology. The study data can thus be generalized to other radiology departments as well. The costing amounts for the different variables will differ due to varying rates, for overhead, human resources, equipment and software contracts as well as organizational structures.

- A 5 year time horizon was used.

- A discount rate of 4.1% was used as per the current Consumer price index

- The interest rate on the cost of the examinations as well as the income was 4.1%.

- All equipment from the X-ray to Servers was purchased and included in the implementation costs.

- All computer hardware was to last for 5 years.

- The depreciation rate for the Capital was over 5 years whereas the RIS software was over 2 years as per SARS wear and tear or depreciation allowance (South African Revenue services, 2010).

- The present values was calculated using the current repo rate which was 5.5% added to this is 2% which the bank will add when loaning money thus totalling to 7.5% which was rounded to the next whole 8%.

- The upgrade costs for software PACS was included in the maintenance costs.

3.8 VARIABLES

3.8.1 List of Variables

- Experience of the radiographer
- Technique by the radiographer
- Protocols in performing x-rays at the x-ray departments
- Mobility of the patient
- Patients age
- The speed of the X-ray, CT and MRI equipment
- Variations in costing from suppliers for consumables
- Variations in salaries for different hospitals

3.8.2 Reliability and Validity of Data Source

- The questionnaire and time sheet was piloted. The questionnaires were given to 10 radiographers to fill out and to check for ambiguity and user friendliness. The time sheets were administered to five patients to check for ambiguity and user friendliness.
- Costs were obtained from suppliers and verified with the practice
- The data used to obtain the number of Chests, CT Brain scans and MRI Brain scans performed will be checked for completeness by a 2nd person.
- The data from the time sheets will be checked against the archive data to ensure reliability and accuracy.

3.9 BIAS AND LIMITATIONS

- Radiographers – Some aspects within the questionnaire did depend on recall from memory and could have resulted in errors due to recall bias.
- The fluctuation in the dollar rand value and exchange rates would affect price of licences and equipment at the time the study was performed.

- The prices obtained from the vendors may not be the actual prices paid by the practice due to discounts given by the vendor. Prices from 2 different vendors will be taken into account to allow for accuracy and reliability.
- Two different speeds of CT scanners were used thus the times taken to do the CT would not be an accurate reflection for both sites.
- Variations in times of procedures would exist due to the different site layouts and radiographers demographics (age and experience with the system). The standard operating procedures were common since it is the same radiology practice running both sites.

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3.10 ETHICS

The ethical approval was obtained from the Biomedical Research Ethics Committee of the Nelson R Mandela School of Medicine South Africa (Reference number EXP003/06) (see Appendix Q).

CHAPTER FOUR - RESULTS

Chapter 4 presents the results in tabular format as well as graphical representations.

4.1 INTRODUCTION

The results are presented as follows:-

a) Capital costs for PACS and conventional radiography.

b) The radiology information system cost for PACS and conventional radiography

c) The costs for imaging using the PACS and conventional radiography

d) Incremental cost for the PACS system

e) Net present value

These comparative costs were determined for the following procedures:-

1) Chest X-rays
2) CT Brain scans
3) MRI Brain scans

The report waiting times for the above studies is also presented. The end user views is summarised at the end of this chapter.

4.2 PRESENTATION OF DATA

All data presented in the study was obtained for the month of August 2009 for both St Augustine's Hospital (SAN) and Westville Hospital.

4.2.1. Capital cost for PACS and conventional radiography

The capital costs for PACS and conventional X-ray equipment is shown in APPENDIX G. These costs show the replacement values of the equipment for PACS and conventional radiography.

The capital costs for PACS includes PACS software, computers, X-ray equipment, CT scanner, MRI scanner, wide monitors, 17 inch monitor screens, CR cassettes, CD Printer, UPS, single slot reader, operator consoles and training costs.

With PACS chest X-rays, the capital costs for the following were determined: - computed radiography equipment and the X-ray unit, PACS software, RIS consoles, Server hardware, Radiographer workstation and computed radiography processors, CD publisher, training and quality control scanner. The equipment costs for conventional radiographs were determined for X-ray cassettes, X-ray equipment, CT scanner, MRI scanner, processors and viewing box. These costs was obtained from Lake, Smit and partners, IT department and determined using current replacement values

Table 1 The overall costs for chest X-rays, CT Brain scans and MRI Brain scans using the PACS system and conventional radiography systems

SUMMARY- CAPITAL COST		
PROCEDURES	**PACS**	**CONVENTIONAL RADIOGRAPHY**
CHEST XRAYS	R 2,953,010.17	R 1,080,876.00
CT BRAIN SCANS	R 6,739,310.17	R 5,204,176.00
MRI BRAIN SCANS	R 10,739,310.17	R 9,084,176.00

Table 1 shows a summary of the capital cost of PACS and conventional radiographs for Chest X-rays, CT Brain scans and MRI Brain scans derived from Appendix G. The important aspect noted in this summary table is that the implementation of PACS has a greater capital cost for all three procedures compared to conventional radiography systems.

4.2.2. Radiology information system cost for PACS and conventional Radiography

The RIS cost was calculated as follows:-

- RIS software costs,
- Human resources required for running the RIS,
- Furniture and equipment.
- The consumable cost for producing jobcards and labels

The detailed costing is shown in APPENDIX F. A single unit cost was calculated for the consumable costs. The human resource costing used the time spent performing the procedure and the salary of the radiographer. The Viking RIS cost includes the anti-virus costs, license costs, dicom costs, switch costs and backup costs.

Table 2 The overall RIS cost for PACS and conventional radiographs

SUMMARY-RIS COST	
PACS	CONVENTIONAL RADIOGRAPHY
R164, 496	R 144, 662

Table 2 shows the overall summary of the total RIS cost for both PACS and conventional radiography. The RIS cost for PACS is greater compared to conventional radiography.

4.2.3. Imaging cost for PACS and conventional radiography

The same RIS was used for PACS and conventional X-rays. The cost of producing images for PACS and conventional radiography included human resources, consumable costs and overhead costs (APPENDIX D). The overhead costs were estimated by dividing the overhead costs by the number of patients seen in the month.

Table 3 The overall image cost per procedure for chest X-rays, CT Brain Scans and MRI Brain Scans for PACS and conventional radiographs.

SUMMARY - IMAGE COST					
	CXR	CT	MRI	CT CONTRAST	MRI CONTRAST
PACS	R 61.44	R 191.55	R 371.92	R 201.77	R 386.79
CONVENTIONAL RADIOGRAPHY	R 84.59	R 205.04	R 433.36	R 237.73	R 498.46

Shown in Table 3 is the cost for producing images for Chest X-rays, CT Brain scans with and without contrast and MRI Brain scans with and without contrast derived from Appendix E. Table 3 and Figure 3 below shows that with the implementation of PACS there is a decrease in image costs of PACS compared to conventional radiography.

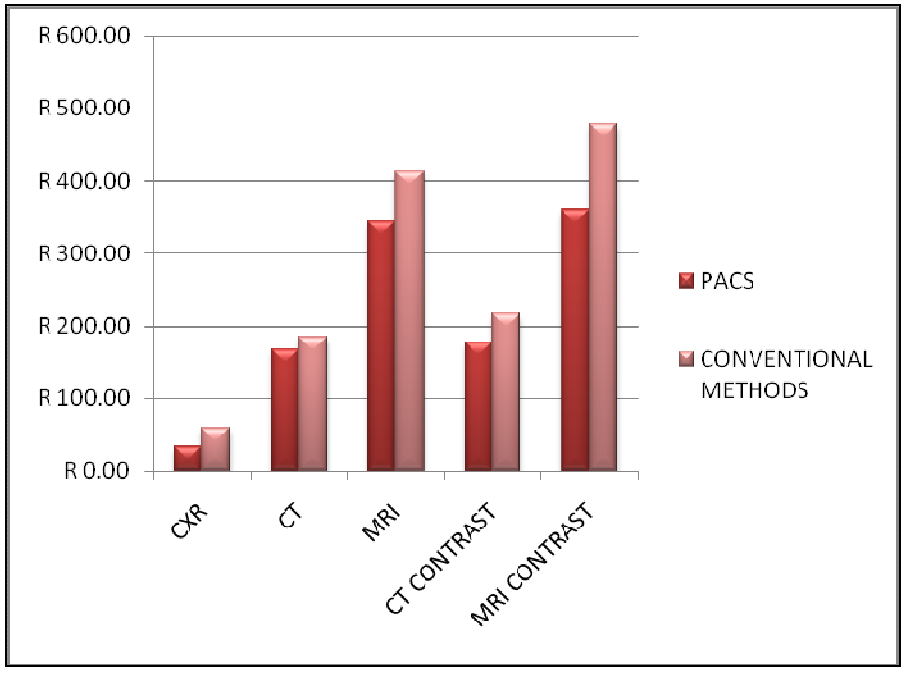

Figure 3 Comparative costs per procedure for PACS and conventional radiographs

4.2.4. Cost for procedures using PACS

The costs per month for PACS were determined for chest X-rays, CT Brain scans and MRI Brain scans. The resources required to determine the cost per month of PACS is shown in APPENDIX A (Chest X-rays), APPENDIX B (CT Brain scans), APPENDIX C (MRI Brain scans). The costs consisted of the following components: - human resources, operating costs, consumable, overhead costs and equipment cost which are summarised in Table 4, 5 and 6.

The weighted cost for the different grades of radiographers (head of department, chief radiographer, senior radiographer, junior radiographer and student radiographer) and a radiologist were included in the study. The salaries for the different grades of radiographers were weighted according to the amount time spent on each procedure (Personnel communication from head of departments at St Augustine's and Westville head of departments, Greogary, L., 2011, Naidoo, V., 2011). The radiologist costs were weighted using an average time taken to report a Chest X-ray, CT Brain scan and MRI Brain Scan. A cost was also included for the PACS administrator. Consumables were aggregated for each procedure (e.g. 4 sheets of film were used to print CT's in conventional methods). An average cost per month was obtained for the operating and overhead costs. The operating costs were determined using the area used for each procedure and the cost for one square meter. The capital costs for PACS and conventional X-rays were determined using the current replacement values. The equipment costs were aggregated over a 12 month period and the financing charges were included in the total (Personnel communication from head of departments at St Augustine's and Westville head of departments, Greogary, L., 2011, Naidoo, V., 2011).

Table 4 The overall cost per month for chest X-rays using the PACS system (St Augustines Hospital)

Summary for cost per month Chest X-rays	
Costs	Cost per month (PACS)
Human resources	R 75,578
Overhead costs	R 115,027
Consumables	R 2,491
Operating costs	R 24,973
Equipment costs	R 412,824
Total	**R 630,893**

Table 4 shows the summary of the cost per month for X-rays taken using the PACS system. The total monthly cost was **R 630 893.00.**

Table 5 The overall cost per month for CT Brain Scans using the PACS system (St Augustines Hospital)

Summary for cost per month CT Brain scans	
Costs	Cost per month (PACS)
Human resources	R 72,794
Overhead costs	R 112,170
Consumables	R 280
Operating costs	R 21,253
Equipment costs	R 1,361,723
Total	**R 1,568,220**

Table 5 shows the cost per month for CT Brain scans using the PACS system. The total monthly cost was **R 1,568,221.00.**

Table 6 The overall cost per month for MRI Brain Scans using the PACS system (St Augustine's Hospital)

Summary for cost per month MRI Brain scans	
Costs	Cost per month (PACS)
Human resources	R 56,308
Overhead costs	R 111,147
Consumables	R 681
Operating costs	R 21,229
Equipment costs	R 1,973,643
Total	**R 2,163,008**

Table 6 shows the cost per month for MRI Brain scans taken using the PACS system. The total monthly cost was **R 2,163,008.00.**

Table 7 Summary of the overall cost for the procedures using the PACS system

PACS COSTING		
PROCEDURES	**NUMBER**	**COST PER MONTH**
Chest X-rays	270	**R 630,894.39**
CT Brain scans	23	**R 1,568,221.53**
MRI Brain scans	56	**R 2,163,008.00**

Table 7 shows the overall summary of the total cost per month for Chest X-rays, CT Brain scans and MRI Brain scans with the use of PACS. Included in this table is the number of patients that was seen at the radiology department for a single month.

4.2.5 Cost for procedures using conventional radiography

The cost per month for conventional radiography was determined for chest X-rays, CT Brain scans and MRI Brain scans. The resources used for costing of conventional X-rays is included APPENDIX A (Chest X-rays), APPENDIX B (CT Brain Scans) and APPENDIX C (MRI Brain scans). The components used, to derive the costing for conventional radiography is similar to the costing components for PACS.

These costing components are human resources, overhead, operating, consumable and equipment costs.

Table 8 The overall cost per month for Chest X-rays using the conventional radiography system (Westville Hospital)

Summary for cost per month Chest X-rays	
Costs	Cost per month (Conventional)
Human resources	R 58,366
Overhead costs	R 41,081
Consumables	R 9,508
Operating costs	R 25,229
Equipment costs	R 71,464
Total	**R 205,648**

The table 8 shows the summary of the cost per month of conventional radiography for Chest X-rays. The total cost per month for Chest X-rays is **R205 648.00.**

Table 9 The overall cost per month for CT Brain Scans using the conventional radiography system (Westville Hospital)

Summary for cost per month CT Brain scans	
Costs	Cost per month (Conventional)
Human resources	R 65,307
Overhead costs	R 46,355
Consumables	R 660
Operating costs	R 18,098
Equipment costs	R 414,133
Total	**R 544,553**

The tables 9 shows the summary of the cost per month of conventional radiography for CT Brain scans. The total cost per month for CT Brain Scans is **R544 533.00.**

Table 10 The overall cost per month for MRI Brain Scans using the conventional radiography system (Westville Hospital)

Summary for cost per month MRI Brain scans	
Costs	Cost per month (Conventional)
Human resources	R 44,949
Overhead costs	R 41,081
Consumables	R 762
Operating costs	R 17,938
Equipment costs	R 787,637
Total	**R 892,368**

The table 10 shows the summary of the cost per month of conventional radiography for MRI Brain scans. The total cost per month for MRI Brain scans is **R892 368.00.**

Table 11 Summary of the overall cost for the Chest X-rays, CT Brains scans and MRI Brain scans using conventional radiography.

CONVENTIONAL COSTING		
PROCEDURES	NUMBER	COST
Chest X-rays	278	**R 205,650.66**
CT Brain scans	20	**R 544,554.36**
MRI Brain scans	23	**R 892,368.00**

Table 11 shows a summary of the overall cost per month and number of patients examined in a month. This was calculated for chest X-rays, CT Brain scans and MRI Brain scans for conventional radiography.

4.3 INCREMENTAL COST

The incremental cost for PACS radiography was determined for the following

- Incremental capital cost
- Incremental RIS cost
- Incremental imaging cost

4.3.1. The incremental capital cost for PACS and conventional radiographs

The incremental capital cost for PACS and conventional radiography was calculated for chest X-rays, CT Brain Scans and MRI Brains scans. The capital cost used for the incremental capital costs for PACS and conventional radiography are shown in APPENDIX G. In order to calculate the incremental capital cost the following data was used: - PACS software, equipment, training and network costs.

Table 12 shows the summary of the incremental capital cost for PACS and conventional radiography.

Table 12 Summary of incremental capital cost for chest X-rays, CT Brain scans and MRI Brain scans

INCREMENTAL COST-CAPITAL			
PROCEDURES	**PACS COST**	**CONVENTIONAL COST**	**INCREMENTAL COST**
Chest X-rays	R 2,953,010.17	R 1,080,876.00	R 1,872,134.17
CT Brain scans	R 6,739,310.17	R 5,204,176.00	R 1,535,134.17
MRI Brain scans	R 10,739,310.17	R 9,204,176.00	R 1,535,134.17

From the results in Table 12 it can be seen that incremental capital costs for PACS requires a major capital outlay compared to conventional radiography costs. A similar incremental capital cost is noted for CT Brain scans and MRI Brain scans due to the fact

that CT and MRI equipment costs is the same for PACS and conventional radiography. Refer to APPENDIX G.

4.3.2 . The incremental cost of the Radiology information system for PACS and conventional radiographs

The incremental RIS cost was determined for PACS and conventional radiography. The RIS incremental cost includes the RIS software, furniture, equipment, human resources and consumable costs for both systems. The data for the incremental cost of RIS is in APPENDIX F. The incremental RIS costs shows that there is an increase in PACS cost of about **R 19 833.74.**

Table 13 shows the total incremental RIS cost for PACS and conventional radiographs.

Table 13 Summary of the incremental cost of RIS for PACS and conventional radiographs

INCREMENTAL RIS COST		
PACS	CONVENTIONAL XRAYS	INCREMENTAL COSTS
R 164,496.10	R 144,662.36	R 19 833.74

The incremental RIS costs for PACS as seen in Table 13 is greater than conventional radiography by **R19 833.74.**

4.3.3. The incremental cost of imaging for PACS and conventional radiographs

The incremental imaging cost for chest X-rays, CT Brain scans with and without contrast and MRI Brain scans with and without contrast was compared to conventional methods. The results show that conventional methods have an extra cost factor. This is displayed in Table 14. Medical consumable costs were not included in the study. The data used for the incremental cost of imaging for PACS and conventional radiographs is in APPENDIX D.

Table 14 displays the overall incremental imaging costs for PACS and conventional X-rays for Chest X-rays, CT brains with and without contrast, MRI brains with and without contrast.

Table 14 Summary of the incremental imaging cost for PACS and conventional X-rays.

INCREMENTAL IMAGING COST			
PROCEDURE	PACS	CONVENTIONAL	INCREMENTAL COST
CHEST X-RAYS	R 61.44	R 84.56	-R 23.12
CT BRAIN	R 192.85	R 205.01	-R 12.16
CT BRAIN WITH CONTRAST	R 201.77	R 237.70	-R 35.93
MRI BRAIN	R 371.92	R 433.33	-R 61.41
MRI BRAIN WITH CONTRAST	R 386.79	R 498.43	-R 111.64

From the results shown in Table 14 there was decrease in imaging cost for PACS compared to conventional radiography. With PACS a significant cost saving is seen for MRI Brain scans and CT Brain scans both with contrast. Chest X-rays and MRI Brain Scans with PACS also show a substantial cost saving on a single examination image cost. PACS incremental image cost for chest X-rays, CT Brain scans, MRI Brain Scans, CT Brain scans with contrast and MRI Brain scans without contrast decreased by 27%, 5%, 15%, 14.17%, and 22% respectively.

4.4. Net present value (NPV) for PACS and conventional methods

The net present value is used commonly for capital budgeting. The capital costs for radiology equipment, computer hardware as well as RIS are weighted according to the number of patients for the different examination procedures. The procedure costs were obtained from using the medical aid rates for the practice. The income after tax was also in-cooperated into the net present value. The tax allowance was calculated using the wear and tear or depreciation allowance from the South African revenue services (SARS). Five year depreciation was used for the X-ray equipment and mainframe equipment and for software two year depreciation was used. The depreciation values were added to the present values. The productivity gains were also included to the

present value totals in order to show the true costs incurred through implementation of PACS (Wear-and-tear depreciation allowance, 2009).

4.4.1. NPV of Chest X-rays for PACS and conventional methods

Table 15 shows the Net present values for chest X-rays when using the PACS system

Table 15 NPV of Chest X-rays for PACS methods

PACS CXR						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 168,322					
RIS costs	-R 9,376					
Image cost		-R 284,933	-R 296,331	-R 308,184	-R 320,511	-R 333,332
Income for Chest X-rays		R 1,109,272	R 1,153,643	R 1,199,789	R 1,247,780	R 1,297,692
Income after Tax		-R 220,076	-R 229,309	-R 240,223	-R 250,209	-R 260,595
Add Depreciation-Capital		R 33,664	R 33,664	R 33,664	R 33,664	R 33,664
Add Depreciation-Software		R 4,688	R 4,688			
Productivity Gains		R 103,680	R 107,827	R 112,140	R 116,626	R 121,291
TOTAL	-R 177,698	R 746,295	R 774,183	R 797,186	R 827,350	R 858,720
Present Value	-R 177,698	R 690,995	R 663,707	R 632,806	R 608,102	R 584,445
Net Present Value of Project	R 3,002,358					

The NPV for PACS chest X-rays as seen in Table 15 shows a positive NPV value. This positive NPV value indicates that PACS chest X-rays are profitable to the radiology practice.

Table 16 shows the Net present values for chest X-rays when using the conventional radiography methods.

Table 16 NPV of Chest X-rays for Conventional methods

CONVENTIONAL CXR						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 105,926					
RIS costs	-R 14,177					
Image costs		-R 213,162	-R 221,689	-R 230,556	-R 239,779	-R 249,370
Income for Chest X-rays		R 1,142,140	R 1,187,825	R 1,235,338	R 1,284,752	R 1,336,142
Income after tax		-R 252,197	-R 262,602	-R 275,407	-R 286,661	-R 298,364
Add Depreciation-Capital		R 21,185	R 21,185	R 21,185	R 21,185	R 21,185
Add Depreciation-Software		R 7,088	R 7,088			
TOTAL	-R 120,103	R 705,053	R 731,808	R 750,560	R 779,498	R 809,593
Present Value	-R 120,103	R 652,809	R 627,379	R 595,794	R 572,931	R 551,009
Net Present Value of Project	R 2,879,819					

The NPV for Conventional radiography chest X-rays as seen in Table 16 is positive. This positive NPV value shows that the older system also was profitable to the radiology practice.

4.4.2. NPV for CT brain scans for PACS and conventional methods

Table 17 shows the Net present values of CT brain scans when using the PACS system

Table 17 NPV of CT brain scans for the PACS system

PACS CT Brain Scans						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 33,697					
RIS costs	-R 822					
Image costs		-R 48,135	-R 50,061	-R 52,063	-R 54,146	-R 56,312
Income for CT Brain Scans		R 484,598	R 503,982	R 524,142	R 545,107	R 566,912
Income after Tax		-R 120,207	-R 125,096	-R 130,295	-R 135,582	-R 141,081
Add Depreciation-Capital		R 6,739	R 6,739	R 6,739	R 6,739	R 6,739
Add Depreciation-Software		R 411	R 411			
Productivity Gains		R 8,832	R 9,185	R 9,553	R 9,935	R 10,332
TOTAL	-R 34,519	R 332,238	R 345,162	R 358,075	R 372,053	R 386,591
Present Value	-R 34,519	R 307,619	R 295,907	R 284,240	R 273,459	R 263,114
Net Present Value of Project	R 1,389,820					

The NPV calculated in Table 17 for PACS CT Brain scans shows a positive NPV value which is a good indication that the used of PACS is profitable to the radiology practice.

Table 18 shows the Net present values for CT brain scans when using the conventional system

Table 18 NPV of CT brain scans for the conventional system

CONVENTIONAL CT Brain Scans						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 36,429					
RIS costs	-R 1,013					
Image costs		-R 51,193	-R 53,241	-R 55,370	-R 57,585	-R 59,889
Income for CT Brain Scans		R 484,598	R 503,982	R 524,142	R 545,107	R 566,912
Income after Tax		-R 119,172	-R 124,026	-R 129,216	-R 134,466	-R 139,926
Add Depreciation-Capital		R 7,285	R 7,285	R 7,285	R 7,285	R 7,285
Add Depreciation-Software		R 506	R 506			
TOTAL	-R 37,442	R 322,025	R 334,507	R 346,840	R 360,341	R 374,382
Present Value	-R 37,442	R 298,163	R 286,773	R 275,322	R 264,851	R 254,804
Net Present Value of Project	R 1,342,470					

The result for the NPV from Table 18 for Conventional radiography CT Brain Scans is positive. This indicates that the conventional radiography CT Brain Scans made a profit for the radiology department.

4.4.3. NPV for MRI brain scans for PACS and conventional methods

Table 19 shows the Net Present value for MRI brain scans for the PACS system

Table 19 NPV of MRI Brain scans for PACS

PACS MRI Brain Scans						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 128,872					
RIS costs	-R 1,974					
Image costs		-R 264,569	-R 275,152	-R 286,158	-R 297,604	-R 309,508
Income for MRI Brain Scans		R 3,890,357	R 4,045,971	R 4,207,810	R 4,376,122	R 4,551,167
Income after Tax		-R 1,007,727	-R 1,048,336	-R 1,090,846	-R 1,134,768	-R 1,180,448
Add Depreciation-Capital		R 25,774	R 25,774	R 25,774	R 25,774	R 25,774
Add Depreciation-Software		R 987	R 987			
Productivity Gains		R 21,504	R 22,364	R 23,259	R 24,189	R 25,157
TOTAL	-R 130,846	R 2,666,326	R 2,771,608	R 2,879,839	R 2,993,713	R 3,112,142
Present Value	-R 130,846	R 2,468,751	R 2,376,100	R 2,286,016	R 2,200,379	R 2,118,124
Net Present Value of Project	R 11,318,525					

The NPV from Table 19 for PACS MRI Brain scans shows a positive result. This indicates that the introduction of the new system is profitable to the radiology practice.

Table 20 shows the net present value of MRI brain scans for conventional methods

Table 20 NPV of MRI brain scans for conventional methods

CONVENTIONAL MRI Brain Scans						
Description	Year 0	Yr1	Yr2	Yr3	Yr4	Yr5
Capital costs	-R 73,633					
RIS costs	-R 1,157					
Image costs		-R 102,751	-R 106,861	-R 111,136	-R 115,581	-R 120,204
Income for MRI Brain Scans		R 3,890,357	R 4,045,971	R 4,207,810	R 4,376,122	R 4,551,167
Income after Tax		-R 1,056,244	-R 1,098,665	-R 1,142,945	-R 1,188,828	-R 1,236,546
Add Depreciation-Capital		R 14,727	R 14,727	R 14,727	R 14,727	R 14,727
Add Depreciation-Software		R 579	R 579			
Total expenses for year	-R 74,791	R 2,746,667	R 2,855,750	R 2,968,456	R 3,086,440	R 3,209,144
Present Value	-R 74,791	R 2,543,139	R 2,448,235	R 2,356,360	R 2,268,533	R 2,184,143
Net Present Value of Project	R 11,725,620					

The result of the NPV from Table 20 for conventional radiography MRI Brain Scans is positive indicating that the system is profitable to the radiology practice.

4.4.4. Summary of Net Present Value

The individual net present values for both the systems were positive indicating that both systems yield a profit to the radiology practice. The difference between the both systems NPV for chest X-rays, CT Brain scans and MRI Brains scans was determined. Chest X-rays and CT brain scans showed an increase in profits for PACS while MRI brain scans showed a negative NPV difference. The summary of the NPV's for PACS and conventional methods including the difference between the both systems is seen in Table 21.

Table 21Summary of the net present values for Chest X-rays, CT Brain scans and MRI Brain scans

SUMMARY OF NET PRESENT VALUES			
PROCEDURE	**PACS**	**CONVENTIONAL**	**NPV(PACS)-NPV(CONVENTIONAL)**
Chest X-rays	R 3,002,358	R 2,879,819	R 122,539
CT Brain scans	R 1,389,820	R 1,342,470	R 47,350
MRI Brain scans	R 11,318,524	R 11,725,620	-R 407,096

4.4.5. Productivity gains

After the PACS installation the practice had decreased the number of radiologist on site from 5 to 3. This was the productivity gains for the practice. There was no decrease in the radiographer staff numbers. The radiologist salary was weighted for the Chest X-ray, CT Brain scan and MRI Brain scan in order to provide an accurate average.

The cost savings for 2 radiologists for a year is about **R1, 832,904 – 00.** The radiologist's salary was taken from the government salary scales and thus may be slightly more or less depending on the actual figures.

Table 22 shows the NPV values for Chest X-rays, CT Brain Scans and MRI Brain Scans as well as the productivity gains in isolation of the NPV value.

Table 22 The productivity gains for Chest X-rays, CT Brain scans and MRI Brain scans after 5 years

SUMMARY OF NET PRESENT VALUES				
PROCEDURE	**PACS**	**CONVENTIONAL**	**NPV(PACS)-NPV(CONVENTIONAL)**	**PRODUCTIVITY GAINS(5 years)**
Chest X-rays	R 3,002,358	R 2,879,819	R 122,539	R 561,564
CT Brain scans	R 1,389,820	R 1,342,470	R 47,350	R 47,837
MRI Brain scans	R 11,318,524.75	R 11,725,620	-R 407,096	R 116,472.60
Total			R 237,207	R 725,873.88

The NPV results for PACS include the productivity gains. The actual values of the productivity gains included in the PACS NPV are seen in Table 22. The results for the productivity gains are calculated for a 5 year period and are weighted on the time spent by a radiologist to diagnose the procedure.

4.5 Report waiting times for PACS versus Conventional methods

The patient report waiting times was obtained through surveys and verified from the RIS. The time motion study took into account when the patient was captured onto the RIS and when the report was typed out.

Figure 4 displays the average waiting times for Chest X-rays at St Augustine's hospital and Westville Hospital.

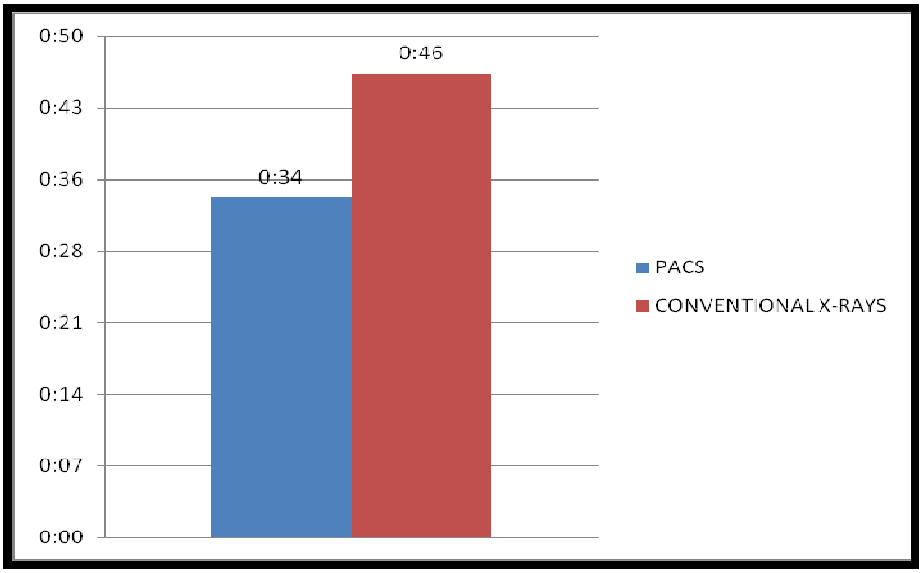

Figure 4 Patient waiting times in minutes for chest X-rays at St Augustine's Hospital (PACS) n=255 and Westville Hospital (Conventional) n=255

The average time for chest X-rays to be reported in St Augustine's Hospital is less than that at Westville hospital by 10 minutes. The mean for PACS (CR) is 0.34 minutes ($^{+}$/.0.0171) and for Conventional (CR) it is 0.46 minutes ($^{+}$/.0.0579) ($P < 0.0001$)

Figure 5 shows the waiting times for CT Brain scans at St Augustine's Hospital and Westville hospital.

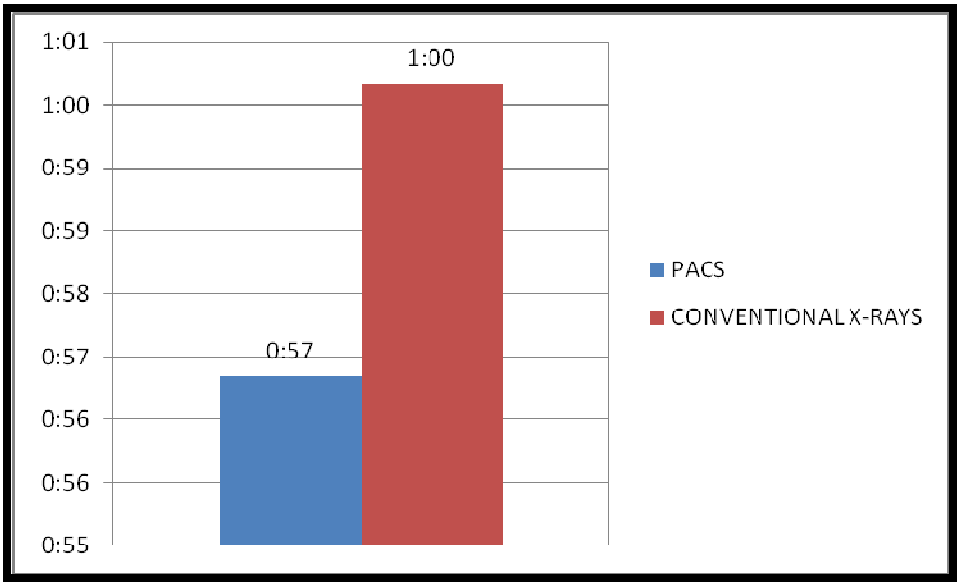

Figure 5 Patient waiting times minutes for CT Brain scans at St Augustine's Hospital (PACS) n=21 and Westville Hospital(Conventional) n=20

Patient waiting times as seen in Figure 4 for CT Brain scans is similar in both St Augustines and Westville hospital. There is a slight difference of 3 minutes between the sites. The mean time for CT Brain(PACS) is 0.57minutes ($^{+}$/.0.0132) and CT Brain(Conventional is 1 minute ($^{+}$/.0.0223) ($P < 0.0001$).

Figure 6 displays the patient waiting times for MRI Brain scans at St Augustines Hospital and Westville hospital.

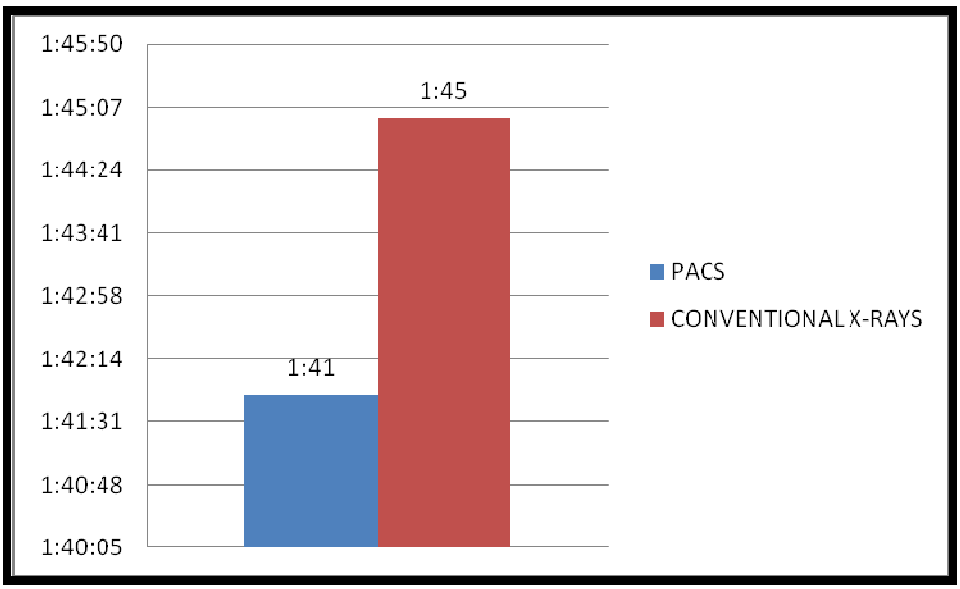

Figure 6 Patient waiting times in minutes for MRI Brain scans at St Augustine's Hospital (PACS) n=52 and Westville Hospital (Conventional) n=18

The time motion results illustrated in Figure 6 reveal that there is an improvement of patient waiting times with the use of PACS as compared to conventional X-ray methods in MRI Brain scans. However, an averaged 4 minute improvement can be seen.

The mean times for MRI(PACS) is 1.41 minutes ($^{+}$/.0.0302) and MRI(Conventional) is 1.45 minutes ($^{+}$/.0.9378) (P =0.7567).

4.6 End User Views

A total of 16 radiographers from St Augustine's Hospital were given the opportunity to participate in this study. 81% of the staff returned their self administered questionnaires. The results show that all the radiographers have over a year or more experience with PACS. 100% of the staff who participated preferred the new PACS system compared to the conventional system.

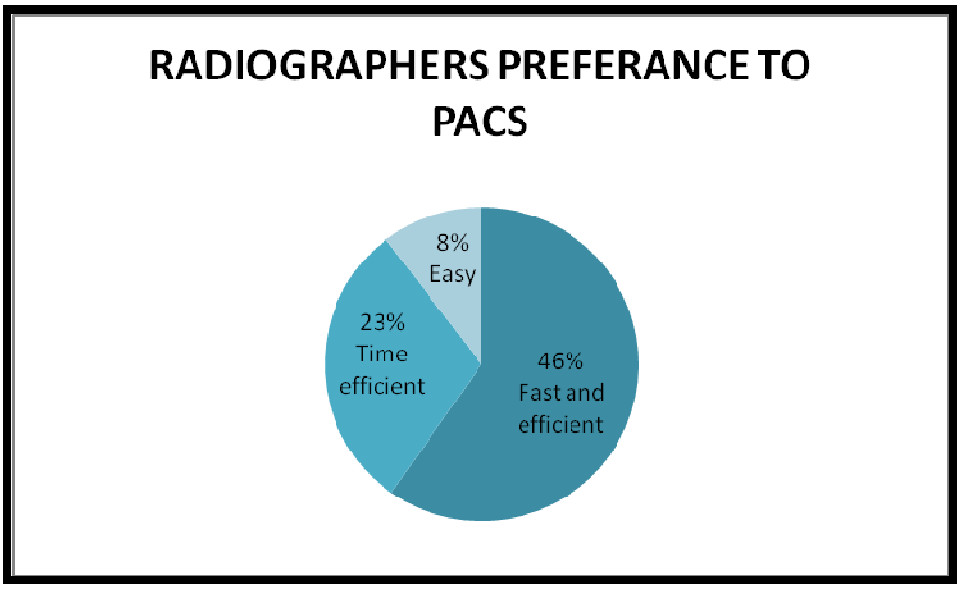

Figure 7 Radiographer's preferences to choosing the PACS system as opposing to conventional radiography systems

Figure 7 shows the radiographers reasons as to why they preferred PACS over conventional radiography. The feedback obtained from the self administered questionnare for radiographers showed 46% found PACS to be fast and efficient in their working environment. 23% observed that time efficiencies was possible with the use of PACS. 8% of the radiographers felt PACS was easier to use when compared to conventional radiography methods.

Figure 8 shows the radiographers problems encountered with the use of the PACS

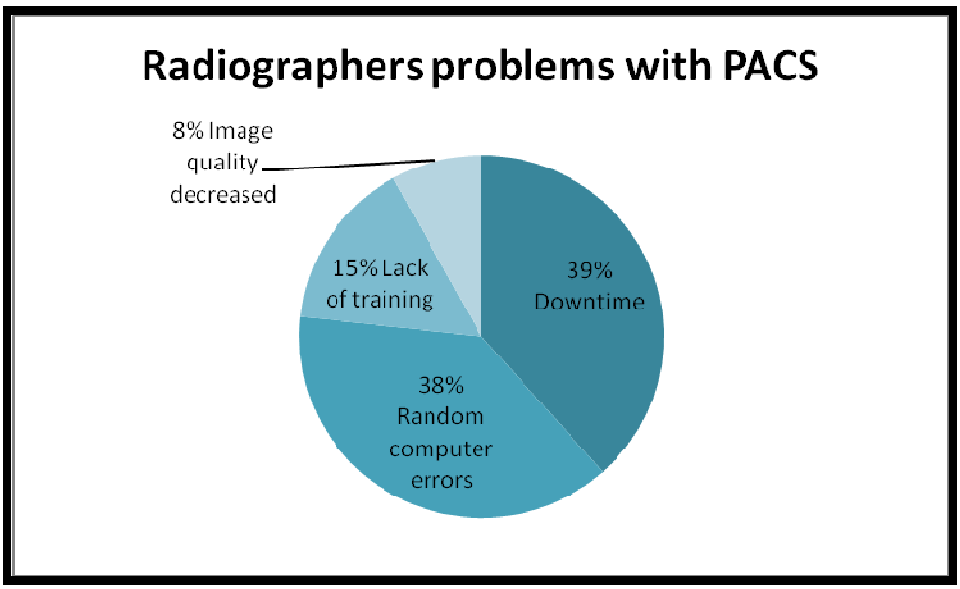

Figure 8 Radiographers problems encountered with the PACS

From the feedback obtained through the radiographer's questionnaires various problem areas were mentioned. Figure 8 demonstrates that the major problem areas for the PACS implementation were the downtime as well as the random computer errors and glitches. These results were 39 % and 38 % respectively. 15 % of the radiographers mentioned that a lack of training during the implementation phase had made the transition from PACS to conventional radiography difficult. 8 % of the radiographers felt that there was a decrease in image quality with the introduction of digital radiography.

The suggested improvements by the radiographers for the system was not simliar. These suggestions were beyond the scope of this study but are mentioned for future PACS sites. The software improvements requested were as follows:-

- After hours system to be simple for data capture.
- The graphical user interface to be colourful.
- Previous request forms to be accessible by the radiographer.

The topic of privacy to the patient had been mentioned in terms of accessibility to all hospital staff. The initial training of staff needed to be improved for future PACS sites. Faster computers were also a request by the radiographers for easing their workflow.

CHAPTER FIVE - DISCUSSION

5.0 INTRODUCTION

Chapter Five interprets and analyses the significance of the research results. The findings of the study is analysed subject to the objectives set earlier in the study. The wider implications of the study are discussed in detail and contrasted with published studies.

5.1DISCUSSION

From the literature review undertaken, to date no previous South African studies were performed for costing. The main purpose of this study was to determine an incremental cost analysis for PACS compared to conventional radiology within a South African context. The major challenge confronting radiology practices is to obtain cost savings and productivity gains once PACS is installed. The study sets out to show the incremental cost for Chest X-rays, CT Brain scans with and without contrast; MRI Brain scans with and without contrast and finally the overall incremental cost. The cost implication of the migration of PACS to conventional radiography is the key outcome of this study.

Radiology in the 21st century is changing rapidly and this is observed globally by the transition of radiology departments to digital imaging technology. Previously conventional X-rays required X-ray films and reports to be printed which required a great amount time as well as image production cost. The use of new technologies like PACS has allowed for practices to eliminate the need for producing X-ray film and paper based reports. When implementing a PACS system a radiology practice would have to consider three main cost areas: - Capital costs, RIS costs and image costs.

Larger practices could consider implementing PACS all at the same time such that the change over from conventional radiography to PACS is immediate. This method could work for larger practices that have a greater capacity for the initial capital outlay.

However, for smaller practices a step wise implementation could be a more viable option. With this option the practice could consider implementing the RIS prior to purchase of any other equipment.

The RIS is the first step within a radiology PACS environment. Without the RIS interface there can be no PACS. The RIS creates the patients unique identifier and this is transmitted to the modality as well as the radiographer worklist. From the results the incremental RIS cost shows that it is 12 % more expensive than that of the conventional RIS. These additional costs are mainly due to the licence fees, interface to PACS, installation and server costs. Previous studies do not include the RIS in their cost analysis. However, Pratt, et al. (1998) did include the RIS interface into their cost summary analysis. The RIS interface was discounted and allocated to sections by a weighting of the total examinations. This study used a similar method to calculate the cost of the RIS interface although no discount was taken into consideration.

If a step wise option is used to implement PACS and the RIS is installed first, it could be fully paid before the additional capital costs are incurred. In the scenario where a radiology department has an existing RIS, the additional cost would be the interface with PACS. This option is a feasible method for radiology practices in order to overcome major capital expenses all at the same time.

When implementing PACS, the capital outlay needed is a significant percentage of the total cost for implementation. The results presented earlier shows that the incremental capital costs for PACS is greater than that of conventional radiography costs. Due to the implementation of new X-ray equipment the greatest percentage difference of 63% is noted for incremental capital costs for Chest X-rays. In the case of CT and MRI scans the percentage difference was 22 % and 14 % respectively. The reason for the lower costs could be that the same equipment was used and only an interface to the PACS was required.

In this study the incremental capital costs included the X-ray equipment thus assuming it was purchased at the time of implementation. This scenario is not always true for all radiology practices since X-ray equipment costs are sometimes fully paid off before a PACS implementation begins. Pratt, et al. (1998) suggests that exclusion of CR equipment could result in a positive financial impact. If the existing CR equipment was taken as a sunken cost the radiology practice would see a positive result when implementing PACS. Pratt, et al. (1998) also states that net cost savings would be possible with a 17% reduction on the PACS hard ware costs. It should be noted that this study did not include reductions or discounts in prices and this could have affected the final results.

The capital cost investment depends on the practice and how they wish to implement their PACS. A suggestion for future PACS implementations is to carefully look at the X-ray equipment costs. The practice would need to decide whether the CR or DR option would best suit their budget. With CR a practice can still use their existing equipment and the only change would be the processors and cassettes. However, with DR the entire X-ray unit needs to be replaced. The CR option would improve the speed by elimination of the film processing steps but DR system would allow for immediate access to images online. However, the DR system is a much more expensive option. The choice of X-ray equipment would affect the final capital costs incurred. In this study the different X-ray equipment options was not included. Only CR equipment was taken into account. It is the decision of the practice to evaluate which option would work for their practice.

A deciding factor for installing PACS is the capital investment. However, determining RIS and capital costs alone is not sufficient. Since there are other cost factors that must be considered before any financial decision can be made. The incremental image costs for the Chest X-ray, CT Brain scan and MRI Brain scan shows contrasting results compared to the incremental RIS and capital costs. Incremental image production costs in the PACS radiology department showed a cost saving in all three procedures.

These results for incremental image costs show that with the implementation of PACS there was an exclusion of film costs and related consumable costs. These finding are consistent with previous findings on costing of PACS (De Backer, et al., 2004; Huda, et al., 1996; Pratt, et al., 1998, Reddy, et al., 2006). The image cost savings is one of the positive aspects of implementing PACS in a hospital-wide PACS environment. Future PACS practices should be aware that this cost benefit would only be seen if the hospital is networked and the images are available online to referring doctors.

Also performed in this study was the net present value for PACS. This capital budgeting method for potential investors indicates the feasibility of new projects. From the results presented earlier a negative NPV value for MRI Brain scans is seen. These findings are not similar with previous studies since a positive NPV value for the PACS was obtained. However, a positive NPV value for chest X-rays and CT Brain scans was identified. The reason for this difference could be the volume of patients seen at the practice which offsets the costs. However, it could also indicate that different examination procedures yield a different NPV values (Duerinckx, et al., 1998; Fang, et al., 2006; Hilsenrath, et al., 1991; Pratt, et al., 1998).

To take the net present value presented in this study as the entire financial value of the PACS radiology department is insufficient since only 7.3 % of the total monthly examination procedures were included. The study results obtained is thus a partial costing. The project time line used in this study was 5 years whereas other studies have used longer time lines of 8 to 9 years resulting in positive NPV values. This could be another factor that affects the results in this study (Duerinckx, et al., 1998, Fang, et al., 2006, Hilsenrath, et al., 1991, Pratt, et al., 1998).

The major direct cost savings with PACS is in the staffing and operational costs which showed a reduction in costs for Chest X-rays, CT Brain scans and MRI Brain scans. A major productivity gain seen with PACS is the reduction in radiologists needed. The PACS radiology department originally had 5 radiologists reporting at the venue. Over time the need for the 2 radiologists had decreased which resulted in a cost saving to the

department. With the inclusion of productivity gains the total NPV value for Chest X-rays and CT brain scans, a positive NPV value was determined. After 5 years the total NPV values for the three procedures is –R177 375 for a R3, 117,506 PACS system. This is a small fraction of the total initial costs of PACS.

Overall from the results of this study, it can be seen that PACS incurs a greater capital cost compared to conventional X-rays but with cost savings for human resources and image production. The hypothesis that there is no significant difference in costs for PACS compared to conventional radiography is not supported by the data presented.
However, these costs do not show the non-monetary benefits to the practice. A true costing of PACS would need to consider both monetary and non-monetary costs of the department to gauge the value of implementing a PACS system. Mweli (2010) points out an interesting aspect on non-monetary costs. The author discusses that while for patients, benefit of implementation of new technologies such as PACS are immediate, the benefit to a radiology practice is in the long term. The author does not determine the actual non-monetary benefits due to the difficulty in quantifying them. Mweli (2010) also states that the benefits to the patients were indirect and can only be seen downstream of the value process (De Becker, et al., 2004; Hilsenrath, et al., 1991).

In South Africa the National Health Insurance is in the process of being implemented in 10 districts around the country. The purpose of the National health insurance scheme is to identify the issues surrounding implementation and one of the key issues being costing required. South Africa spends 8.8% of GDP on health care which is a very high level of spending for a third world country. With systems such as PACS in place costing in radiological services can be reduced without affecting the quality of patient care (Economist Intelligence unit, 2010, Masombuko, 2012).

One of the benefits of implementing PACS is the reduction in waiting times. While waiting times for patient's to undergo a complete radiology workflow is not markedly improved they no longer need to wait in the X-ray department for the report as this now can be transmitted electronically to the requesting doctor. The referring doctor also benefits since the images of the patient are available for viewing at the same time as the interpretation of the examination by the radiologist. Once the report is entered and verified by the radiologist it is available online to the referring doctor together with the current images, previous images and other reports as well which in turn assists in improving patient care and treatment. The patient waiting time objective addresses the challenge related to the national core standard for access to care. With the new PACS system long queues and waiting times for the patient is reduced while maintaining patient care, thus upholding an important National Core Standard in South Africa (National department of health, 2011).

The study also shows that the introduction of PACS has improved the working environment of the radiographers. Radiographers who are the end users are important in making any system work successfully especially in a PACS environment. The productivity of the radiographer was not evaluated in this study. However, during the self administered questionnaire they reported improved speed and efficiency of workflow with PACS. The new system has made the radiographers working environment easier by eliminating the slow and tedious processes used in conventional radiology. Some of the initial disadvantages of using the PACS system are the downtime due to the initial errors and computer glitches during the setup phase. However, this occurs only in the first few months of the implementation. Once this phase is over there is very few incidences that may occur and there is always onsite assistance available at all times.

While this study showed that the incremental capital and RIS costs increased, there are certain non-monetary benefits of PACS implementation. Some of the benefits can be measured while others cannot. The PACS radiology practice found that with the introduction of PACS a radiologist could work from any practice or venue and report any case anywhere with PACS facilities. Now any radiologists anywhere can access the images, patient referring letter and history immediately and clear the work lists at anytime. The workload on the radiologists was eased through even distribution of work. Thus, back logs in reporting can now be avoided and patient turnaround time has improved. The central work list that was introduced allowed a radiologist at a practice with low volumes to assist with reporting at another practice. This improved productivity and patient treatment time. Radiologists benefited by reporting after hours cases immediately thus preventing delays in workflow in the morning.

The central work list feature has allowed specialist radiologists to be at any practice to report a case even if the patient was not X-rayed there. The result of these changes was improved patient services and efficient workflow for the radiologist as well as improved turnaround time for referring doctors.

Voice recognition and its integration into PACS can also improve the speed of reporting radiology results. With this additional system, the radiologists can dictate, correct and present reports as soon as the diagnosis has been made. The result is the elimination of time spent sending reports to the typist for correction. Some practices in South Africa have reduced their typing pool due to the introduction of this system.

Referring doctors can now benefit through faster turnaround times for patient diagnosis since images are immediately accessible to them. The referring doctors can also be given after hour's access to radiographs via the internet thus assisting in faster patient treatment times. The mobility of the radiology images increases with the use of wide area networks and this assists referring doctors who work at a number of different hospitals.

Practices with PACS could even look at expanding their businesses with teleradiology and remote reporting for other radiology practices. The impact of teleradiology costs was not included in this study. However, the opportunities to increase patient volumes and revenue become effortless with a PACS site. Radiology practices with PACS can use teleradiology in areas in South Africa where there is a lack of specialist radiologist's i.e. In the government sector with mutual benefit through public-private sector collaborations.

The intention of this study was to show practices who wish to introduce PACS, either in private or public sectors on some of the costs and non-monetary benefits that could potentially accrue. Practices need to be cognisant of both the monetary and non-monetary gains of implementing PACS in order to make an informed decision regarding the system.

5.1 BIAS AND LIMITATIONS

- Cost was only collected for a single month in the year. Thus, the annual costs were based on these and are not a true reflection of the actual costs incurred in a year.

- Only 3 procedures where analysed and thus the actual cost savings of the entire PACS implementation will be difficult to be determined in this study alone. The patients costs would vary according to the type of the case being performed and no medical consumables were accounted for in this study.

- Waiting times for patients may differ for each examination depending on the experience of the radiographers and the patient's mobility.

- Reporting times may vary due to different radiologists reporting on cases.

- Radiographers recall bias may occur when answering the self administered questionnaires.

CHAPTER SIX - RECOMMENDATIONS AND CONCLUSION

6.0 INTRODUCTION

This chapter is a summary of the findings of the study and concludes with some recommendations for future studies

6.1 CONCLUSIONS

This cost analysis shows that PACS requires a large capital outlay for equipment and software compared to conventional radiology for Chest x-rays, CT Brain scans and MRI Brain Scans. This is mainly due to the introduction of the new digital technology which at present is more expensive to implement. The hypothesis that there is no difference in costs between PACS and conventional radiography is not supported by the data.

The incremental RIS and capital cost proved to be the largest increase in cost when comparing PACS and conventional systems for Chest x-rays, CT Brain scans and MRI Brain scans. With the introduction of PACS for Chest x-rays, CT Brain scans and MRI Brain scans, there is a reduction in the cost for the imaging component of the system. This is due to reduction in costs associated with film processing and staff required. However, a full cost analysis of all the procedures in a radiology practice needs to be performed to determine if these savings actually do offset the final net present value. While these costs can be seen as a barrier when introducing PACS, it is important for the non-monetary benefits to be evaluated.

The patient waiting times for Chest x-rays, CT Brain scans and MRI Brain scans using PACS shows an improvement since patients are no longer required to wait to take the x-rays to their doctors. There is also a benefit for the referring doctor who can now immediately access the x-ray and the report electronically. This reduction in patient waiting times is in line with the National core standards and would address the challenge

of timely access to healthcare faced in the South African public health sector. PACS technology in radiology departments has the potential of increasing the efficiency and quantity of workflow.

In this study the PACS radiology practice has seen productivity gains due to reduced need for radiologists, thus, contributing to cost savings to the practice. Private radiology departments in South Africa have also seen the opportunity of enhancing their workflow by introducing remote reporting, voice recognition, teleradiology etc. through the PACS technology. The PACS could potentially be of benefit to the proposed National Health Insurance scheme by reducing the number of radiologists required and image processing costs thereby while containing costs there will be no compromise in the quality of patient care.

Costing of a new investment is a key factor. However, radiology practices need to evaluate the PACS technology both in terms of its monetary and non-monetary benefits before coming to an implementation decision. This study could be used as a model for future PACS practices. It should be noted that the return of investment might not be seen in the short term. However, the benefit to the practice, radiologists, referring physicians and patients in terms of time and efficiency is more immediate. Further cost benefit studies would be required to evaluate this.

6.2 RECOMMENDATIONS

- **COMPUTED RADIOGRAPHY VERSUS DIGITAL RADIOGRAPHY**

With the use of CR, practices have the option of using their existing equipment and only need to purchase cassettes for digital recording and processors. This option is a cheaper option and feasible for smaller practices with small workloads. In contrast, DR would require the practice to remove all existing equipment for the installation of a new digital system. The practice would see increased efficiency but must be cognisant of the costs involved. DR is feasible for larger departments with larger workloads.

- **EMAILING REPORTS**

Further reduction in costs is possible with the use of email technology for report distribution. With a hospital-wide PACS solution referring doctors would have online access to reports at all times. However, doctors outside the hospital without email facilities would still require paper based reports.

- **EQUIPMENT LEASING**

Equipment leasing should be considered as an option when costing for PACS in order to determine the most cost efficient method to implement and finance PACS.

- **STEP WISE IMPLEMENTATION**

It can be seen from experience of practices that implementing the RIS before PACS as a step wise scenario allows for a cost effective and efficient solution. This will allow the practice to monitor their costs carefully and not overspend. The services to the patients are also not compromised during the changeover.

- **FULL COST ANALYSIS**

This study evaluated a partial financial costing of a radiology department. Future research into a full cost analysis should be undertaken to evaluate the true potential costs of PACS in the South African setting.

- **TELERADIOLOGY AND PACS**

The in-corporation of teleradiology into a fully digitised system would be an interesting aspect to look into in terms of the current South African health care environment. With the lack of healthcare professional staff, the use of PACS and telemedicine working together with private practices could be a means of alleviating the pressures in our public health care system. Research should be done to determine the feasibility and sustainability of this system in terms of private public partnership.

- **COST BENEFIT ANALYSIS**

A suggestion for further studies is a cost benefit analysis. This would show both the monetary and non-monetary benefits for installing a PACS system. It would be a better indicator of the value of PACS in a radiology practice. In terms of the monetary values this would be the investment and cost savings incurred and the non monetary values would be reduction in staff, faster accessibility of images to referring doctors, storing and archiving images for life, efficient workflow for radiologists, voice recognition and introduction of teleradiology.

CHAPTER SEVEN - REFERENCES

Beard, D., Parris, D., and Stevenson, D., 1990. A Cost analysis of film Image management and Four PACS based Different Network protocols. Journal of Digital imaging, **3**(2): 108-118.

Becker, S.H., and Arenson, R.L., 1994. Costs and Benefits of Picture archiving and communication Systems.Journal of the Medical Informatics association **,1**(5): 361-371.

Bryan, S., Justin, K., Muris, N., Weatherburn, G., Buxton, M., 1995.Issues in the evaluation of picture archiving and communication systems. Health Policy, **33:** 31-42.

Chan, B., W, Dorl, J., R, DeJong, M. R., and Hamper, U.M., 1998.Cost assessment of Filmless Ultrasound Using Unit cost analysis, **11**(3):115-116.

Charvet-Protat, S., and Thoral, F.,1998.Economic evaluation and Organizational benefits of Picture archiving and communication systems (PACS).Jouranl de Radiologie, **79**(12).

Duerinchkx, A. J., Kenagy, J. J., Grant, E. G.,2006. Cost analysis of PACS: Fact or Fiction. SPIE-Digital library.

Dwyer, S.J. and Jost, R.G.,1990.PACS systems design and evaluation. SPIE-Digital library, **1234**: 10-17.

Economist Intelligence Unit, 2010. Healthcare and pharmaceuticals report South Africa-Market data at a glance. [online]Economist Intelligence Unit. Available at: http:// store.eiu.com/article.aspx?.productid=1557096955.[Accessed 26 April 2012]

Fang, Y. C., Yang, M. and Hsueh, Y.S.,2006. Financial assessment of a Picture archiving and Communication system implemented all at once. Journal of Digital Imaging, **19**(1): 44-51.

Gregory, L.,2011. Percentage of time allocated to radiographers in each section. [Phone call](Personnel communication, 10 January 2011).

Hilsenrath, P. E., Smith, W. L., Berbaum, K.S., Franken, E.A., Owen, D.A.,1990. Analysis of the cost effectiveness of PACS. American Journal of Radiography, **156**: 177-180.

Huda, W., Honeyman, J.C., Frost, M.M., Staab, E.V.,1996.A Cost Analysis of Computed Radiography and Picture Archiving and Communication systems in Portable radiography. Journal of Digital imaging, **9**(1):39-44.

Kato, H., Kubota, G., Kojima, K., Hayashi, N., Nishihara, E., Kura, H., Aizawa, M.,1995.Preliminary time flow study: comparison of interpretation times between PACS workstations and films. Computer Medical Imaging Graphics , **19**(3): 261-265.

Kurihara, Y., Yoshida, S., Geshi, H., Kubo, Y., Kitazoe, Y.,2001 .Economic Analysis of filmless System Based on the Hospital Information System. Studies in Health Technology and Information, **84**(2):1166-70.

Langer, S. and Wang, J.,1996. A Goal Based Cost-Benefit Analysis for film versus Filmless Radiology Departments .Journal of Digitial Imaging, **9**(3): 104-112.

Langlois, S. L. P., Vytialingam, R. C., Aziz, N. A.,1999. A time-motion study of digital radiography at implementation. Diagnositic Radiology, **43:**201-205.

Lemke, H. U.,2003 .PACS developments in Europe. Computerised Medical Imaging and Graphics , **27**:111-120.

Maas, M., Kosanen, M., Karmano, M .,2001 .Cost analysis of Turku University Central hospital PACS in 1998. Computer Methods and Programs in Biomedicine , **66**:41-45.

Mackinnon, A. D., Billington, R. A., Adam, E. J., Dundas, D. D., Patel, L.,2008.Picture archiving and communication systems lead to sustained improvements in reporting times and productivity results of a 5 year audit.Clinical Radiology, **63:**796-804.

Margulis, A. R.,and Sunshine, J.H.2000., Radiology at the Turn of the Millennium. Radiology , **214**: 15-23.

Masombuka, S., 2012. NHI plan now on a roll. The Times. 23 March 2012

Mweli, T.2010., An exploratory business case for Radiology information system (RIS)-A South African firm level analysis.Graduate School of business Leadership-UNISA, Johannesbury, University of South Africa, Masters Degree in Business leadership: 118

Naidoo, V.,2011.Percentage of time allocated to radiographers in each section.[Phone call] (Personal conversation, 10 January 2011).

National Department of Health., 2011. National Core Standards for Health Establishments in South Africa. [online] Available at:

http://www.sarrahsouthafrica.org/LinkClick.aspx?fileticket=YnbSHfR8S6Q%3D&tabid=2327 [Accessed at 26 April 2012].

Orand, R. M .,2004.Cost Analysis:Film vs PACS, **5**(10): 38-39.

Pratt, H.M., Langlotz.C.P., Feingold, E. R., Schwartz, J.S., Kundel, H.L.,1998. Incremental cost of department wide implementation of a Picture archiving and communication system and computer radiography.Radiology, 206: 245-252

Reddy, A. S., Loh, S., Kane, R. A.,2006. Budget Variance Analysis of a Department wide Implementation of a PACS at a major Academic Medical Center.Journal of Digital Imaging, **19**(1):66-71.

Reiner, B., Siegel, E., Bradhma, D., Saunders, H., Johnson, B.,2009.Establishing Benchmarks for Creation of a Pro-Forma Economic Model to Evaluate Filmless PACS operation.Journal of Digital Imaging. **13**(3):129-135.

Reiner, B.I., Salkever, D., Siegel, E.L., Hooper, F. J., Siddiqui, K.M., Musk, A.,2005. Multi-institutional Analysis of Computed and Direct Radiography-Part 2. Economic Analysis .Radiology , **236**: 420-426.

Saini, S., Seltzer, S.E., Bramson, R. T., Levine, L. A., Kelly. P., Jordan, P.K., Chiango, B. F.,Thrall, J. H.,2000.Technical cost of Radiologic examinations:Analysis across Imaging Modalities.Radiology(July) : 269-272.

Samuel, J., Dwyer III. and Jost, R.G.,1990.PACS systems design and evaluation. SPIE-Digital library ,**1234**: 10-17.

Seigel, E and Reiner, B.,2002. Work Flow redesign. American Journal of Roentgenology. **178**: 564-566

Schomer, D. G., Schomer. B. G. and Chang, P.J.,2001. Value innovation in the Radiology. Radiographics **21**:1019-1024.

Schulze, O. C., Greyling, J., Hayes, M., Andronikou, S., 2002. Talking PACS:Part 1-What is PACS?. SA Journal of Radiology. Septemeber: 50-53.

Schuster, S.,2003. Market update-PACS: Cost - benefit. Medical Imaging. September 2003

Siegel, E. and Reiner, B.,2002. Work flow redesign-The key to success when using PACS .American Journal of Radiography, **178**:536-566.

Siegel, E.L. and Reiner, B. L.,2003.Filmless radiology at the Baltimore VA Medical Center: a 9 year retrospective. Computer Medical imaging and Graphics, **27:**101-109.

Sim, L.H.,2008. Budgeting for PACS.Biomedical imaging and Intervention Journal, **4**(4):e32.

Singer, M. E.,2008.Cost-effectiveness Analysis-Developing Nations left behind. Pharmacoeconomics, **26**(5): 359-361.

South African Revenue Services.,2010.Wear and tear or depreciation allowance. [online](Updated 10 January 2010) [Available at: http:// www.sars.gov.za / home.asp?pid=55888]

Sprengel, C., Schwarzer, J. and Kaden, L.,2003. Business process analysis for diagnostic

imaging.International congress Series,**1256**:823-827.

Stefani, P., Sacco, P., Pozzebon, E., Mazzei, M. A., Barberini, P., Borello, E., Baffoni, L., Conti, P., Piuri, D.,2001. Implementations of PACS and informatics in the Radiology of Siena University: a cost/benefit analysis.International Congress series, **1230**:1277-1278.

Terae, S., Miyasaka, K., Fujita, N., Shirato, H.,1998. A hospital wide PACS- 7 year experience and new developments.Computer Methods and Programs in Biomedicine,**57**: 5-12.

van Gennip, E. M. S. J., Ennig, J., Fischer, F., Glaser, K. H., Killbinger, M., Klose, K., List-Hellwig, E., Van den Broeck, R., Wein, B.,1996. Guidelines for cost effective implementations of Picture Archiving and Communication systems-A approach building or practical experiences in 3 European hospitals.International Journal of Biomedical Computing, **41**:161-178.

CHAPTER EIGHT – APPENDICES

APPENDIX A-COST PER MONTH FOR CHEST X-RAYS

Cost/pt for Chests(SAN)		Cost/pt for Chests(WEST)	
HUMAN RESOURCES		*HUMAN RESOURCES*	
Head radiographers	R0.00	Head radiographers	R0.00
Senior radiographers	R6738.3	Senior radiographers	R6406.80
Junior radiographers	R20363	Junior radiographers	R12620.30
Student radiographers	R6184	Student radiographers	R6184
Receptionist	R9 108	Receptionist	R8 413
Radiologists	R1496.87	Radiologists	R763.71
Typists	R12 840	Typists	R9 483
Runner	R3 598	Runner	R5 194
PACS administrator	R10 366	Driver	R884
Driver	R884	Darkroom	R5 018
Porter	R4 000	Porter	R3 400
	R75578.17		**58366.81**
OVERHEAD COSTS		*OVERHEAD COSTS*	
Rental	R112763.49	Rental	R41081.42
Electricity separate	R4260.47	Electricity	Included in rental
Water	Included in rental	Water	Included in rental
Waste disposal	Included in rental	Waste disposal	Included in rental
	R115027.45		**R41081.42**
CONSUMABLES		CONSUMABLES	
Jobcards	R1,614.60	Jobcards	R1662.44
Packet Labels	R421.20	Gummed labels	R6.95
Bar code labels	R97.20	X-ray Envelops-438x362 (.100)	R3,469.44
CDs + CD Sleeves	R242.20	X-ray film(CR)	R2,788.34
Rimmage ribbon	R43.20	Developer	R467.04
CD label *(Rimmage transfer roll)	R72.9	Fixer	R550.44
		Report paper- Bond paper	R475.38
		Report paper- Letterheads	R49.76
		Printer ink	38.92
	R2,491.30		**R9,508.71**

OPERATING COSTS		***OPERATING COSTS***	
Telephone	8606.75	**Telephone**	5148.08
Insurance	R11745.912	**Insurance**	R11745.912
Security	Included in rental	**Security**	Included in rental
Laundry costs	R4221.04	**Laundry costs**	R7935.19
Internet	R 400.00		R 400.00
	R24,973.70		**R25,229.18**
EQUIPMENT COSTS		**EQUIPMENT COSTS**	
Maintenance Equipment	R133.42	**Maintenance Equipment**	R23732.91
Equipment cost	R79865.38	**Equipment cost**	12,171.08
Network costs	R21 620.00	**Network costs**	R 9,176.00
Software Maintenance	R14 400.00	**Software Maintenance**	R25228.30
Software	R 264,125.81		
Additional costs/software	R25,091.95	**Additional costs**	R1,156.25
Additional costs	R7587.21		
	412823.77		**R71,464.54**
Total/mnth	**R630894.39**	**Total/mnth**	**R205,650.66**
Cost/patient incl equipment	**R2 474.00**	**Cost/patient incl equipment**	**R806.00**
Cost/patient excl equipment	**R855.00**	**Cost/patient excl equipment**	**R526.00**

APPENDIX B-COST PER MONTH FOR CT BRAIN SCANS

Cost/pt for CT Brain scans(SAN)		Cost/pt for CT Brain scans(WEST)	
HUMAN RESOURCES		**HUMAN RESOURCES**	
Head radiographers	R13221	**Head radiographers**	R11793.5
Senior radiographers	R15722.7	**Senior radiographers**	R14949.20
Junior radiographers	0	**Junior radiographers**	R5408.70
Student radiographers	0	**Student radiographers**	R 0.00
Receptionist	R9 108	**Receptionist**	R8 413
Radiologists	R3054.84	**Radiologists**	R763.71
Typists	R12 840	**Typists**	R9 483
Runner	R3 598	**Runner**	R5 194
PACS administrator	R10 366	**Driver**	R884
Driver	R884	**Darkroom**	R5 018
Porter	R4 000	**Porter**	R3 400
	R72794.54		**R65307.11**
OVERHEAD COSTS		**OVERHEAD COSTS**	
Rental	R112990.15	**Rental**	R44830.77
Electricity used for unit	R1403.30	**Electricity used for unit**	R1525.33
Water	Included in rental	**Water**	Included in rental
Waste disposal	Included in rental	**Waste disposal**	Included in rental
	112170.66		**R46356.10**
CONSUMABLES		**CONSUMABLES**	
Jobcards	R137.54	**Jobcards**	R119.60
Packet Labels	R35.88	**Gummed labels**	R0.05
Bar code labels	R8.28	**CT/MRI Envelopes**	R50.00
CDs + CD Sleeves	R88.09	**Laser film(CT)**	R450.00
Rimmage ribbon	R3.68	**Report paper- Bond paper**	R34.20
CD label *(Rimmage transfer roll)	R6.21	**Report paper- Letterheads**	R3.28
		Printer ink	R2.80
	R 279.68		**R 659.93**
OPERATING COSTS		**OPERATING COSTS**	
Telephone	8606.75	**Telephone**	R 5,148.08
Insurance	R11745.912	**Insurance**	R11,745.912

Security	Included in rental	**Security**	Included in rental
Laundry costs	R 500.45	**Laundry costs**	R 804.98
Internet	R 400.00		R 400.00
	R21253.12		**R18098.07**
EQUIPMENT COST		**EQUIPMENT COST**	
Maintenance	R134230.83	**Maintenance**	R438.83
Equipment cost	R 823,977.89	**Equipment cost**	R346383.58
Network costs	R21 620.00	**Network costs**	R 9,176.00
Software Maintenance	R14 400.00	**Software Maintenance**	R25,228.30
Software	R 264,125.80		
Additional cost-interest	R78 277.89	**Additional cost**	R 32,906.44
Additional cost-software	R25091.95		
Total	**R1,361,723.53**		**R414,133.15**
Total cost/month	**R1,568,221.53**	**Total cost/month**	**R544,554.36**
Cost/patient excl equipment	**R10 868.00**	**Cost/patient excl equipment**	**R6521.00**

APPENDIX C -COST PER MONTH FOR MRI BRAIN SCANS

Cost/pt for MRI Brain scans(SAN)		Cost/pt for MRI Brain scans(WEST)	
HUMAN RESOURCES		**HUMAN RESOURCES**	
Head radiographers	R13221.00	**Head radiographers**	R11793.5
Senior radiographers	0	**Senior radiographers**	0
Junior radiographers	0	**Junior radiographers**	0
Student radiographers	0	**Student radiographers**	0
Receptionist	R9 108.00	**Receptionist**	R8 413.00
Radiologists	R2291.13	**Radiologists**	R763.71
Typists	R12 840.00	**Typists**	R9 483.00
Runner	R3 598.00	**Runner**	R5 194.00
PACS administrator	R10 366.00	**Driver**	R884.00
Driver	R884.00	**Darkroom**	R5 018.00
Porter	R4 000.00	**Porter**	R3 400.00
	R56308.13		**R44949.21**
OVERHEAD COSTS		**OVERHEAD COSTS**	
Rental	R106887.32	**Rental**	R41081.42
Electricity separate	R4260	**Electricity**	Included in rental
Water	Included in rental	**Water**	Included in rental
Waste disposal	Included in rental	**Waste disposal**	Included in rental
	R111147.32		**R41081.42**
Consumables			
Jobcards	R 334.88	**Jobcards**	R137.54
Packet Labels	R 87.36	**Gummed labels**	R0.58
Bar code labels	R 20.16	**CT/MRI Envelopes**	R57.50
CDs + CD Sleeves	R214.48	**Laser film(CT)**	R520.00
Rimmage ribbon	R 8.96	**Report paper- Bond paper**	R39.33
CD label *(Rimmage transfer roll)	R 15.12	**Report paper- Letterheads**	R4.12
		Printer ink	R3.22
	R680.96		**R762.29**
OPERATING COSTS		**OPERATING COSTS**	
Telephone	8606.75	**Telephone**	5148.08
Insurance	R11745.912	**Insurance**	R11745.912
Security	Included in rental	**Security**	Included in rental
Laundry costs	R476.52	**Laundry costs**	R643.83

Internet	R 400.00		R 400.00
	R21229.18		**R17937.82**
EQUIPMENT COST		**EQUIPMENT COST**	
Maintenance Equipment	R89,149.00	**Maintenance Equipment**	0
Equipment cost	R 1,423,977.89	**Equipment cost**	687,883.58
Network costs	R21 620.00	**Network costs**	R 9,176.00
Software Maintenance	R14 400.00	**Software Maintenance**	R25228.30
Software	R 264,125.80	**Software**	
Additional costs-interest	R135,277.89	**Additional costs**	R65,348.94
Additional costs-	R25,091.95		
	R1,973,642.53		**R787,636.82**
Total cost/month	**R2,167,392.27**	**Total cost/month**	**R894,998.76**
Cost/patient excl equipment	**R3725.00**	**Cost/patient excl equipment**	**R5650.00**

APPENDIX D - IMAGING COST FOR CONVENTIONAL RADIOGRAPHY

COST OF IMAGING-CONVENTIONAL RADIOGRAPHY					
	CXR	CT	MRI	CONTRAST CT	CONTRAST MRI
HUMAN RESOURCES					
Head radiographers	R0.00	R 1.45	R 7.25	R 2.90	R 10.15
Senior radiographers	R 1.98	R 1.86	R 11.93	R 3.71	R 16.69
Junior radiographers	R 3.94	R 0.68	R 0.00	R 1.35	R 0.00
Student radiographers	R 1.88	R 0.00	R 0.00	R 0.00	R 0.00
Radiologists	R 11.42	R 143.82	R 269.79	R 143.82	R 269.79
Darkroom assistant	R 0.74	R 0.00	R 0.00	R 0.00	R 0.00
CONSUMABLES					
Jobcards	R 5.98	R 5.98	R 5.98	R 5.98	R 5.98
CT/MRI Envelopes	R 0.00	R 2.50	R 2.50	R 2.50	R 2.50
X-ray Envelops-438x362 (.100)	R 12.48	R 0.00	R 0.00	R 0.00	R 0.00
X-ray film(CR)	R 20.06	R 0.00	R 0.00	R 0.00	R 0.00
Laser film(CT)	R 0.00	R 28.72	R 0.00	R 57.44	R 0.00
Laser film(MRI)	R 0.00	R 0.00	R 114.88	R0.00	R 172.32
Developer	R 0.59	R 0.00	R 0.00	R 0.00	R 0.00
Fixer	R 0.49	R 0.00	R 0.00	R 0.00	R 0.00
Operating costs	R 25.00	R 20.00	R 21.00	R 20.00	R 21.00
Total cost/patient	R 84.56	R 205.01	R 433.33	R 237.70	R 498.43

APPENDIX E - IMAGING COST FOR PACS

COST OF IMAGING-PACS					
	PACS CXR	CT	MRI	CT CONTRAST CT	MRI CONTRAST MRI
HUMAN RESOURCES					
Head radiographers	R 0.00	R 1.30	R 9.75	R 3.25	R 13.00
Senior radiographers	R 3.44	R 4.65	R 34.86	R 11.62	R 46.48
Junior radiographers	R 3.45	R 0.00	R 0.00	R 0.00	R 0.00
Student radiographers	R 1.04	R 0.00	R 0.00	R 0.00	R 0.00
Radiologists	R 11.41	R 143.82	R 269.79	R 143.82	R 269.79
PACS administrator	R 8.84	R 14.82	R 26.26	R 14.82	R 26.26
Darkroom assistant					
CONSUMABLES					
CD Sleeves	R 0.89	R 0.89	R 0.89	R 0.89	R 0.89
CD	R 2.94	R 2.94	R 2.94	R 2.94	R 2.94
Rimmage Ribbon	R 0.16	R 0.16	R 0.16	R 0.16	R 0.16
CD label(transfer roll)	R 0.27	R 0.27	R 0.27	R 0.27	R 0.27
Operating costs	R 29.00	R 24.00	R 27.00	R 24.00	R 27.00
Total cost/patient	R 61.44	R 192.85	R 371.92	R 201.77	R 386.79

APPENDIX F-INCREMENTAL RIS COST

	PACS COST	CON COST	INCREMENTAL COST
RIS-Radiology information system			
Software Maintenance/upgrades incl. PACS	R 14,400.00	R 25,228.30	-R 10,828.30
			R 0.00
Viking capturing system(RIS)(hardware, licenses and anti-virus)	R 43,900.00	R 32,180.00	R 11,720.00
HUMAN RESOURCES			
Receptionist	R 54.05	R 54.05	R 0.00
			R 0.00
FURNITURE & EQUIPMENT			
Computer with PC	R 58,500.00	R 58,500.00	R 0.00
Desks	R 12,150.00	R 8,100.00	R 4,050.00
Chairs	R 7,191.00	R 4,794.00	R 2,397.00
Document scanner	R 116,000.00		R 116,000.00
Job card printer		R 8,000.00	-R 8,000.00
Bar code printer	R 16,800.00		R 16,800.00
Head phone for typists	R 1,200.00	R 800.00	R 400.00
UPS	R 6,000.00	R 3,000.00	R 3,000.00
Report printer		R 4,000.00	-R 4,000.00
Head phone for typists		R 800.00	-R 800.00
Label printer	R 4,300.00		
CONSUMABLES			
Packet Labels	R 0.64		R 0.64
Bar code labels	R 0.41		R 0.41
Jobcards		R 5.98	-R 5.98
Gummed labels		R 0.03	-R 0.03
TOTAL	R164,496.10	R144,662.36	R 19 833.74

APPENDIX G - CAPITAL COST

PACS COST	COST CXR	COST CT	COST MRI	COST CT CONTRAST	COST MRI CONTRAST
COST					
PACS SOFTWARE	R 912,000.00	R 912,000.00	R 912,000.00	R 912,000.00	R 912,000.00
EQUIPMENT					
CR cassettes	R 10,000.00	R0.00	R0.00	R0.00	R0.00
CT	R0.00	R 5,000,000.00	R0.00	R 5,000,000.00	R0.00
MRI	R0.00	R0.00	R 9,000,000.00	R0.00	R 9,000,000.00
Radiologists workstations	R 204,026.90	R 204,026.90	R 204,026.90	R 204,026.90	R 204,026.90
CD Publisher	R 239,205.00	R 239,205.00	R 239,205.00	R 239,205.00	R 239,205.00
QC Workstation	R 121,738.90	R 121,738.90	R 121,738.90	R 121,738.90	R 121,738.90
Server and hardware	R 337,982.86	R 337,982.86	R 337,982.86	R 337,982.86	R 337,982.86
RIS Consoles including software/hardware	R 618,736.51	R 618,736.51	R 618,736.51	R 618,736.51	R 618,736.51
X-ray unit	R 991,200.00	R0.00	R0.00	R0.00	R0.00
Single slot reader + Operator consoles	R 212,500.00	R0.00	R0.00	R0.00	R0.00
Training and labour(Radiology)	R 154,000.00	R 154,000.00	R 154,000.00	R 154,000.00	R 154,000.00
Training and labour(Hospital)	R 42,000.00	R 42,000.00	R 42,000.00	R 42,000.00	R 42,000.00
Network costs	R 21,620.00	R 21,620.00	R 21,620.00	R 21,620.00	R 21,620.00
Totals	R 2,953,010.17	R 6,739,310.17	R 10,739,310.17	R 6,739,310.17	R 10,739,310.17

CONVENTIONAL COST	COST CXR	COST CT	COST MRI	COST CT CONTRAST	COST MRI CONT
COSTS					
EQUIPMENT					
Conventional X-ray cassette(1)	R 5,500.00	R0.00	R0.00	R0.00	R0.00
CT	R0.00	R 5,000,000.00	R0.00	R 5,000,000.00	R0.00
MRI	R0.00	R0.00	R 9,000,000.00	R0.00	R 9,000,000.00
Laser printer	R 75,000.00	R 75,000.00	R 75,000.00	R 75,000.00	R 75,000.00
X-ray unit	R 991,200.00	R0.00	R0.00	R0.00	R0.00
Processor(Westville)-Axim	R0.00	R 120,000.00	R 120,000.00	R 120,000.00	R 120,000.00
Network costs	R 9,176.00	R 9,176.00	R 9,176.00	R 9,176.00	R 9,176.00
Totals	R 1,080,876.00	R 5,204,176.00	R 9,204,176.00	R 5,204,176.00	R 9,204,176.00

APPENDIX H- RADIOGRAPHER QUESTIONNAIRE

1. How many years of experience do you have in radiography?

   _____

2. How many years of PACS experience do you have?

   _____

3. PLEASE ENTER THE TIMES IN EACH STEP e.g. 8h00, 8h02

BEFORE PACS	**TIMES**
1. Register the patient	
2. Create job card	
3. Call patient for X-ray	
4. Change patient before X-ray	
5. X-ray patient for requested procedure	
6. Processing X-ray	
7. Check X-ray once processed	
8. Give X-ray to doc to check	
9. Send patient back to waiting room	

4.

WITH PACS **TIMES**	
1. Register the patient	
2. Create the job card	
3. Receive job card and scanned letter	
4. Call patient for examination	
5. Change patient before examination	
6. Perform X-ray	
7. Processing X-ray	
8. Check X-ray once processed	
9. Send X-ray to doc	
10. Change patient and send patient back to waiting room	
11. Patient sent to referring doctor	

5. Which system do you prefer? (Please select answer by shading within circle)

   O conventional radiography system O PACS

   Please state the reasons for your answer.

   _____

   _____

   _____

_____

_____

_____

6. What problems have you encountered with the PACS system?
   - O Difficult to learn and understand
   - O Not user friendly
   - O Lack of proper training
   - O Downtime occurs often
   - O other, please state your reasons

_____

_____

_____

_____

_____

_____

7. Would you prefer to revert to the conventional method of radiography?(Reason)
   O Yes O No

_____

_____

_____

_____

_____

8. What improvements would you suggest to improve the PACS system?

_____

_____

_____

_____

Thank you for your time.

APPENDIX I - PATIENT TIME SHEETS

TYPE OF EXAMINATION DONE: _____ Patient Identifier: _____

NAME OF RADIOGRAPHER: _____

Date: _____

Please fill out the form below as you go through your X-ray in the department.

This is for research purposes and will be totally anonymous.

Once completed, please return to the receptionist.

Thank you for co-operation in assisting with this study.

Patients sequence of events	**Times e.g. 8h30**	**Minutes waiting**
Please indicate the time you arrived at the X Ray department.		
Enter the time you are registered in reception		
How long did you wait before the X-rays were performed?		
What time were you called by radiographer?		
How long did the procedure take?		
Enter the time you finished the procedure/X-ray?		
If there was delays or repeats with X-rays please state the times		
Enter the time you was sent back to the waiting room-(waiting for films and report)		
Please indicate the time you was sent back to referring doctor - images transferred on PACS		

THANK YOU FOR YOUR TIME.

IF YOU WOULD LIKE THE INFORMATION GAINED FROM THIS REASEARCH PROJECT PLEASE LEAVE WRITE YOUR EMAIL ADDRESS BELOW.

_____

APPENDIX J -CONSENT

You have been asked to participate in a research study.

You have been informed about the study by SIVANI MOODLEY.

Your information provided will be strictly confidential and will by anonymous for the purpose of this study.

You may contact **Sivani Moodley at 0836534446** any time if you have questions about the research.

You may contact the Medical Research Office at the Nelson R Mandela School of Medicine at 031-260 4604 if you have questions about your rights as a research subject.

Your participation in this research is voluntary, and you will not be penalized or lose benefits if you refuse to participate or decide to stop.

If you agree to participate, you will be given a signed copy of this document and the participant information sheet which is a written summary of the research.

The research study, including the above information, has been described to me orally. I understand what my involvement in the study means and I voluntarily agree to participate.

_____ _____

Signature of Participant Date

_____ _____

Signature of Witness Date
(Where applicable)

_____ _____

Signature of Translator Date
(Where applicable)

APPENDIX K- INFORMATION SHEET

Study title: A Comparative Cost Analysis of Picture Archiving and Communications Systems (PACS) with Conventional Radiology in a Private hospital

Dear Participant

Introduction:
I am Sivani Moodley currently a Masters student at the Nelson Mandela School of Medicine. I am conducting research on the PACS system with regards to its benefits. In this study we want to learn about the time benefits of the picture archiving system as compared to the conventional system. We are inviting you to participate in this research study.

What is involved in the study – All radiographers from this private practice will be involved in this research. You will be expected to fill out the questionnaire which will be anonymous. It will require 20 minutes of your time and the results can be made available to you if you require.

Risks – There are no risks involved in this study.

Benefits – As a radiographer you can be able to contribute to the pool of knowledge for your profession and to make other radiographers aware of what systems exist.

The subject will be given pertinent information on the study while involved in the project and after the results are available.

Participation is voluntary, that refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and that the subject may discontinue participation at any time without penalty loss of benefits to which the subject is otherwise entitled.

Confidentiality: Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.
Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the Research Ethics Committee and the Medicines Control Council (where appropriate).
If results are published, may lead to individual / cohort identification.

Contact details of researcher/s – Sivani Moodley

-083 653 4446.

Contact details of REC administrator and chair – for reporting of complaints / problems.

Medical Research Office at the Nelson R Mandela School of Medicine at 031-260 4604

APPENDIX L – PERMISSION LETTER

Miss Sivani Moodley
35 Silverglen Dr
Chatsworth,
4092

Lake, Smit and partners
St Augustines Hospital
Chelmford Rd,
Durban

Dear Sir

RE: Request permission to conduct a cost analysis study

I am currently studying my Masters in Public Health at the Nelson Mandela School of Medicine. I wish to undertake a study at your radiology practice, St Augustine's Hospital. The study will be a comparative cost analysis of picture archiving and communications systems in radiology and conventional radiology. The study will be a micro-costing each step in the workflow with film and film less radiology. This will only be performed for a single CT case and a general X-ray. I will also observe and use self administered questionnaires for the radiographers in order to obtain information with regards to workflow and PACS.

The data obtained for this study will be strictly confidential and will only be used for academic purposes. There will not be any public disclosure of the data obtained for this study.

Hoping for a favorable outcome.
Yours sincerely
Sivani Moodley

APPENDIX M – RADIOLOGY PRACTICE APPROVAL VIA EMAIL

EMAIL FOR APPROVAL OF STUDY FROM THE PRACTICE

I sent out an email to all partners just before I went on leave, asking them if anybody objected.

I only checked all my emails today and I have received no objections, so I assume agreement from all partners.

Please take it as official – we have no problem with the research project.

Thanks

Ix

From: Karen Roper [mailto:karen@lakesmit.co.za]

Sent: 27 August 2007 14:58

To: Sivani Moodley

Cc: Barry Isaacs

Subject: Fw: Yes

----- Original Message -----

From: Karen Roper

To: Sivani Moodley

Sent: Wednesday, August 22, 2007 4:22 PM

Subject: Yes

Hi Sivani

Partners have agreed to your request - Dr Mann says Dr Ix was supposed to tell you.

Thanks

Karen Roper

Radiographic Manager

Lake Smit & Partners.

Tel: 031 - 2773300

Cell: 082 561 8102

Fax: 031 - 2014410

APPENDIX N- WESTVILLE HOSPITAL APPROVAL LETTER

Life Group
HEALTH CARE

Westville Hospital
7 Spine Road, Westville 3630
PO Box 457, Westville 3630
Telephone +27 31 251 8911
Facsimile +27 31 265 0902
www.westvillehospital.co.za

30 June 2009

TO WHOM IT MAY CONCERN

This letter serves to confirm that Miss Sivani Moodley has been granted permission by Lake, Smit & Partners to conduct her study in their Radiology department, and that we have no problem with her conducting her study at the hospital.

Yours faithfully

JANE VAN DER MERWE
HOSPITAL MANAGER

APPENDIX O- ST AUGUSTINES HOSPITAL APPROVAL LETTER

107 Chelmsford Road, Durban, 4001, South Africa

26th June 2009

Dear Sivani Moodley

STUDY TO BE CONDUCTED IN RADIOLOGY

This letter stands to confirm that your request to conduct a study in radiology has been approved by Augusta Dorning, The Hospital Manager of S. Augustines' Hospital.

Yours sincerely

HEATHER SKINNER
PA to Hospital Manager

Tel: 031 268 5629
Fax: 031 201 4598
heather.skinner@ [illegible]care.co.za

Netcare Hospitals (Pty) Ltd T/A Netcare St Augustines Hospital

APPENDIX P-UKZN APPROVAL LETTER

UNIVERSITY OF
KWAZULU-NATAL

03 March 2009

Professor Indres Moodley
Department of Public Health Medicine
NRMSM

PROTOCOL: "A Comparative Cost Analysis of Picture Archiving and Communications Systems (PACS) with Conventional Radiology in the Private Sector" Sivani Moodley, 206500269, Master of Public Health. Protocol number: MPH 015/08

Dear Professor Moodley

The Postgraduate Education Committee ratified the approval of the above mentioned study on 03 March 2008.

Please note:

The Postgraduate Education Committee must review any changes made to this study.

The study may not begin without the approval of the Biomedical Research Ethics Committee.

May I take this opportunity to wish the student every success with the study.

Yours sincerely

Dr A Voce
Dean's Assistant: Coursework Programmes
Postgraduate Administration

CC: Ms S Moodley

Nelson R Mandela School of Medicine, College of Health Sciences,
Medical Research Administration

Postal Address: Private Bag 7, Congella 4013, South Africa

Telephone: +27 (0)31 260 4495 Facsimile: +27 (0)31 260 4529 Email: [illegible] Website: [illegible]

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

APPENDIX Q- BREC APPROVAL LETTER

UNIVERSITY OF
KWAZULU-NATAL

RESEARCH OFFICE
Biomedical Research Ethics Administration
Westville Campus, Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604769 - Fax: 27 31 2604609
email: BREC@ukzn.ac.za
Website: http://research.ukzn.ac.za/ResearchEthics/BiomedicalResearchEthics.aspx

28 September 2010

Ms. S. Moodley
Department of Community Health
Nelson R. Mandela School of Medicine
University of KwaZulu- Natal

Dear Ms Moodley

PROTOCOL: A comparative Cost analysis of Picture Archiving and Communications Systems (PACS) with Conventional Radiology in the Private Sector. Department of Community Health, Ms S Moodley. REF: BE036/09.

RECERTIFICATION APPLICATION APPROVAL NOTICE

Approved: 15 July 2010
Expiration of Ethical Approval: 14 July 2011

I wish to advise you that your application for Recertification dated 25 August 2010 for the above protocol has been noted and approved by a sub-committee of the Biomedical Research Ethics Committee (BREC) for another approval period. The start and end dates of this period are indicated above.

If any modifications or adverse events occur in the project before your next scheduled review, you must submit them to BREC for review. Except in emergency situations, no change to the protocol may be implemented until you have received written BREC approval for the change.

The approval will be ratified by a full sitting of the Committee at a meeting to be held on 09 November 2010.