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Telemedicine for Primary Healthcare

Development of a decision support framework for a clinical pull approach to telemedicine implementation

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Final year project presented in partial fulfilment of the requirements for the degree of Bachelors of Industrial Engineering at Stellenbosch University.

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November 2009

DECLARATION

I, the undersigned, hereby declare that the work contained in this final year project is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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MJ Treurnicht Date

ECSA EXIT LEVEL OUTCOMES REFERENCES

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SYNOPSIS

Telemedicine refers to the delivery of healthcare services by means of information and communication technology (ICT). Telemedicine, being an ICT, has appealed to engineers as an opportunity for innovative development, making technology the primary driver of telemedicine development. This technology-push model where engineers pursue challenging technological goals primarily does not guarantee appropriate and quality healthcare. It is therefore also necessary to assess the true need of the population and develop a comprehensive framework to implement and develop technology only as a means and not a goal in itself.

The Medical Research Council (MRC) and Stellenbosch University (SU) department of Electrical and Electronic engineering jointly developed a telemedicine workstation, specifically for primary healthcare in South Africa. This workstation ensures effective communication between healthcare facilities to capture and send diagnostic data of patients between the facilities. Although the technology-push approach followed was successful, further development of the workstation requires a clinical-pull approach to address the specific needs of the population.

The purpose of this project is therefore to support decision making with respect to the future development and implementation of telemedicine workstations. A decision support framework is developed and validated using the MRC/SU telemedicine workstation as a reference.

The decision support framework developed in this project can be used as a tool for developing regional telemedicine strategy. Future use of this tool requires the population of a data warehouse developed in this project by extracting, transforming and loading data from clinical data sources. The data warehouse serves as a platform for specification analysis and mathematical models to evaluate possibilities for telemedicine in the region.

The data sources for this project are health information systems and patient files. Data are extracted from the patient files, transformed and loaded into a database, developed for this purpose. Data from three facilities (Grabouw Community Health Centre, Robertson- and Ceres Hospitals) in the Western Cape are used, representing a region relevant for telemedicine implementation. The data warehouse is populated from the data loaded into the database to package the data in a usable format for data analysis. Diagnosis data together with telemedicine device profiles are used in the data analysis.

The possibility of telemedicine implementation at a facility is evaluated using mathematical models. Engineering economics are used to determine the economic feasibility of a basic telemedicine workstation at a chosen facility. Potential telemedicine device utilisation at this facility is evaluated using mixed integer programming.

This study serves as a pilot project to develop and validate the decision support framework. The scope of this project is limited to a specific region suitable for telemedicine workstation implementation. This project is therefore not aimed to provide only general solutions for telemedicine. It is a generic tool to enable decision makers to implement telemedicine as a needs driven technology in specific regions in South Africa.

OPSOMMING

Daar word na telemedisyne verwys as die lewering van gesondheidsorgdienste deur die gebruik van inligting- en kommunikasietegnologie (IKT). Telemedisyne, as 'n IKT, het die verbeelding van ingenieurs aangegryp as 'n geleentheid vir innoverende ontwikkeling wat tegnologie die primêre dryfveer vir telemedisyne wêreldwyd gemaak het. Hierdie *tegnologie-druk* model waar ingenieurs uitdagende tegnologiese doelwitte nastreef verseker egter nie noodwendig toepaslike en gehalte gesondheidsorg nie. Dit is nodig om die ware behoefte van die bevolking te bepaal en 'n raamwerk te ontwikkel sodat tegnologie slegs 'n middel tot 'n doel bly en nie die doel op sigself nie.

Die Mediese Navorsingsraad (MNR) het in samewerking met die Stellenbosch Universiteit (US) se departement van Elektriese- en Elektroniese ingenieurswese 'n telemedisyne werkstasie ontwikkel, spesifiek vir primêre gesondheidsorg in Suid-Afrika. Hierdie werkstasie is veronderstel om telemedisyne konsultasies oor 'n afstand te bewerkstellig, deur die vasvang en stuur van diagnostiese data tussen fasiliteite met behulp van IKT. Om aan die spesifieke behoeftes van die populasie te voldoen is dit nodig dat verdere ontwikkeling van die werkstasie op 'n *kliniese-trek* benadering gebaseer word, alhoewel die volg van 'n *tegnologie-druk* benadering aanvanklik geslaagd was vir die eerste iterasie van ontwikkeling.

Die doelwit van die projek is om besluitneming te ondersteun met betrekking tot toekomstige ontwikkeling en implementering van telemedisyne werkstasies. 'n Besluitnemings-ondersteuningsraamwerk is ontwikkel en gevalideer aan die hand van die MNR/SU telemedisyne werkstasie as verwysing te gebruik.

Die besluitnemingsondersteuningsraamwerk wat in hierdie projek ontwikkel is, is geskik om as hulpmiddel gebruik te word vir die ontwikkeling van telemedisyne implementering strategie op streeksvlak. Toekomstige gebruik van die gereedskap vereis die populasie van die datastoor wat in die projek ontwikkel is deur onttrekking, verwerking en laai van data vanuit kliniese databronne. Hierdie datastoor dien as 'n platform vir spesifikasie analise en wiskundige modelle om moontlikhede in telemedisyne te evalueer in streeksverband.

Die databronne wat vir hierdie projek gebruik is, is gesondheidsinligtingstelsels en pasiëntlêers. Data word onttrek vanuit pasiëntlêers, verwerk en gelaai in 'n databasis wat vir hierdie doel ontwikkel is. Data van drie fasiliteite, (Grabouw daghospitaal, Robertson- en Ceres hospitale) in die Wes-Kaap word gebruik, wat 'n streek geskik vir telemedisyne implementering is. Die

datastoor word gepopuleer met data wat gelaai word in die databasis sodat data verpak kan word in ’n bruikbare formaat vir data analise. Diagnose data tesame met telemedisyne randapparaat aanwendings moontlikhede word gebruik in die analise.

Die moontlikheid van telemedisyne implementering word by ’n fasiliteit evalueer deur middel van wiskundige modelle. Ingenieurs ekonomie word gebruik om die ekonomiese lewensvatbaarheid van ’n basiese telemedisyne werkstasie by ’n spesifieke fasiliteit te ondersoek. Potensiële telemedisyne randapparaat benutting by hierdie fasiliteit word evalueer met behulp van gemengde heeltal programmering.

Hierdie studie dien as ’n loodsprojek om ’n besluitneming ondersteuningsraamwerk te ontwikkel en valideer. Die omvang van die projek is beperk tot ’n spesifieke streek geskik vir telemedisyne implementering. Dus is die projek nie beperk tot algemene oplossings vir telemedisyne nie. Dit is ’n generiese instrument om besluitnemers te bemagtig om telemedisyne as ’n behoefte gedrewe tegnologie in spesifieke streke van Suid-Afrika te implementeer.

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GLOSSARY

CHC	Community Health Centre
DHIS	District Health Information System
DSS	Decision Support System
ICT	Information and Communication Technology
MRC	Medical Research Council
PHC	Primary Health Care
PREHMIS	Patient Record and Health Management Information System
Clinical-pull	The demand-pull approach specific to healthcare applications
Demand-pull	An approach where demand defines the need for a product
Headcount	Number of people (heads) counted for a specific classification
Technology-push	An approach where technology is pushed onto the market
Telemedicine system	The entire system that interacts with the telemedicine workstation, including the healthcare professionals
Telemedicine workstation	Telemedicine equipment, excluding the persons interacting with the workstation

1 INTRODUCTION

1.1 BACKGROUND

Telemedicine is defined in the National Library of Medicine as the "delivery of health services via remote telecommunications. This includes interactive consultative and diagnostic services" (Medline, 2009).

Formal projects for the implementation of telemedicine for primary healthcare in South Africa were initiated approximately a decade ago when, amongst others, the Department of Health assigned a task team to develop a strategy for telemedicine primary healthcare in South Africa. The South African government is committed to providing basic healthcare to all South African citizens, not as a privilege, but as a fundamental right, for the many who lack the most basic services. To do this, the government identified telemedicine as a strategic tool to improve delivery of equitable healthcare and educational services (Benatar, 2004).

Recently the Medical Research Council (MRC) partnered with the Department of Health for the purpose of advancing telemedicine. One of the projects arising from this initiative was the development of a telemedicine workstation to enable the communication of diagnostic information between community health centres (CHC) and hospitals as well as between district and regional hospitals (Fortuin-Abrahams & Molefi, 2006).

This workstation was technically developed and completed as a joint effort between the Medical Research Council (MRC) and the Department of Electrical and Electronic Engineering of Stellenbosch University. It was installed at the Grabouw CHC in 2004/2005 on a pilot scale (Fortuin-Abrahams & Molefi, 2006).

At the time of the introduction of the workstation, the predominant opinion of the participating healthcare professionals was that the workstation was easy to use and that it was well integrated into the workflow. The patients did not feel intimidated by the workstation and those who utilised it, were satisfied with the quick response. From a technical perspective the workstation functioned according to specification (Fortuin-Abrahams, 2006). This pilot study presented strong positive evidence supporting the potential of the concept even though all challenges were not conclusively resolved, eventually leading to the pilot being suspended. The healthcare and research funding authorities realised the potential and initiated the next step, namely a research and implementation unit within the Medical Research Council. At a later stage, the department of Industrial and Systems Engineering of Stellenbosch University became involved in this project as a part of the research and development initiative by the MRC and a network of professional partners.

The business strategy of pushing a product onto the market is referred to as a *technology-push* approach. This is most often done without thoroughly considering whether or not it satisfies a user need. The *demand-pull* approach is on the other end of the spectrum. Within the context of telemedicine this is also referred to as a *clinical-pull* approach (Wyatt, 1996). Part of the eventual suspension of the pilot implementation of the telemedicine workstation at Grabouw CHC could possibly be attributed the fact that the pilot implementation closely following the *technology-push* phase was not preceded by a formal needs assessment.

1.2 PROBLEM STATEMENT

The current telemedicine workstation was implemented in the healthcare system by a *technology-push* approach. To enhance the effectiveness of this current telemedicine technology, it is necessary at this stage to follow a pull approach to assure that the technology addresses the needs of primary healthcare in South Africa. .

Engineers at Stellenbosch University are envisaging further telemedicine development to enhance the service level of the current workstation. The development team are however dedicated to develop only relevant technologies that will be implemented and used effectively.

MRC project managers are also concerned that synergy between the telemedicine workstation and the needs of the country's people may not be maximised with the current design. At this point in time, a needs assessment, executed with a pull approach is perceived to be an essential step in the national implementation of telemedicine. The technological development and the implementation of the workstation can then be directed according to the needs of the South African population.

1.3 GOAL AND OBJECTIVES

The purpose of this project is to support decision making with respect to the future development of telemedicine workstations, based on the clinical needs, hence following a *clinical-pull* approach with respect to the introduction of telemedicine workstations.

In order to accomplish this goal, the following objectives are set:

- Develop a decision support system to enable decisions with respect to the assembling of telemedicine workstations for a specific region.
- Collect and analyse data to identify and assess needs of stake-holders, including
    - Healthcare professionals and patients
    - Design engineers
    - Telemedicine project managers
- Assess the needs of end users (patients) to direct technology development
- Identify gaps between needs addressed by existing technology and the actual need
- Evaluate appropriateness of available equipment

1.4 SCOPE

The objectives of a final year project are fundamentally to solve a problem in a given time frame, using industrial engineering tools and techniques. It is therefore important to scope the project according to the time and resources available. The data collection and analysis in this project are restricted to enable the student to build a model for decision making from a sample of data.

It is expected that the needs for a telemedicine workstation are not the same in the different provinces and PHC facilities in South Africa. For example rural districts in the Eastern Cape will not have the same needs as the urban Cape Town Metropolitan district. The data for this project are collected at three different facilities in the Western Cape, with the goal of establishing tools and a method to determine the telemedicine needs profile in other regions.

Data collection can be done using different methods. The method used in this project is the collection of patient information from medical files and books. Interviews and questionnaires would also gather valuable data but are beyond the scope of this project.

1.5 METHODOLOGY

To accomplish the goal of this project, a clinical decision support system (DSS) is developed. According to the National Library of Medicine a clinical DSS is “computer-based information systems used to integrate clinical and patient information and provide support for decision-making in patient care” (Medline, 2009). The framework for this system is a culmination of the respective DSS and data warehouse design frameworks by Turban (2005) and Kimball (2002) respectively. It is specifically adapted to describe the approach and outcomes of this project as shown in Figure 1.

As shown on the right hand side of Figure 1, the adoption of telemedicine technology is influenced by policy decisions makers, medical practitioners, patients as well as technology developers. The focus of this project is to assist technology developers to base development decisions on patient needs. They are concerned about the usage trends as well as the cost of the technology, as addressed by the respective data analysis approaches shown in Figure 1. The data input for these analyses are taken from a data warehouse, which is populated by data that was extracted, transformed and loaded (ETL) from physical patient files and other transactional systems, as shown on the left hand side of Figure 1.

To convert the data gathered into useful information, firstly the synchronisation of the needs versus the technological capability of the workstation was assessed in the form of a trend analysis. The second part of the method provides for an economic analysis to present the economic implications of the appropriate technologies identified in the first part. These two areas are then integrated into a linear programming model to present an appropriate service level versus cost solution and ensure more effective telemedicine implementation.

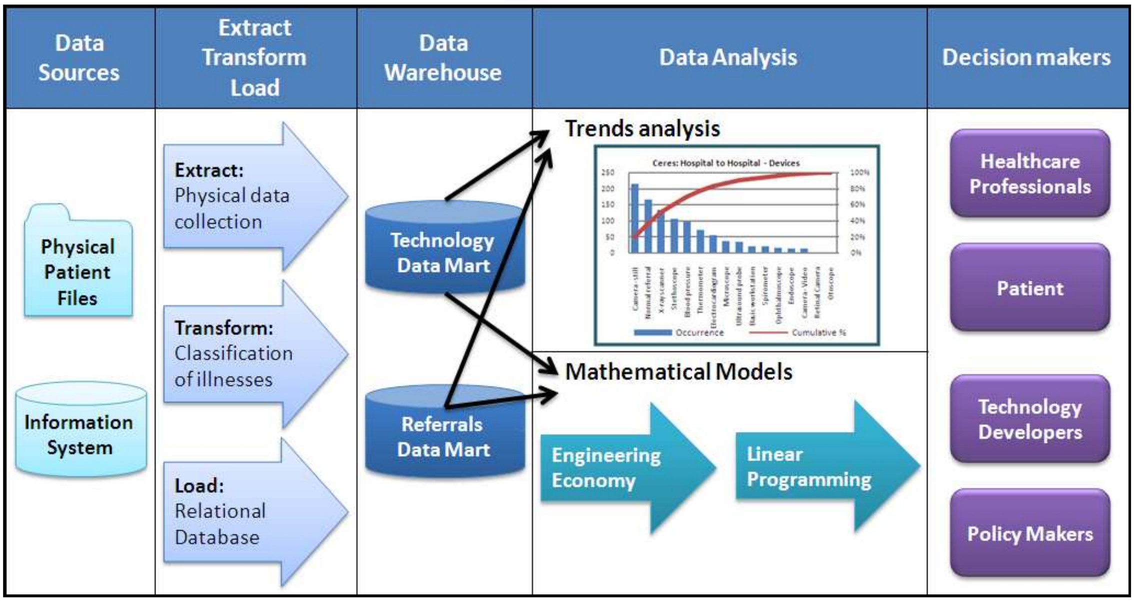


FIGURE 1: FRAMEWORK FOR A CLINICAL TELEMEDICINE DECISION SUPPORT SYSTEM

The remainder of this report is devoted to a discussion of rationale and practice behind the design of this DSS, the approach followed in developing this system as well as results obtained from the data analysis done in the DSS. To conclude this report, the application of this DSS and future developments are anticipated.

2 TELEMEDICINE

Telemedicine can be defined in broad terms as medicine at a distance (‘Telemedicine’ 2006). It includes a comprehensive range of medical activities such as diagnosis, treatment and prevention of diseases, education of those giving and receiving health-care as well as research activities. Telecare and telehealth are related concepts to telemedicine. Telecare refers to the nursing and community support that is provided over a distance to a patient. Telehealth on the other hand refers to public health services that are delivered over a distance to people who wish to maintain their health. Telemedicine, telecare and telehealth are modes of healthcare service delivery that strive to advance healthcare by transferring information about health related issues from one location to another. Information transfer is made possible using a telecommunications network (Craig & Patterson, 2005).

The history of telemedicine can be traced back to as far as the mid-19th century. Telegraphy as well as postal services served as media to enable medical services to be rendered over a distance. Modern telemedicine practice has the advantage of more sophisticated telecommunication technology. Television broadcasting serves as an effective medium for educational purposes. Medical documentaries create healthcare awareness among ordinary people, enabling them to take responsibility for their own health. Since the latter part of the 20th century the internet emerged as an important development tool promoting global communication. In the telemedicine context the public is increasingly seeking specialised information concerning both diagnosed and perceived health conditions. Medical data can be transmitted through the internet from one location to another. Some of the most significant, recent developments in telecommunication technology are mobile phones and satellite communications. With all these resources for telecommunication, telemedicine is an expanding field with a growing number of applications (Craig & Patterson 2005).

2.1.1 TYPES OF TELEMEDICINE

Different applications of telemedicine can be subdivided into the following categories. The interaction between the client and the specialist as well as the type of information being transmitted forms the basis of the categorisation (Craig & Patterson 2005:5). The interaction between the client and the specialist is referred to as a consultation. More specifically in telemedicine, this consultation over a distance could be termed a teleconsultation. There are two types of consultations, namely synchronous and asynchronous. Asynchronous consultations, also referred to as pre-recorded or store-and-forward consultations involves data being captured, stored and transmitted at a later stage. Synchronous or real-time consultation refers to an interaction between the client and the specialist at the same point in time resulting in live interaction (Ferguson 2006:221).

The information transmitted between the different nodes of the network can be any data suitable for sending via the telecommunications networks. This data includes among others text, audio, still images, and video files. The different types of data can be applicable to both types of consultations. The choice of consultation type is dependent on factors such as quality, desired effectiveness and availability of specialists (Ferguson 2006:222).

Asynchronous consultations can be effected in numerous ways. They include in the most basic form health related questions sent via letters to a magazine and answered by a specialist in a following edition. More contemporary examples include questionnaires completed by a patient and sent via email. Promising new developments provide for patients to submit ECG files in acute cases to a healthcare centre facilitated by inexpensive specialist software. The advantage of this type of consultation is that the sender and receiver do not have to be present at the same time during the consultation. This way of communication is however unsuitable for emergency situations because of the uncertainty of appropriate lead time response. There is also a considerable variance in the quality of services rendered (Ferguson 2006:222).

Synchronous consultation on the other hand could be a simple phone call where medical data is discussed or even a more detailed and complex videoconference. The quality of home based care synchronous consultations is largely dependent on the patient’s ability to communicate symptoms from self examination. At present the equipment for videoconferencing requires a reliable and fast data connection. The requirement that both the patient and practitioner should be available at a specific time could impose a number of difficulties. Another disadvantage is that a synchronous telemedicine consultation generally takes a longer time than a normal, face-to-face consultation (Ferguson 2006:222).

2.1.2 TELEMEDICINE IN RURAL AREAS

Quality healthcare is a significant challenge in developing countries. Telemedicine has proven to be a rather effective solution in bringing quality healthcare to isolated communities. The need for quality healthcare in rural areas is much larger than in urban communities. The challenges to implement telemedicine systems in these areas are however also significantly larger. Many rural areas in developing countries do not have access to electricity, and therefore telephone networks and computers are rare. Another important factor is the lack of an efficient transport system which both magnifies the need for telemedicine and constrains appropriate maintenance. Health personnel in these areas are trained specifically to address the immediate needs and are mostly not trained technologically. (Martinez et al. 2008:13-14).

2.1.3 TECHNOLOGY PUSH VERSUS CLINICAL PULL IN TELEMEDICINE

Engineers worldwide are inspired by the opportunities available in telemedicine development and healthcare. Engineers often develop new technologies based primarily on innovations and not on the need for the technology. As mentioned in chapter one, this is called a technology-push approach. This approach is sound in the early stages development where novel applications of new technologies are unproven and effective implementation is not a key priority yet.

It is vitally important to consider the needs of the system's users in developing technology for the purposes of implementation. Developing technologies based on a needs analysis can also be referred to as a clinical-pull approach. In the pull approach, the technologies are only developed if there is a need for it. This approach ensures that the technologies developed will be implemented and will be relevant to the needs identified. Not every country in the world has similar healthcare profiles and therefore telemedicine must be implemented appropriately according to the needs of each individual country. Therefore it is essential that telemedicine systems and models be revised according to the needs of each location for effective implementation. The clinical-pull approach must be followed at some stage in the implementation of telemedicine at a new country or location with unique needs.

Following a technology push approach has numerous benefits. However, this technological development should be supported by a needs assessment at the appropriate times in the development cycle to ensure application appropriateness.

3 TELEMEDICINE DECISION MAKERS IN SOUTH AFRICA

The decision support system is focused on providing tools for telemedicine decision makers. It is therefore important to identify who the decision makers and stakeholders are for telemedicine implementation and development in South Africa. This chapter contains a study of the decision makers, determining the outcomes for telemedicine in South Africa.

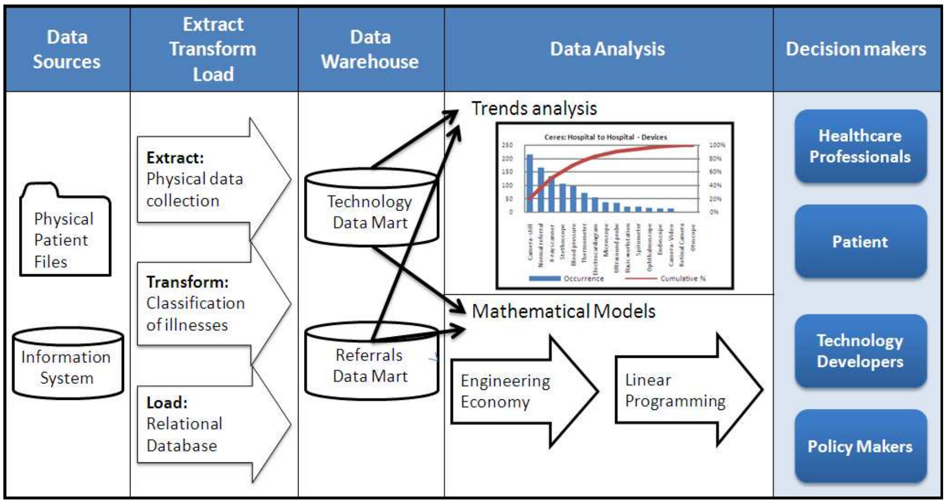


FIGURE 2: CLINICAL TELEMEDICINE DSS FRAMEWORK – DECISION MAKERS

3.1 HEALTHCARE DECISION MAKERS

3.1.1 PRIMARY HEALTHCARE IN SOUTH AFRICA

Generally primary healthcare (PHC) refers to the first contact a patient, requiring medical attention would have with a health professional ('Primary Health Care', 2006). The Alma-Ata declaration defines primary healthcare as "essential healthcare based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost that the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination" (WHO, 1978).

Being the first level of contact the national health system has with the community, primary healthcare reflects and evolves from the characteristics of the country. Economic conditions, socio-cultural and political characteristics of a country all influence primary healthcare. Each country is unique in its social, economic and political characteristics, primary healthcare is therefore based on relevant social realities, public health experience as well as biomedical and health research (Alma-Ata declaration WHO, 1978).

The Alma-Ata declaration that forms the foundation of primary healthcare in the world was signed in 1978 by 134 countries in Kazakhstan. South Africa was however not one of these countries who signed the declaration. In 1978 South Africa was in a pariah state following the Soweto uprising in 1976. The country was driven by the apartheid government whose political ideology was the complete antithesis of the principles of primary healthcare. There were however pioneers like Dr Sydney Kark who established community health centres in the late 1940's and early 1950's. These initiatives were prototypes of the primary healthcare approach, but were unfortunately undermined by the apartheid government (Kautzky & Tollman, 2008).

The apartheid era was a dark period for South Africa. Primary healthcare was affected to a large extent by the apartheid developments. The two apartheid developments that did the most damage to the country's healthcare were the racial fragmentation of the health services and the deregulation of the health sector. So-called 'ethnic homelands' were defined and citizenship was involuntarily designated to Africans. Health and other public services were provided for these homelands. They were however poorly organized and inefficient, struggling to provide adequate medical and healthcare (Kautzky & Tollman, 2008).

During and prior to apartheid, committed practitioners and the church made a meaningful contribution to healthcare in South Africa. Missionaries from other countries tried to fill the gap between rural and urban healthcare. Although many of the mission hospitals were highly competent, the overwhelming demand was too much for these hospitals (Kautzky and Tollman, 2008).

In 1994, shortly after the apartheid was ended, the new political party, the African National Congress (ANC) presented a National Health Plan to the public. The new National Health Plan was framed on the Alma-Ata declaration and designed consulting technical experts at the WHO and UNICEF. This promised a new and brighter future to those impaired by the apartheid government's health regulations (Kautzky & Tollman, 2008).

Much can be said about the implementation of the 1994 National Health Plan. The expectations and enthusiasm for the transformation of the system were very high. The policies for the implementation of the plan as well as the management of PHC and social services were problematic. This however was a critical step in primary healthcare in South Africa. Although many challenges and failures occurred the health plan has and is being shaped to conform to the Alma-Ata vision of health for all (Kautzky & Tollman, 2008).

It is 15 years since 1994 and although primary healthcare has come a long way through the years, witnessing many successes and failures, primary healthcare in South Africa is still a considerable challenge. It is vitally important for primary healthcare in South Africa to call on the same innovative culture from the 1950's, building a sustainable health sector providing health for all (Kautzky & Tollman, 2008).

It is clear that primary healthcare is not cheap and requires considerable investments from government. The opportunities to improve healthcare have never been as good as it is currently with the rapid growth of technology especially in the biomedical and health fields. The World Health Organization dedicated their Health review of 2008 to primary healthcare to inspire and call those to new heights in healthcare. As Dr Margaret Chan says, "the time is ripe, now more than ever, to foster joint learning and sharing across nations to chart the most direct course towards health for all" (World Health Report WHO, 2008).

3.1.2 PRIMARY HEALTHCARE FACILITIES IN SOUTH AFRICA

Primary healthcare challenges in South Africa are understood better by assessing the medical facilities in South Africa. As illustrated in Figure 3, there are different levels of medical facilities in South Africa. The pyramid in the figure ranks these facilities according to their speciality level.

Medical facilities are categorised into different levels. The district hospital is defined as a facility offering a range of outpatient and inpatient services (Cullinan, 2006). It has a capacity of between 30 and 200 beds, 24h emergency service and an operating theatre. There are 253 district hospitals in South Africa (Monitoring and evaluation directorate, 2008).

The regional hospitals are defined as a facility providing care that requires the intervention of a specialist and general practitioner. There are 66 regional hospitals in South Africa. The tertiary or central hospital is defined as a facility that provides specialist and sub-specialist care. There are 15 tertiary hospitals in South Africa. The tertiary hospital is a referral hospital for the regional hospitals, and the regional hospital is a referral hospital for the district hospitals. There are also 54 specialised hospitals in South Africa. These hospitals provide specialised care to patients, e.g. psychiatric hospitals (Monitoring and evaluation directorate, 2008).

Community health centres are smaller than hospitals. These centres mostly provide day care, and most centres have a 24h emergency unit. In most cases CHC's have general practitioners in either fulltime or part time employment.

Clinics are strictly day time facilities. Clinics rarely have general practitioners on their staff and mostly make use of the 'visiting doctor' structure. Professional nurses have the highest authority in the clinics and together with the nurses and other administration staff provides basic medical services. Mobile clinics offer similar services to the clinics. These clinics are run from little buses that drive to remote rural locations where the people do not have access or transport to the clinic.

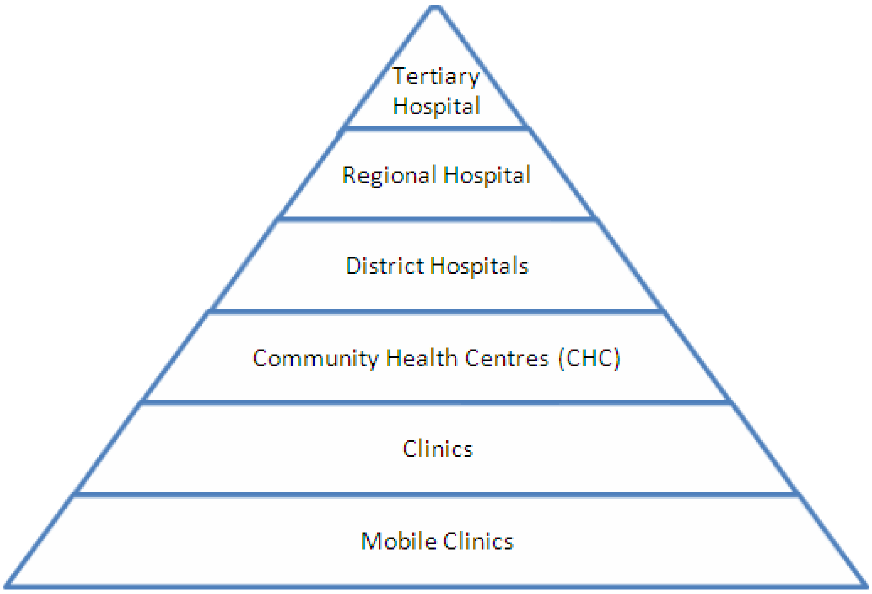


FIGURE 3: MEDICAL FACILITIES IN SOUTH AFRICA

3.1.3 DISEASES IN SOUTH AFRICA

South Africa is one of countries in the world with the highest burden of diseases. The HIV prevalence in South Africa is among the highest in the world (Kautzky & Tollman 2008). The high tuberculosis statistics are related. In Table 1 can be seen that HIV and tuberculosis is prevalent in South Africa. It should be noted that HIV is often the root cause of several other causes of death such as infectious diseases and others.

TABLE 1: THE TEN LEADING UNDERLYING NATURAL CAUSES OF DEATH, 2006

Causes of death (based on the tenth revision, International Classification of disease, 1992)	Rank	Number	%
Tuberculosis (A15 – A19)	1	77 009	12.7
Influenza and pneumonia (J10 - J18)	2	52 791	8.7
Intestinal infectious diseases (A00 – A09)	3	39 239	6.5
Other forms of heart disease (I30 – I52)	4	26 628	4.4
Cerebrovascular diseases (I60 – I69)	5	25 246	4.2
Diabetes mellitus (E10 – E14)	6	19 549	3.2
Chronic lower respiratory diseases (J40 – J47)	7	15 823	2.6
Certain disorders involving the immune mechanism (D80-D89)	8	15 736	2.6
Human immunodeficiency virus (HIV) disease (B20 – B24)	9	14 783	2.4
Ischaemic heart diseases (I20 – I25)	10	13 025	2.1
Other natural causes		254 741	42.0
Non-natural causes		52 614	8.7
All causes		607 184	100

Source: Statistics South Africa, 2006

The high burden of disease in South Africa is the primary cause of fully utilised or capacity constrained hospitals (Söderlund, 1999). The bed utilisation rate for tertiary hospitals 2005/2006 were 72.2% (Monitoring and evaluation directorate, 2008). Telemedicine could possibly reduce the utilisation of healthcare professionals and hospitals by allocating resources more effectively.

3.2 TELEMEDICINE SYSTEMS FOCUS

According to Taylor (2005) in implementing telemedicine systems it is necessary to determine whether it is safe, practical and worthwhile. The focus should be on the system, service and healthcare that are provided. Kastania (2008) confirms this and further identifies the following goals for applying telemedicine in primary healthcare:

- The specialist should give immediate and complete participation in the treatment of the incident that can be treated only partially by the general practitioner
- Estimations of diagnosis, therapy and transfers of the patient to secondary care services should be combined
- Socio-economic consequences should be reduced in the family and society of a patient
- Technical training of general practitioners and other healthcare professionals

According to Kastania (2008) a primary healthcare telemedicine system should consist of a physician, basic diagnostic devices, the necessary equipment materials to handle emergencies and telephone devices. A matrix of telemedicine devices relevant for medical specialisation areas are illustrated in Table 2.

TABLE 2: MATRIX OF TELEMEDICINE DEVICES AND MEDICAL SPECIALISATION AREAS

Devices	Cardiology	Gynaecology	Radiology	Paediatrics	Ophthalmology	Dermatology	Pathology	Ear/Nose/Throat
Camera, still	X	X	X	X	X	X		X
Camera, video	X	X	X	X	X	X		X
Stethoscope	X	X		X				
Electrocardiogram	X			X				
Colposcope		X						
Ultrasound probe	X	X	X					
X-ray scanner / digital x-ray			X	X				
Doppler flow measurement device	X							
Retinal Camera					X			
Otoscope				X				X
Ophthalmoscope				X	X			
Dermascope				X		X		
Spirometer	X			X				
Microscope							X	

Source: AMD Telemedicine (2009)

3.3 POLICY MAKERS

The South African national department of health has identified telemedicine as a key technology to improve health systems in South Africa. Recent improvements in telecommunications resulting in digital globalisation have created networks connecting the urban communities of the country. There is an acute awareness that this communications network enabling development on a wide front is not available to rural communities. This includes the potential for telemedicine. Part of the strategy is to develop local expertise and sufficient skills to support implementation as well as the utilisation of opportunities such as mobile network expansion (NHIS 2001).

Key deliverables identified by government include:

- Functional Clinical Services to be provided in rural areas
- Rural healthcare professionals to be educated and trained
- Technical task teams are responsible for tele-education, clinical protocols, legal licensing ethics, infrastructure systems and guidelines
- Development of an affordable, clinically acceptable primary care telemedicine workstation
- Efficient management of data collected
- Use and development of telecommunication infrastructure

Telemedicine is focused on addressing the needs of historically disadvantaged communities. An objective of the telemedicine system will be to enhance the referral systems between community health centres, regional hospitals and central hospitals. The overriding goal is to effectively deliver primary healthcare (NHIS 2001).

The telemedicine policy clearly states the goal that the implementation of telemedicine in South Africa should contribute to development priorities of the South African Development Community (SADC) region. The government is committed to render basic services to all South Africans as a fundamental right. This is in accordance with the Alma Ata declaration stating that healthcare is a fundamental human right (NHIS 2001).

4 BUILDING THE DATA WAREHOUSE

The data warehouse can be described as the heart or distribution centre of this model. Data are extracted, transformed and loaded from data sources into the data warehouse for a data analysis that will provide tools for decision makers. The data warehouse is therefore central in this model. Data are collected and stored in a data warehouse from where analysis can be done.

This chapter consist of the methods followed in this project to populate the data warehouse as well as the analysis methods and mathematical models used in building the decision support system.

4.1 IDENTIFYING DATA SOURCES

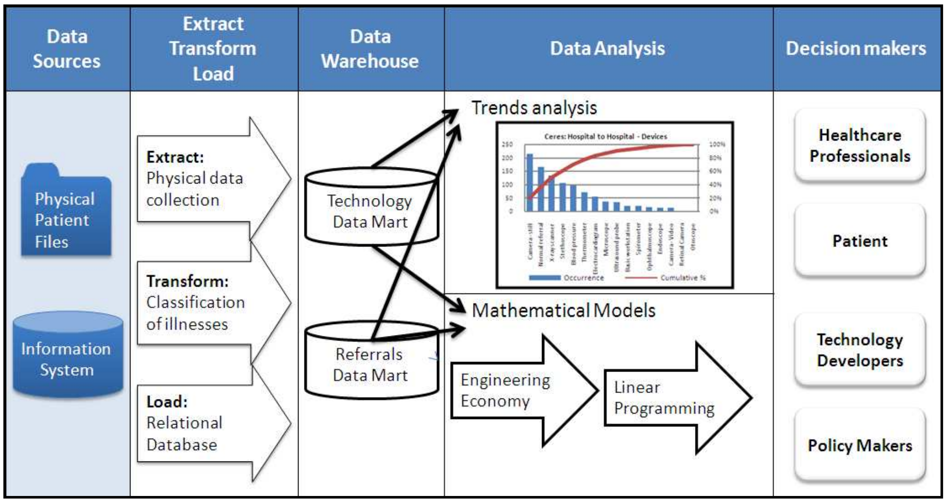


FIGURE 4: CLINICAL TELEMEDICINE DSS FRAMEWORK - DATA SOURCES

4.1.1 PLAYING FIELD

Gathering data in die healthcare environment is a complex problem. In the initial phases of the project, it was important for the author to build up a network of people involved in healthcare. The author was invited to the Health Information Systems assessment workshop. This workshop was initiated by Statistics South Africa and held in collaboration with the Department of Health. Only key stakeholders in health information systems were invited to attend the workshop. The author attended the workshop on 12-13 March, in Johannesburg on behalf of ms Jill Fortuin-

Abrahams of the MRC. The aim was to determine whether the data needed for the study existed and to identify and meet the people that have possibly already gathered the data needed.

The focus of the workshop was to assess current health information systems, and therefore was not directly relevant to this project. However, the workshop served as a good opportunity for the author to gain a broader knowledge of healthcare in general, the stakeholders involved and challenges concerning information systems. It became clear that the complexities in information systems are one of the reasons why gathering data in healthcare remain to be a challenge.

The data relevant for telemedicine studies are mostly referral data and -patterns from one facility or specialist to another. This data are not specifically covered in most information systems. Another major problem is that in many clinics in South Africa the infrastructure is not adequate for good information systems. The result is that data are not electronically available, and must be gathered from clinic- or hospital files.

The author met the following key persons at the workshop:

- Dr S Khotu – Director of National Health Information System
- Ms R Visser - Health System Trust, a non government organisation
- Mr J Daniels - Head of health information and technology, City of Cape Town DOH

4.1.2 INFORMATION SYSTEMS

Mr J Daniels, head of health information and technology, at City of Cape Town health department agreed to meet with the research team regarding data. He is working on the Prehmis (Patient Record and Health Management Information System) project. The Prehmis system is an electronic patient record system co-developed by BDS (Business Data Solutions) for the City of Cape Town. The vision is to install this system in all clinics managed by the City of Cape Town. The Prehmis system will use wireless internet access and will store all patient details and visits centrally to ensure accurate and up-to-date statistics for decision making.

The Prehmis system will enable the Health Directorate to make accurate and fast decisions with the accurate data available from the information system. This information can also be used for research purposes. However the Prehmis system is still under construction and therefore no data are available from this system at the moment.

Mr J Daniels was cooperative and gave the research team access to DHIS (District Health Information system) data for the Cape Town Metropolitan district. These are high level aggregate statistics that do not include any patient records, but from this data trends of patient visits to all the health facilities in the Cape Town Metropolitan district can be analysed. This data however are the property of Department of Health, and may not be published without ethical approval and permission from officials at the Department of Health.

After permission was declined, a consensus decision was made that authorisation to publish the data would take too long for the purposes of this project. The research team decided that the student should visit facilities and collect data directly. Although it was not authorised that the aggregate data from the Cape Town Metropolitan district could be used, the processing of the data into histograms served a valuable purpose. This data processing served as a pilot study to show the author what was required and resulted in large time saving when the actual data was collected.

The data from the Cape Town Metropolitan district proved that these were not the ideal regions to gather data for telemedicine applications in primary healthcare. In an urban district the clinics are close to hospitals and specialists. The logical conclusion can be made that patients often directly visit hospitals without being referred from a clinic or CHC. A patient will often informally be told to visit a hospital without a formal referral process. Academic hospitals and specialists are close to clinics, and transport is not as big a challenge as in rural districts. Telemedicine applications in South Africa will firstly be implemented in rural districts where doctors and specialists are scarce resources and transport costs are much higher because of typical South African rural characteristics. However, when authorities plan the implementation of telemedicine in urban areas, the data of the Cape Town Metropolitan district will be a key resource, later to be supplemented by the Prehmis data.

4.1.3 ETHICAL APPROVAL

Ethical approval is of high importance in the healthcare and medical fields. Medical records of patients should be confidential and the privacy of the patients must be protected. However it is also necessary for healthcare researchers to have access to patient records, and ultimately improve healthcare. The access of patient records and other medical information should however be controlled by ethical guidelines and frameworks.

Jill Fortuin-Abrahams, managing director of telemedicine at the MRC, has obtained ethical approval for telemedicine projects done at the MRC. This project falls under the ethical approval of these projects. It was therefore not necessary to go through a separate ethical approval process for this study.

Patient records were accessed and captured under ethical guidelines. Names and addresses of patients were not included in the database. It was however necessary to include the file numbers of the patients, to reference the patient files for future use. The patients' personal information can only be accessed from the patient files stored at the facilities, and not the database. The database therefore does not expose the privacy of the patients.

4.1.4 FACILITIES CHOSEN FOR DATA COLLECTION

The data collection facilities were chosen for developing a framework by which needs could be assessed, region by region throughout the whole of South Africa, with specific reference to rural areas where primary healthcare services are marginally supplied. With this end goal in mind the research team decided to use peri-urban areas in the Western-Cape (relatively close to the university) as the target areas for data collection. The facilities selected were Grabouw CHC, Robertson hospital and Ceres hospital.

Initially Grabouw CHC, Villiersdorp Clinic and Elgin Clinic were targeted because of the ease of transport of the data collection team. It however became evident that some patients typically visit two or more of these clinics alternatively depending on transport opportunities. The result would have been duplications in the data and hence unreliable data. It also became clear from the data collected at Grabouw clinic that data of concern to telemedicine implementation namely referral cases would be more effectively captured from larger facilities such as small district hospitals. The decision was therefore made to shift the focus towards Robertson and Ceres hospitals. Table 3 contains general information of the facilities visited.

TABLE 3: INFORMATION ON THE FACILITIES VISITED FOR DATA COLLECTION

Elements	Grabouw CHC	Robertson Hospital	Ceres Hospital
Type of Facility	Community Health Centre	District Hospital	District Hospital
Population Served	unknown	85 000	94 000
PHC Services / Hospital services	Day care clinic 24-Hour maternity service	Number of beds: 46 Outpatients / month: 456 Admissions / month: 38 Deliveries / month: 70 Caesarlan sections / month: 7	Number of beds: 76 Outpatients / month: 510 Admissions / month: 671 Deliveries / month: 112 Caesarlan sections / month: 16
Facilities		4-hour casualty, Theatre, Labour ward, X-ray facility, Ultrasound facility	4-hour casualty, Theatre, Labour ward, X-ray facility, Ultrasound facility

Specialists	Grabouw CHC	Full time	Part time	Robertson Hospital	Full time	Part time	Ceres Hospital	Full time	Part time
	Family Physician	3	1	Family Physician / PMO	1		Senior Medical Super	1	
				Medical officer	1	2	Family Physician / PMO	1	
				Community service doctors	2		Medical officer	1	5
				Physiotherapist	1		Community service doctors	3	
				Occupational Therapist	1		Physiotherapist		1
				Radiographer	1		Occupational Therapist		1
							Radiographer	2	
							Dietician	1	

Elements	Grabouw CHC	Robertson Hospital	Ceres Hospital
Clinics supported	N/A	Bergsig Clinic, Robertson Hospital PHC Clinic, Nqubela Clinic	Nduli, Annie Brown, Bella Vista, Ceres Hospital PHC Clinic, Tulbagh, Wolseley, Op-die-berg
Mobile clinics supported	1 team	3 teams	4 teams
Home based care program	Temba Care	Breede River Hospice	Sr Truter
Referral Transport	Ambulances	Ambulances	Ambulances

Source: Worcester Region Family Medicine Training Complex, 2009

4.2 DATA EXTRACT, TRANSFORM, LOAD

The data sources were identified as discussed previously in this chapter. Data sources are however of little value if it can not be extracted, transformed and loaded in a suitable format to be analysed. In this section the extraction, transformation and loading processes of the data sources are discussed.

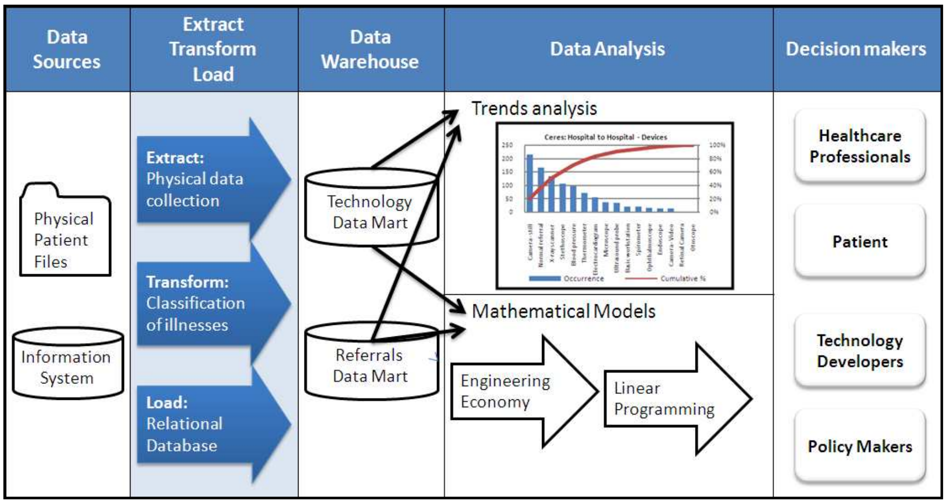


FIGURE 5: CLINICAL TELEMEDICINE DSS FRAMEWORK - EXTRACT, TRANSFORM, LOAD

4.2.1 DATA EXTRACTION

Data were primarily extracted from physical hand-written patient files primary healthcare facilities in the Western Cape. The author and her team of two data capturers spend 8 days at Grabouw CHC, 2 days at Robertson and 2 days at Ceres district hospitals. As discussed previously these facilities were selected, because they are considered to be representative of the type of facilities that correspond to the focus of this project.

A secondary data source is selected, namely data captured by hospital information systems (HIS), in this case Delta 9. The ideal situation would be one where all necessary data are available within the HIS and extracted, transformed and loaded (ETL) to the data warehouse through standard and automatic processes.

There are different levels of specialisation of healthcare professionals in South Africa. In primary healthcare the patients’ first consultation is at the professional nurse. The professional nurse might refer the patient to the doctor if necessary. The doctor will then diagnose the patient and in some cases he will refer the patient to a specialist doctor. The specialist doctor might also refer the patients to another specialist or hospital. A diagram for patient referrals between healthcare professionals is illustrated in Figure 6.

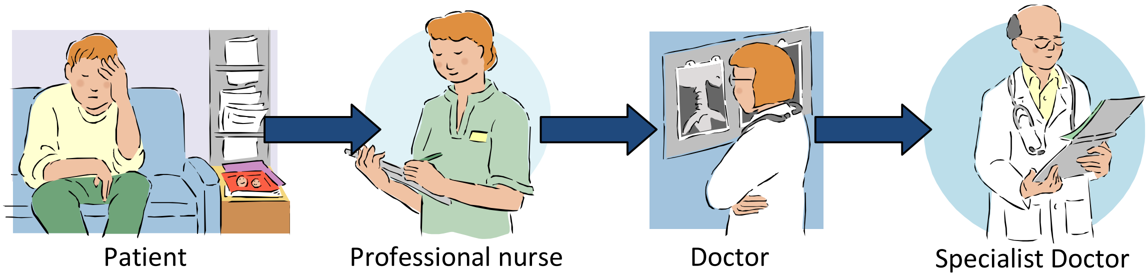


FIGURE 6: PATIENT REFERRALS

Thus, for this project two types of patient referrals are identified, patient referrals from a professional nurse to a doctor and patient referrals from a doctor to a specialist doctor. The data obtained from the two different types of referrals are expected to have different characteristics. The data from each type of referral are therefore stored and analysed separately. The data from different facilities are also expected to be different and are analysed separately.

The extraction processes from the different facilities are compared in Table 4. Data extraction processes were similar for the different types of referrals as well as for the different facility types. Data were extracted from patient files at Grabouw in contrast to the trauma books used and Robertson- and Ceres hospitals. The hospital-to-hospital referral data were extracted from an information system at Ceres hospital that resulted in a less complex extraction method and more accurate data.

TABLE 4: DATA EXTRACTION AT THE FACILITIES

Description	Grabouw CHC	Robertson Hospital	Ceres Hospital	
Facility type	CHC	District Hospital	District Hospital	
Sequence visited	First	Second	Third	Fourth
Type of referrals	Professional nurse-to-doctor	Professional nurse-to-doctor	Professional nurse-to-doctor	Doctor-to-specialist
Referral processes	Patients are seen by professional nurses and then referred to doctor if necessary. Only doctors refer to other facilities.	Patients visit trauma unit first and are seen by the professional nurse and doctor. They can be admitted or referred from here	Patients visit trauma unit first and are seen by the professional nurse and doctor. They can be admitted or referred from here	After patients were admitted they can be referred to other hospitals. Emergency cases can be referred from trauma
Data Sources	Patient files	Trauma books	Trauma books	Delta 9 - information system
Attributes collected	Facility, file number, gender, birth date, visitation date, reason for visitation, referral facility	Facility, file number, gender, birth date, visitation date, reason for visitation	Facility, file number, gender, birth date, visitation date, reason for visitation	Facility, gender, birth date, referral date, reason for referral, referral facility
Data sets collected	299	369	307	518
Sample %	3.7%	unknown	2.1%	100%
Overhead Statistics	Collected for 2008	Unavailable at the time	Collected for 2008	Collected for 2008
Data collection method	Random dates in 2008 were generated using MS Excel. Random cases were selected from the doctors' appointment books for each date. Files were drawn and data entered into the database	Random dates in 2008 were generated using MS Excel. Random cases were selected from the trauma books for each date. Data were entered into the database	Random dates in 2008 were generated using MS Excel. Random cases were selected from the trauma books for each date. Data were entered into the database	A report of all the referrals from Ceres hospital to other hospitals was drawn from the Delta 9 information system. The report was printed and entered into the database
Assumptions made	Internal referrals from Professional nurse to doctor are the same as referrals to other facilities if there were no doctor	Internal referrals from Professional nurse to doctor are the same as referrals from clinics to district hospital	Internal referrals from Professional nurse to doctor are the same as referrals from clinics to district hospital	All referrals from Ceres hospital to other hospitals were documented
Some challenges faced	• Referral cases not specifically documented • Unfamiliar/vague diagnoses • Limited space in admin room	• Unfamiliar/vague diagnoses • Overhead statistics unavailable at the time of data collection • Collection done on a Friday, admin staff not very helpful	• Unfamiliar/ vague diagnoses • Abbreviations used • 1 trauma book was unavailable • Some file numbers were not documented	• Unfamiliar/vague diagnoses • File numbers unavailable

4.2.2 DATA TRANSFORMATION

As part of the data transformation process, firstly data were cleaned in order to eliminate ambiguity and incomplete or incorrect entries. Furthermore, to protect the anonymity of patients, data that could reveal the identity of patients were removed.

In many cases symptoms were documented in the patient files. The data capturers did not make assumptions from patient symptoms, but recorded the symptoms as documented by the healthcare professionals into the database. The list of diagnoses and symptoms from the database was revised, transforming the symptoms to existing medical terms where necessary.

The data transformation process ensured uniformity of diagnoses that made data analysis possible. The list of diagnoses obtained from this project can be used in future projects that would result in a less extensive data transformation process.

4.2.3 DATA LOADING

A MS-Access database was developed to contain the referrals data mart. It served as an effective tool that can be used to store information. The information stored can be accessed at any time, in a number of different formats. Reports can be drawn from the database to selectively examine only certain aspects of the data. These reports can then be used to do a data analysis relevant for the study or research purposes.

The database was developed after the arrangements had been made to visit primary healthcare facilities for data capturing. The database was designed to store the data obtained from the data collection in a suitable format that will enable the user to obtain the data at a later stage.

Data storage can be considered as the core of an information system. The development of the database as part of an information system for this project is discussed with reference to the system development life cycle according to Kendall (2008). A database is only a part of an information system. The information system designed for this project consists mainly of the database and therefore all the phases in the system development life cycle are not equally relevant to the system development within this project. In designing a database it is important to consider the database as part of a system. The whole development cycle was therefore conceptualised with little reference to the details of the development of the database. A diagram of the system development life cycle is illustrated in Figure 7 below.

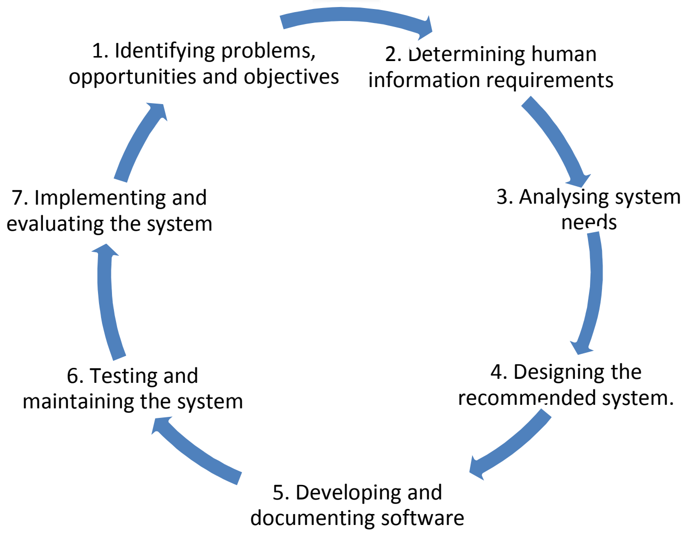


FIGURE 7: SYSTEM DEVELOPMENT LIFE CYCLE (KENDALL, 2008)

4.2.3.1 SYSTEM DEVELOPMENT LIFE CYCLE

1. IDENTIFYING PROBLEMS, OPPORTUNITIES, AND OBJECTIVES

The objective of the information system is to store and use the data collected effectively. The database will be used for further data collection and analysis in similar research that will follow on this project.

Some of the challenges identified in developing the database were the following:

- PHC facilities work primarily with paper files, little data are available in electronic format
- Not all PHC facilities use the same information systems
- Different types of PHC have different patient diagnostic and treatment processes

2. DETERMINING HUMAN INFORMATION REQUIREMENTS

The requirements of these people involved were the following:

- Author and study leader
  - Reliable data in the form of reports for data analysis
- Data capturing assistants
  - User friendly data input interface, enabling more than one data capturer
- Database developer expert
  - Adequate information about the system to ensure a functional database
- Telemedicine project managers
  - Database should be a generic tool usable for future data collection and research

3. ANALYZING SYSTEM NEEDS

A database that will store data from the data obtained from patients' files was proposed. Conceptual level data flow diagrams were constructed. As the project progressed, changes were made regarding the type of data stored. This resulted in the system requirements being revised and refined over the course of the project.

4. DESIGNING THE RECOMMENDED SYSTEM

A basic system was designed as a prototype. It was necessary to design the system before viewing typical patient files. This resulted in the situation that the system was developed based on anticipated requirements (technology push). During a system demonstration, prior to implementation, further requirements were identified that were incorporated into the design.

5. DEVELOPING AND DOCUMENTING SOFTWARE

The database was developed and enhanced as a continuous process. Necessary improvements were identified, developed and implemented during the first week of data capturing.

6. TESTING AND MAINTAINING THE SYSTEM

The system was tested several times within the development life cycle. A demonstration with fictional data served as the first formal test. After the demonstration the system was enhanced and tested again with fictional data. Within the first week of data collection the system was tested with the real data and enhanced daily. After visiting the second and third facilities respectively, further maintenance of the system took place.

7. IMPLEMENTING AND EVALUATING THE SYSTEM

The system was originally designed for only one person. However as the project developed it was decided that three data capturers were necessary. A web interface needed to be designed in order for more than one person to capture data simultaneously. However this was not done in this project because the data requirements changed regularly.

DATABASE DEVELOPMENT A CONTINUOUS PROCESS

The process or life cycle for developing the database will continue in future projects. Figures of the database developed can be seen in Appendix A. The relationship diagram of the database is shown in Appendix C. The entities in the database can be seen on the relationship diagram.

4.3 DATA WAREHOUSE

The data warehouse comprises of two data marts, namely the *Technology Data Mart* and the *Referrals Data Mart*. The technology data mart is a repository of medical equipment and subcomponents that can potentially make up a telemedicine workstation. Component, assembling, operational and maintenance costs are typically included in this data mart. For the purposes of this project the technology data mart was populated specifically directed towards the data analysis done in this project.

A significant portion of this project went into the extraction, transformation and loading (ETL) of patient data into the Referral Data Mart as discussed previously in this chapter.

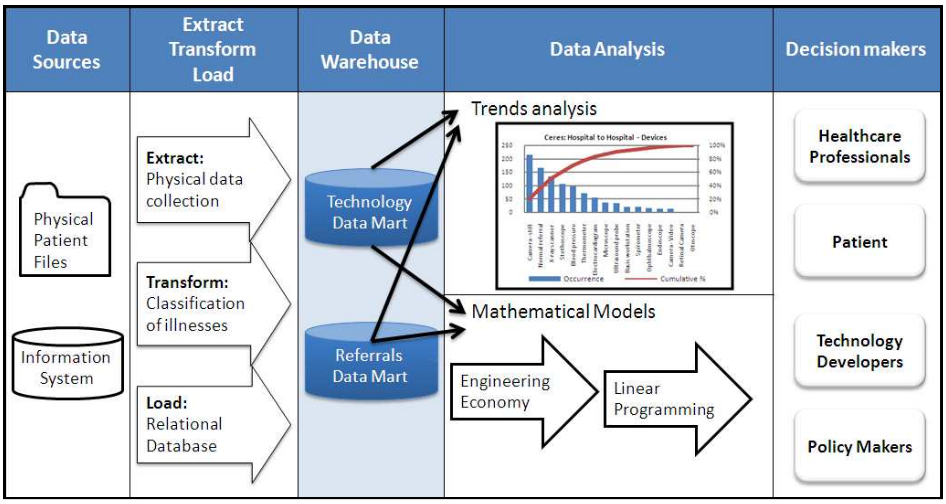


FIGURE 8: CLINICAL TELEMEDICINE DSS FRAMEWORK – DATA WAREHOUSE

4.3.1 REFERRALS DATA MART

The referrals data mart was populated using the patient diagnosis data extracted, transformed and loaded into the database. The types of diagnoses occurring at the healthcare facilities are contained in the referrals data mart. Aggregate data contributing to referral patterns at the healthcare facilities are also contained in the referral data mart.

The diagnoses extracted from the patient files and information systems were transformed into existing medical terms. The referrals data mart therefore contains a generic list of diagnoses.

The referrals data mart was used to do the diagnoses data analysis according to the decision support system. For the purposes of this project the amount of data contained in this data mart is adequate only for a specific region. This data mart should therefore be populated with data representing a larger region to broaden the scope of decisions made using the data warehouse.

4.3.2 TECHNOLOGY DATA MART

Market research was done to identify the standard telemedicine devices available for implementation. The goal of this market research was not to identify the best devices available but simply to identify the scope of telemedicine equipment and functionalities.

The devices used for different telemedicine applications were used together with the diagnosis data to determine what devices would be used in the different facilities.

The relationship between devices and diagnosis were determined. Devices were assigned to each diagnosis. A study was done to determine the functionality of each device. The symptoms and procedures of each diagnosis were taken into consideration with the assignment of devices to diagnoses. The relationship between devices and diagnosis are considered adequately accurate as the work was done in collaboration with a biomedical engineer experienced in telemedicine. It is beyond the scope of this project to do a detailed analysis of telemedicine devices applicable to each diagnosis. A more detailed analysis is however to be conducted on the level of comprehensive medical process analysis for each diagnosis. This is considered to be advisable to ensure accurate results and decision making, before this needs analysis is deployed as a tool for actual telemedicine implementation.

4.4 DATA ANALYSIS

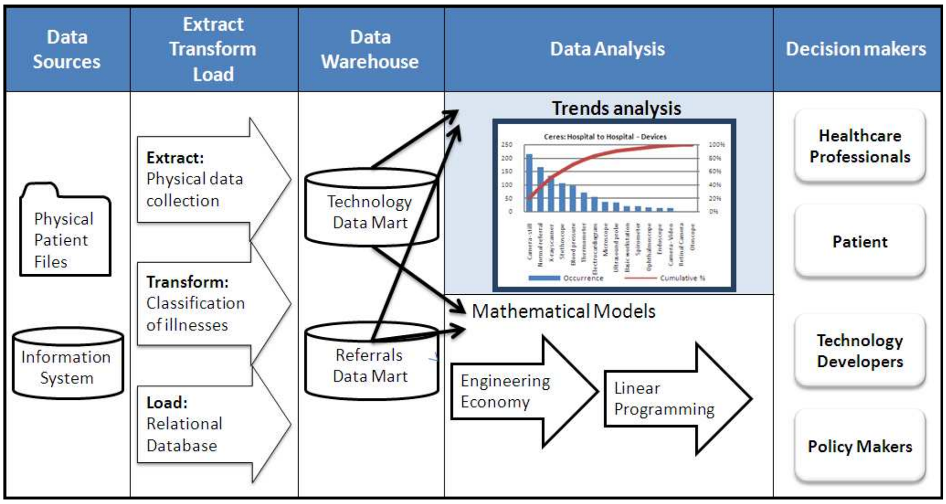


FIGURE 9: CLINICAL TELEMEDICINE DSS FRAMEWORK – DATA ANALYSIS

4.4.1 TRENDS ANALYSIS

Pareto analysis is a statistical technique in decision making that is used for selection of a limited number of tasks that produce a significant overall effect. It uses the Pareto principle, namely by focusing on approximately 20% of the effort or cost, approximately 80% of the benefit can be accomplished (Allais, 1968). An example of one of the Pareto diagrams compiled to support decision making, is shown under the Data Analysis heading of Figure 9. Such a Pareto diagram can guide the technology developers in deciding, within a certain context, what is the minimum configuration of devices that will address the maximum of patient needs.

The trend analysis is not limited to the Pareto analyses. For example, it was found that the pattern of referral between CHC and hospitals differs significantly from the patterns of referral between district hospitals and tertiary hospitals. The output of the DSS can guide decision making with respect to the positioning of technology within certain healthcare facilities. The telemedicine needs at a DHC differs from the healthcare needs of a tertiary hospital.

4.4.2 PARETO ANALYSIS OF DIAGNOSIS

Reports are drawn from the database. Diagnoses are categorised according to the medical classification, facility and type of referral. The occurrence of each diagnosis within each category is accumulated. The occurrences of the diagnoses are presented in a table, detailed in Appendix C. For each diagnosis a percentage was calculated according to total referrals at the facility. A cumulative distribution is drawn for every facility (refer Chapter 5.2).

4.4.3 PARETO ANALYSIS OF DEVICES RELEVANT TO DIAGNOSES

Reports, from the database, were drawn for the devices that would have been used if available at each facility. These reports contained the occurrence of each potential device utilisation according to the facility, medical category and type of referral. The occurrences of the devices utilised are presented in the tables in Appendix C. The occurrences are also presented as a percentage of total referrals at the facility. A cumulative distribution is presented in Chapter 5.

4.5 MATHEMATICAL MODELS

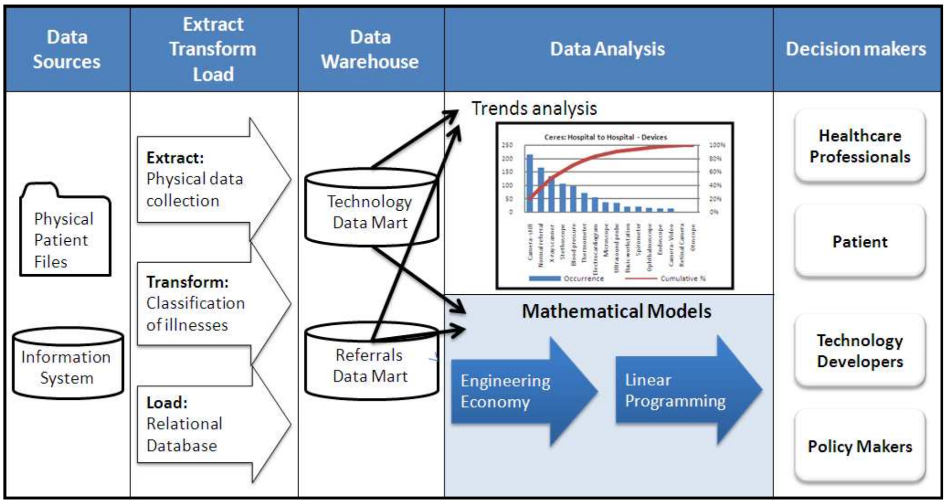


FIGURE 10: CLINICAL TELEMEDICINE DSS FRAMEWORK – MATHEMATICAL MODELS

4.5.1 ENGINEERING ECONOMICS

Engineering economics is a subset of economics for application to engineering projects. Engineers seek solutions to problems, and the economic viability of each potential solution is normally considered along with the technical aspects (Boehm, 1981). The combined outputs from the referral data mart and technology data mart are used to support decision making related to the time value of money, buy-or-lease options and cash flow implications.

In the economic analysis the cost implications for the implementation of each device are calculated. Capital-, implementation-, running- and referral costs were taken into consideration. It was beyond the scope of this project to do a detailed cost analysis of telemedicine implementation. The economic analysis is a prerequisite for the decision making model. It was therefore done as a broad overview, making use of various estimates. Outstanding issues are the situation that local development has not been completed and preferable imported equipment has not been identified. A more accurate analysis will however be required to ensure more accurate results from the decision making model when used for actual implementation decisions, even though it may be an iterative process.

4.5.2 FIXED CHARGED MIXED INTEGER PROGRAMMING

Linear programming (LP) is a mathematical modelling technique for optimisation of a linear objective function. It determines the way to achieve the best outcome - such as maximum profit or lowest cost – in a given mathematical model and given some list of requirements represented as linear equations (Winston, 1994). The Fixed Charge Mixed Integer Programming problem is a specific LP application that is suitable to support decisions with respect to the selection of equipment and components.

The objective function of this model is to maximize the benefit from a certain technology configuration, given the cost thereof. This model uses information drawn from both data marts as input. The output is a function of the number of expected referrals that can be facilitated by the selected technology configuration (Referrals Data Mart), whilst the technology costs are contained by the Technology Data Mart. This LP model is validated and verified based on some cost estimates. However, until the Technology Data Mart is not completely stocked, this part of the DSS is not available.

By linking these mathematical models to the data warehouse, this clinical DSS could be used to support decision making towards the needs driven development and implementation of telemedicine.

5 RESULTS

5.1 AGGREGATE STATISTICS OF THE FACILITIES

It is a standard procedure at health facilities to document statistical data for the facility. In this project the aggregate statistics of the facilities visited was used to evaluate referral trends at the facilities for 2008. The aggregate statistics of a facility are involves patient headcounts for the relevant categories in a facility. The headcount figures taken into consideration for this project are as follows:

- Total headcount at the facility
- Number of patients seen by professional nurses
- Number of patients seen by doctors that were referred by professional nurses
- Number of patients seen by doctors that were not referred by professional nurses

In Figures 11 and 12 it is shown that the amount of cases seen by the different healthcare professionals varies for the different facilities. At Ceres hospital the majority of cases were seen by the doctors, while at Grabouw CHC the majority of cases were seen by the professional nurses. This trend could be expected because of the level of specialisation at the different healthcare facilities.

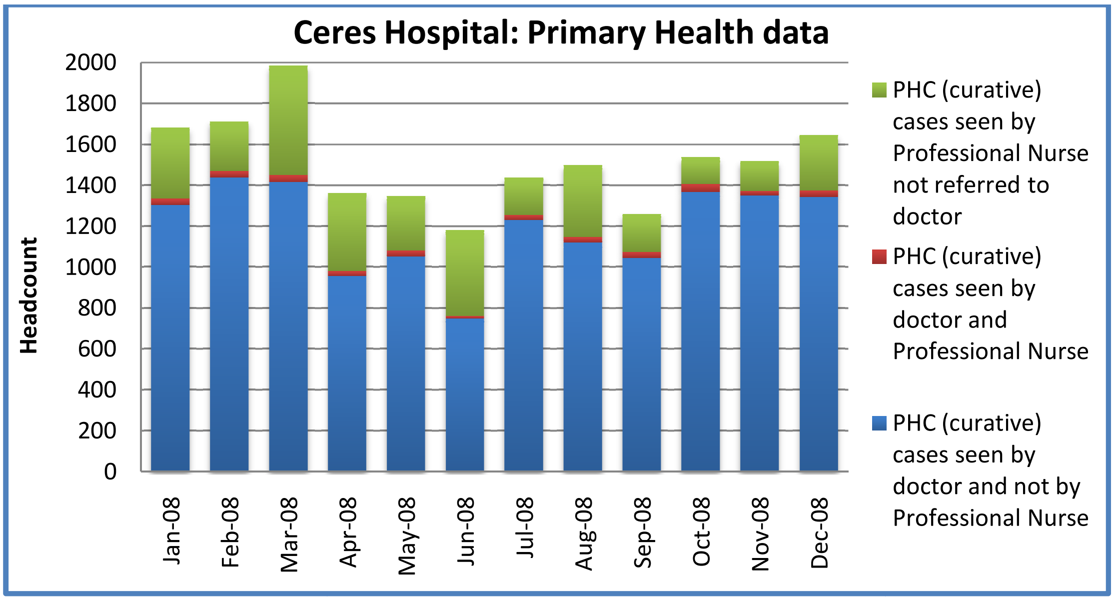


FIGURE 11: CERES HOSPITAL - AGGREGATE STATISTICS

The percentage of referrals between the professional nurse and the doctor are substantially higher at Grabouw CHC than at Ceres hospital. This can be explained by the fact that the cases treated at the hospital are already specialised. The professional nurse would therefore not have a formal consultation with the patient and a doctor would be consulted immediately.

It is expected that the aggregate statistics for a clinic would show an even lower percentage of cases seen by the doctor. Clinics mostly function utilising a visiting doctor. If the doctor is not available, patients are informally referred to the nearest district hospital. The professional nurses might also consult with a doctor telephonically. This consultation can be classified as telemedicine. However this mostly occurs informally and is rarely documented.

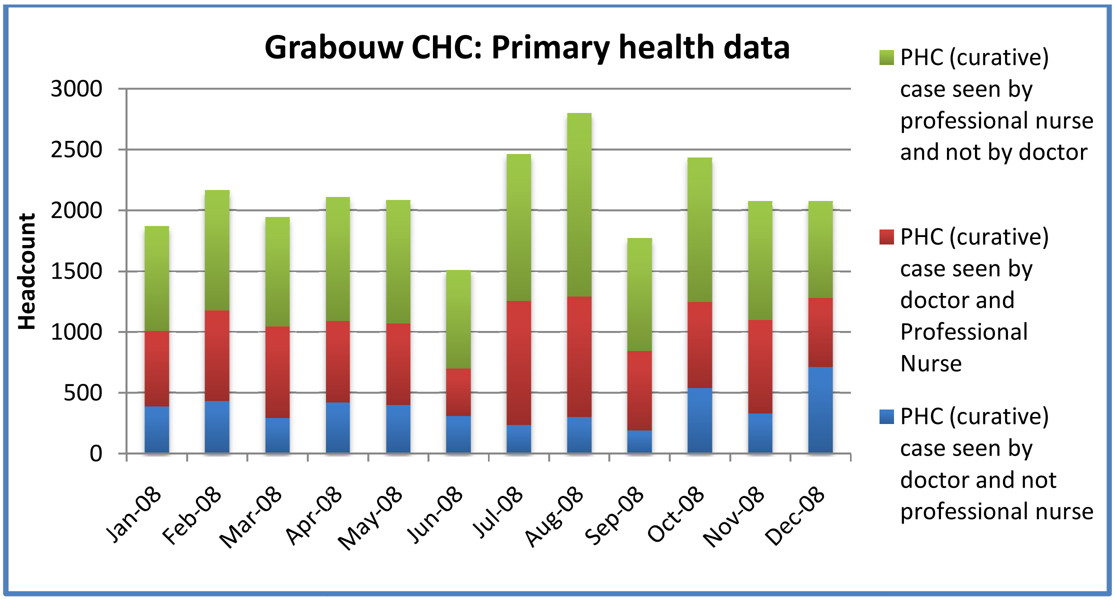


FIGURE 12: GRABOUW CHC - AGGREGATE STATISTICS

The number of referrals from Ceres hospital to other hospitals is depicted in figure 13 below. In this figure it can be seen that the percentage of referral cases with respect to the total number of cases seen by the doctor is very low. The total number of cases seen by the doctor in 2008 is 14708. The total number of referrals for 2008 is 500 cases. The percentage of cases referred to other hospitals with reference to the total number of cases seen by the doctor was only 3.4%.

Although the percentage of referrals was very low for this hospital, it is expected that other district hospital might have a higher percentage of referrals. It is possible that Ceres hospital refers fewer patients because it is seen as one of the best district hospital in its region.

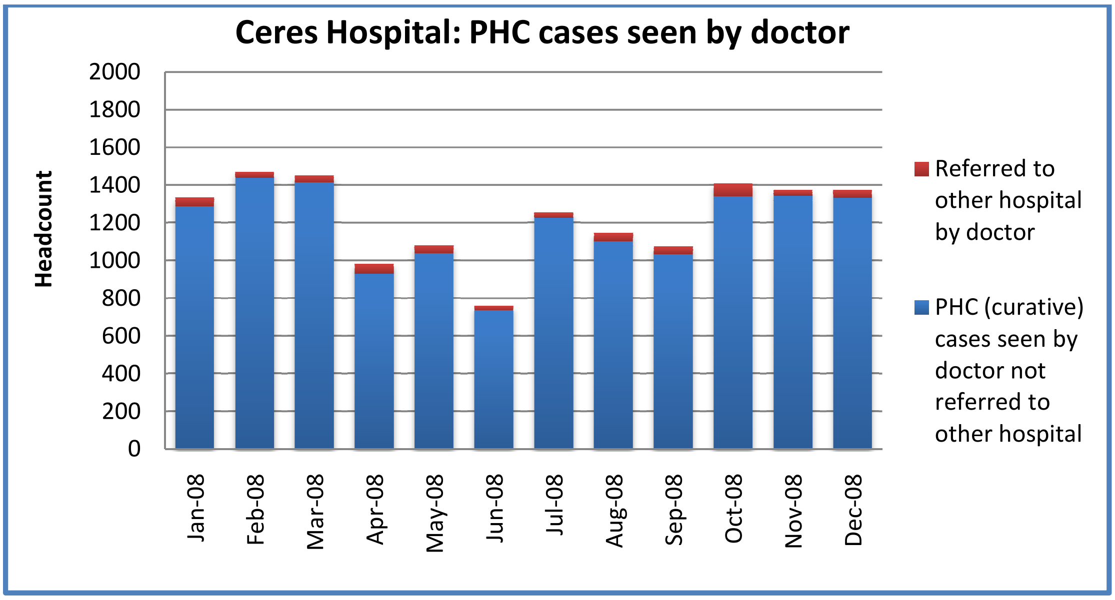


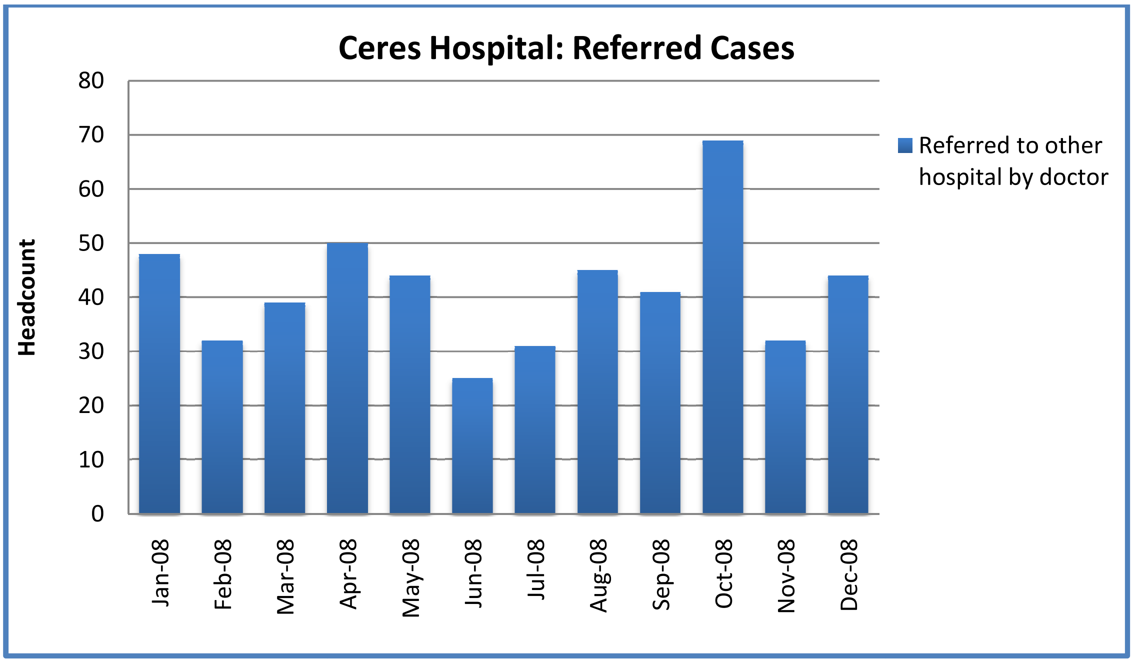
FIGURE 13: CERES HOSPITAL - CASES SEEN BY DOCTOR

Figure 14 illustrates the distribution of the referrals on a monthly basis for 2008. In October 69 patients were referred to other hospitals that make it the month with the highest number of referrals. June, with 25 referred cases is the month with the least referrals. An average of 1.4 cases per day was referred to other hospitals.

Not all of the 500 referrals can be considered as telemedicine cases. Referrals from one hospital to another include for example, surgery cases that are not considered as primary healthcare telemedicine cases. Further analysis of the specific cases within the 500 referrals was done in the Pareto analysis.

1.4 referrals per day appear to be very low. It might be argued that this indicates a low feasibility for implementing telemedicine at this hospital. The feasibility of implementing a workstation at this facility will however be determined by taking into consideration the various factors, and are not based upon these statistics alone. The feasibility of the telemedicine workstation at this facility is determined using the clinical telemedicine decision support system as explained previously in the introduction and methodology chapters of this report.

FIGURE 14: CERES HOSPITAL - REFERRALS TO OTHER HOSPITALS



5.2 PARETO ANALYSES

The Pareto analysis for the diagnoses was done separately from the devices Pareto analysis. In this section the Pareto analyses for Ceres Hospital (hospital-to-hospital) are discussed in detail. The diagnoses and devices Pareto analyses for the other facilities are illustrated in two separate tables. Detailed data tables and graphs are included in Appendix D.

5.2.1 CERES HOSPITAL: HOSPITAL-TO-HOSPITAL REFERRALS

As discussed in the aggregate statistics section, 500 patients were referred from Ceres hospital to other hospitals in 2008. From the 500 patients, and their related cases, 518 diagnoses were captured into the database. The reason for this is the fact that a patient may have more that one diagnoses. E.g. a patient can have lacerations and a fracture. These diagnoses are treated differently and will require different telemedicine equipment.

Figure 15 illustrates the occurrences and the cumulative percentages of the diagnoses at Ceres hospital. The diagnoses are sorted from highest to lowest occurrences, and are shown horizontal axis of the graph. The graph demonstrates the trend for the diagnoses. The Pareto principle states that 20% of the cases occur 80% of the time. In this distribution 42% of the diagnoses occurred 80% of the time. The data therefore did not precisely follow the Pareto principle. However the principle of some diagnoses occurring significantly more than others did occur.

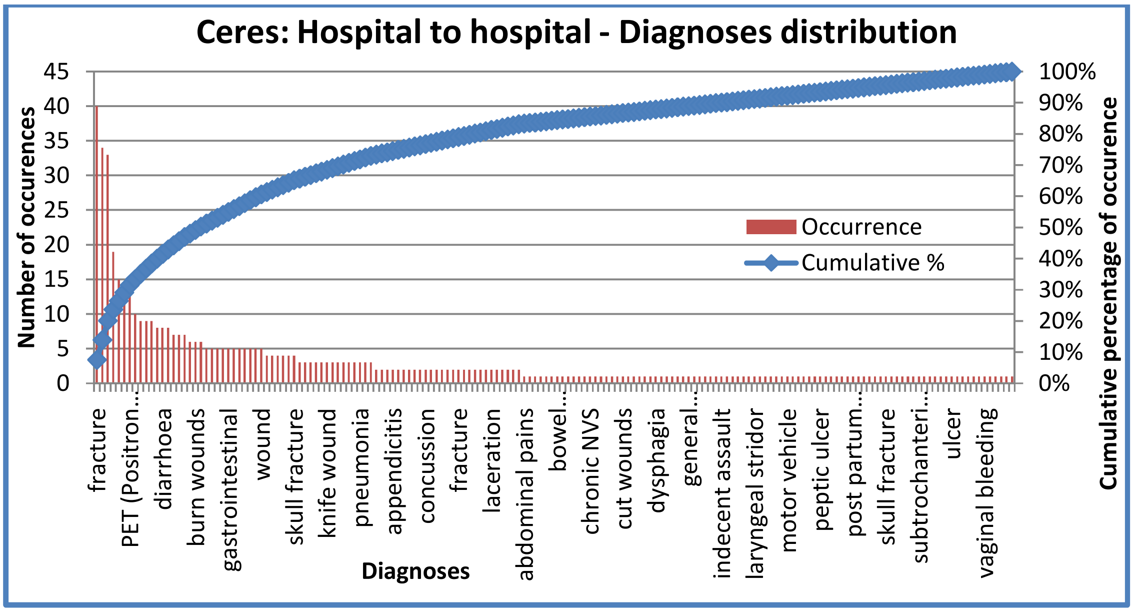


FIGURE 15: CERES HOSPTIAL - CASES REFERRED TO OTHER HOSPITAL PER DIAGNOSES

The diagnosis that occurred most frequently were orthopaedic fractures with 40 referrals made for this reason in 2008. Table 5 illustrates that psychosis, tuberculosis, lacerations, concussions and diabetes were some of the other diagnoses that occurred frequently.

There were 90 diagnoses that only occurred only once. These cases included for example a surgical amputation, a paediatric skull fracture and an orthopaedic spinal injury. Tables with all the diagnoses used for the Pareto analysis can be found in Appendix D.

TABLE 5: TOP 10 DIAGNOSIS OCCURENCES AT CERES HOSPITAL (TO OTHER HOSPITALS)

Rank	Category	Diagnosis	Occurrence	%
1	Orthopaedic	fracture	40	7.505%
2	Medical	psychosis	34	6.379%
3	Medical	Tuberculosis	33	6.191%
4	Surgical	laceration	19	3.565%
5	Medical	concussion	15	2.814%
6	Medical	diabetes	14	2.627%
7	Obstetric	PET (Positron emission tomography)	13	2.439%
8	Obstetric	giving birth	10	1.876%
9	Paediatric	Pneumonia	9	1.689%
10	Paediatric	premature baby	9	1.689%

It is inadequate to identify the devices relevant for the top 40% of the diagnoses for telemedicine devices implementation and development. The diagnoses with lower occurrences could require the same devices as the frequent diagnoses and may cumulatively result in a different Pareto distribution. For device requirements therefore, a fundamental Pareto analysis using the full data set for a facility, is used.

A modified Pareto analysis was done on the devices used for each diagnosis. The Pareto graph showing the devices necessary for telemedicine used in 2008 at Ceres hospital is shown in Figure 16. The term “not telemedicine” is used for the cases that could not have been replaced with telemedicine. These cases, not referred were mostly surgical cases. The “not telemedicine” cases are shown in the colour orange on the graph but are not calculated in the cumulative percentage as they are not considered to be telemedicine cases.

The “basic workstation” concept in this context is a telemedicine workstation without digital medical devices added to the workstation. The basic workstation “device” is always chosen first of the devices because no other devices could be used without the basic workstation.

For the Ceres hospital-to-hospital cases the digital still camera is required for most cases, with a total of 216 occurrences and 21.16% of the total cases. 168 of the referrals, or 16.45% were “not telemedicine” cases. The second most important device at this facility, apart from the basic workstation and camera, was the X-ray scanner (digitiser) with 135 cases, 13.22%. The least used device was the otoscope which would have been used only once in 2008.

The Pareto majority or 80% of the referral cases are utilising telemedicine using the basic workstation and 70% of the devices. 70% of the devices are 10 of the devices. This is largely because 16.45% of the referral cases cannot be handled with telemedicine regardless of the devices used. More realistically, 6 devices will cover 70% of referral cases using telemedicine.

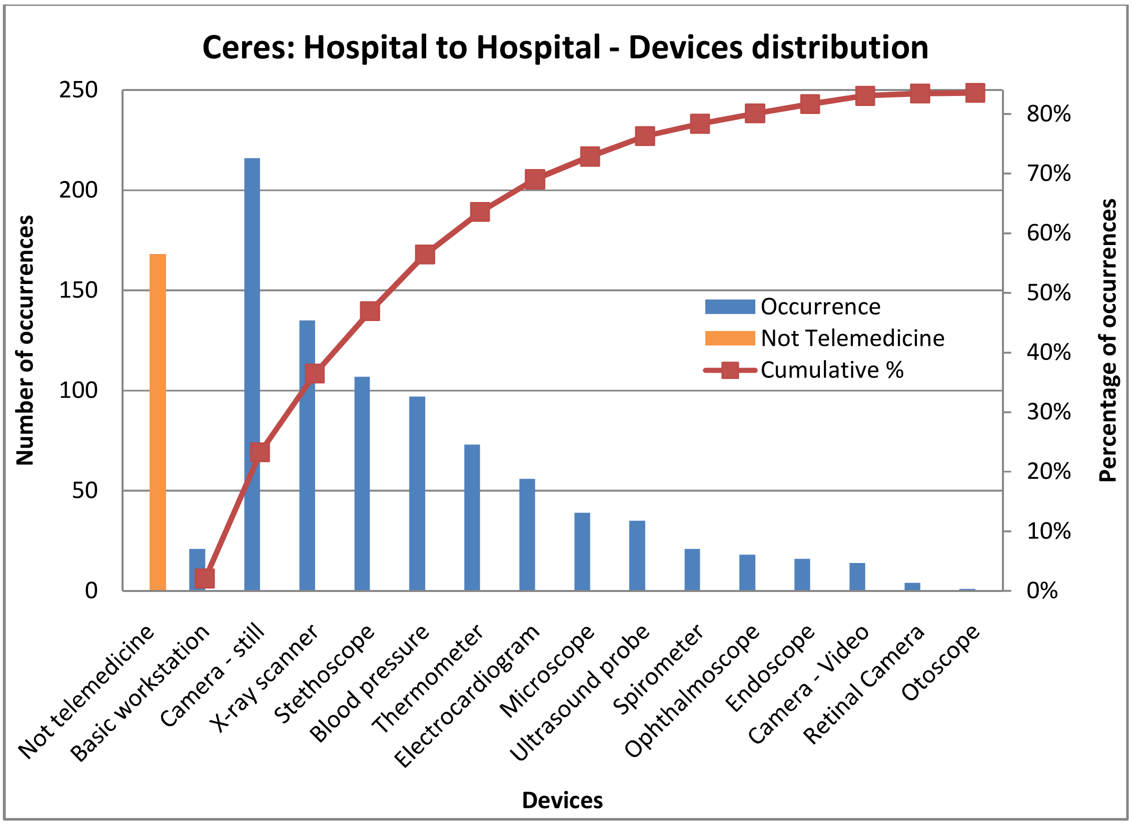


FIGURE 16: CERES HOSPTIAL - CASES REFERRED TO OTHER HOSPITAL PER DEVICE

TABLE 6: DIAGNOSES DISTRIBUTIONS PER FACILITY

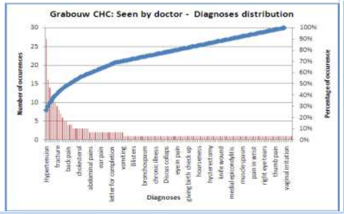
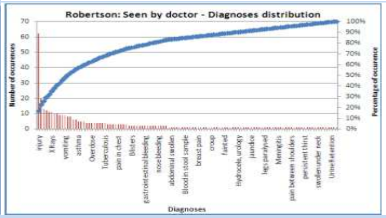
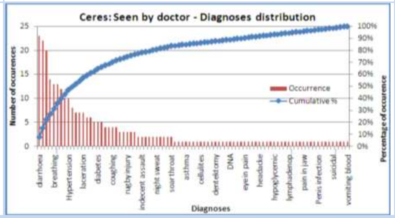
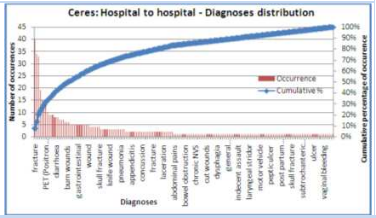
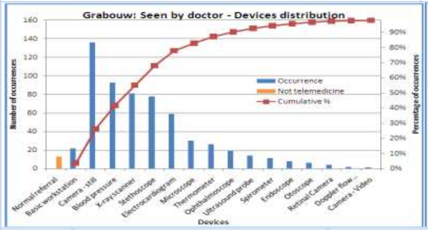
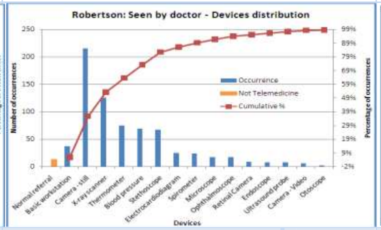
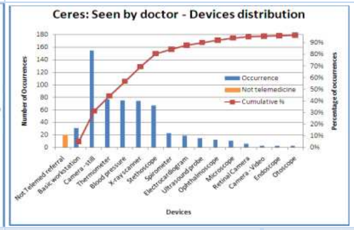
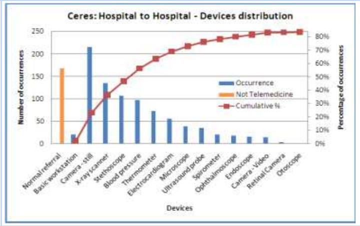
Description		Grabouw CHC		Robertson Hospital		Ceres Hospital			
Type of referrals		Professional nurse-to-doctor		Professional nurse-to-doctor		Professional nurse-to-doctor		Doctor-to-specialist	
Graph of distribution									
Top 10 occurrences of diagnoses		**Diagnoses**	**%**	**Diagnoses**	**%**	**Diagnoses**	**%**	**Diagnoses**	**%**
	1	hypertension	9.03	injury	16.8	diarrhoea	7.88	fracture	7.50
	2	tuberculosis	5.35	abscess	5.42	assault	7.53	psychosis	6.37
	3	diabetes	4.68	hypertension	3.52	injury	6.85	tuberculosis	6.19
	4	arthritis	3.68	epilepsy	3.25	X rays	4.80	laceration	3.56
	5	epilepsy	3.68	diarrhoea	2.98	difficult breathing	4.45	concussion	2.81
	6	injury	3.34	X rays	2.98	vomiting	4.45	diabetes	2.62
	7	fracture	3.01	difficult breathing	2.71	abscess	4.11	PET	2.43
	8	diarrhoea	2.68	wound	2.71	fracture	3.43	giving birth	1.87
	9	angina	2.34	assault	2.43	hypertension	3.43	Pneumonia	1.68
	10	asthma	2.01	vaginal bleeding	2.43	psychosis	2.74	premature baby	1.68
		56% of diagnoses occurred 80% of the time		39% of diagnoses occurred 80% of the time		38% of diagnoses occurred 80% of the time		42% of diagnoses occurred 80% of the time	

TABLE 7: DEVICES DISTRIBUTIONS PER FACILITY

Description		Grabouw CHC		Robertson Hospital		Ceres Hospital			
Type of referrals		Professional nurse-to-doctor		Professional nurse-to-doctor		Professional nurse-to-doctor		Doctor-to-specialist	
Graph of distribution									
Occurrences of devices		**Device**	**%**	**Device**	**%**	**Device**	**%**	**Device**	**%**
		Not Telemedicine	2.16	Not Telemedicine	1.81	Not Telemedicine	3.37	Not Telemedicine	16.45
		Basic workstation	3.65	Basic workstation	5.15	Basic workstation	5.22	Basic workstation	2.06
	1	Camera - still	22.55	Camera - still	30.04	Camera – still	26.09	Camera - still	21.16
	2	Blood pressure	15.42	X-ray scanner	17.52	Thermometer	12.96	X-ray scanner	13.22
	3	X-ray scanner	13.43	Thermometer	10.43	Blood pressure	12.63	Stethoscope	10.48
	4	Stethoscope	12.94	Blood pressure	9.60	X-ray scanner	12.46	Blood pressure	9.50
	5	Electrocardiogram	9.78	Stethoscope	9.32	Stethoscope	11.28	Thermometer	7.15
	6	Microscope	4.98	Electrocardiogram	3.48	Spirometer	3.87	Electrocardiogram	5.48
	7	Thermometer	4.31	Spirometer	3.34	Electrocardiogram	3.20	Microscope	3.82
	8	Ophthalmoscope	3.15	Microscope	2.36	Ultrasound probe	2.53	Ultrasound probe	3.43
	9	Ultrasound probe	2.32	Ophthalmoscope	2.36	Ophthalmoscope	2.02	Spirometer	2.06
	10	Spirometer	1.82	Retinal Camera	1.25	Microscope	1.85	Ophthalmoscope	1.76
	11	Endoscope	1.33	Endoscope	1.11	Retinal Camera	1.01	Endoscope	1.57
	12	Otoscope	1.00	Ultrasound probe	1.11	Camera – Video	0.51	Camera - Video	1.37
	13	Retinal Camera	0.66	Camera - Video	0.83	Endoscope	0.51	Retinal Camera	0.39
	14	Doppler flow	0.33	Otoscope	0.28	Otoscope	0.51	Otoscope	0.10
	15	Camera - Video	0.17						
80% of the cases addressed with:		Basic workstation & 6 devices		Basic workstation & 5 devices		Basic workstation & 5 devices		Basic workstation & 10 devices	

5.3 COMPARISON BETWEEN THE FACILITIES

A comparison between the facilities is made in terms of the devices relevant for each facility. In Figure 17 the devices relevant to each facility are shown in terms of percentage usage. From this figure it can be seen that the digital still camera are the device with the highest utilisation across the facilities. The device with next highest average occurrences between the facilities is the x-ray scanner. The blood pressure measurement device, stethoscope and thermometer are all devices that would have been frequently used if implemented in the facilities in 2008.

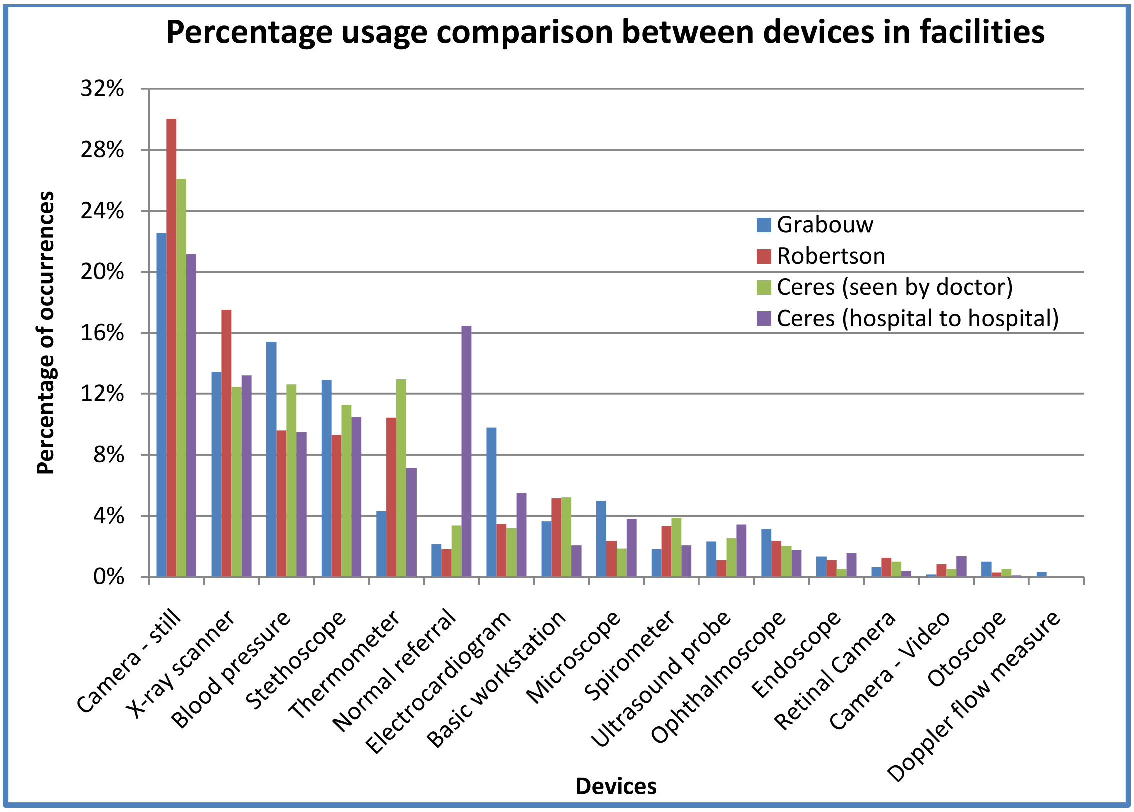


FIGURE 17: COMPARISON BETWEEN DEVICES FOR ALL THE FACILITIES

5.4 ECONOMIC FEASIBILITY OF TELEMEDICINE APPLICATIONS

There are many different telemedicine workstations with peripheral devices available on the market today. However, at the stage this project was completed, suppliers and support structures had not been finalised resulting in costs being estimates rather than accurate figures. The engineering economy analysis was done to illustrate the clinical telemedicine decision support system as discussed in throughout this report.

It is beyond the scope of this project to do a detailed cost analysis. The amounts in this section should therefore be seen as approximate but realistic figures. Table 8 illustrates the estimated costs with a description and a price (in SA Rand) for telemedicine devices as well as the MRC/SU and other basic workstations. The project did not include research to identify the broad spectrum of telemedicine manufacturers and determine the best prices for the devices. Prices of the devices were given by a telemedicine expert and are considered to be conservative estimates. Although the prices used for the devices are not those of AMD Telemedicine, descriptions and photographs of the AMD telemedicine devices can be found in Appendix G.

TABLE 8: GENERAL TELEMEDICINE EQUIPMENT PRICES

Devices	Description	Price (SA Rand)
Basic telemedicine workstation	MRC/SU Workstation	R 50,000.00
Basic vital signs monitor	Chinese workstation	R 150,000.00
Basic workstation with video conferencing	Tanburg	R 175,000.00
	Polycom	R 155,000.00
	Sony	R 120,000.00
Blood pressure meter		R 3,000.00
Camera, still		R 20,000.00
Camera, video		R 20,000.00
Dermascope		R 20,000.00
Doppler flow measurement		R 25,000.00
Electrocardiogram		R 20,000.00
Endoscope		R 30,000.00
Microscope		R 3,000.00
Ophthalmoscope		R 25,000.00
Otoscope		R 15,000.00
Retinal Camera		R 25,000.00
Spirometer		R 10,000.00
Stethoscope		R 10,000.00
Thermometer		R 4,000.00
Ultrasound probe		R 12,000.00
X ray scanner		R 65,000.00

As illustrated in Table 8, the MRC/SU telemedicine workstation developed for South African telemedicine implementation is a fraction of the cost of the other telemedicine workstations. The economic analysis is done with reference to the MRC/SU workstation. The reason for this is because this project was jointly initiated by the MRC and Stellenbosch University for further development and implementation of this workstation. The workstation uses a 3G communication device and includes a blood pressure measurement device, scale and digital still camera. The implementation and running cost for the MRC/SU telemedicine workstation have already been calculated by the MRC and is shown in Table 9.

TABLE 9: TELEMEDICINE IMPLEMENTATION AND RUNNING COSTS

Cost item	Description	Price (SA Rand)
Implementation costs	per workstation	R 5,000.00
Running costs	per year, per workstation	R 9,000.00

Source: Jill Fortuin-Abrahams, MRC Telemedicine managing director

Literature reviews have shown that it is rather complex to accurately calculate telemedicine cost benefits in terms of referral cost between primary healthcare facilities (Taylor, 2005). There are many factors that need to be taken into consideration for example transport cost per distance unit, the distance travelled for referrals, specialist salaries, specialist time spent with the case, hospitalisation costs, hospital utilisation, administration costs etc.

It is beyond the scope of this project to calculate referrals costs accurately. However referral costs are an essential part of the economic analysis, and therefore also the decision making model. A first estimate of referral costs are calculated in Table 10.

The Ceres hospital-to-hospital data were used to estimate the average distance travelled for referrals in this estimation. These averages include the kilometres travelled per patient referral in 2008, the difference between the hospitalisation costs for Ceres hospital and Worcester hospital (the hospital most of the Ceres case were referred to in 2008). For the purposes of this analysis it is assumed that the doctors and specialists spend the same time on a case with using telemedicine as without telemedicine. The doctor and specialist rates are therefore not incorporated in the calculations.

In the government rates for ambulances, the rate for long distance patient transport is quoted as R 14.10 per km (Ambulance Services, 2009). This is the rate charged to paying patients. It is unknown how this rate is compiled. There is little doubt that this rate includes fixed costs distributed on a per km basis. It would be inaccurate to claim that this full cost would be saved by using telemedicine. In accordance with the throughput accounting approach advocated by the Theory of Constraints philosophy, only direst variable costs will be saved when the number of trips is reduced by the use of telemedicine. Direct variable costs are estimated to be R 7-00 per km based on the running cost of a similar vehicle in the university's fleet. In the long term however, successful implementation will reduce the demand for ambulances implying that capital expenditure will ultimately be reduced.

The same argument does not apply to the hospitalisation. In healthcare the capacity of tertiary (academic) hospitals is fully utilised or capacity constrained (Söderlund, 1999). It could be seen as the constraint or bottleneck in the healthcare system as bed utilisation in tertiary hospitals is 72.2% (Monitoring and evaluation directorate, 2008). Taking population growth and pandemic illness (AIDS, TB) increase into account, the demand on hospital beds is expected to rise (Söderlund, 1999). In the calculation in Table 10 only the estimated difference between the different hospitals is taken into account. This amounts to a conservative estimate of the savings that can be attributed to telemedicine healthcare.

TABLE 10: REFERRAL COSTS SAVINGS FOR TELEMEDICINE PER TELEMEDICINE CASE

Symbol	Referral Costs	Description	Averages	Price (SA Rand)
A	Ambulance transfer	R 7/km*	120 km	R 840.00
C	Hospitalisation (District hospital)	R 1128/day	3.3 days	R 3722.00
W	Hospitalisation (Academic hospital)	R 1300/day	3.3 days	R 4290.00
	Cost saved per referral with telemedicine = A+(W-C)			R 1012.00

Table 11 illustrates the telemedicine referral cost saving estimates for Ceres Hospital. The calculations were made to estimate annual cost savings with the telemedicine workstation. As illustrated in Table 8 and 9, the MRC/SU workstation would require a capital amount of R 50 000 and implementation cost of R 5000. It is expected that the telemedicine workstation would have a lifetime of 5 years. After 5 years the technology would become obsolete and it would most probably be replaced. Annual payments are calculated as R 13 189.87 using the Excel Formula for payments, PMT with inflation estimated at 10%.

It was observed from the Ceres Hospital-to-hospital device distribution that 164 cases could have been referred in 2008 with the MRC/SU workstation. In this calculation we assume that 80% of these cases were successfully referred with the telemedicine workstation, and were not referred at a later stage. The annual cost savings for 2008 at Ceres hospital are therefore calculated using 80% of the 164 cases multiplied by the cost saved per referral from Table 10. By subtracting the annual costs from the annual cost savings the total annual cost savings are calculated as R 248 216.53, illustrated in Table 11.

TABLE 11: TELEMEDICINE REFERRAL COST SAVING ESTIMATES FOR CERES HOSPITAL

Description	Annual cost savings	Annual cost
Annual payments for workstation and implementation		R 13,189.87
Running cost		R 9,000.00
Referral cost savings (80% of 164 cases)	R 132,774.40	
Total annual cost savings	**R 110,584.53**	

5.5 LINEAR PROGRAMMING

The annual cost savings for the workstation, without any devices added, were calculated in the previous section. Telemedicine decision makers were however at the time this report was written interested in the type of devices necessary for successful telemedicine implementation. Therefore a further analysis was needed to determine which of the identified devices are beneficial for telemedicine implementation PHC facilities, in this case Ceres Hospital.

Integer programming was used to determine the best alternative given the utilisation and cost of the telemedicine devices. The variables identified are listed below. Only referral data from Ceres Hospital to other hospitals are used in this project. The integer programming model is however defined to enable future use with a larger data input.

THE VARIABLES

i	=	telemedicine devices
y_i	=	0 if device is not chosen 1 if device is chosen
x_i	=	number of cases diagnosed with device i
c_i	=	equal payments for device i with a lifetime of 5 years
b	=	referral cost savings per case
m	=	equal payments for implementation cost of a telemedicine workstation with a lifetime of 5 years
r	=	running cost for the telemedicine workstation

THE OBJECTIVE FUNCTION

$$\text{Max } z = \sum x_i . b . y_i - [\sum c_i . y_i + y_1 (r + t)]$$

The objective function is defined to maximize annual referral cost savings. Annual payments for the devices, implementation and running cost are subtracted from the referral cost savings per device. The devices with the highest net annual referral cost savings are then chosen to maximize the objective function.

THE CONSTRAINTS

1) $\sum x_{i.}.y_i \geq 320$
2) $\sum c_{i.}.y_i \leq 30\ 000$
3) $\sum b\ .x_i\ .y_i \geq 250\ 000$
4) $\sum_2^{13} y_i \leq M.y_1$

Some limitations on the objective function are set by the constraints given. Constraint 1 ensures that more than or equal to 320 cases must be referred with telemedicine. Constraint 2 limits the annual payment for capital costs of the devices to be lower that R 30 000. The referral cost savings multiplied by the number of telemedicine cases referred with the devices chosen should be more than or equal to R250 000 according to constraint 3.

Constraint 4 ensures that if the telemedicine workstation was not chosen, no other devices can be chosen. It should be remembered that the devices are peripherals to the workstation and can not be implemented without the basic workstation. M represents a large number. Therefore if y_1 = 0 the sum of the other y's must equal to 0 as well. If y_1 = 1 the sum of the other y's can equal any large number given that it can only sum up to 12, being defined as binary.

VALUES

The values for the variables are given in Table 12 and 13. Table 13 does not include values for the still digital camera and the blood pressure meter because these devices are included in the MRC/SU telemedicine workstation.

The values in Table 12 and 13 were used in calculating the solution for Ceres Hospital, using LINDO software.

TABLE 12: VALUES OF FIXED VARIABLES

	Fixed Variables	Cost (SA Rand)
m	Implementation costs(annually – 5 years)	R 1,199.08
r	Running costs	R 9,000.00
b	Referral cost savings per case	R 1,012.00

TABLE 13: VALUES OF DEVICE RELATED VARIABLES

i	Devices	%	X_i	Once off capital	C_i
1	Basic workstation	32.71%	164	R 50,000.00	R 11,990.79
2	Camera – Video	1.37%	7	R 20,000.00	R 4,796.32
3	X-ray scanner	13.22%	66	R 65,000.00	R 15,588.03
4	Stethoscope	10.48%	52	R 10,000.00	R 2,398.16
5	Electrocardiogram	5.48%	27	R 20,000.00	R 4,796.32
6	Thermometer	7.15%	36	R 4,000.00	R 959.26
7	Endoscope	1.57%	8	R 30,000.00	R 7,194.48
8	Otoscope	0.10%	0	R 15,000.00	R 3,597.24
9	Ophthalmoscope	1.76%	9	R 25,000.00	R 5,995.40
10	Retinal Camera	0.39%	2	R 25,000.00	R 5,995.40
11	Microscope	3.82%	19	R 3,000.00	R 719.45
12	Ultrasound probe	3.43%	17	R 12,000.00	R 2,877.79
13	Spirometer	2.06%	10	R 10,000.00	R 2,398.16

LINDO OUTPUT

LINDO calculated the maximum objective function for the constraints specified. LINDO input and report figures are shown in Appendix E. The following results were obtained:

- An objective function / Annual referral cost savings of R 292 561.00
- $y_1, y_4, y_5, y_6, y_{11}, y_{12}, y_{13} = 1$ these are the chosen devices
- $y_2, y_3, y_7, y_8, y_9, y_{10} = 0$ these are not the chosen devices
- The chosen devices were: the basic workstation, stethoscope, electrocardiogram, thermometer, microscope, ultrasound probe and Spirometer
- 1) 325 of the 500 cases were referred with telemedicine
- 2) The annual capital payments for the workstation and devices were R26 140.07
- 3) The annual referral cost savings were R 103 900.00
- 4) The workstation and 6 devices were chosen

The LINDO results indicated that the basic workstation, stethoscope, electrocardiogram, thermometer, microscope, ultrasound probe and spirometer should have been implemented at Ceres Hospital in 2008. This would have enabled the doctors to use telemedicine for 325 patients with a total annual referral cost saving of R 292 561.00.

6 CONCLUSIONS AND RECOMMENDATIONS

This project was initially undertaken to provide a decision support framework to contribute towards congruency between true user needs and further development of telemedicine workstations and peripheral devices, using a clinical-pull approach.

To achieve this goal the following objectives were reached:

- A decision support system was defined and constructed
- Development of a MS Access database to record and process data
- Extraction, transformation and loading of patient data
- Diagnoses at different facilities were analysed using the Pareto principle
- Potential devices usage that would utilise telemedicine effectively at different facilities
- Economic feasibility of the MRC/SU telemedicine workstation was determined for Ceres Hospital in 2008
- Mathematical programming were used to determine the feasibility of individual telemedicine peripheral inclusion in the system

The decision support system that was developed was proven to be effective through the course of this project. This DSS including a data collection method, database, analyses and reporting format has been proven suitable to perform a needs assessment for another region.

The MS Access database proved to be an effective tool providing structure during the loading process of data extraction from patient records. The database was limited in the sense that only one data capturer could enter data at a time. This challenge was overcome by merging database master files from different computers into a single master file. This transformation process was a rather inefficient and time consuming process. The development of a web interface for the database will ensure that more than one data capturers could work simultaneously. The web interface will also ensure uniform data capture, and therefore minimal data transformation, since the diagnosis list has been standardised and aligned with standard medical practice in the facilities.

The Pareto principle was successfully utilised to identify the most frequently occurring diagnoses at the different facilities. Approximately 40% of the diagnoses occurred 80% of the time for the majority of the facilities. In this manner telemedicine can be focussed on the predominant medical conditions. During the analysis process it was realised that the Pareto analysis should be done directly for the list of devices. This was executed yielding the potentially most frequently used devices. In the case of Professional nurse-to-doctor referrals, 80% of the cases could potentially be diagnosed by the telemedicine workstation and 5 peripheral devices as detailed in Table 7. For Hospital-to-hospital referrals a higher percentage (16.5% vs. approx. 3%) of the cases was not potential telemedicine cases. This resulted in the potential telemedicine utilisation in 80% of the cases requiring the telemedicine workstation and 10 peripheral devices (Table 7).

Economic feasibility of the workstation was investigated and proved to be positive within the constraints of the component costs used. The MRC/SU workstation was used for economic feasibility calculations. From discounted cash flow analysis it was estimated that the total annual savings for hospital-to-hospital referrals done by telemedicine would have be R 110,584.53 if the workstation was implemented at Ceres Hospital in 2008. It is recommended that the cost analysis be populated with cost factors relevant to the specific region being investigated for telemedicine implementation.

Mathematical programming served a rather valuable purpose in this project. The integer programming model was constructed to determine the minimum cost alternative for the telemedicine workstation with peripheral devices. The results obtained from the LINDO mathematical programming software provided an equipment profile as the result of a cost constraint combined with diagnoses profiles. Practically interpreted the model chose some of the lesser utilised peripherals such as the spirometer and the ultrasound probe on the ground of their relatively lower cost versus the benefit achievable. The x ray scanner was not chosen because the ratio of its high cost versus the benefit of diagnoses achievable was on a lower level. If the same ratio of cost saving that was achieved for the local workstation versus the imported workstations can be repeated for an x-ray scanner it will be a valuable addition to the workstation. Local the development of the x-ray scanner is therefore recommended as a priority. The implementation of imported x-ray scanners are not recommended for conditions similar to those in the study.

In this project it was initially hypothesised that a clinical-pull approach has significant benefits to offer for telemedicine implementation. The decision support framework yielded valuable new insights and proved to be a useful tool that can be employed in unexplored regions.

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APPENDIX A: MRC RESEARCH DAY ABSTRACT

A TECHNOLOGY PULL APPROACH TO TELEMEDICINE IN SOUTH AFRICA

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BACKGROUND

Telemedicine has appealed to the innovation skills of engineers, making technology the primary driver of telemedicine development world wide. This technology push model where the engineers pursue challenging technological goals primarily does not guarantee appropriate and quality healthcare. The challenge is therefore to assess the true need of the population and develop a comprehensive system to enable efficient service delivery using technology only as a means and not a goal in itself.

METHODOLOGY

A data sample was collected from primary healthcare facilities in the Western Cape, including Grabouw day hospital, Robertson hospital and Ceres hospital. Patient treatment cases were examined for the possibility of telemedicine application. Cases were pre-sorted in two categories namely referrals from clinics to regional hospitals and regional to academic hospitals. This project included the development of a database in which the data was entered and analysed. A Pareto analysis following categorisation of medical conditions is envisaged.

RESULTS

Preliminary results are presented in graphical format. Cases seen by doctors, therefore potential telemedicine applications, are presented as a percentage of total headcount of the facility visits. A Pareto analysis indicates the percentage of cases broken down per medical condition category seen by a doctor. The experimental results indicate two distinct categories of telemedicine application, namely clinic-to-hospital and hospital-to-hospital. Two separate data sets were collected to facilitate this investigation.

CONCLUSIONS

This study serves as a pilot project to validate the feasibility of the data collection methods introduced in this project. Although this research is incomplete, convergence can be demonstrated to assess the regional telemedicine specification requirements. It also becomes clear that the results of this study cannot be generalised throughout South Africa. A follow-up study with a larger scope, categorising the country in homogeneous regions and determining the telemedicine specification requirements specifically for each, needs to be done.

APPENDIX B: MRC RESEARCH DAY POWERPOINT PRESENTATION

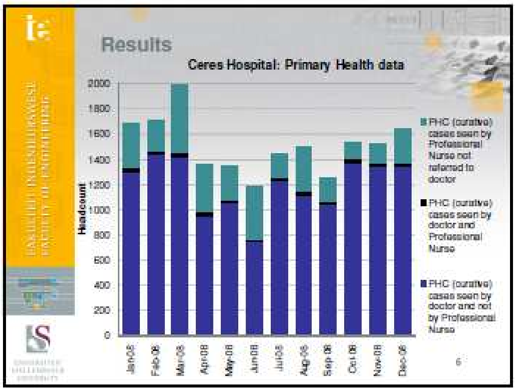

A Technology Pull Approach
to Telemedicine in
South Africa
MJ Treurnicht
1

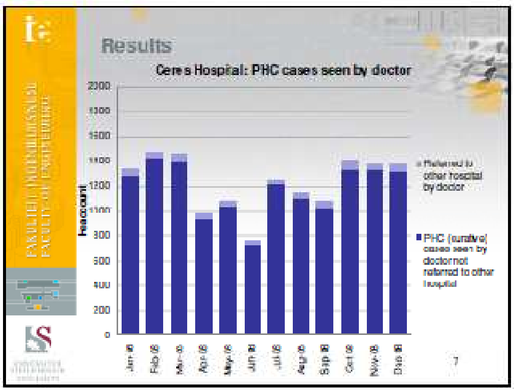

Telemedicine Overview
Definition: Telemedicine is medical service provision over a distance, made possible through communication media
Telemedicine and technology
USA and European contributions
Telemedicine in South Africa
2

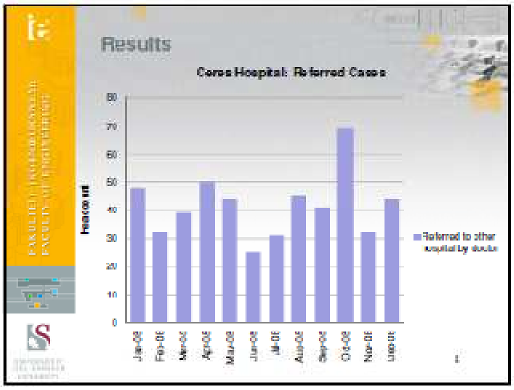

Introduction and Background
• Problem Statement / Challenge
Need for telemedicine in South Africa?
What is the need?
How should the technology address this need?
3

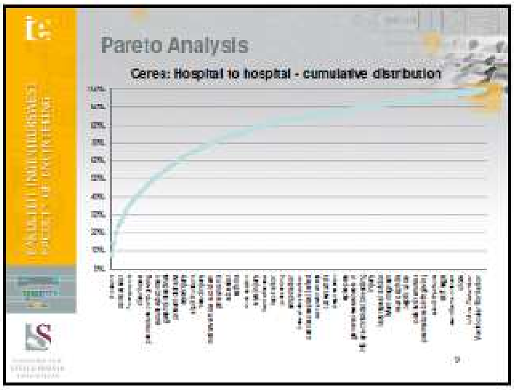

Technology Push vs Technology Pull
Technology Push Strategy
• Developing Technology without proof that there is a need for this technology
Technology Pull Strategy
• Developing Technology based on a proven need
4


Methodology
Needs Assessment
• Database Development
• Data collection - Grabouw CHC
- Robertson Hospital
- Ceres Hospital
• Data organisation - PHC statistics
- Referral diagnoses
- Pareto analysis
• Data validation
5


Results
Ceres Hospital: Primary Health data
Headcount
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
PHC (curative) cases seen by Professional Nurse not referred to doctor
PHC (curative) cases seen by doctor and Professional Nurse
PHC (curative) cases seen by doctor and not by Professional Nurse
6


Results
Ceres Hospital: PHC cases seen by doctor
Frequency
Referred to other hospital by doctor
PHC (curative) cases seen by doctor not referred to other hospital
Jan 08
Feb 08
Mar 08
Apr 08
May 08
Jun 08
Jul 08
Aug 08
Sep 08
Oct 08
Nov 08
Dec 08
7

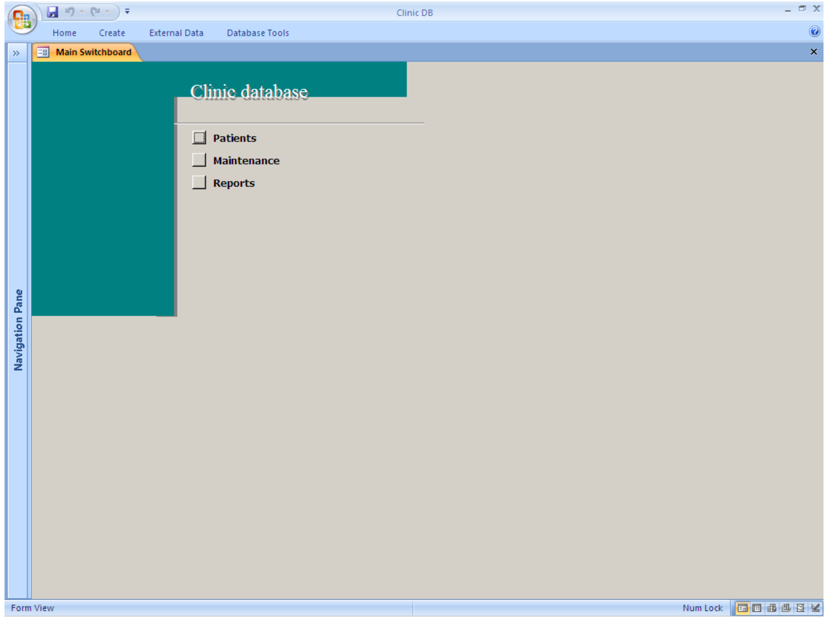

Results
Ceres Hospital: Referred Cases
Frequency
Referred to other hospital by doctor
80
70
60
50
40
30
20
10
0

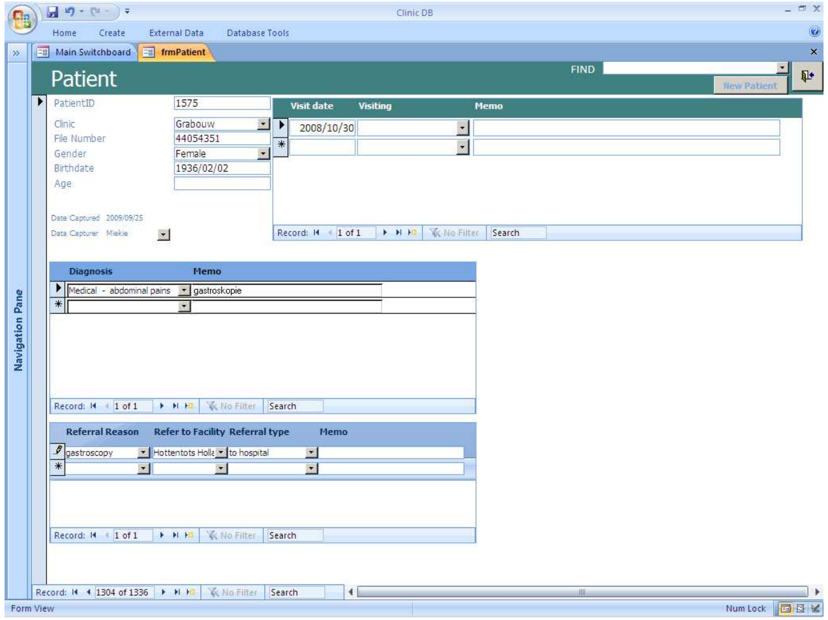

Pareto Analysis
Ceres: Hospital to hospital - cumulative distribution
9

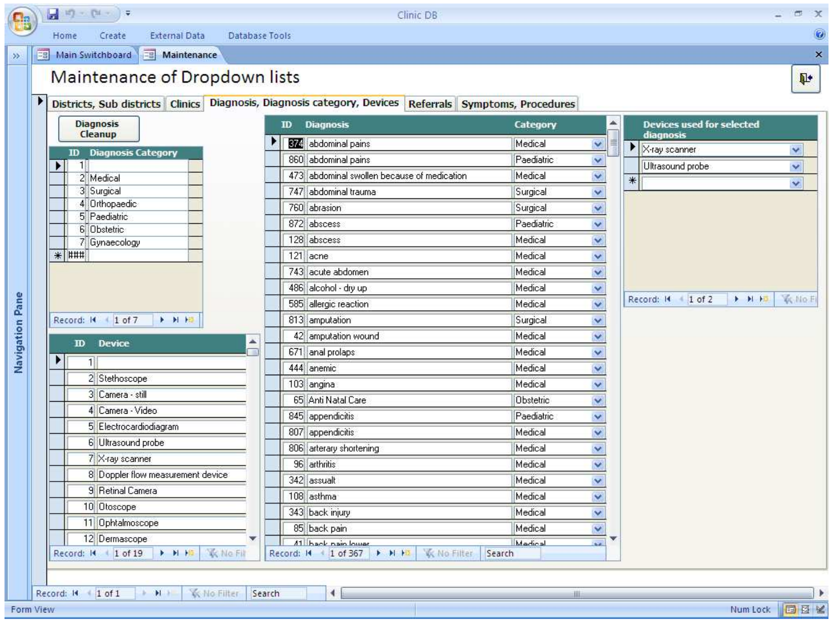

Next steps
Grouping diagnoses into relevant classifications
Technology applications to groups of diagnoses
Economic analysis
Linear Programming to prove / disprove feasibility
Creating a model for decision making

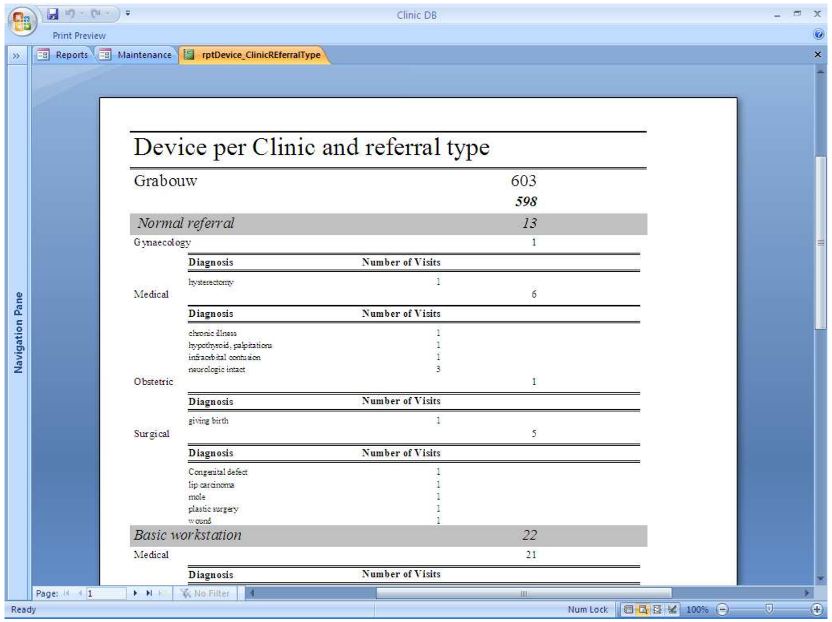

Feedback and Questions

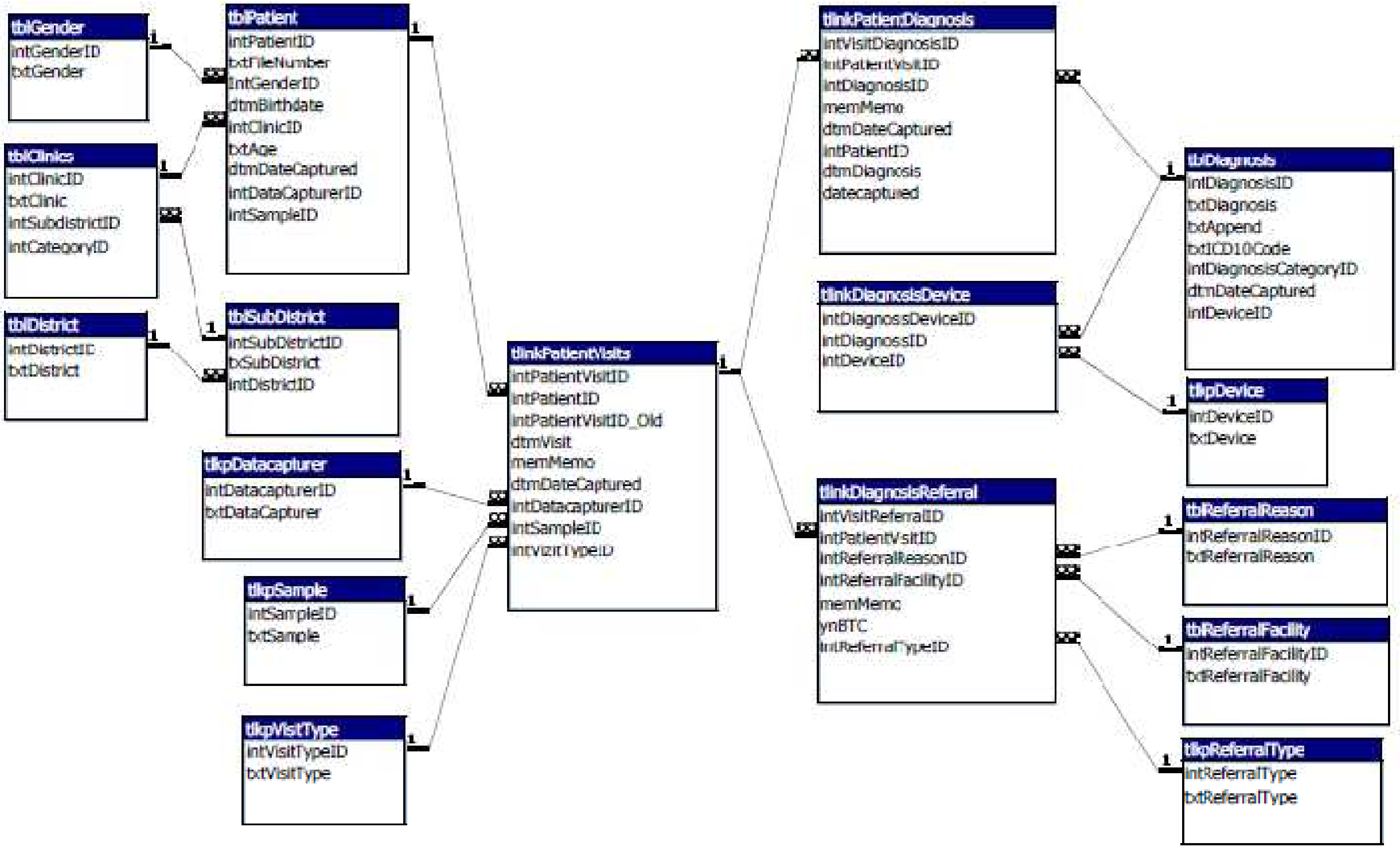
APPENDIX C: ACCESS DATABASE (MS ACCESS)


Clinic DB
Home
Create
External Data
Database Tools
Main Switchboard
Clinic database
Patients
Maintenance
Reports
Navigation Pane
Form View
Num Lock


Clinic DB
Home
Create
External Data
Database Tools
Main Switchboard
frmPatient
Patient
FIND
New Patient
PatientID
1575
Clinic
Grabouw
File Number
44054351
Gender
Female
Birthdate
1936/02/02
Age
Visit date
Visiting
Memo
2008/10/30
Diagnosis
Memo
Medical - abdominal pains
gastroskopie
Referral Reason
Refer to Facility
Referral type
Memo
gastroscopy
to hospital
Record: 1304 of 1336
Search
Navigation Pane
Form View
Num Lock


Clinic DB
Home
Create
External Data
Database Tools
Main Switchboard
Maintenance
Maintenance of Dropdown lists
Districts, Sub districts
Clinics
Diagnosis, Diagnosis category, Devices
Referrals
Symptoms, Procedures
Diagnosis Cleanup
ID
Diagnosis Category
Medical
Surgical
Orthopaedic
Paediatric
Obstetric
Gynaecology
Device
Stethoscope
Camera - still
Camera - Video
Electrocardiodiagram
Ultrasound probe
X-ray scanner
Doppler flow measurement device
Retinal Camera
Otoscope
Ophtalmoscope
Dermascope
Diagnosis
Category
abdominal pains
abdominal swollen because of medication
abdominal trauma
abrasion
abscess
acne
acute abdomen
alcohol - dry up
allergic reaction
amputation
amputation wound
anal prolaps
anemic
angina
Anti Natal Care
appendicitis
arterary shortening
arthritis
assualt
asthma
back injury
back pain
Devices used for selected diagnosis
X-ray scanner
Ultrasound probe
Record: 1 of 367
Navigation Pane
Form View
Num Lock


Clinic DB
Print Preview
Reports
Maintenance
rptDevice_ClinicREferralType
Device per Clinic and referral type
Grabouw
603
598
Normal referral
13
Gynaecology
Medical
Obstetric
Surgical
Diagnosis
Number of Visits
hysterectomy
chronic illness
hypothyroid, palpitations
intracerbral contusion
neurologic intact
giving birth
Congenital defect
lip carcinoma
mole
plastic surgery
wound
Basic workstation
22
21
Navigation Pane
Ready
Num Lock
100%



RELATIONSHIP DIAGRAM OF THE DATABASE DEVELOPED

APPENDIX D: DATA REPORTS

Diagnosis	Occurrence	%
Ceres: hospital to hospital	**518**	
Gynaecology	4	0.772%
PET (Positron	2	0.386%
premature birth giving	1	0.193%
vaginal bleeding	1	0.193%
Medical	254	49.035%
psychosis	34	6.564%
Tuberculosis	33	6.371%
concussion	15	2.896%
diabetes	14	2.703%
cerebral vascular	8	1.544%
Hypertension	8	1.544%
abdominal pains	7	1.351%
acute abdomen	5	0.965%
epilepsy	5	0.965%
gastrointestinal	5	0.965%
laceration	5	0.965%
Meningitis	5	0.965%
Overdose	5	0.965%
vomiting	5	0.965%
convulsions	4	0.772%
headache	4	0.772%
Melaena	4	0.772%
chest pain	3	0.579%
diarrhoea	3	0.579%
head injury	3	0.579%
myocardial infarcire	3	0.579%
organophosphate	3	0.579%
pneumonia	3	0.579%
retroviral disease	3	0.579%
appendicitis	2	0.386%
arterary shortening	2	0.386%
asthma	2	0.386%
breathing with difficulty	2	0.386%
ca oesophagus	2	0.386%
ca tong	2	0.386%
COPD (Chronic)	2	0.386%
Deep vein thrombosis	2	0.386%
feverish	2	0.386%
kidney failure	2	0.386%
poisoning	2	0.386%
abscess	1	0.193%
anaemic	1	0.193%
back pain lower	1	0.193%
bacterial endocarditic	1	0.193%
ca lung	1	0.193%
ca stomach	1	0.193%
cholecystitis	1	0.193%
chronic NVS	1	0.193%
confusion, acute	1	0.193%
cor pulmonary	1	0.193%
cranial nerve	1	0.193%
CT Scan	1	0.193%
delirium	1	0.193%
depression	1	0.193%
dysphasia	1	0.193%
eye injury	1	0.193%
Finger dislocation	1	0.193%
general weakness in body	1	0.193%
Haemoptysis	1	0.193%
HB arachnoidal bleeding	1	0.193%
hyperglycaemic	1	0.193%
keratitis	1	0.193%
laryngeal stridor	1	0.193%
lower respiratory	1	0.193%
lung abscess	1	0.193%
Mammogram	1	0.193%
mental	1	0.193%
motor vehicle	1	0.193%
muscle dystrophy	1	0.193%
neurosiphilis	1	0.193%
osteitis	1	0.193%
pain in leg	1	0.193%
Pelvic Inflammatory	1	0.193%
peptic ulcer	1	0.193%
pericardial effusion	1	0.193%
PET (Positron emission tomography)	1	0.193%
rectal bleeding	1	0.193%
stiff legs	1	0.193%
stroke	1	0.193%
throat cancer	1	0.193%
tooth abscess	1	0.193%
ulcer	1	0.193%
Urine Retention	1	0.193%
Ventricular fibrillation	1	0.193%
wound	1	0.193%
Obstetric	51	9.846%
PET (Positron emission tomography)	13	2.510%
giving birth	10	1.931%
preeclampsia	7	1.351%
premature birth giving	7	1.351%

birth giving false alarm	6	1.158%
hypertension in pregnancy	2	0.386%
caesarean	1	0.193%
epigastria break	1	0.193%
polyhydramnios	1	0.193%
post partum bleeding	1	0.193%
pre natal	1	0.193%
uterus prolapsed	1	0.193%
Orthopaedic	64	12.355%
fracture	40	7.722%
injury	4	0.772%
skull fracture	4	0.772%
inguinal hernia	3	0.579%
laceration	3	0.579%
motor vehicle accident	3	0.579%
head injury	2	0.386%
dislocation	1	0.193%
spinal injury	1	0.193%
subtrochanteric osteotomy	1	0.193%
unknown	1	0.193%
wrist dislocation	1	0.193%
Paediatric	77	14.865%
Pneumonia	9	1.737%
premature baby	9	1.737%
diarrhoea	8	1.544%
fracture	6	1.158%
Breathing with	5	0.965%
burn wounds	5	0.965%
appendicitis	2	0.386%
concussion	2	0.386%
convulsion	2	0.386%
eye injury	2	0.386%
jaundice	2	0.386%
laceration	2	0.386%
meningitis	2	0.386%
abdominal pains	1	0.193%
bowel obstruction	1	0.193%
cardiac septal defect	1	0.193%
croup	1	0.193%
deep venous thrombosis	1	0.193%
dehydration	1	0.193%
epilepsy	1	0.193%
general weakness in	1	0.193%
hagienmembrane sickness	1	0.193%
indecent assault	1	0.193%
injured soft tissue	1	0.193%

knife wound	1	0.193%
Kwashiorkor	1	0.193%
lower respiratory tract illness	1	0.193%
Peripheral vascular	1	0.193%
septic shock	1	0.193%
skull fracture	1	0.193%
soft tissue injury, knee	1	0.193%
swollen scrotum	1	0.193%
Tuberculosis	1	0.193%
vomiting	1	0.193%
Surgical	68	13.127%
laceration	19	3.668%
burn wounds	6	1.158%
pneumotoraks	5	0.965%
wound	5	0.965%
eye injury	4	0.772%
head injuries	3	0.579%
knife wound	3	0.579%
motor vehicle accident	3	0.579%
abdominal trauma	2	0.386%
abrasion	2	0.386%
fracture	2	0.386%
hemothorax	2	0.386%
neck injury	2	0.386%
tendon injury	2	0.386%
amputation	1	0.193%
cut wounds	1	0.193%
gastrointestinal bleeding	1	0.193%
injury	1	0.193%
soft tissue injury	1	0.193%
swollen orbital area	1	0.193%
ulcers eye	1	0.193%
ulcers foot	1	0.193%
Gynaecology	15	2.896%
vaginal bleeding	9	1.737%
ultrasound (sonar)	3	0.579%
post natal stress	1	0.193%
prolapsed uterus	1	0.193%
vaginal discharge	1	0.193%

Diagnosis	Occurrence	%
Ceres - Seen by doctor	**307**	
Medical	271	88.274%
diarrhoea	23	7.492%
assault	22	7.166%
injury	20	6.515%
X Rays	14	4.560%
breathing with difficulty	13	4.235%
vomiting	13	4.235%
abscess	12	3.909%
Hypertension	10	3.257%
psychosis	8	2.606%
epilepsy	7	2.280%
Haemoptysis	7	2.280%
abdominal pains	6	1.954%
wound	6	1.954%
convulsions	5	1.629%
diabetes	5	1.629%
feverish	5	1.629%
back pain lower	4	1.303%
burn wounds	4	1.303%
coughing	4	1.303%
eye injury	4	1.303%
dog bite	3	0.977%
Overdose	3	0.977%
rugby injury	3	0.977%
stomach pain	3	0.977%
tonsillitis	3	0.977%
blood test results	2	0.651%
indecent assault	2	0.651%
light-headedness	2	0.651%
Meningitis	2	0.651%
nausea	2	0.651%
night sweat	2	0.651%
panic attack	2	0.651%
pneumonia	2	0.651%
soar throat	2	0.651%
allergic reaction	1	0.326%
anal prolapsed	1	0.326%
angina	1	0.326%
asthma	1	0.326%
Bedsores	1	0.326%
blood pressure check-up	1	0.326%
bronchitis	1	0.326%
cellulites	1	0.326%
chest pain	1	0.326%
circumcision	1	0.326%
dehydration	1	0.326%
dentektomie	1	0.326%
depression	1	0.326%
dizziness	1	0.326%
DNA	1	0.326%
drunk driving	1	0.326%
drunk poison	1	0.326%
eye (unidentified object)	1	0.326%
eye in pain	1	0.326%
eye infection	1	0.326%
fainted	1	0.326%
general weakness in body	1	0.326%
headache	1	0.326%
haemorrhoid	1	0.326%
Hepatitis B	1	0.326%
herpes	1	0.326%
hypoglycaemic	1	0.326%
jaundice	1	0.326%
lipoma	1	0.326%
low blood pressure	1	0.326%
lymphadenopathy	1	0.326%
nose bleeding	1	0.326%
pain in chest	1	0.326%
pain in jaw	1	0.326%
pain in lateral side of	1	0.326%
pain in ribs	1	0.326%
paralysed	1	0.326%
Penis infection	1	0.326%
results	1	0.326%
ring stuck on finger	1	0.326%
snake bite	1	0.326%
suicidal tendency	1	0.326%
swollen neck	1	0.326%
tooth removal	1	0.326%
Tuberculosis	1	0.326%
vomiting blood	1	0.326%
Obstetric	2	0.651%
pregnancy	2	0.651%
Orthopaedic	12	3.909%
fracture	10	3.257%
dislocation	1	0.326%
motor vehicle accident	1	0.326%
Surgical	7	2.280%
laceration	7	2.280%

Diagnosis	Occurrence	%
Robertson - Seen by doctor	**369**	
Medical	346	93.767%
injury	62	16.802%
abscess	20	5.420%
Hypertension	13	3.523%
epilepsy	12	3.252%
diarrhoea	11	2.981%
X Rays	11	2.981%
breathing with difficulty	10	2.710%
wound	10	2.710%
assault	9	2.439%
vomiting	9	2.439%
diabetes	8	2.168%
eye injury	8	2.168%
Haemoptysis	6	1.626%
asthma	5	1.355%
burn wounds	5	1.355%
dog bite	5	1.355%
convulsions	4	1.084%
feverish	4	1.084%
Overdose	4	1.084%
pain in leg	4	1.084%
pneumonia	4	1.084%
psychosis	4	1.084%
stomach pain	4	1.084%
Tuberculosis	4	1.084%
back pain	3	0.813%
blood test results	3	0.813%
cellulites	3	0.813%
indecent assault	3	0.813%
pain in chest	3	0.813%
referral	3	0.813%
skin rash	3	0.813%
back pain lower	2	0.542%
Blisters	2	0.542%
confusion, aggression	2	0.542%
coughing	2	0.542%
coughing blood	2	0.542%
dehydration	2	0.542%
gastrointestinal bleeding	2	0.542%
hypoglycaemic	2	0.542%
knife wound	2	0.542%
nausea	2	0.542%
nose bleeding	2	0.542%
pain in lateral side of body	2	0.542%
sick letter	2	0.542%
tonsillitis	2	0.542%
abdominal pains	1	0.271%
abdominal swollen	1	0.271%
because of alcohol - dry up	1	0.271%
anaemic	1	0.271%
arthritis	1	0.271%
back injury	1	0.271%
Blood in stool sample	1	0.271%
blood in urine	1	0.271%
blood pressure check-up	1	0.271%
breast abscess	1	0.271%
breast lump	1	0.271%
breast pain	1	0.271%
cerebral vascular	1	0.271%
cervicitis	1	0.271%
chicken pocks	1	0.271%
clavicle swollen	1	0.271%
croup	1	0.271%
crying, weepiness	1	0.271%
dizziness	1	0.271%
echocardiogram	1	0.271%
eczema	1	0.271%
fainted	1	0.271%
flu	1	0.271%
general weakness in body	1	0.271%
headache	1	0.271%
HIV Positive	1	0.271%
Hydrocele, urology	1	0.271%
infective parotids (mumps)	1	0.271%
ingrown nail	1	0.271%
Insanity	1	0.271%
insect bite	1	0.271%
jaundice	1	0.271%
kadiomiepentie	1	0.271%
kidney failure	1	0.271%
kidney stone check up	1	0.271%
legs paralysed	1	0.271%
letter for school	1	0.271%
lipoma	1	0.271%
lung abscess	1	0.271%
macular infection	1	0.271%
Meningitis	1	0.271%
neck injury	1	0.271%
night sweat	1	0.271%
pain between shoulders	1	0.271%

pain in body	1	0.271%
pain in neck	1	0.271%
paralysed hand	1	0.271%
peptic ulcer	1	0.271%
persistent thirst	1	0.271%
retroviral disease	1	0.271%
rugby injury	1	0.271%
scorpion sting	1	0.271%
stiale patella	1	0.271%
swollen under neck	1	0.271%
trigger finger	1	0.271%
unknown	1	0.271%
unstable blood pressure	1	0.271%
urine burns	1	0.271%
Urine Retention	1	0.271%
vomiting (koffiemoer)	1	0.271%
vomiting blood	1	0.271%
Obstetric	3	0.813%
pregnancy	3	0.813%
Orthopaedic	9	2.439%
fracture	6	1.626%
knee replacement check-up	1	0.271%
motor vehicle accident	1	0.271%
orthopaedic	1	0.271%
Surgical	2	0.542%
laceration	2	0.542%
Gynaecology	9	2.439%
vaginal bleeding	9	2.439%

Diagnosis	Occurrence	%
Grabouw: seen by doctor	**299**	
Gynaecology	**11**	3.679%
vaginal bleeding	3	1.003%
vaginal discharge	2	0.669%
hysterectomy	1	0.334%
menstruate 3 week	1	0.334%
Pap smear	1	0.334%
ultrasound (sonar)	1	0.334%
vaginal infection	1	0.334%
vaginal irritation	1	0.334%
Medical	**242**	80.936%
Hypertension	27	9.030%
Tuberculosis	16	5.351%
diabetes	14	4.682%
arthritis	11	3.679%
epilepsy	11	3.679%
diarrhoea	8	2.676%
angina	7	2.341%
asthma	6	2.007%
pain in knees	5	1.672%
back pain	4	1.338%
gout	4	1.338%
laceration	4	1.338%
abscess	3	1.003%
back pain lower	3	1.003%
cataract	3	1.003%
cholesterol	3	1.003%
gastro-oesophageal reflux disease	3	1.003%
neurologic intact	3	1.003%
report medical	3	1.003%
wound	3	1.003%
blood pressure check-up	2	0.669%
breast abscess	2	0.669%
breast lump	2	0.669%
chest pain	2	0.669%
ear pain	2	0.669%
eye injury	2	0.669%
fungal infection	2	0.669%
heart failure	2	0.669%
heart palpitations	2	0.669%
letter for completion	2	0.669%
otitis media	2	0.669%
stomach pain	2	0.669%
syphilis	2	0.669%
thyroid enlarged	2	0.669%

vomiting	2	0.669%
abdominal pains	2	0.669%
acne	1	0.334%
amputation wound	1	0.334%
assault	1	0.334%
Bladder injury	1	0.334%
Blisters	1	0.334%
blood test results	1	0.334%
breast cancer	1	0.334%
breathing with	1	0.334%
bronchitis	1	0.334%
bronchospasm	1	0.334%
buerger's disease	1	0.334%
burn wounds	1	0.334%
cardiomigaly	1	0.334%
cervicitis	1	0.334%
check up on triple	1	0.334%
chronic illness	1	0.334%
conjunctivitis	1	0.334%
constipation	1	0.334%
crepitus knees	1	0.334%
disability letter	1	0.334%
drug abuse	1	0.334%
echocardiogram	1	0.334%
eczema	1	0.334%
enlarged heart	1	0.334%
Excision middle	1	0.334%
eye in pain	1	0.334%
fibrositis	1	0.334%
gastrointestinal bleeding	1	0.334%
gastroscopy	1	0.334%
heart attack	1	0.334%
hematoma	1	0.334%
hemiparesis	1	0.334%
Hepatitis B	1	0.334%
HIS	1	0.334%
hoarseness	1	0.334%
hyper cholesterol	1	0.334%
hyperinflation	1	0.334%
hyperlipidaemia	1	0.334%
hyperparathyroidism	1	0.334%
hypothyroid, palpitations	1	0.334%
influenza	1	0.334%
infraorbital contusion	1	0.334%
Ischaemic Heart Disease	1	0.334%
Ischaemic nerve damage	1	0.334%

kidney operation check up	1	0.334%
knife wound	1	0.334%
leucocytes	1	0.334%
liver problem	1	0.334%
malaria test	1	0.334%
medial epicondylitis	1	0.334%
metacarpal ganglion	1	0.334%
migraine	1	0.334%
muscle spasm	1	0.334%
pain in arm	1	0.334%
pain in lateral side of	1	0.334%
pain in neck	1	0.334%
pain in ribs	1	0.334%
pain in wrist	1	0.334%
Peripheral vascular disease	1	0.334%
pharyngitis	1	0.334%
retroviral disease	1	0.334%
right eye tears	1	0.334%
sexual transmitted infections	1	0.334%
supraclavicular gland	1	0.334%
swollen face	1	0.334%
thigh pain	1	0.334%
tonsillitis	1	0.334%
ulcer	1	0.334%
urine burns	1	0.334%
Obstetric	**10**	**3.344%**
pregnancy	5	1.672%
Anti Natal Care	2	0.669%
giving birth	1	0.334%
giving birth check up	1	0.334%
miscarriage risk	1	0.334%
Orthopaedic	**25**	**8.361%**
injury	10	3.344%
fracture	9	3.010%
head injury	2	0.669%
Discus collaps	1	0.334%
foot bone adhesion	1	0.334%
lumberspine	1	0.334%
thumb pain	1	0.334%
Paediatric	**6**	**2.007%**
abscess	1	0.334%
bronchospasm	1	0.334%
nightmares	1	0.334%
strabismus (squint eyes)	1	0.334%
vaginal irritation	1	0.334%
wound	1	0.334%
Surgical	**5**	**1.672%**
Congenital defect	1	0.334%
lip carcinoma	1	0.334%
mole	1	0.334%
plastic surgery	1	0.334%
wound	1	0.334%

Ceres: Hospital to Hospital devices			
Device	Occurrence	%	cum %
Camera - still	216	21.16%	21.16%
Normal referral	168	16.45%	37.61%
X-ray scanner	135	13.22%	50.83%
Stethoscope	107	10.48%	61.31%
Blood pressure	97	9.50%	70.81%
Thermometer	73	7.15%	77.96%
Electrocardiogram	56	5.48%	83.45%
Microscope	39	3.82%	87.27%
Ultrasound probe	35	3.43%	90.70%
Basic workstation	21	2.06%	92.75%
Spirometer	21	2.06%	94.81%
Ophthalmoscope	18	1.76%	96.57%
Endoscope	16	1.57%	98.14%
Camera - Video	14	1.37%	99.51%
Retinal Camera	4	0.39%	99.90%
Otoscope	1	0.10%	100.00%

Diagnosis	Occurrence	%
Ceres hospital to hospital	**1021**	**100.00%**
Normal referral	**168**	**16.45%**
Gynaecology	2	0.20%
Medical	57	5.58%
Obstetric	24	2.35%
Orthopaedic	5	0.49%
Paediatric	8	0.78%
Surgical	72	7.05%
Basic workstation	**21**	**2.06%**
Medical	11	1.08%
Obstetric	6	0.59%
Paediatric	4	0.39%
Blood pressure	**97**	**9.50%**
Gynaecology	1	0.10%
Medical	61	5.97%
Obstetric	19	1.86%
Orthopaedic	2	0.20%
Paediatric	14	1.37%
Camera - still	**216**	**21.16%**
Gynaecology	2	0.20%
Medical	105	10.28%
Obstetric	8	0.78%
Orthopaedic	59	5.78%
Paediatric	37	3.62%
Camera - Video	**14**	**1.37%**
Medical	5	0.49%
Paediatric	9	0.88%
Electrocardiogram	**56**	**5.48%**
Medical	36	3.53%
Obstetric	9	0.88%
Paediatric	11	1.08%
Endoscope	**16**	**1.57%**
Medical	16	1.57%
Microscope	**39**	**3.82%**
Gynaecology	1	0.10%
Medical	37	3.62%
Paediatric	1	0.10%
Ophthalmoscope	**18**	**1.76%**
Medical	16	1.57%
Paediatric	2	0.20%
Otoscope	**1**	**0.10%**
Medical	1	0.10%
Retinal Camera	**4**	**0.39%**
Medical	2	0.20%
Paediatric	2	0.20%
Spirometer	**21**	**2.06%**
Medical	14	1.37%
Paediatric	7	0.69%
Stethoscope	**107**	**10.48%**
Medical	57	5.58%
Obstetric	11	1.08%
Orthopaedic	2	0.20%
Paediatric	37	3.62%
Thermometer	**73**	**7.15%**
Medical	37	3.62%
Orthopaedic	2	0.20%
Paediatric	32	3.13%
Ultrasound probe	**35**	**3.43%**
Gynaecology	1	0.10%
Medical	15	1.47%
Obstetric	18	1.76%
Paediatric	1	0.10%
X-ray scanner	**135**	**13.22%**
Gynaecology	1	0.10%
Medical	66	6.46%
Orthopaedic	56	5.48%
Paediatric	10	0.98%

Ceres: Seen by doctor devices			
Device	Occurrence	%	cum %
Camera - still	155	26.09%	26.09%
Thermometer	77	12.96%	39.06%
Blood pressure	75	12.63%	51.68%
X-ray scanner	74	12.46%	64.14%
Stethoscope	67	11.28%	75.42%
Basic workstation	31	5.22%	80.64%
Spirometer	23	3.87%	84.51%
Normal referral	20	3.37%	87.88%
Electrocardiogram	19	3.20%	91.08%
Ultrasound probe	15	2.53%	93.60%
Ophthalmoscope	12	2.02%	95.62%
Microscope	11	1.85%	97.47%
Retinal Camera	6	1.01%	98.48%
Camera - Video	3	0.51%	98.99%
Endoscope	3	0.51%	99.49%
Otoscope	3	0.51%	100.00%

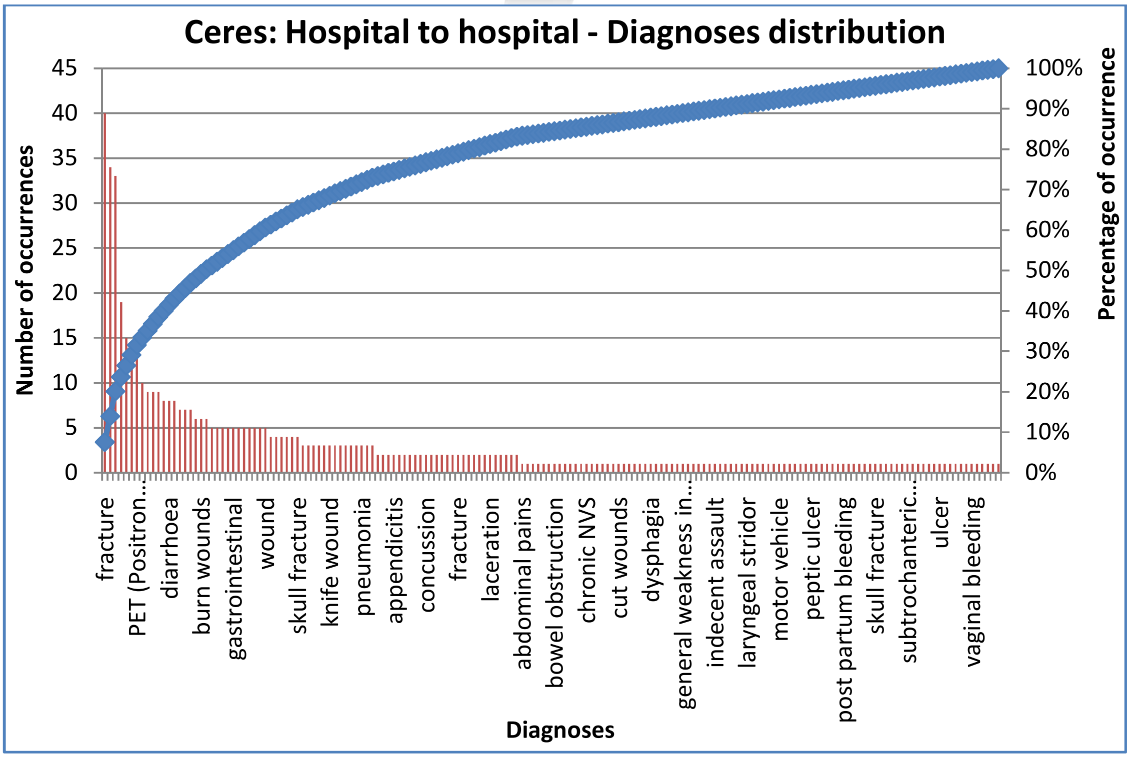
Diagnosis	Occurrence	%
Ceres: seen by doctor	**594**	**100.00%**
Normal referral	**20**	**3.37%**
Medical	13	2.19%
Surgical	7	1.18%
Basic workstation	**31**	**5.22%**
Medical	31	5.22%
Blood pressure	**75**	**12.63%**
Gynaecology	4	0.67%
Medical	69	11.62%
Obstetric	2	0.34%
Camera - still	**155**	**26.09%**
Gynaecology	12	2.02%
Medical	131	22.05%
Orthopaedic	12	2.02%
Camera - Video	**3**	**0.51%**
Medical	3	0.51%
Electrocardiogram	**19**	**3.20%**
Medical	19	3.20%
Endoscope	**3**	**0.51%**
Medical	3	0.51%
Microscope	**11**	**1.85%**
Gynaecology	10	1.68%
Medical	1	0.17%
Ophthalmoscope	**12**	**2.02%**
Medical	12	2.02%
Otoscope	**3**	**0.51%**
Medical	3	0.51%
Retinal Camera	**6**	**1.01%**
Medical	6	1.01%
Spirometer	**23**	**3.87%**
Medical	23	3.87%
Stethoscope	**67**	**11.28%**
Gynaecology	1	0.17%
Medical	66	11.11%
Thermometer	**77**	**12.96%**
Medical	77	12.96%
Ultrasound probe	**15**	**2.53%**
Gynaecology	4	0.67%
Medical	9	1.52%
Obstetric	2	0.34%
X-ray scanner	**74**	**12.46%**
Gynaecology	9	1.52%
Medical	53	8.92%
Orthopaedic	12	2.02%

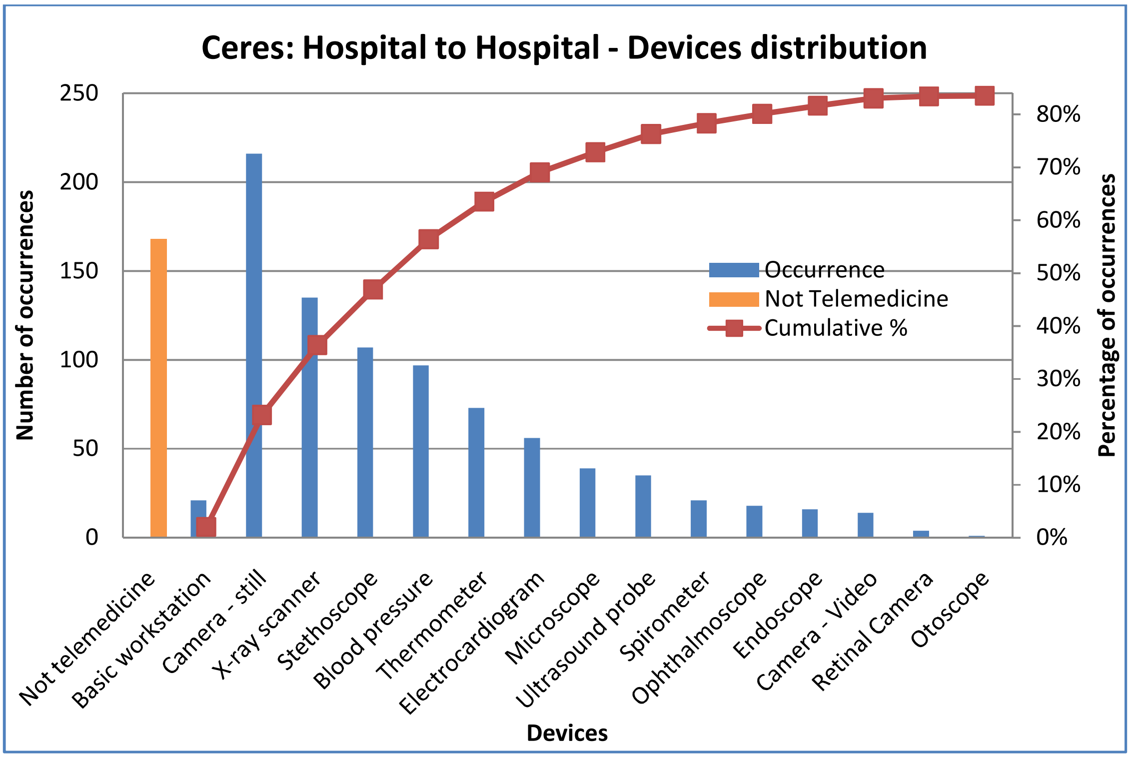
Robertson: Seen by doctor devices			
Device	**Occurrence**	**%**	**cum %**
Camera - still	216	30.04%	30.04%
X-ray scanner	126	17.52%	47.57%
Thermometer	75	10.43%	58.00%
Blood pressure	69	9.60%	67.59%
Stethoscope	67	9.32%	76.91%
Basic workstation	37	5.15%	82.06%
Electrocardiodiagram	25	3.48%	85.54%
Spirometer	24	3.34%	88.87%
Microscope	17	2.36%	91.24%
Ophthalmoscope	17	2.36%	93.60%
Normal referral	13	1.81%	95.41%
Retinal Camera	9	1.25%	96.66%
Endoscope	8	1.11%	97.77%
Ultrasound probe	8	1.11%	98.89%
Camera - Video	6	0.83%	99.72%
Otoscope	2	0.28%	100.00%

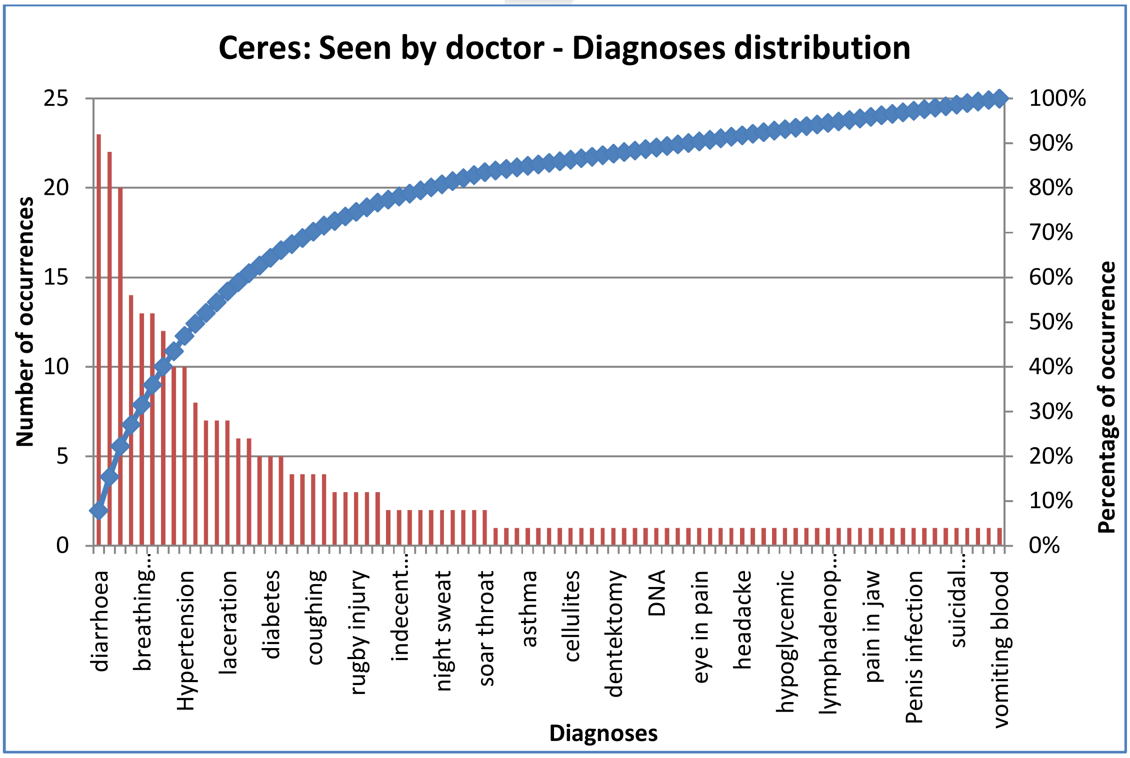
Diagnosis	Occurrence	%
Robertson: Seen by doctor	**719**	**100.00%**
Normal referral	**13**	**1.81%**
Medical	11	1.53%
Surgical	2	0.28%
Basic workstation	**37**	**5.15%**
Medical	37	5.15%
Blood pressure	**69**	**9.60%**
Medical	66	9.18%
Obstetric	3	0.42%
Camera - still	**216**	**30.04%**
Gynaecology	9	1.25%
Medical	198	27.54%
Orthopaedic	9	1.25%
Camera - Video	**6**	**0.83%**
Medical	6	0.83%
Electrocardiodiagram	**25**	**3.48%**
Medical	25	3.48%
Endoscope	**8**	**1.11%**
Medical	8	1.11%
Microscope	**17**	**2.36%**
Gynaecology	9	1.25%
Medical	8	1.11%
Ophthalmoscope	**17**	**2.36%**
Medical	17	2.36%
Otoscope	**2**	**0.28%**
Medical	2	0.28%
Retinal Camera	**9**	**1.25%**
Medical	9	1.25%
Spirometer	**24**	**3.34%**
Medical	24	3.34%
Stethoscope	**67**	**9.32%**
Medical	67	9.32%
Thermometer	**75**	**10.43%**
Medical	75	10.43%
Ultrasound probe	**8**	**1.11%**
Medical	5	0.70%
Obstetric	3	0.42%
X-ray scanner	**126**	**17.52%**
Gynaecology	9	1.25%
Medical	108	15.02%
Orthopaedic	9	1.25%

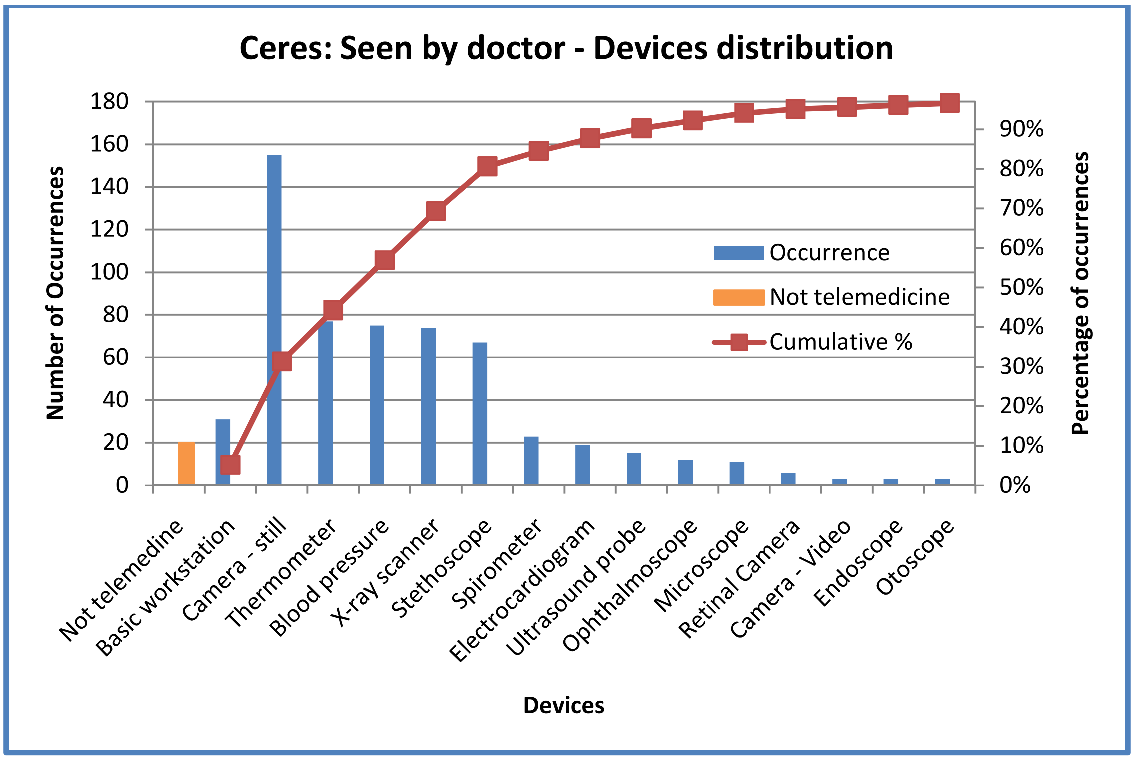
Grabouw: Seen by doctor device			
Device	**Occurrence**	**%**	**cum %**
Camera - still	136	22.55%	22.55%
Blood pressure	93	15.42%	37.98%
X-ray scanner	81	13.43%	51.41%
Stethoscope	78	12.94%	64.34%
Electrocardiogram	59	9.78%	74.13%
Microscope	30	4.98%	79.10%
Thermometer	26	4.31%	83.42%
Basic workstation	22	3.65%	87.06%
Ophthalmoscope	19	3.15%	90.22%
Ultrasound probe	14	2.32%	92.54%
Normal referral	13	2.16%	94.69%
Spirometer	11	1.82%	96.52%
Endoscope	8	1.33%	97.84%
Otoscope	6	1.00%	98.84%
Retinal Camera	4	0.66%	99.50%
Doppler flow measure	2	0.33%	99.83%
Camera - Video	1	0.17%	100.00%

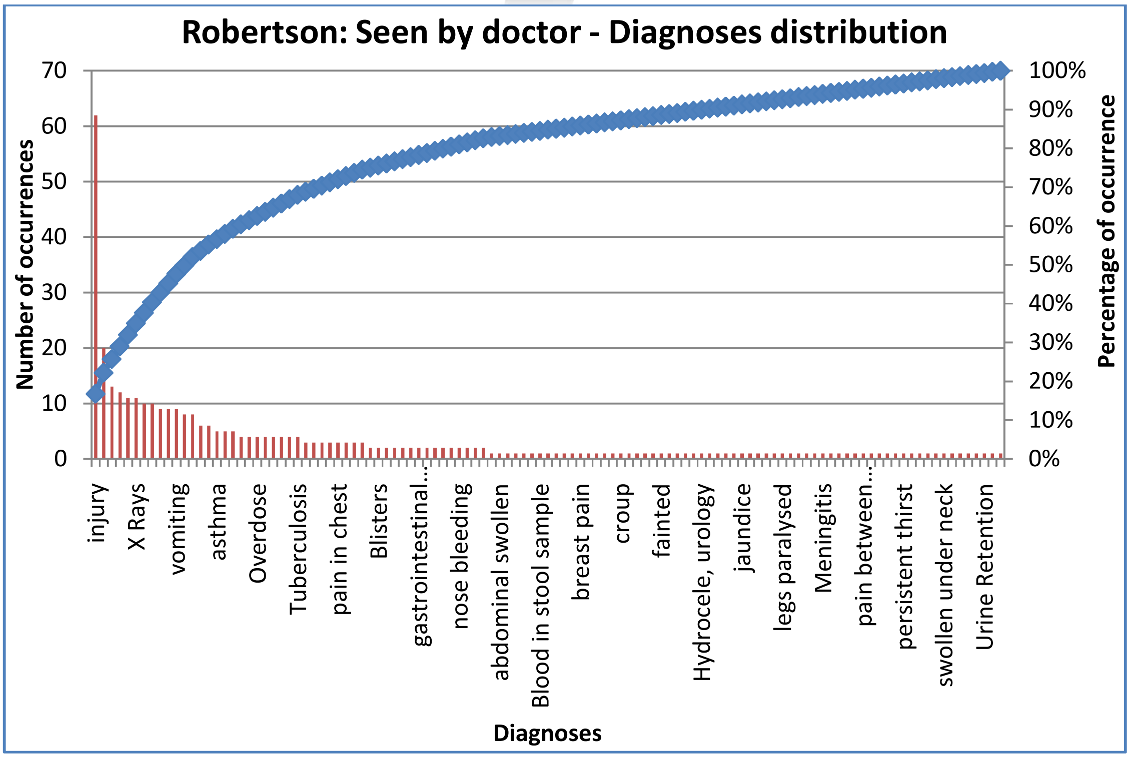
Diagnosis	Occurrence	%
Grabouw: Seen by doctor	**603**	**100.00%**
Normal referral	**13**	**2.16%**
Gynaecology	1	0.17%
Medical	6	1.00%
Obstetric	1	0.17%
Surgical	5	0.83%
Basic workstation	**22**	**3.65%**
Medical	21	3.48%
Paediatric	1	0.17%
Blood pressure	**93**	**15.42%**
Gynaecology	1	0.17%
Medical	84	13.93%
Obstetric	6	1.00%
Orthopaedic	2	0.33%
Camera - still	**136**	**22.55%**
Gynaecology	7	1.16%
Medical	99	16.42%
Obstetric	1	0.17%
Orthopaedic	25	4.15%
Paediatric	4	0.66%
Camera - Video	**1**	**0.17%**
Medical	1	0.17%
Doppler flow measurement device	**2**	**0.33%**
Obstetric	2	0.33%
Electrocardiogram	**59**	**9.78%**
Medical	59	9.78%
Endoscope	**8**	**1.33%**
Medical	8	1.33%
Microscope	**30**	**4.98%**
Gynaecology	9	1.49%
Medical	20	3.32%
Paediatric	1	0.17%
Ophthalmoscope	**19**	**3.15%**
Medical	19	3.15%
Otoscope	**6**	**1.00%**
Medical	6	1.00%
Retinal Camera	**4**	**0.66%**
Medical	4	0.66%
Spirometer	**11**	**1.82%**
Medical	10	1.66%
Paediatric	1	0.17%
Stethoscope	**78**	**12.94%**
Medical	74	12.27%
Obstetric	1	0.17%
Orthopaedic	2	0.33%
Paediatric	1	0.17%
Thermometer	**26**	**4.31%**
Medical	24	3.98%
Orthopaedic	2	0.33%
Ultrasound probe	**14**	**2.32%**
Gynaecology	2	0.33%
Medical	4	0.66%
Obstetric	8	1.33%
X-ray scanner	**81**	**13.43%**
Gynaecology	3	0.50%
Medical	54	8.96%
Orthopaedic	24	3.98%

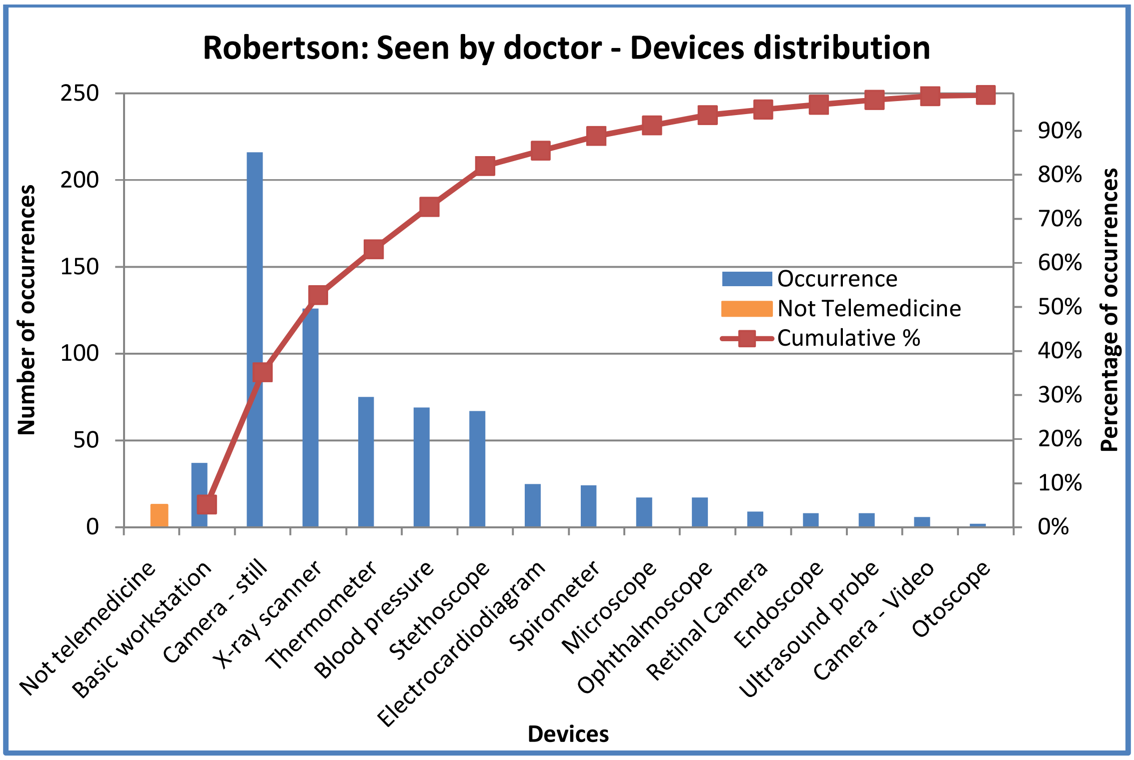

Ceres: Hospital to hospital - Diagnoses distribution
Number of occurrences
Percentage of occurrence
45
40
35
30
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
fracture
PET (Positron...
diarrhoea
burn wounds
gastrointestinal
wound
skull fracture
knife wound
pneumonia
appendicitis
concussion
fracture
laceration
abdominal pains
bowel obstruction
chronic NVS
cut wounds
dysphagia
general weakness in...
indecent assault
laryngeal stridor
motor vehicle
peptic ulcer
post partum bleeding
skull fracture
subtrochanteric...
ulcer
vaginal bleeding
Diagnoses

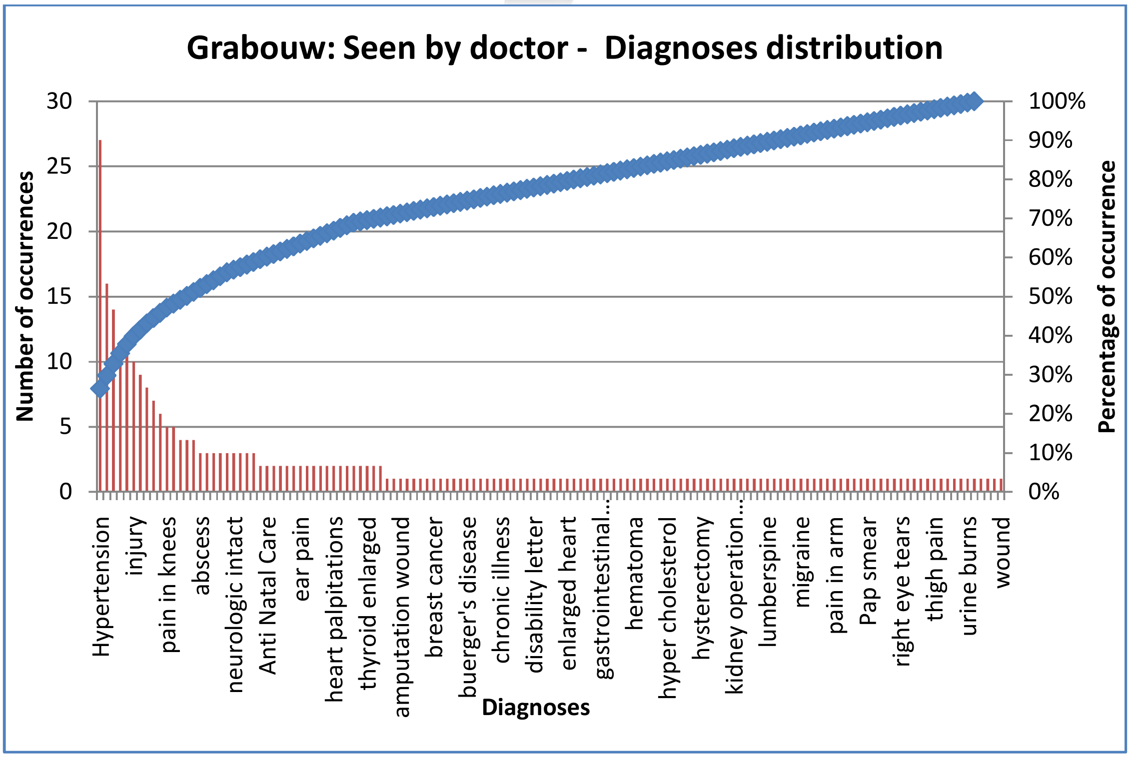

Ceres: Hospital to Hospital - Devices distribution
Number of occurrences
Percentage of occurrences
250
200
150
100
50
0
80%
70%
60%
50%
40%
30%
20%
10%
0%
Occurrence
Not Telemedicine
Cumulative %
Not telemedicine
Basic workstation
Camera - still
X-ray scanner
Stethoscope
Blood pressure
Thermometer
Electrocardiogram
Microscope
Ultrasound probe
Spirometer
Ophthalmoscope
Endoscope
Camera - Video
Retinal Camera
Otoscope
Devices

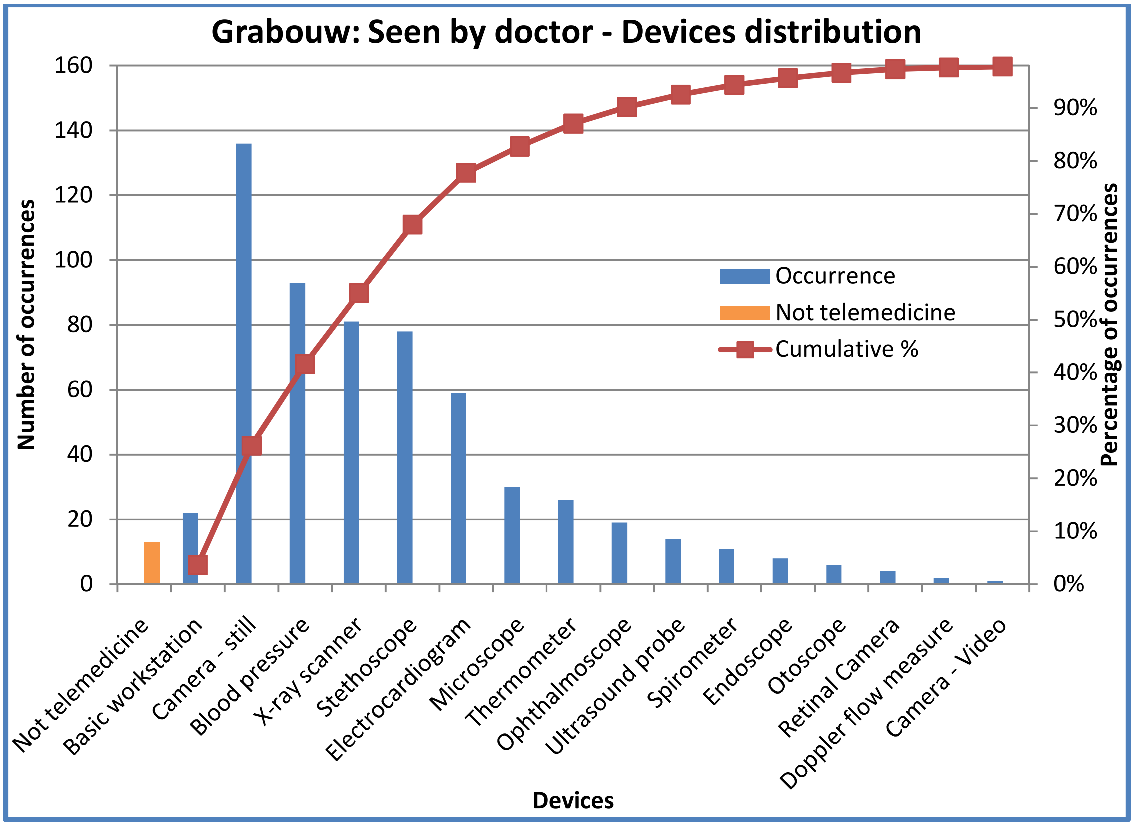

Ceres: Seen by doctor - Diagnoses distribution
Number of occurrences
Percentage of occurrence
0
5
10
15
20
25
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
diarrhoea
breathing...
Hypertension
laceration
diabetes
coughing
rugby injury
indecent...
night sweat
soar throat
asthma
cellulites
dentektomy
DNA
eye in pain
headacke
hypoglycemic
lymphadenop...
pain in jaw
Penis infection
suicidal...
vomiting blood
Diagnoses


Ceres: Seen by doctor - Devices distribution
Number of Occurrences
Percentage of occurrences
0
20
40
60
80
100
120
140
160
180
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
Occurrence
Not telemedicine
Cumulative %
Not telemedine
Basic workstation
Camera - still
Thermometer
Blood pressure
X-ray scanner
Stethoscope
Spirometer
Electrocardiogram
Ultrasound probe
Ophthalmoscope
Microscope
Retinal Camera
Camera - Video
Endoscope
Otoscope
Devices


Robertson: Seen by doctor - Diagnoses distribution
70
60
50
40
30
20
10
0
Number of occurrences
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of occurrence
injury
X Rays
vomiting
asthma
Overdose
Tuberculosis
pain in chest
Blisters
gastrointestinal...
nose bleeding
abdominal swollen
Blood in stool sample
breast pain
croup
fainted
Hydrocele, urology
jaundice
legs paralysed
Meningitis
pain between...
persistent thirst
swollen under neck
Urine Retention
Diagnoses


Robertson: Seen by doctor - Devices distribution
250
200
150
100
50
0
Number of occurrences
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of occurrences
Occurrence
Not Telemedicine
Cumulative %
Not telemedicine
Basic workstation
Camera - still
X-ray scanner
Thermometer
Blood pressure
Stethoscope
Electrocardiodiagram
Spirometer
Microscope
Ophthalmoscope
Retinal Camera
Endoscope
Ultrasound probe
Camera - Video
Otoscope
Devices


Grabouw: Seen by doctor - Diagnoses distribution
Number of occurrences
Percentage of occurrence
30
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Hypertension
injury
pain in knees
abscess
neurologic intact
Anti Natal Care
ear pain
heart palpitations
thyroid enlarged
amputation wound
breast cancer
buerger's disease
chronic illness
disability letter
enlarged heart
gastrointestinal...
hematoma
hyper cholesterol
hysterectomy
kidney operation...
lumberspine
migraine
pain in arm
Pap smear
right eye tears
thigh pain
urine burns
wound
Diagnoses


Grabouw: Seen by doctor - Devices distribution
Number of occurrences
Percentage of occurrences
160
140
120
100
80
60
40
20
0
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Occurrence
Not telemedicine
Cumulative %
Not telemedicine
Basic workstation
Camera - still
Blood pressure
X-ray scanner
Stethoscope
Electrocardiogram
Microscope
Thermometer
Ophthalmoscope
Ultrasound probe
Spirometer
Endoscope
Otoscope
Retinal Camera
Doppler flow measure
Camera - Video
Devices

APPENDIX E: LINEAR PROGRAMMING (LINDO)

```
MAX     153977.21 y1 + 2287.68 y2 + 51203.97 y3 + 50225.84 y4 + 22527.68 y5 + 35472.74 y6 + 901.52 y7
        - 3597.24 y8 + 3112.60 y9 - 3971.40 y10 + 18508.55 y11 + 14326.21 y12 + 7721.84 y13 - 10199.08 y1


SUBJECT TO
        164 y1 + 7 y2 + 66 y3 + 52 y4 + 27 y5 + 36 y6
        + 8 y7 + 9 y9 + 2 y10 + 19 y11 + 17 y12 + 10 y13 >= 320

        11990.79 y1 + 4796.32 y2 + 15588.03 y3 + 2398.16 y4 + 4796.32 y5 + 959.26 y6 + 7194.48 y7
        + 3597.24 y8 + 5995.40 y9 + 5995.40 y10 + 719.45 y11 + 2877.79 y12 + 2398.16 y13 <= 30000

        165968.00 y1 + 7084.00 y2 + 66792.00 y3 + 52624.00 y4 + 27324.00 y5 + 36432.00 y6 + 8096.00 y7
        + 9108.00 y9 + 2024.00 y10 + 19228.00 y11 + 17204.00 y12 + 10120.00 y13 >= 250000

        y2 + y3 + y4 + y5 + y6 + y7 + y8 + y9 + y10 + y11 + y12 + y13 - 50 y1 <= 0

END

INTE Y1
INTE Y2
INTE Y3
INTE Y4
INTE Y5
INTE Y6
INTE Y7
INTE Y8
INTE Y9
INTE Y10
INTE Y11
INTE Y12
INTE Y13
```

```
LP OPTIMUM FOUND AT STEP      8
OBJECTIVE VALUE =   305396.344


NEW INTEGER SOLUTION OF    292561.000     AT BRANCH      0 PIVOT       8
RE-INSTALLING BEST SOLUTION...

       OBJECTIVE FUNCTION VALUE

       1)      292561.0

 VARIABLE        VALUE          REDUCED COST
       Y1         1.000000     -143778.125000
       Y2         0.000000       -2287.679932
       Y3         0.000000      -51203.968750
       Y4         1.000000      -50225.839844
       Y5         1.000000      -22527.679688
       Y6         1.000000      -35472.738281
       Y7         0.000000        -901.520020
       Y8         0.000000        3597.239990
       Y9         0.000000       -3112.600098
      Y10         0.000000        3971.399902
      Y11         1.000000      -18508.550781
      Y12         1.000000      -14326.209961
      Y13         1.000000       -7721.839844


      ROW   SLACK OR SURPLUS     DUAL PRICES
       2)         5.000000          0.000000
       3)      3860.070312          0.000000
       4)     78900.000000          0.000000
       5)        44.000000          0.000000

NO. ITERATIONS=       8
BRANCHES=     0 DETERM.=   1.000E    0
```

APPENDIX F: AMD TELEMEDICINE EQUIPMENT

AMD-3700 Telephonic Stethoscope

The AMD-3700 features low data bandwidth and high performance. One model can be either transmit or receive.

AMD-3100 Auscultette II Electronic Stethoscope

The AMD-3100 Auscultette II electronic stethoscope provides the highest sound fidelity in the industry with a host of mechanical and electrical signal filters when used in conjunction with the AMD-3200 and AMD-3600. It delivers excellent sound capture, amplification and attenuation as part of this popular stethoscope system.

AMD-3200 Simulscope

The AMD-3200 Simulscope electronic stethoscope provides th highest sound fidelity in the industry with a host of mechanical and electrical signal filters when used in conjunction with the AMD-3100 and AMD-3600. It delivers excellent sound capture, amplification and attenuation as part of this popular stethoscope system.

AMD-3550 SmartSteth Digital Electronic Stethoscope

The SmartSteth™ is AMD's most flexible electronic stethoscop and transmits on almost any communications platform, including "live" and "store and forward" IP. Great sound quality powerful analytical software and communications flexibility make the SmartSteth™ a popular choice.

AMD-3875 12 Lead Interpretive ECG for PC (Software/Hardware combination)

The AMD-3875 12 Lead Interpretative Electrocardiogram (ECG) for PC combines unparalleled ease-of-use, flexibility an portability in primary care, paediatrics, and cardiology applications.

AMD-2300 Video Colposcope with Articulating Arm.

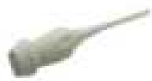
The AMD-2300 Video Colposcope with Articulating Arm provides excellent image quality for all women's health applications.

AMD-5500 SmartProbe™ Ultrasound/Curved Array with Laptop PC

You have to see it to believe it!! The AMD-5500 SmartProbe™ Ultrasound is the laptop ultrasound that offers big system feature and performance at an affordable price. The curved array probe supports all OB and abdominal scanning applications.

AMD-5600 Curved Array Probe for SmartProbe Ultrasound™

The AMD-5600 Curved Array Probe for the SmartProbe Ultrasound™ is used for all obstetrical and abdominal scanning applications.



AMD-5625 Phased Array Probe for SmartProbe™ Ultrasound

The AMD-5625 Phased Array Probe for the SmartProbe™ Ultrasound is the probe of choice for all cardiac, thoracic and emergency medicine scanning applications. A true 128-channel phased array offers resolution not available from other portable ultrasound systems.

AMD-5100 SmartScan 3.3 X-ray Scanner

Deliver full tele-radiology capabilities within your telemedicine clinic with the SmartScan 3.3 X-Ray Scanner. The vertical design low moving parts and high level performance make the SmartScan 3.3 X-ray Scanner a favorite of mobile or remote tele-radiology programs.

AMD-5200 SmartScan 4.0 X-ray Scanner

The SmartScan 4.0 X-Ray Scanner is AMD's highest performance x-ray scanner, offering high speed scanning at up to 1000 dpi and an optical density of up to 4.7. The choice for the most demandin tele-radiology programs.

AMD-5300 SmartScan PACS Software

AMD-5300 SmartScan PACS Software integrates your telemedicine clinic with a full scale PACS tele-radiology network. Also used with the AMD SmartProbe™ Ultrasound to support full tele-radiology applications.

AMD-5400 SmartScan Automatic Document Feeder

The AMD-5400 SmartScan Automatic Document Feeder scans u to 100 X-ray films at a time, maximizing efficiency in the scanning and transmission of images.

AMD-5505 Color Flow & Pulse Wave Doppler Software

AMD-400s Camera & Illumination Source - NTSC

The AMD-400s Camera and Illumination Source is the analog and digital camera and light source that drives a wide variety of diagnostic scopes and produces the superior quality images you need for accurate diagnosis. Found in almost all primary care telemedicine clinics.

AMD-400p Camera & Illumination Source - PAL

The AMD-400p Camera and Illumination Source is the analog and digital camera and light source that drives a wide variety of diagnostic scopes and produces the superior quality images you need for accurate diagnosis. Found in almost all primary care telemedicine clinics.

AMD-950 Non-Mydriatic Retinal Camera NW6.

The AMD-950 Non-Mydriatic Retinal Camera is a popular choice for programs conducting diabetic screening or delivering top quality diagnostic support in ophthalmology.

AMD-2020 Direct Ophthalmoscope

AMD brings you the video version of a diagnostic direct ophthalmoscope used by primary care and pediatric physicians worldwide for primary care ophthalmology examinations of the retina." Another of the scopes used with the AMD-400 to bring a broad range of diagnostic capabilities to your telemedicine program."

AMD-2015 ENT/Otoscope

A must for comprehensive ear, nose and throat (ENT) examinations, the AMD-2015 ENT/Otoscope is the most popular choice with the AMD-400 Camera and Light Source. Combines the functionality of a high performance otoscope, short sinus scope and oral exam scope in a single diagnostic device.

AMD-2030 Dermascope

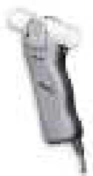
The AMD-2030 is a superior skin surface contact microscope for use in primary care, pediatrics or dermatology. The AMD-2030 Dermascope is easy to operate, clean and sterilize. A very popular choice with the AMD-2015 to bring multi-scope functionality to the AMD-400 Camera and Light Source.

AMD-2500s General Examination Camera - NTSC video format

The AMD-2500 general examination camera combines power zoom, auto focus, freeze frame, and electronic image polarization in one diagnostic device, giving the AMD-2500 wide application in primary care, emergency medicine/trauma care, dermatology, ophthalmology, and wound care.

AMD-2500p General Examination Camera - PAl video format

The AMD-2500 general examination camera combines power zoom, auto focus, freeze frame, and electronic image polarization in one diagnostic device, giving the AMD-2500 wide application in primary care, emergency medicine/trauma care, dermatology, ophthalmology, and wound care.



AMD-3920 Digital Spirometer for PC

The AMD-3920 Digital Spirometer for PC is the PC-based digital spirometer that supports a full range of diagnostic cardia and pulmonary applications.

AMD-400 Microscope with Analog Video Camera includes 4X, 10X, 20X and 40X objectives

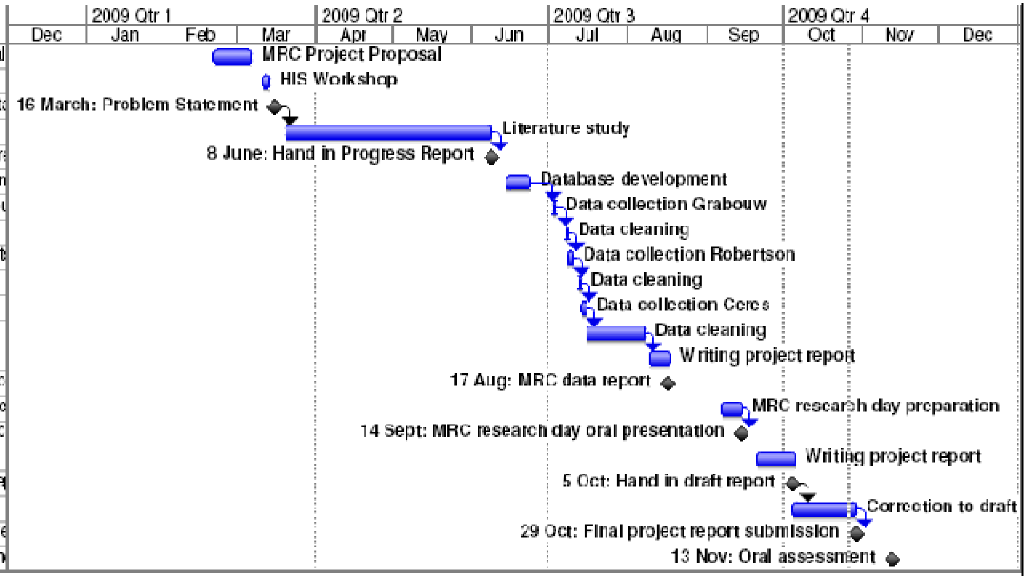
The AMD-400 Microscope with Analog Camera allows your rural hospital or remote clinic to collaborate with regional medical centers to offer tele-pathology services.

AMD-410 Microscope with Digital Camera includes 4X, 10X, 20X and 40X objectives

The AMD-400 Microscope with Digital Camera allows your rural hospital or remote clinic to collaborate with regional medical centers to offer tele-pathology services.

APPENDIX G: PROJECT PLANNING

ID	Start	Finish	Predecessors	Resource Names
1	Fri 09/02/20	Fri 09/03/06		MRC Project Proposal
2	Wed 09/03/11	Fri 09/03/13		HIS Workshop
3	Mon 09/03/16	Mon 09/03/16		16 March: Problem St
4	Fri 09/03/20	Mon 09/06/08	3	Literature study
5	Mon 09/06/08	Mon 09/06/08	4	8 June: Hand in Progr
6	Mon 09/06/15	Tue 09/06/23		Database developmen
7	Fri 09/07/03	Fri 09/07/03	6	Data collection Crabou
8	Wed 09/07/08	Wed 09/07/08	7	Data cleaning
9	Thu 09/07/09	Fri 09/07/10	8	Data collection Robert
10	Mon 09/07/13	Mon 09/07/13	9	Data cleaning
11	Tue 09/07/14	Wed 09/07/15	10	Data collection Ceres
12	Thu 09/07/16	Fri 09/08/07	11	Data cleaning
13	Mon 09/08/10	Mon 09/08/17	12	Writing project report
14	Mon 09/08/17	Mon 09/08/17		17 Aug: MRC data rep
15	Mon 09/09/07	Mon 09/09/14		MRC research day pre
16	Mon 09/09/14	Mon 09/09/14	15	14 Sept: MRC researc
17	Mon 09/09/21	Mon 09/10/05		Writing project report
18	Mon 09/10/05	Mon 09/10/05		5 Oct: Hand in draft re
19	Mon 09/10/05	Thu 09/10/29	18	Correction to draft
20	Thu 09/10/29	Thu 09/10/29	19	29 Oct: Final project re
21	Fri 09/11/13	Fri 09/11/13		13 Nov: Oral assessm



Project: Project1
Date: Tue 09/10/27

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

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