The Remodelling of Patient Care Pathway for E-health

A Thesis Submitted for the degree of Doctor of Philosophy

by

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ABSTRACT

The interdependencies within the health care system are seldom taken into account prior to implementation of e-health projects, and there tends to be little change management as part of the plan.

Our proposal offers a systems analysis model that gives e-health a framework to consider and manage the introduction, changes and outcomes.

This research describes the use of a modified Patient Care Pathway as a method to design and implement e-health projects, presenting as a case study the pre-implementation phase of a teleradiology project in rural Thailand.

The proposal is that a modified version of Patient Care Pathways can be used as a prospective design model for e-health services.

The method adopts systems engineering principles and applies a “whole systems approach” thereby providing a much richer schematic representation of the patient care pathway illustrating both the patient’s journey through the system and also the information flow.

Our method was applied to the design of a new teleradiology service that was to be established in Thailand, to connect GP’s in a rural hospital to the radiology department in a tertiary hospital with a further connection to a specialist radiologist in a medical school in Bangkok.

By comparing the pre-implementation Patient Care Pathway with the proposed pathway using the teleradiology, a systems analysis model was developed to identify critical points in the system and identify and anticipate how the system would support the changes in clinical practices.

The method produced a valuable framework to better understand and thereby manage the implications of change prior to implementation of an e-health project.

DEDICATION

I dedicate this thesis to

Owena, Nia and Morgan.

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I would like to thank Dr Malcolm Clarke for supervising my work and for providing support and guidance throughout the research. Dr Clarke kept me focused on the thesis and due to his patience; I have learned invaluable lessons in research methods and technical writing. His genuine interest and passion for e-health has been an inspiration.

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My thanks are also extended to my fellow students who tirelessly offered moral support and camaraderie.

Finally, I would like to thank my friends whose diplomatic skills could only be admired when they avoided asking about the thesis completion date.

This thesis like all others was not achieved alone.

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GLOSSARY

ARC	American College of Radiology
AIDS	Acquired Immune Deficiency Syndrome
ATA	American Telemedicine Society
BPR	Business Process Re-engineering
DICOM	Digital Imaging and Communications in Medicine
EHR	Electronic Health Record
GP	General Practitioner
GLIF	Guideline Interchange Format
HIS	Health Information Systems
HIV	Human Immunodefiency Syndrome
ICT	Information Communication Technology
IHC	Internet Health Coalition
INCOSE	International Committee of Systems Engineering
IT	Information Technology
MoPH	Ministry of Public Health
NEMA	National Electronic Manufacturers' Association
NeLH	National Electronic Library for Health
PACS	Picture Archiving and Communication System
PCP	Patient Care Pathways
PNR	Pong Nam Ron Hospital
SE	Systems Engineering
SSM	Soft Systems Methodology
WfMC	Workflow Management System
VATAM	Validation of Telematics Applications in Medicine

CHAPTER ONE - INTRODUCTION

This opening chapter sets the backdrop and defines the problem addressed by the research. The thesis starts by placing the research in context and defines the scope. This is followed by a breakdown of the domain of the research and a short summary of the main disciplines applied.

Thereafter, the research objectives are identified and linked to the problem. The methods adopted within the research are summarised in the subsequent section and the case study is introduced.

The contribution made by the research is summarised and finally, an outline of the thesis is presented in the form of the content of each chapter.

1.1 RESEARCH CONTEXT

This research describes the use of the Patient Care Pathway (PCP) as a method to design and implement e-health projects, presenting as a case study the pre-implementation phase of a teleradiology project in rural Thailand.

PCPs are traditionally used to describe the “journey” that a patient “takes” in the course of resolving the presentation of a clinical problem, and would normally depict decisions and treatment. This research serves to extend this methodology to an e-health context and identifies all the paths and processes that contribute to the delivery of health care to that patient, which includes information flow.

As a tool the PCP can identify the interface between providers, communication paths and give insight to optimum design for delivery of services. This thesis proposes that it can be used for prospective design of e-health services.

This research considers that the PCP can provide an important tool for designing and analysing the effects of introduction of technology by depicting the movement of information in addition to patients. This provides a model for systems analysis.

There is currently no generally accepted notation method for documenting patient pathways. The PCP is commonly presented in a linear fashion, with a form similar to a flow chart. For example, an NHS web site http://www.nelh.nhs.uk contains over 2000 "pathways", plus full text of 100 sample "pathways". This work is being carried out by the National Electronic Library for Health (NeLH) in conjunction with the Royal College of Nursing. The NeLH launched a national Care Pathways Database in 2001 (National Electronic Library for Health Care Pathways Database.) However, these pathways are primarily flow charts for clinical decision making, and are not designed for system analysis.

The approach of the PCP and systems analysis presented in this research was first developed to consider the effects of introducing remote patient monitoring to capture the PCP in terms of the clinical processes and depict the pathways as the workflow between them (Bratan 2007). The notation does not depict clinical decision, rather indicates patient movement between centres of activity and the associated information flow. In the proposed method, existing clinical practice is captured as a holistic model, and by doing so, introduces a whole systems thinking adopted from engineering principles.

This proposed evolved PCP model provides a valuable tool in systems analysis of e-health projects and allows a better understanding of the introduction of a proposed technology based system.

The resulting model is a step towards the potential introduction of frameworks into e-health and by default, could assist with the increased integration of e-health into the main stream health care delivery mechanism.

1.2 RESEARCH DOMAIN

1.2.1 E-HEALTH AND TELERADIOLOGY

A systematic review identified 51 separate definitions of e-health that had no clear consensus and contained a wide range of themes (Oh 2005).

Eysenbach's definition is cited as being the most often referenced on the Internet:

"e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology"(Eysenbach 2001).

Despite the popularity of Eysenbach's definition the author favours that of Pagliari, which is succinct and direct:

"The use of Information communication technology (ICT) to enable health and health care"(Pagliari 2005).

This definition is preferred as being concise and indicating e-health to be an integral part of the health care system.

Even the need to have a separate definition for e-health illustrates the lack of integration. Other sectors such as banking consider the use of ICT to support business practices not as e-banking, but just plain banking. E-health will have reached the same level of maturity and integration when there is no need for a definition and e-health has evolved to become a seamless element in the delivery of health care.

There is no consensus on the spelling of e-health, and for the purpose of this research e-health will be hyphenated, in lower case and follow grammatical rules for the use of capitals.

This research has the context of a teleradiology project based in Thailand and has been chosen to support and illustrate the research theory.

Teleradiology is one of the numerous applications of e-health. Furthermore, there are even many and varied definitions of teleradiology. However, as a simple extension of e-health, this research considers teleradiology as being:

“The use of ICT to enable the electronic transmission and storage of radiological images from one location to another” (Ruggiero 1998).

For the past 100 years, X-ray film has been almost the exclusive medium for capturing, storing and displaying radiographic images. With the latest digital imaging and compression techniques, partnered with secure communications and information technology, a Picture Archiving and Communication System (PACS) enables X-rays and other digital imaging modalities to be stored electronically and reviewed on screens. Coupling a PACS system with the capability of transmitting images allows remote viewing, diagnostics and consultations and provides a proven method for increasing the standard of delivery of health care.

1.2.2 PATIENT CARE PATHWAYS

The PCP concept first appeared at the New England Medical Centre Boston, USA in 1985 and was developed by Karen Zander and Kathleen Bower (de Luc 2001). PCPs evolved as a result of concepts taken from the Standard Operating Procedures, as used in industrial quality control.

Once again, many terms have been used for the concept of the PCP, for example, de Luc found 17 different names; care pathways and care map being the most frequently used (de Luc 2001).

In this research, Patient Care Pathways (PCP) will be used throughout.

A definition of PCP is provided by Coughlan:

“Tools that assist in providing general guidelines for dealing with individuals and groups of patients suffering for a wide variety of diseases” (Coughlan 2006).

The concept was expanded by defining the components of PCPs as comprising a time line, encapsulating the categories of care, activities, or interventions, and designating the intermediate and long term outcome criteria.

This concept has become formalised in one approach, where the PCP becomes viewed as an algorithm that depicts the decisions to be made about the care to be provided for a given patient or patient group for a given condition as a flow chart in a step-wise sequence. PCPs of this type may be used by a multidisciplinary team to provide agreed common protocols that represent best practice and have a focus on quality and co-ordination of care. For example, see Map of Medicine (http://www.mapofmedicine.com/). Such PCPs are sometimes referred to as “standards”, but might better be referred to as clinical guidelines.

PCP may be developed to depict the clinical pathway as a series of interconnected processes. In this type of PCP, the nodes of the PCP represent the clinical process, but do not need to define the logic or decisions of the nodes. The connections between the nodes in this type of PCP, represent the flow of information, which might be through physical transfer of the patient or their data (e.g. the X-ray), or through ICT. Such PCPs may be considered to be a first level model of the clinical system that they represent. It is this latter type of PCP that is the basis of the work of this thesis.

1.2.3 SYSTEMS ENGINEERING

The field of systems theory provides a number of concepts and techniques which are considered relevant to the development of PCPs and their application to e-health (de Luc 2003).

This research examines how system engineering (SE) tools can be employed in the pre-implementation phase of e-health projects and identifies the role for PCPs within their framework.

In 1990 The International Committee of Systems Engineering (INCOSE) was formed and one year later a consensus was reached on the definition of SE and describes it as:

“an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. A system is considered as a construct or collection of different elements that together produce results not obtainable by the elements alone” (Haskins 2006).

A system engineering approach proposes that the only way to fully understand the problem is to understand all the elements and their relation to the whole and suggests viewing systems in a holistic manner. System engineering therefore concerns the understanding of a system by examining the linkages and interactions between the elements that compose the entity of the system.

1.2.4 SYSTEMS ANALYSIS

Systems analysis deals with the analysis of sets of interacting entities or systems. In this research, two different methods of delivering health care are captured schematically and compared. This method of systems analysis gives an invaluable and clear insight into the benefits of one delivery system over another and how to transition from one to the other.

Systems analysis has also been described as:

“an explicit formal enquiry carried out to assist a decision maker in identifying a better course of action and make better decision than otherwise would have been made” (Chase 1974).

1.3 PROBLEM DEFINITION

E-health has challenges associated with its implementation and numerous factors have been identified as the cause of their failure including the lack of standards, frameworks and guidelines.

A literature review in 2003 by the Telemedics Unit, University of Calgary concluded that:

“There is a recognised need for national standards for health care professionals and guidelines for the accreditation of health organisations and facilities that provide telehealth services. The lack of standards and guidelines has been considered to be a barrier to the successful integration of telehealth into health care facilities” (Yeo 2003).

In contrast to the many mature and robust technical standards, operational standards and guidelines remain few. This research focuses on operational and organisational methodologies that pertain to the pre-implementation phase of e-health programmes, and that might form the basis of future standards or guidelines.

In reviewing the literature, it is often the case that the term guideline is used with different interpretations, and can often be used synonymously with the word standard. Strictly, these have distinct meanings.

The dictionary definitions include:

Standard:

1) A degree or level of requirement, excellence or attainment.

2) An acknowledged measure of comparison for quantitative or qualitative value; a criterion.

Guideline

1) A statement or other indication of policy or procedure by which to determine a course of action;

2) Guidance relative to setting standards or determining a course of action;

3) A rule or principle that provides guidance to appropriate behaviour.

In the context of this thesis, we would interpret standards to define strict technical specification and require technical conformance. Whereas guidelines might describe best practice and recommend practices that should be adopted and followed.

This research examines specifically the pre-implementation phase of an e-health project in terms of organisational and management aspects. The case study examines a teleradiology project, for which technical and clinical standards exist.

Pilot schemes of e-health have, for more than a decade, demonstrated progress in technology, but this has not been matched by the progress in delivery nor its uptake.

This may be due to e-health often being considered as a separate activity from existing health care delivery and that the management and organisational elements of the existing system are not fully understood and captured prior to the introduction of e-health.

This thesis investigates the use of the PCP to capture and thereby understand the existing delivery method of health care. The resulting model can be used to consider the physical pathway and any new information pathways and information needs and consequently any organisational changes.

Once the current system is understood, it becomes possible map the proposed system and consider optimum design. Furthermore, by integrating the PCP methodology within the overall framework of engineering project management such as INCOSE, then an enhanced model can be developed and applied specifically to the e-health environment.

This methodology can contribute by providing a formal approach to the design of e-health systems, using the modified PCP to ensure that e-health is an integral part of the system and not an isolated independent application.

The purpose of this thesis is to address concerns that e-health fails to understand how the organisation can best take advantage of the technology. Health services must change their delivery practices to take advantage from the technology. Currently, e-health lacks a formal and standardised framework to capture the e-health pathway and the methodology to effect change management.

The increasing availability of new forms of technology will offer no advantage whilst there is a lack of guidelines and standards for e-health (Loane 2002). For example, it is reported that 75% of telemedicine initiatives fail during the operational phase (Broens 2007).

The Welsh Assembly Government has identified only 25 e-health guidelines, and most of these have been developed by professional associations and colleges. The report states that:

“To the best of our knowledge, National Institute for Clinical Excellence (NICE) has yet to produce any clinical guidelines, audit methods or good practice guidelines specifically relating to e-health or telemedicine applications in use in the NHS. Neither have any evidence based National Service Frameworks (NSFs) for such applications been published” (Healthcare Alliances 2004).

One explanation for this lack of guidelines is that standards have been traditionally based upon evidence based clinical research, but this is severely limited by high cost and the difficulties associated with measuring the effects of introducing technology (Shea 2006).

A further explanation, offered by Loane in their review of guidelines, is that the lack of guidelines confirms the immaturity of e-health and that a critical mass does not yet exist to produce robust standards (Loane 2002).

The lack of guidelines and standards is inhibiting the implementation of e-health. For example, the Welsh Assembly believes that e-ehealth and telemedicine will not achieve mainstream acceptance unless and until the professional and regulatory bodies produce guidelines or policy information which specifically identifies these technologies and considers the clinical context in which they are being used, and how this impacts on good practice (Health Alliances 2004).

The research in this thesis addresses these issues and proposes that the method of PCPs is a valuable tool to capture and better understand the e-health environment. This set within the supporting framework of systems analysis would provide a formal approach to the design and introduction of e-health programmes.

1.4 RESEARCH OBJECTIVES

1. Investigate Patient Care Pathways as a standard management methodology to represent schematically e-health projects.
2. Identify Systems Engineering tools that support and enhance the method of Patient Care Pathway and model the holistic approach to systems analysis of e-health.
3. Create and evaluate a framework based on Systems Engineering that uses the PCP.
4. To apply the systems analysis methodology prospectively to the pre-implementation phase of a teleradiology project in Thailand.

1.5 RESEARCH METHODS

The research approach is both theoretical and grounded in an empirical application, that is, the pre-implementation phase of a teleradiology project in Thailand.

The approach to identify the traditional PCP was modified from the practical tool kit proposed by Luc et al (de Luc 2001). Although there are as yet, no standard methods for the development of a PCP, this basic model provided the framework to which additional features from the literature were added to develop the final form.

Although there is no agreed method to develop PCPs, most authors have adopted a common format and the salient points remain consistent.

The traditional PCP was modified to analyse the entire system by taking principles from systems engineering and soft systems management methodology; this being chosen for its applicability to e-health.

Fundamental to the development of the PCP and its modified form is to depict the e-health system was to consider the Human Factors. This must include frequent consultation with the medical professionals and other relevant users and planning for the modified system in terms of change management. These factors are deemed pivotal in creating accurate and meaningful pathways within the PCP and to ensure successful delivery of the e-health system.

Whilst the focus of the e-health project is deemed patient centric, the approach to the systems analysis and design must be holistic and consider this from a whole system perspective. The PCP will therefore need to be a representation of the entire system.

The final step in the method is the novel application of the holistic, complete system model for the PCP and a comparative systems analysis of health care delivery, pre- and post-implementation of a teleradiology project.

1.6 CASE STUDY

The method was applied to the design of a new teleradiology service that was to be established in the North East Province of Thailand, to connect General Practitioners (GP) in a rural hospital to the radiology department in a tertiary provincial hospital with a further connection to specialist radiologists in a medical school in Bangkok.

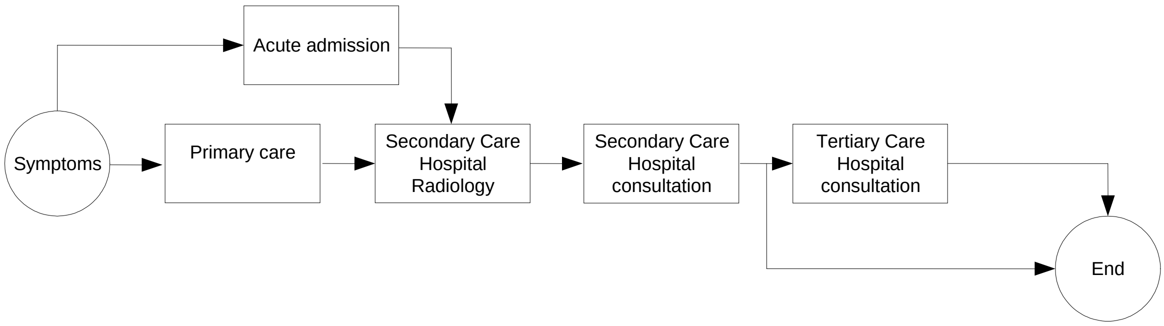

Figure 1: Initial Patient Care Pathway showing the movement of patients and x-ray sites (no electronic information flow present in this system).

The initial Patient Care Pathway, figure 1, shows the existing X-ray service and how patients travel from primary care through each of the various routes between hospitals to receive their X-ray and associated care. All the flows are as a result of the physical movement of the patients, there currently being no information flow.

To support this work, documentary evidence was gained detailing the events of representative patient episodes and staff members were interviewed.

It is evident that the current service is linear with little or no interaction between primary, secondary or tertiary care. X-rays were film based and, at best, patients might take the X-ray with them when they went to the tertiary care hospital, but frequently the X-ray would be repeated.

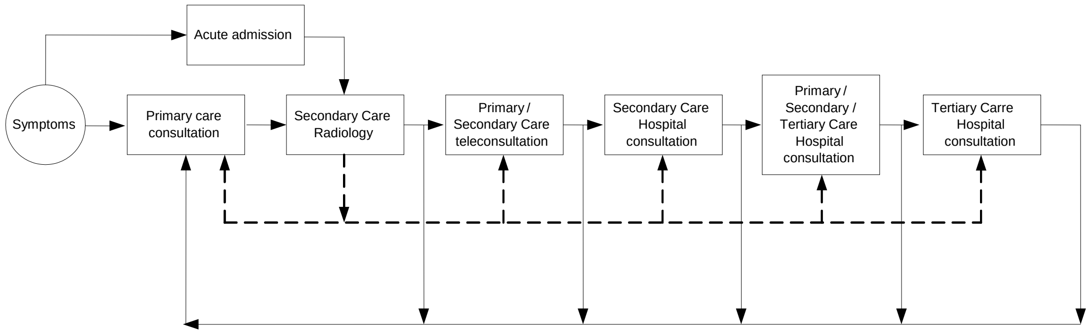

Figure 2: Modified Patient Care Pathway for the e-health service

The modified Patient Care Pathway for the new teleradiology service, figure 2, was derived from the PCP of the existing service. In the modified PCP, the teleradiology service was placed at the entry point to secondary care in order to be closer to the patient and be sufficiently resourced.

Images and data were to be made accessible to medical staff throughout the digital health network (shown dotted), and in this way case conferences using the teleconsulation facility could be scheduled without need for the patient to travel to the tertiary care centre.

Initial specifications were to include the primary health care centre as the ideal situation as that would include all levels of health care. However, in practice it did not always prove possible to include the primary health care centres. The MoPH planed to expand the service to include primary health, which would have the advantage that management of the patient could be continuous across all the health sectors.

This results in a change to the pathway whereby patients may be returned to primary or secondary care much earlier and, having the data, encourages a greater level of shared care. This is depicted by the much increased number of feedback paths of the modified PCP of figure 2.

The framework was then used to identify the critical points in the system by comparing the pre-implementation PCP with the proposed teleradiology based PCP. This allows the ways in which the system would support the changes in clinical practice to be anticipated. Furthermore, by defining the PCP in terms of its processes and workflow, information flow in addition to the physical patient journey can be superimposed. In this way the full impact of the e-health approach and the implications for the Information Communication Technology (ICT) may be considered.

1.7 CONTRIBUTION

The approach to use the modified PCP within a systems engineering framework offers a formal methodology to consider and manage the introduction, change and outcomes of introducing e-health to a traditional health care delivery mechanism.

This research has demonstrated that PCP can be used as a pre-implementation tool to better understand the system, understand the variables that can affect the system, and inform decisions concerning the system and their consequences.

1.8 THESIS OUTLINE

The first chapter places the research in context and opens with a section that contextualises the work and serves to provide a summary of the thesis. This is followed by a description of each element of the research in terms of domain. This chapter also considers the issues, obstacles and outcomes associated with the lack of standards and formal methodologies within e-health. This lack of formal methods is seen as one of the main themes of the research and is the impetus for three clear and concise research objectives.

The first chapter then presents a summary of the research methods that will be developed in chapter three. A case study is introduced demonstrating use of the PCP and systems analysis of a pre-implementation phase of a teleradiology project in Thailand.

The contribution made by the research is summarised.

The literature review in chapter two examines the benefits of the use of modelling as a standard methodology. The advantages and risks associated with modelling are considered and examples of modelling within health care are presented.

The literature review builds a case for PCPs as a modelling method for e-health and expands by detailing some of the applications and projects of electronic pathways and the benefits that this would offer.

The PCP is proposed as a formal methodology to be used within systems analysis of e-health projects. The concept is further developed to demonstrate the holistic view of the PCP and how it may represent e-health systems diagrammatically and support a systems engineering approach. This is supported by the literature. The chapter concludes that the use of the PCP is valuable and might be a formal methodology for e-health.

The third chapter describes the methods applied within the research, and covers in detail the use of the PCP and the ways in which it was developed, the systems engineering framework and how the PCP was integrated, how the framework was applied and the ways in which it was evaluated.

The framework is then applied within the case study. The criteria for inclusion of the hospitals in the study are detailed before moving to the development stage.

The following chapter describes how the initial PCP of the current health system was produced and discusses its significance. This is followed by the development of the PCP for the proposed teleradiology network and considers implications.

A significant point is reached in chapter three when systems engineering and life cycle management is introduced as part of the methodology, starting with a brief summary of the choice of the management tool and how this relates to PCP and systems analysis.

Chapter four examines the results and development of the PCP in relation to the case study. Background is provided on the hospitals and local demographics followed by the development of the pathways.

This chapter closes with a series of modified PCPs which schematically represent the current health care delivery mechanism and also the proposed e-health system. Concise diagrams showing information flow for the systems pre and post e-health allows systems analysis and demonstrates the implications of introducing e-health.

The fifth and final chapter discusses and concludes the research. The application of the research is considered along with the implications of the work. Recommendations are made in terms of recommendations for future work.

Each research objective identified in chapter one is then discussed and concluded. A summary of the main conclusions leads to a discussion of the limitations and a critique of the work.

CHAPTER TWO - LITERATURE REVIEW

2.0 INTRODUCTION

The literature review will consider four important aspects that pertain to the work of this thesis:

1) Descriptors and Definitions of Patient Care Pathways
2) Standards, Formal Methods and the Pre-implementation Phase of e-health projects
3) Modelling within Healthcare
4) The Role of Systems Analysis in Patient Care Pathways

The review by Loane (Loane 2002) is often cited to highlight the lack of progress made to apply frameworks, standards and formal methods in e-health. In contrast, significant advances have been made to develop technical standards. For the purpose of this research, unless otherwise indicated, “Standards” will refer to those that pertain to organisation and management.

The research in this thesis proposes to employ the PCP as a methodology to develop models that might be used to predict and manage change in the pre-implementation phase of e-health projects.

This chapter will define the PCP and describes how the traditional format of the PCP is modified to provide the methodology to analyse and manage e-health projects and how it may be used within the framework of a systems engineering approach.

The next section uses the case study to highlight the importance of frameworks and formal methodology for analysis and planning in the pre-implementation phase of e-health projects.

The review then examines modelling and with specific consideration of the PCP and its relevance to e-health in terms of how it may be used for systems analysis and to capture schematically information flow using the modified PCP format.

Finally, the ways in which the PCP is integrated within specific systems analysis tools are considered.

2.1 DESCRIPTORS AND DEFINITIONS OF PATIENT CARE PATHWAYS

PCP traditionally describes the "journey" that a patient "takes" in the course of resolving the presentation of a clinical problem. It will depict the clinical processes that may be involved and the information flow between them. It might depict decisions and treatment.

There is no single agreed definition of PCP, however, Pearson et al provide a well citied definition of care pathways as being:

"A management plan that displays goals for patients and provides the sequence and timings of actions necessary to achieve these goals with optimal efficiency" (Pearson 1995).

PCPs have also been presented as a concept and described as:

"An outline or plan of anticipated clinical practice for a group of patients within a particular diagnosis or set of symptoms. It provides a multidisciplinary template of the plan of care, leading each patient towards a desired objective" (Middleton 2000).

These definitions would appear somewhat restrictive in the purpose to which the PCP might be used, and imply that these authors view the PCP as defining the decision process and the timeline associated with any one decision path.

This traditional view of PCP is commonly presented in a linear fashion, with a form similar to a flow chart. For example, the UK NHS web site (http://www.nelh.nhs.uk) contains over 2000 pathways, plus full text of 100 sample pathways. This work is being carried out by the National electronic Library for Health (NeLH) in conjunction with the Royal College of Nursing.

The NeLH launched a national Care Pathways Database in 2001 (National Electronic Library for Health Care Pathways Database). However, these pathways are primarily flow charts for clinical decision making.

The NHS has a similar development in the Map of Medicine (http://www.mapofmedicine.com/) which depicts the decision paths to manage conditions.

In the UK the emphasis of the PCP has been on improving the quality of care, integrating services to make them reflect the patient's journey and acting as a model for best practice and guidelines.

In Belgium, however, the emphasis is on cost containment whilst recently they have concentrated on the achievement of clinical outcomes (Sermeus 2001). Again, the majority of these PCPs take the form of check lists of task and goals.

This highlights three main points:

1) The traditional form of the PCP includes information on decisions and management of the patient and is presented in a linear fashion, typically as a flow chart.

2) The traditional form of the PCP does not include information flow.

3) The traditional form of the PCP is recognised within the International health care community and the concept is accepted.

The concept of the PCP has been adapted and in place of an algorithmic decision and procedure tree or flow chart, it is now used to depict the processes encountered by the patient in receiving their diagnosis and treatment. Traditionally this would show the physical journey of the patient as they present themselves to successive points in the system.

Currently patient information is held in hard copy, either as a paper record or as film. As the current form of PCP depicts only the patient journey, with the assumption that information in hard copy remains in each institution, or at best travels with the patient, then this has not been adapted to depict any movement of information in the form of paper records. In contrast, an e-health service will make the patient information available at each of the separate institutions, and this information flow must be included in the PCP.I as it may move in place of the patient. The PCP evolves to show flow of information and is analogous to the data flow diagram (DFD).

PCPs of this form have been used to analyse the effect of introducing technology within an existing health care system (Bratan 2007). In their work, the PCP is used to analyse remote patient monitoring projects in the UK to determine the impact of changing work practices, concluding that the PCP may be used to determine the benefits of e-health. In particular they note the advantage of moving the information instead of the patient.

E-health has the further advantage to support patients by keeping the care local by moving the information to specialist centres rather than having the patient travel for a traditional “face to face” consultation. E-health can accomplish this through exchange of information, for example Hands et al (Hands 2006) describe how peripheral vascular referral can be kept in primary care using e-health with advantage for the patient in health outcome as well as convenience.

It has been extensively reported that teleradiology reduces the number of unnecessary transfers, i.e. patient movement (Daucourt 2005), and clearly demonstrates the advantages of e-health in terms of keeping the care local and moving digital X-rays between primary/secondary health care and specialist centres.

This research considers the PCP as a modelling tool to demonstrate the advantages of e-health in a teleradiology context and will be applied to the pre-implementation phase as a case study.

No examples of PCPs being applied to a pre-implementation phase of an e-health project have been identified.

2.1.1BENEFITS AND RISKS OF APPLYING PATIENT CARE PATHWAYS TO E-HEALTH

Three main points are addressed within this section:

1) Generic benefits of mapping PCPs to the existing traditional health care delivery system i.e. prior to the introduction of e-health.
2) Benefits of modifying the PCP to schematically illustrate and capture information flow due to the introduction of e-health, thereby developing a modified PCP for systems analysis.
3) Using the PCP to identify the risks associated with introducing e-health.

The PCP provides an ability to determine how a system will respond to different changes in assumptions and identifying the decisive factors (Heathfield 1997). In this way it is possible to estimate the potential for improvements and suggest changes to the organisation (Shahar 2002).

PCPs can be used to predict and manage change and can address the concerns of the e-health community over the general lack of project management and the resulting poor integration of e-health into the mainstream health care delivery system.

The lack of adoption and integration of e-health projects is in part due to the entrenched health care accreditation system and the emphasis on the proof of efficacy before any new product or innovation is adopted (Barlow 2006).

PCPs offer a part solution by allowing the e-health system to be modelled and can be used to predict the outcome from actions and developments before making changes to the existing health care system. They further provide a framework and support the development of standard change management procedures.

Gaining the evidence of efficacy in e-health remains a challenge. It is often not feasible to evaluate e-health using the “gold-standard” of a randomised clinical trial and there is a growing acceptance that a pragmatic approach to evidence gathering will be needed (Finch et al 2003).

It is clear that the use of PCPs can remove some of the fear associated with negative outcomes of a project by pre-empting the challenges before the study is implemented (Ammenwerth 2002). As the proposed introduction of the teleradiology project in Thailand was working in a politicised, high profile International context within a hierarchical management structure, PCPs were adopted as offering a safe environment that gave an opportunity to increase the chance for successful introduction.

An additional proven benefit of PCP is that it supports the users’ understanding and trust of the application, this is in part due to the PCPs reflecting the process as described by the user, not as observed or perceived by the modeller. This characteristic would have direct positive benefits to an e-health project as the literature cites a “top-down” management approach has directly contributed to the failure of e-health projects (Karsh 2004).

Process redesign is still considered more of an art than a science (de Luc 2003). However, there are ways of managing an e-health project and using modelling techniques to increase the likelihood of success. One of the objectives of this research is to contribute to increasing the chances of success of e-health projects by proposing a management tool in the form of PCPs.

In addition to their role for the management, PCPs can also be utilised to evaluate the proposed changes of introducing an e-health project and its alternative scenarios and form the basis for, modelling the application i.e. studying the effects of proposed changes in the system without actually modifying or disturbing the system itself. PCPs then allow evaluations to be undertaken on all the possible solutions, prior to implementation of any changes in practice or policies. This approach is rarely adopted in healthcare today, least of all in e-health (Sanches 2000).

PCP is able to provide an understanding of the system and the alternative solutions before committing to one solution and is imperative when working with complex systems such as e-health (Eldabi 2002). Indeed, through lack of planning, the opportunity and need to redesign health care delivery systems when introducing e-health is often lost. For example, in a qualitative study of the organisational changes due to the introduction of e-health, five dermatologists noted little organisational changes (Aas 2001). PCPs are a tool that can help change clinical practice. Unlike the traditional approach, which considers only the clinical components of a healthcare process (Gordon 1995), the PCP of this research seeks to determine how to improve the processes and so improve performance.

Central to the approach is to ensure that the problems are well understood before investing in solutions (Rittel 1984). This supports the decision to invest effort in the pre-implementation phase of e-health projects to fully understand the issues and provide an analysis of the system.

Recently a small number of research projects have reported positive outcomes of traditional PCPs (Kalra 1999). The Clinical Resources and Audit Group (CRAG 1999) project evaluating 103 care pathways at two hospitals in Scotland concluded:

”… this report demonstrates the effectiveness of integrated care pathways in almost all of the areas evaluated. Evidence is copious, consistent and statistically significant.”

Similarly, reports from other countries, including China and the USA have shown real and definitive improvements in the quality of care in specific areas due to PCPs (Turley 1994).

Evidence shows that PCPs are well recognised and understood by the majority of service providers within the UK health care system and the concept of PCPs is internationally understood and accepted. Therefore, the modification of the PCP for use within e-health is expected to see it become accepted as a management tool.

The proposed method is that the existing system should first be understood. This is achieved by creating a traditional PCP of the current health care system. This takes advantage of the generic benefits of mapping the PCP.

This is followed by mapping the information flow within the proposed e-health project. In this way the implications of introducing technology may be demonstrated in a readily understood format.

This proposed PCP e-health modelling tool takes a step towards introducing a framework that supports change management that includes organisational restructuring, process simplification and systems redesign.

Use of the PCP can bring benefits to situations involving multi agent groups by supporting the analysis and evaluation of interactions across the separations between the groups and by considering the numerous professional inputs and thereby address all aspects of the multiple processes of healthcare (Gordon 1995). The teleradiology case study would cross several healthcare boundaries and make information available across three hospitals and to more than 20 medical professionals. This contrasts with the previous system where the information was available to only four medical professionals.

Using PCPs to understand the implications of implementing e-health increases the chance of success by facilitating risk management.

Risk factors associated with introducing an e-health project include (Mayer et al 1999):

- Multiple, uncoordinated activities.
- Lack of commitment to establishing an in-house capability.
- Insufficient or inadequate methodology, methods, tools.
- Attempts to outsource key decision making.
- Failure to concurrently address business, information system and organisational change together with process change.
- Inability to leverage information technology and realign information systems quickly enough to make a smooth transition.
- Inability to align process intent with organisational vision and goals, structure and job performance management.
- Lack of top level commitment and understanding.

These risk factors can also provide a useful benchmark and checklist for the process redesign and change management aspects of development at all levels. The risk factors were considered and addressed in the methodology thereby avoiding the recognised pitfalls.

The PCP can address these risk factors by:

- Providing a top level organisational perspective of the health system
- Analyse the health system using a holistic approach
- Represent all the sectors and group and identify the information flows between them
- Determine changes in current practice and scope for change management
- Information needs and its organisation

2.1.2 THE APPLICATIONS OF PATIENT CARE PATHWAYS

The use of the PCP has expanded from its initial introduction to health care in the USA during the 1980's to many countries, including Australia, New Zealand, Japan and as well as several European countries.

There is a difference of emphasis in the use of PCPs in different countries. For example, in Belgium and the Netherlands the emphasis is on cost containment and on the development of patient centred care (Sermeus 2001).

In the UK, the emphasis is on improving the quality of care, integrating services to make them reflect the patient's journey and acting as a model to ensure best practice and that guidelines are implemented.

Whereas in the USA PCPs have been seen as a tool to control costs whilst maintaining the same level of quality and clinical outcomes (Currie 2000).

These examples serve to demonstrate both the flexibility and range of application of PCPs and further illustrate the general acceptance.

Migration of this established PCP model into e-health will be eased by the familiar format and terminology.

2.2 STANDARDS AND THE PRE-IMPLEMENTATION PHASE OF E-HEALTH PROJECTS

A weak foundation at the pre-implementation phase can adversely affect the successful implementation of an e-health project (Ammenwerth 2005).

Therefore, failed e-health programmes might have been avoided by adopting formal methodologies at the pre-implementation phase.

Even seemingly minor problems at the implementation phase can destabilise a project, emphasising the requirement of a model to consider and evaluate the environment prior to implementation (Pagliari 2007).

This thesis proposes a methodology that may be used to produce a pre-implementation model that may be used to determine and avoid problems that might affect an e-health project in its later phase. It utilises a management methodology to better understand and predict the implications of introducing e-health.

The health care professions have favoured a "top-down" development of e-health systems but this has the weakness that problems only become apparent during implementation (Karsh 2004). Therefore, there is a requirement to understand the current system and managing and predicting the implications of introducing changes within e-health projects.

Although developing technical solutions remains an important element to e-health, recent years have seen a growing emphasis in identifying and resolving barriers to implementation (Pagliari 2007). The introduction of e-health requires organisational as well as technical solutions.

Teleradiology operates within global technology standards and is supported by strong professional associations and there is general agreement and co-operation within these organisations on technical standards and operational guidelines (ARC). The Thai MoPH accepted the technical standards for the teleradiology project thereby allowing the focus on the organisational issues.

The MoPH decision to accept the technical and clinical aspects of teleradiology was supported by the evidence of The American College of Radiology which conducted a survey in 1999 of teleradiology services. The survey had a 66% response rate and found that 71% of multiradiology practices and 56% of diagnostic radiology practices reported using teleradiology (Dimmick 2006).

Teleradiology has been the most researched and reported topic in the telemedicine literature. A persistent shortage of radiologists combined with the ease of transmission of radiology images has led to the adoption of teleradiology as a viable and sustainable form of telemedicine.

One reason for its success is that teleradiology was more readily accepted because it fitted into an already technology intensive discipline.

The adoption of PACS also paved the way for archiving images internally and exporting images in a standard format. Relatively early reimbursement for teleradiology for both private and state funded patients also facilitated the early adoption of teleradiology.

Integration of teleradiology into a rural health care system has been shown to be more problematic and numerous research publications have documented that the success of these rural programmes varies by community (Yellowlees 2001).

A case study of two rural e-health projects concluded that e-health was only one aspect of provision for rural health and that its success would be wholly dependent on the organisational and cultural influences of the health system (Whitten 2002).

The focus of this research is to develop a formal methodology that includes both a modelling approach to consider the clinical aspects and project management that can be applied to the pre-implementation phase of a rural e-health project. Such an approach to examine the organisation as the first step is well supported in the literature (Whitten 2003).

Key strengths from previously successful e-health projects can be traced to organisational issues. In most instances care taken on the people and organisational factors, such as stakeholder resistance to change and the appropriate integration of new technologies into work patterns was found to have greatest impact on success (Kaplan 2001). In contrast, the most often cited reason for failure was unanticipated technical, human or organisational issues (Southon 1999). For example, design flaws at an early phase can affect ease of use and reliability of systems; this causes ill feeling and reduces the willingness of the medical professional to use e-health systems (Dumay 2004, Ammenwerth 2003).

Health systems research has traditionally focused on sampling and involved a meticulous time and cost intensive approach to acquiring quantitative and qualitative data as evidence of effectiveness. However the same approach may not be easily applicable to e-health programmes due to the difficulty in defining the control group for comparison, the difficulties with separating effects, and often the technology or context of the project has progressed by the end of the study (Pagliari 2007).

Use of the PCP may represent a compromise solution for the pre-implementation of an e-health project. Although not providing the evidence, it can identify the key issues, the main changes, predict the benefits and identify the risk factors at appropriate times within the project lifetime and offer a formal methodology that can improve the chance for successful implementation.

Previous efforts to develop formal methodologies include the Tyrolean teleradiology project linking a University and a district hospital (Soegner 2003). The group developed a twelve step teleradiology workflow; this described the medical responsibilities at each stage. Whilst the guidelines incorporated workflow this does not reflect the impact of introducing e-health and does not detail any information flow. In conclusion, the work on the Tyrolean project recognises that a high quality e-health workflow requires more than a technical solution and to ensure continuous quality assurance, the whole teleradiology workflow was ISO 9001:2000 certified by the Austrian Quality Assurance Society. The work demonstrates the value of quality assurance procedures for the operational phase, however it fails to address the planning and pre-implementation phase that are the focus of this research.

Campbell (1999) examines a programme management model for the Nova Scotia telemedicine network and focuses on three critical factors linked to success:

1) Process Guidelines, and establishing a process to identify the stakeholders, choosing technology based on clinical needs, avoid central decision making, establish training protocols and identify evaluation criteria.

2) Self- Assessment Indicators, identification of all the detail and present the problems identification of the challenges. Format design to capture the perceived health care service.

3) Service Modelling, Identification of the risks.

This work clearly identifies the factors that need to be considered to implement a successful teleradiology programme, however it does not detail the process nor consider how to achieve the three critical factors.

The proposed formal methodology of the PCP gives a framework within which some of these critical factors could be addressed and considered.

E-health is very broad and comprises a wide range of applications and the implementation of e-health initiatives in health care is difficult. For example, over 1500 evaluations of health IT published between 1967 and 1995 reported problems in implementing healthcare (van der Loo 1995). Many authors report problems during evaluation, including:

- Unclear, conflicting or changing evaluation goals during the study (Heathfield 1998).
- Large efforts needed for the preparation and execution of the study (Burkle 1995).
- Complex and sometimes contradictory results.
- Dependence of the evaluation results on the motivation and expectations of the users (Henderson 1996).
- Uncertainty whether results can be applied to other environments (Mair 2000, Heathfield 1998).

These problems have been identified as arising from a non-systematic study design and inexperienced management. A framework to support the implementation of e-health studies is advocated (Tierney 1994).

Whilst the view of the stakeholders is equally important in both pre-implementation and post implementation phases, it is preferable to be open to unwanted and unexpected effects of an e-health project. This requires the system to be fully understood at the earliest opportunity, rather than implement a costly project and discover problems at the evaluation phase.

Furthermore, the reluctance to report results of e-health projects with unexpected outcomes or breakdown in the project (Tierney 1996) denies the e-health community with important information and learning. Certainly the repeated reporting of failure illustrates the need for a greater investment of time and effort in developing a methodology to predict and manage the problems associated with e-health projects at the earliest juncture.

The resulting outcome has been that specific applications within e-health, such as telecare, continue to be considered as experimental, whereas, other applications such as electronic health records are widely used and accepted.

There are several benefits to adopting a formal methodology that has a pre-emptive approach to the design of e-health: the introduction of IT in an organisation is a far reaching intervention that may have significant consequences and it is difficult to remove an IT system once it has been introduced, especially in terms of re motivating personnel who have had a negative experience from an e-health project (Bates 2001).

Within healthcare the system is generally under constant and high pressure. Moreover, introducing e-health into the system will initially increase the workload and, therefore, care must be exercised in how it is accomplished. Careful planning in the pre-implementation phase is essential to maximise likelihood of success and adoption of the e-health system (Ammenwerth 2003).

Others (Jennett 2003) support the case for investment of effort in the pre-implementation phase, and suggest that the organisational preparation for an e-health project is related to:

1) Planning readiness and the development of strategic and business plans, needs assessment and analysis, the identification of clinical care, care provider and senior administrative champions.
2) 'Workplace readiness', preparing staff, introducing change management processes. "Ownership issues' are important factors that shape the e-health project in terms of outcomes (Finch 2003).

Within informatics the preferred method is first to model the existing real life system. From this the ICT system may be designed and implemented (Berg 2003). This approach has in general resulted in greatest chance of successful implementation (Tunnicliffe 1981). Therefore, in an e-health context, adopting a formal methodology that includes modelling should address concerns about the failures. Such an approach might include adopting emerging standards or inform the standards process.

With this in mind, the literature review moves on to examine a possible new "perspective brought to bear in planning" referred to previously by discussing the benefits and risks associated with PCP modelling, making specific reference to e-health.

2.3 MODELLING WITHIN HEALTHCARE

2.3.1 DEFINITIONS OF MODELLING

Modelling aims to increase the understanding of how systems function (Lagergren 1998).

From an operational research and technical perspective, modelling is taken to mean an:

“Abstract, formal – usually computerised – mathematical or logical description of some system of objects and activities” (Lagergren 1998).

In common with the majority of definitions of modelling, models are used as tools for learning and aim at increasing the understanding of how systems function, often being used to predict their response to different changes.

Modelling has a number of meanings and interpretations. This may include developing only a representation of the system that supports conceptual understanding, or developing models that depict increasingly greater levels of detail and that is executed in some form of simulation environment to predict results of the systems in response to varying conditions, examples including discrete event simulation.

For the purposes of this thesis, models and modelling will refer only to a representation of the system unless otherwise indicated.

2.3.2 ADVANTAGES AND RISKS OF MODELLING

Mismanaged implementation of e-health projects is well reported. Modelling can provide a method to give insight into the system under study and offers the possibility to investigate the mechanism by which changes in performance in a system can occur.

Modelling is an objective way to demonstrate an operational area but its true power lies in the “what if” scenarios and allows decisions to be made (Sanches 2000).

Modelling an e-health project can highlight the interdependence of the different parts of the health organisation or system and by this support a systems approach to the planning or decision problem (Vissers 1994).

An additional advantage of modelling is its potential to act as a focus point of discussions for the different stakeholders involved in the decision making process. By modelling it is possible to create a shared understanding about the problems, and, therefore, produce an effective communication tool (Davies 1994, Vissers 1994). Typically, model building will help in posing the right questions and even initiate a host of questions concerning the system, and in this way modelling can also be of assistance in the definition of research needs (Jager 1995).

Modelling aims to increase the understanding of how systems work and make it possible to predict consequences of actions and developments. Often the objective of developing a model is to develop a deeper insight into the properties of a system, so called “what if modelling”. This insight could be invaluable in scoping and communicating an e-health project and gaining clear understanding of the dynamics prior to implementation.

One of the many opportunities that modelling offers e-health is to allow investigation into the effect of alternatives. An operational system can be modelled without interfering with the day to day running of the health care systems.

Modelling makes it possible to study systems that do not exist, to predict consequences of actions and developments and conduct experiments, which are impossible or too costly to perform in reality.

For this thesis, the objective of the modelling is to investigate operational aspects and uses a modelling approach to develop a deeper insight into the properties of the system i.e. system analysis. This insight may then be used for design or evaluation.

2.3.3 MODELLING AND E-HEALTH

This thesis recognises the many approaches and types of modelling that have been applied to health and in this section provides an overview in order to place the modelling of the PCP in context.

Some modelling of IT in health care has been concerned with the operation of the health care system itself, e.g. monitoring of blood glucose levels. Traditionally, this category of application has been confined to administrative issues; the appointment system, waiting line management, and short term prediction of demand (Van der Loo 1992).

From an operational perspective, models are now becoming applied more often for analysis and decision making in medical practice, either on the clinical level or in direct relation to the treatment of the individual patient (Shahani 1993).

Many kinds of models exist for differing purposes in health. The choice of model type, method or development environment is partly determined by the problem under study, but is also a matter of subjective choice (Lagergren 1998).

However, not all modelling techniques offer the same insight into the system structure and the choice of technique will depend on the specific objective of the modelling exercise. The guiding principle should be:

"To construct as simple a model as possible without losing relevance to the problem under study" (Lagergren 1998).

Models in health care should be simple and easily understood in order to fit into the complex personnel structure and entrenched hierarchal historical element of health care (Davies 1994).

If this approach is taken, then the purpose of the task has to be clearly defined and understood. In this work we conclude that an accurate PCP must be developed of the existing system prior to the implementation of e-health.

The basis for the work in this thesis is the adaptation of the PCP to be a longitudinal model for the pre-implementation phase and can be a component of a formal methodology for systems analysis of e-health projects.

2.4 PATIENT CARE PATHWAYS AND SYSTEMS ANALYSIS

There is a commonly held viewpoint that engineering modelling tools can be applied successfully to innovation led health care projects. In contrast, others view healthcare systems as too complex and unique to apply traditional engineering based modelling (Eldabi 2002). However, this research shows that a suitable selection and amalgamation of pertinent elements of systems engineering can complement use of the PCP to provide a holistic approach to implementing e-health systems.

The introduction of e-health offers a new pathway that moves away from single clinical specialty and the physical boundaries previously surrounding health care information. This requires new methods of working and managing these innovation led delivery mechanisms.

An integrated and holistic approach to e-health is essential and one that should promote debate on the systems approach and its application to e-health and systems analysis (Lagergren 1998).

From an external perspective, there can be issues concerning the delivery of health care in an integrated way when even at the organisation level departments may often operate autonomously, creating so-called "silos." Elements of the health care delivery mechanism often operate independently (Reid 2005).

In addition, the current organisation, management and regulation of health care delivery provide little incentive for the use or development of systems engineering tools. Current reimbursement practices, regulatory frameworks and the lack of support for research have all discouraged the development or adoption and use of systems engineering tools (Reid 2005).

Indeed the majority of companies would be unable to operate their business in today's competitive environment without the benefit of comprehensive information systems and the extensive use of systems engineering for the design, analysis and control of complex production and distribution systems. Health care seems far behind (Reid 2005).

There are examples of the benefits when health care adopts a systems approach, however, care is needed when comparing the needs of health care and manufacturing and other service industries. Certainly the complexities of health care prevent a simple copy approach to improving health care processes (Reid 2005).

A move from the current conglomeration of independent entities towards an integrated “system” will require that every participating unit recognises its dependence and influence on all the other units (Blandeau 2004). Furthermore, each unit must not only achieve high performance but must also recognise the requirement of joining with other units to optimise the performance of the system as a whole

If a system is to be established then every participating unit will need to recognise the imperative of joining with other units to optimise the performance of the system as a whole. Moreover, each individual care provider must also recognise the dependence and influence on other members of the care team (IOM 2003). Such underlying attributes would indicate that a systems approach should be adopted.

2.5 CONCLUSION

The PCP can be used as part of a formal methodology based on systems engineering that may be used in the planning and pre-implementation phase of e-health projects. The goal of the thesis is to determine the interdependent entities within e-health projects through the use of PCPs as a systems analysis tool, thereby developing a better understanding of the issues of implementing an e-health project and manage its introduction.

CHAPTER THREE – METHODOLOGY

3.1 INTRODUCTION

This research develops and tests a methodology within the framework of a case study of the pre-implementation phase of a teleradiology project in Thailand.

The basic research approach will be deductive with the hypothesis that a modified PCP can provide a representative model that may be used for systems analysis of the pre-implementation phase of e-health projects. The proposed methodology is enhanced by using the PCP within the systems engineering INCOSE life cycle management.

Within the context of this thesis, the framework has as its initial step to understand the current teleradiology system and represent it schematically as a PCP.

There are no universally accepted methods for developing PCPs; therefore, the method adopted was based on a list of recommendations from recent research publications.

The publications referenced in this chapter were used to identify the methodology, the issues of implementation and the areas of risk associated with PCPs.

This approach extends the PCP developed for the teleradiology e-health project to represent diagrammatically the movement of information as well as patients. Representing both with the PCP allows the traditional delivery mechanism for radiology to be compared with the proposed e-health system.

Finally, INCOSE systems engineering techniques are applied to the entire project, of which PCP is one element.

3.2 FRAMEWORK DEVELOPMENT

One of the key elements of the development process for the PCP is to examine the existing evidence, guidelines and research and incorporate this into the model. In this case, no comparable studies were found to have been applied to the local practice of Thailand to inform the process.

The author therefore developed the PCP only from information that was collated from discussions held with staff and politicians and examination of the specific delivery mechanism of hospitals in Thailand.

The framework to manage the project was adopted from an existing model taken from Worcestershire Acute Hospital NHS Trust and included addressing the following issues:

- Has the membership of the development group been identified?
- Have you identified a topic?
- Have you identified objectives?
- Have you identified inclusion criteria?
- Have you identified exclusion criteria?
- Have you identified a start point?
- Have you identified an end point?
- Within which geographical location will the project be implemented?
- Is there a lead person identified?
- Has a baseline audit of the care provided been undertaken?

- Have sample pathways been reviewed from other organizations?
- Has a literature search of the relevant evidence been completed?

The above features were satisfied however the following were not satisfied for the stated reasons.

- Which relevant guidelines, policies, procedures are referenced?

(de Luc 2003).

The MoPH did not have written guidelines and policies for radiology at the secondary care level, therefore, no local policies could be included. Note that secondary care radiology was observed to have excellent working practices.

- Have you incorporated assessment tools, charts and questionnaires, and have patient/users views been reported?

A questionnaire had been prepared to assess the impact of teleradiology and address the above points, however, due to a change in Government the project was prevented from progressing to the implementation phase. Consequently the questionnaire was not applied.

3.3 KEY ELEMENTS OF THE FRAMEWORK

The framework used to support the design and implementation of this e-health project was developed from the key components and factors identified by many, for example, (de Luc 2001)

The four main factors identified are:

1) The Facilitator.

The importance of the individual to take responsibility for organisational change perspective has been widely reported. In an e-health context, there is the added requirement for these individuals to have skills in the area of health, management and technology.

It is stated that:

“The central importance of a facilitator is that they understand the world of the developer and of the user. They can therefore play a key role in the improvisation of both design and reality, and help improve the success rates. They may do this by taking direct action themselves to alter design or to alter current user realities. Or they may do this by enabling others; particularly through a translation or interpretation role that helps communication” (de Luc 2001).

In this project the author assumed the role of facilitator.

2) The multidisciplinary team of staff that have first-hand experience of delivering care.

The blend of personnel that constitutes a successful team and project delivery is important. The crucial factor for implementing an e-health project is the involvement of all key stakeholders and especially frontline service personnel in the early planning and implementation process and that they be included from the early stages of project development.

3) Effective Communication.

Two way communications can only happen if a participative method is followed. The INCOSE iterative process gave structure to the communication and formed an important element of the project. The method for team development allowed for two-way communication between users and developers.

Two way communications can only happen properly if a participative method is followed; one that allows users to better understand the design, and the designers to better understand user needs. It is reported that where such methods have been used, they have typically formed an important element in successful e-health implementation.

It is reported that an absence of communication within e-health projects has been associated with e-health project failure (de Luc 2001).

4) Identification of user requirements

For innovation to be successful, technological opportunities need to match user needs. The lack of attention to user needs has been shown in innovation research to be a major factor in the lack of adoption. The literature cities that this is partly due to suppliers pursuing a technological push, rather than demand – pull approach, resulting in a gap between consumer requirements for a system which are useful in managing everyday tasks and the products that are available. This is particularly seen as a problem in development of e-health. However, for this research the user needs were clearly identified and the project was not technology driven.

Having established a framework to conduct the project, the e-health application was selected and the PCP developed.

3.4 PRODUCING THE PATIENT CARE PATHWAY

The scope of the e-health project was to provide a pilot teleradiology programme that enabled the Thai MoPH to install and test the viability of a networked PACS solution for teleradiology referral between chosen sites.

Once the sites had agreed to participate, a more detailed understanding of the dynamics of each hospital had to be scoped. The first stage was to understand the physical layout of the hospital. This was achieved by simply walking the boundary with an escort from the Hospital. The information was mapped (Figure 6).

Data were also collected on the geography, population and external factors that influenced the hospital.

To define and understand the existing PCP for patients needing an X-ray the following method was applied to the remote hospital

a) Map of the hospital was used to illustrate the physical route patients took following admission for an X-ray.

b) A member of staff explained the routes a patient could take.

c) Digital images were taken at each critical point in the pathway.

d) Patients were followed through the hospital system and amendments made to the pathway where necessary.

e) Documents and relevant computer information were collated and translated.

f) PCPs were mapped (Figures 7-13).

The above method was replicated for the referral hospital; however, due to patient confidentiality digital photos were not taken.

This approach is confirmed by others:

"Even if a stepped and participative method provides the context, improvised design-reality gap closure can only take if those involved have the right tools to hand. One basket of these will be the type of ethnographic tools that provide a proper understanding of current realities. These will include observational techniques such as self or third party observation, and use of soft systems tools such as pictures that provide a graphical and in-depth means of recording reality, including the informal and socio-political components of reality" (Checkland 1999).

3.5 SYSTEMS ENGINEERING

3.5.1 INTRODUCTION

Over the past 50 years industry has developed theories and management tools to encourage adaptation and survival in the market place. These include, “Just in time”, Total quality management”, “Lean Manufacturing” and “Systems Management”.

The systems management approach attempts to understand the basic structure of the system, and the behaviour that this produces. At this point, it should be recognised that although systems management can be used as an organisational tool, the advocates of this approach believe that it can also be used in a wider context (Checkland 1999).

Indeed human factors are seen as so important to the success of e-health projects that specific methodologies such as Soft System Management (SSM) that take into account the human and social factors of organisations during systems design, are adopted.

3.5.2 SOFT SYSTEMS METHODOLOGY

Soft System Methodology is one of a group of approaches that factors in the human and social elements of organisations during re-design. SSM was founded as an approach to design information systems and examined the systemic modelling of human activity in organisations as perceived by the stakeholders. It is one of the strengths of SSM that it uses “systemic” analysis based on modelling the whole system, and recognises that the whole is greater than the sum of the parts.

It is frequently observed that problems are associated with senior management taking a lead role. SSM identifies common problems that have been observed in e-health projects and this is considered a characteristic of human dominated systems.

For example:

- Organisational goals may conflict. It is wrong to assume that all organisation members accept the views and goals of top management.
- Formal methods usually begin with a problem statement but solving that problem too early tends to hide other problems.
- The method itself can restrict what will be elicited.

With SSM the process is considered as important as the outcome. The experience of applying an SSM approach will itself change the organisation. This will arise from changed views about the problem and its possible solution. In principle, an SSM project is carried out by the people of the organisation, with the aid of a facilitator. It covers:

- Problem Situation
- Analysis
- Root definition of relevant systems
- Conceptualisation
- Definition
- Selection
- Design
- Implementation

SSM is a goal driven approach which, rather than seeking to improve a current situation, looks for the most desirable system and then attempts to bring that system into being.

The basic methodology has seven distinct stages:

1) Finding out about the problem.

2) Expressing the problem situation, described as the “rich picture of the real world”.

3) Selection i.e. selecting how to view the situation to produce insights and to produce root definitions.

4) Building conceptual models of what the system must do for each root definition.

5) Comparison of the conceptual model with the real world.

6) Recommendations for taking action to improve the problem situation.

This approach was used as the foundation of the methodology, with the PCP providing the means to identify many of the important new relationships. Others have observed similar strengths of such a framework (de Luc 2002).

3.5.3 LIFE CYCLE MANAGEMENT

System engineering principles provided by the International Council on Systems Engineering (INCOSE) were chosen as the management tool for the e-health project and had the strength of providing a methodology to cover the entire life cycle of the system.

ISO/IEC 15288 states: “A life cycle model comprises of one or more stage models, as needed. It is assembled as a sequence of stages that may overlap and/or iterate, as appropriate for the scope, magnitude and complexity, changing needs and opportunities” (Haskins 2006).

The PCP provided the approach within the methodology to depict information flow within the wider context of the health system and followed generic systems engineering principles.

Although INCOSE covers all the phases of the life cycle, circumstances restricted this research to examine only the pre-implementation phase. and therefore it investigates only application to the first elements of the systems engineering life cycle. This is termed as the concept stage and described by INCOSE as being:

"The concept stage is executed to assess new business opportunities and to develop preliminary systems requirements and a feasible design solution".

During the Concept Stage, the team builds in-depth studies that evaluate multiple candidate concepts and eventually provide justification for the chosen system concept. Many commissions reviewing failed systems have identified insufficient or superficial study in the concept stage as a root cause of failure (Haskins 2006).

It is the hypothesis of this research that the PCP offers a formal methodology that can elicit and represent the information of e-health projects to be used within the Concept Stage of INCOSE.

3.6 CASE STUDY METHODOLOGY

3.6.1 OVERVIEW

The project was initiated as an expression of interest by the Thai Minister of Public Health (MoPH) to develop a Thai e-health programme.

The Minister's support initiated telephone contact between the MoPH and the author. Several subsequent video conference calls with Thailand started the dialogue and established the commitment and capabilities of the stakeholders. This confidence building exercise was the foundation for a series of "in-country" meetings.

3.6.2 SOURCES OF INFORMATION

a) Governmental Trade and Industry Reports

A Sector Report by The Foreign and Commonwealth Office and the Department of Trade and Industry (1999) contained commercial information on the health care sector in Thailand

b) Interviews

Interviews with key stakeholders were conducted in order to determine information specific to the e-health project. Interviews were conducted as part of a series of workshops that were held within the country at the offices of the MoPH.

c) Overseas Visits

13 overseas visits were made during which up to two months was spent at the clinical sites that would participate in the project to interview the key stakeholders. This included:

i) Two Provincial Hospitals

ii) Three Primary Health Care Centres

iii) Two tertiary Hospitals

iv) Two Medical Schools

The author was supported during 13 in country visits by a Thai National who provided secretarial and translating services.

3.6.3 CRITERIA FOR IDENTIFYING THE E-HEALTH APPLICATION

The following aspects were considered in selecting the application to be developed (de- Luc 2001).

- Simple clinical condition i.e. not a chronic condition involving different specialities
- Clinical staff expressed a desire for the project
- Clear start and end point for the project
- An area that creates maximum impact
- Subject of national guideline/policy initiative

Following lengthy discussions and consultations, teleradiology was chosen as the e-health application which fulfilled all the suggested aspects. Information on the chosen e-health application was circulated around the hospitals and regular lunch time meetings were held and presentations were given to all hospital staff, including all ancillary workers.

3.6.4 SELECTION CRITERIA FOR THE HOSPITALS

The main criteria used for the choice of the hospitals to be included in the e-health network included:

- The lack of radiologists at the remote Pong Nam Ron Hospital (the films were currently read by one of three GPs).
- Time delay and difficulty for patients to travel to the reference hospital. Roads become impassable during the rainy season.
- The quality of relationships between the medical professionals in the referral sites.
- Medical professionals were supportive of the programme.
- The availability of high speed communication links.
- Users with a positive and enthusiastic approach and users had existing good IT skills.

- Excellent IT support.
- A “champion” at each hospital.
- Political support.

The stakeholders identified and agreed on the following hospitals for inclusion in the teleradiology project:

1. Pong Nam Ron Secondary care hospital in Chanthaburi Province
2. Prapokklao Provincial Tertiary care Hospital in Chanthaburi Province
3. Chulalongkorn Medical School, Bangkok.

For planning purposes the projected X-ray volumes per annum were determined.

	Average no of Patients / Year	Avg. Images per Patient	X-Rays per Year	Single x-ray Size	X-Ray size per Year	Compression 2:1
				(Mb)	(Gb)	(Gb)
X-ray	4,800	4.0	19,200	8.00	150	75
Forms (assume 2 per Patient)	9,600	2.0	19,200	2.00	38	19

Table 1 Annual Volume of X-rays

Approximately 400 X-rays were acquired per month in the remote Secondary Care Hospital, approximately 20-30 X-ray required consultation with the tertiary hospital, but only half of these received a consultation due to the lack of an agreed procedure between the hospitals.

In order to allow for sufficient capacity on the server, an allowance was made of two forms per patient. In practice, one duplicate form was taken for each set of X-rays and when a referral was made, a further paper form was generated with the patient details. As the information on the paper forms was needed for a teleradiology consultation, the forms would be scanned and stored on the server. The server would need to have the necessary capacity.

Teleradiology typically represents an increase in case reading volume and, therefore, adjustments have to be made in the operation and management of a department (Dimmick 2006). For this reason, it was anticipated that the numbers of consultations would increase and this had to be factored in to the storage capacity of the server.

An exchange of information and good communication between medical, finance and administrative managers improved the quality of the requirements. A discussion between managers' representatives and system developers in the pre-design phase is therefore a way to distribute risk-bearing factors, while minimizing unexpected costs. It follows that any communication gaps between managers were considered.

Additionally, it took a substantial amount of time to gain consensus within the team and clearly define the roles and responsibilities. It was an advantage to have a written agreement to summarise the salient points and to demonstrate commitment and understanding of the project.

Good documentation of process was important and for this reason minutes of meetings were taken and at the end of each in-country visit a report was generated and its content agreed and authorised by the MoPH.

Whilst this process of communication was time consuming it not only acted as a record but helped gain an understanding of the risks and pitfalls associated with changing a delivery system.

Furthermore, the degree to which all stakeholders are involved and cooperate and the stability of management structures are fundamental. Hence the research methods took into consideration the issues surrounding the communication and worked towards avoiding clearly identified pitfalls.

Based on the foundation of human factors within systems engineering the research maintained a focus on communication, appreciating that political, organisational and ownership issues are important in shaping e-health implementation processes and outcomes. To avoid these potential barriers the facilitator developed positive links with the local hospitals and also the MoPH at National level.

Trust and openness are further factors identified for success of e-health projects. However, these must be balanced by cultural considerations. For example when working with an interdisciplinary team in Thailand it was considered disrespectful to question the actions of a more senior member of staff, therefore, time was allocated to individuals to allow a private forum for discussion.

Size of the team can influence success and de Luc (de Luc 2001) suggests that the maximum number of people in a team should be between 10 and 15. This study had 13 people including politicians.

It is interesting to note that a political change in the country prevented the project from continuing and this reinforces de Luc’s opinion that all elements must support the project for it to succeed.

3.6.5 PROJECT PERSONNEL

For the pilot phase of the teleradiology project, it was expected that there would be the following users of the system:

- Medical records and Scanning staff – responsible for managing and scanning the paper-based patient data into the PACS
- Clinical Staff – appropriate clinical staff and other healthcare professionals (as chosen by the hospitals) who will use the scanned data in routine clinical use and record results for the evaluation
- Technical Staff – will manage the technical operation of the system

Specifically within the three healthcare sites, the initial users consisted of:

- In the Remote Hospital – Site Champion, 3 GPs, 2 Administration staff (who do the scanning), 1 IT staff.
- In the Referral Hospital – Site Champion, Team Leader (IT), 5 Radiologists, 1 administration staff.
- In the Medical School – Site Champion, 1 Specialist Radiologist, 1 IT support staff (A specialist radiologist has additional expertise and special interest in a particular area of radiology specific to a condition e.g. spine specialist)

3.6.6 GOALS AND OBJECTIVES OF THE TELERADIOLOGY PROJECT

The goal of the pilot was to provide an X-ray scanning, referral and consultation teleradiology service between the remote Secondary Hospital and Tertiary Provincial hospital with specialist referrals to the Radiologists at the Medical School in Bangkok. The network was to be achieved with minimal change in working practice and through the cooperation of all the stakeholders.

The following illustrates the distances involved in the transfer of patients from secondary care to tertiary care:

Figure 3: Distance between Secondary care and Tertiary care hospitals and the Medical school in Bangkok was 50km/245km respectively

The project goals specific to the project were to:

- Transfer appropriate (active) and inactive paper patient files and films to an electronic format
- Incorporate scanned images, medical records and appropriate forms into a centralised patient database.

- Link disparate healthcare settings by facilitating web-based teleradiology across sites, thereby, providing an element of integrated care delivery.
- Record all the clinical information electronically
- Expedite patient diagnosis and treatment process
- Collect feedback on the pilot project and evaluate its effectiveness and measure its performance against the goals.

3.6.6 GOALS AND OBJECTIVES OF THE TELERADIOLOGY PROJECT

E-health and specifically teleradiology was identified by the Thai MoPH as a key project that would benefit the people of Thailand. The project was confirmed as being driven by a need to provide a better service and addressed the following:

1) Shortage of Radiologists

2) Unacceptable high referral rate from Secondary to Tertiary Health Care. This was considered by the Thai MoPH as being a national issue, the pilot project was considered to test the approach, with a view to replicating the project in other sites. It is recognised that the referral rate of 20-30 patients per month could be considered as low, however, when a patient is referred; members of the family will accompany the patient and remain in the referral hospital until the patient returns to the community. The social and economic impact is significant.

   The MoPH consider that the referral rate is due to newly qualified doctors being placed in a rural health care setting. The doctors tend to work in isolation and often lack experience and confidence. As these doctors are expected to treat a wide spectrum of conditions the outcome is that reassurance is sought by referring patients to a tertiary hospital where more experienced medical professionals and specialists are available. In some cases, newly qualified doctors did not seek any support and the referral rate fell even lower.

3) Inequality of health care provision in rural areas compared to inner cities.

The proposed teleradiology solution provides an opportunity to create a health care system that provides an equitable distribution of high quality services in a cost effective way. This development is particularly important in Thailand where there is a shortage of radiologists and a disproportionate distribution of medical professionals i.e. few medical professionals choose to work in the rural hospitals.

3.6.7 PROPOSED DEPLOYED ARCHITECTURE

Figure 4 shows an overview of the proposed mode of operation for the teleradiology network.

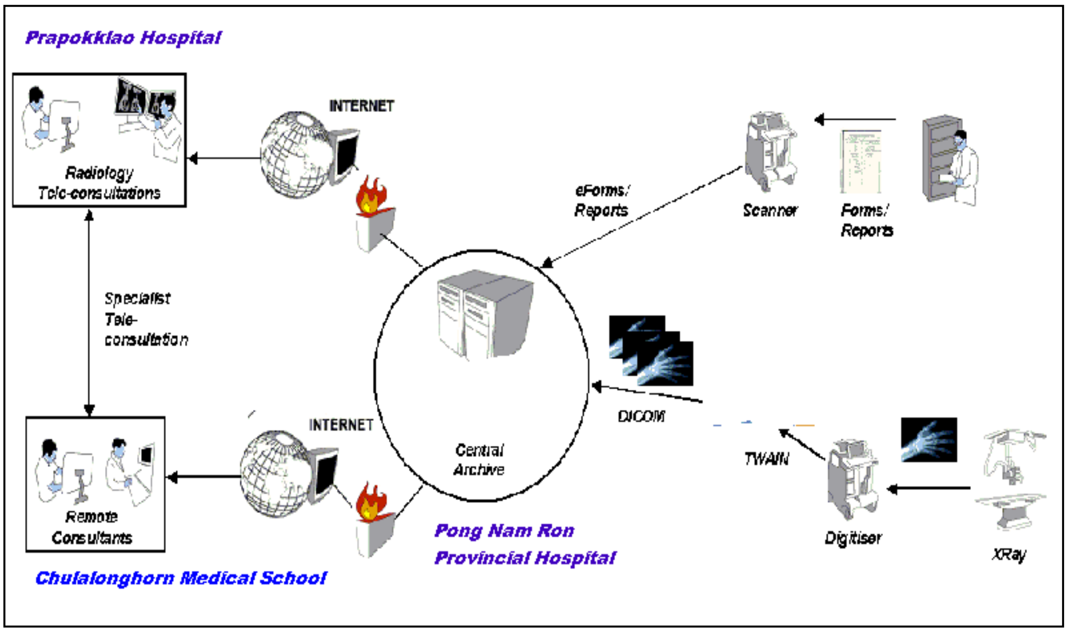

Figure 4: Mode of Operation for the Teleradiology Network

The network would link the remote hospital with the Radiology Department of the referral Hospital. A further internet link to the Medical School would provide specialist teleradiology consultation.

Proposed Data Management

- The X-rays at the remote hospital are digitised. The Image Viewer converts the images into DICOM and stores them in the central archive.
- The related paper forms/reports are also scanned, indexed and stored together with the other patient data in the central server at the remote hospital
- The patient X-ray is referred for reporting to the teleradiology service
- The teleradiology service will be provided by radiologists at the referral hospital for these selected cases. The radiologists will be able to report on the X-rays and also provide a teleradiology consultation/reporting service to the GPs at the provincial hospital.
- The radiologists at the referral hospital will select relevant complex cases as they occur for specialist referrals. These cases are directed to the specialist consultant radiologists at the medical school in Bangkok.
- One random case per day will be viewed and commented on by a specialist radiologist at medical school as part of the system evaluation and testing process.
- The specialist radiologists at the medical school will be able to view the complete patient record, including referral forms, reports and associated images and provide a teleradiology consultation/reporting service to the Radiologists at the referral hospital for more complex cases.

Technical details of the implementation of the system are given in Appendix A.

CHAPTER FOUR – DEVELOPING THE PCP MODEL

4.1 INTRODUCTION

This chapter describes the development of the PCP model and presents the findings.

The first section opens with background data on the hospitals which provides the context for the PCP model and supports the case study.

The framework for developing the PCP for each hospital is detailed and supported by diagrams. From this information the mapping of the "patient's journey" within three hospitals is represented in the form of a PCP. A modified PCP depicting information flow is then developed to include a systems' engineering approach and a holistic representation of the entire system.

Finally, the findings of the research culminate in the modified PCP illustrating information flow for the proposed teleradiology case study and demonstrates the impact of introducing e-health.

The chapter concludes with a summary of the findings.

4.2 BACKGROUND DATA

4.2.1 SECONDARY HOSPITAL DATA

The rural referring hospital, Pongnamron, serves an official population of 38,409, however, due to the district boarders and a migrant population illegally crossing the Cambodian border the population is known to fluctuate. The population is further influenced by the transient workforce employed in seasonal agricultural work.

Pongnamron Hospital was therefore included in the project as these factors, and especially the seasonal increase in the population, would place significant strain on staff and resources. The teleradiology project was viewed as a more efficient way of increasing the quality and delivery of patient care compared to the existing method of working with X-ray films and might alleviate the pressures.

Within this district the secondary care hospital supports and works with eight primary health care centres.

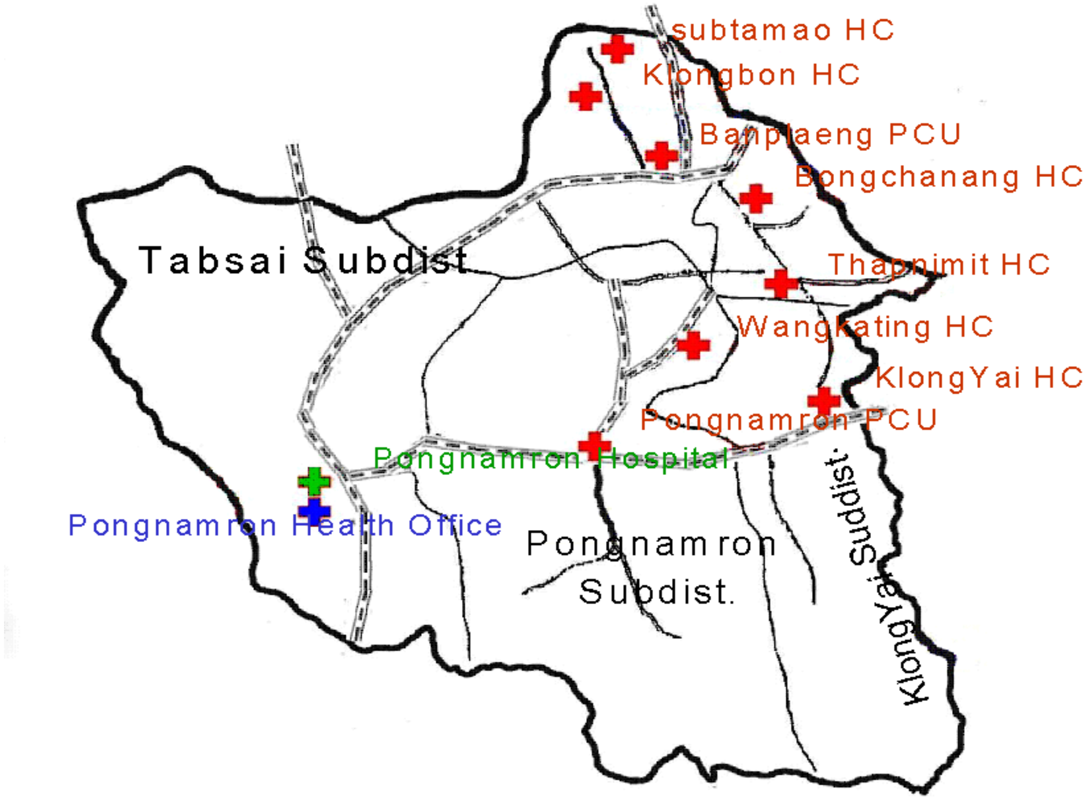

Figure 5: Location of the Primary Health Care Centres in relation to the Referring Hospital.

Pongnamron is considered a stable and affluent district. Its productive agricultural base is supported by a good climate and the land is ideal for fruit production. This has effects on the hospital. The transportation of the crops along the busy single lane inter-province road contributes to a higher than normal incidence of road traffic accidents with a subsequent increase in admissions of patients requiring X- rays and referral.

The roads pass through mountains and during the rainy season become impassable. This in turn makes patient transport between the secondary hospital and the referring hospital impossible and further highlights the potential importance of a communication link and joint consultation provided by the teleradiology network.

Pongnamron was officially opened as a Primary Health Care Centre in 1961 and expanded to a 10 bed Secondary Care Hospital in 1979. Today it is a 73 bed hospital, covering 0.03 square kilometres and serving a population of 38,000

The annual hospital budget is based on the registered population that has been issued with a health card. Pongnamron has 32,000 members, which provides an annual budget of £180,000. This proves inadequate and the hospital has outstanding debt and is unable to maintain a level of care on the allocated budget.

Private insurance makes a further contribution to the hospital budget of approximately £21,000. Government employees do not make any contribution towards health care.

There are four general physicians within the hospital, one of whom is a surgeon. Currently, the surgeon is a permanent member of staff whilst the remaining doctors are newly qualified from medical school.

Newly qualified doctors, whose education is financially supported by the Thai Government, are contractually bound to serve two years working in a rural area. If there is a lack of newly qualified graduates available for Pongnamron then doctors from the neighbouring Provincial Hospital will rotate and cover staff shortages.

The doctors work a two shift system from 08.30-16.00 and “on call” between 16.30 – 08.30

The level of spoken and written English is very good amongst the doctors, dentist and pharmacist and tends to be at a basic level for the nurses, technical and medical support staff.

All staff is very competent in IT and the hospital supports its own software applications and network. One of the key reasons that this site was selected for the project was the IT competence of the hospital staff.

The hospital employs 55 nurses. They tend to be recruited from the local community and stay in the same hospital for between 10-15 years. The Government provides incentives for medical staff to work in rural communities by providing free housing, extra welfare and increased wages. This coupled with the low cost of living, good schools, excellent weather and entertainment within a relatively short distance contributes to the low turn-over within the staff at Pongnamron and hence the stability of the hospital and its services.

The nurses work three shifts:

08.00-16.00, 16.00-24.00, 24.00-08.00

There are also three pharmacists, one dentist, one X-ray technician and assistant. There are a further 91 general hospital support staff.

The X-ray technician and nursing assistants work from 08.30 a.m. -16.30 p.m. with overtime from 16.30 a.m. - 08.30 p.m.

There are 38 computer terminals in the hospital network; their locations are:

Health Security Office – 5

Emergency Room – 3

Pharmacy – 3

Out Patients – 10

Primary Care Unit – 5

Administration – 8

Laboratory – 2

Dental Department – 2

The operating system for the network is Netware and the terminals are DOS based. The patient information system was developed locally and fulfils the requirements of the hospital.

There is no cross billing between referring hospitals despite the fact that the numbers of referrals are increasing.

4.2.2 PROJECTED X-RAY VOLUMES

There were approximately 1600 films acquired per month in the referring Pongnamron Provincial Hospital. Approximately 20-30 films need consultation but only half of the films were consulted due to communications limitation. On average 20 patients per year were transferred.

The GPs expressed a need for the service and a personal requirement for clinical support. Despite the relatively low numbers of referrals this site was chosen in part due to its suitability as a pilot site for the application. Therefore, issues such as cost are not included in the objectives of the research.

4.3 DEVELOPMENT OF THE PATIENT CARE PATHWAY

Chapter 3 details the method adopted to collect the following information. The findings are diagrammatically represented in Figure 6.

Figure 6: Ground Floor Plan for the Referring Secondary Care Hospital

Key to Figure 6

- Thick lined arrow illustrates the pathway for patient emergency admissions by ambulance.
- Thin lined arrow illustrates the pathway for patient self admission.
- Numbered boxes illustrate a networked computer terminal.

- No. 1, 2, 4, 5 - Desks manned by nurses who register, measure and record standard basic health checks together with logging symptoms.
- No. 3, 6 - Waiting areas.
- No. 7 - Examination room with a networked computer, desk and a patent examination table.
- No. 8 - Laboratory.
- No. 9 - Physiotherapy room.
- No. 10 - Pharmacy and cashier.
- No. 11 - Emergency room (ER).
- No. 12 - Computer work station in the ER.
- No. 13 - Gynaecological examination, obstetrics and delivery room.
- No. 14 - X-ray room.
- No. 15 - Computerised working area for X-ray technician.
- No. 16 - Staircase to the second floor.
- No. 17 - Visitors Information area.
- No. 18 - X-ray storage and archive room (reference picture No1).

4.3.1 PATHWAY TAKEN BY SELF ADMISSION PATIENTS.

- The patient will follow the thin arrow on Figure 1 to table No. 1, 2, 4 and 5 before seeing a doctor.
- Table No.1 - This table is stationed by a nurse who advises on methods of payment and directs patients to the relevant sections.
- General Out Patients proceed to table No. 2.
- Table No.2 - This table is stationed by a nurse who electronically records the patient's history, measures blood pressure, pulse and temperature. The patient will then be asked to wait in area No.3 before being called by a nurse at table No. 4. The patient information record will be forwarded to table No. 4.

- Table No. 4. - This table is stationed by a nurse who electronically records the patient symptoms and sends the information to table number 5.
- The patient will wait in area number 6 to be called to see the doctor.
- Table No. 5 is stationed by a nurse who allocates the patients to one of the three General Practitioners (GP) and directs the patients to rooms numbered 7. The patient consults the GP. There are three GPs in total in the hospital.
- A patient needing an X-ray will walk or be wheeled into the X-ray room. An electronic request will have been generated by the GP and alerts the technician to the arrival of a patient.
- The technician will access the electronic patient record and follows the GP recommendations.
- The X-rays are taken and hand delivered to the referring GP by the X-ray technician.
- The patient returns to waiting area No 6.
- The GP calls the patient back to room 7 for a diagnosis and discussion of the proposed treatment.

4.3.2 PATHWAY FROM THE SECONDARY TO THE TERTIARY CARE HOSPITAL

When necessary, patients are referred from the regional secondary care hospital to the tertiary care provincial hospital. The tertiary care hospital employs 5 fully qualified radiologists and has a greater range of facilities and medical disciplines.

The GP in the secondary care hospital fills out a referral form. A referral form has two sides and 3 copies; one copy is kept by the secondary care hospital, and the patient takes 2 copies to the referring hospital.

Patients can travel to the tertiary care hospital by ambulance or by public or private transport depending on severity and urgency.

The patient may take their X-ray from the secondary hospital, but in the majority of cases the X-rays are repeated by the tertiary hospital.

The X-rays is accompanied by a paper request form and report of the clinical outcome. This information is duplicated by the EHR. The secondary and tertiary EHR are not compatible.

When the tertiary care hospital discharges the patient, a copy of the completed referral form is given to the patient to return to the secondary care hospital. Alternatively, forms are collected from the tertiary care hospital by an ambulance driver based in the referring hospital during subsequent visits. At the referring secondary care hospital the detail of the treatment is entered into the local EHR from the returned referral form.

As part of the follow up procedure, the tertiary care hospital will monitor the patient progress on an appointment basis and request the patient to attend the out patient department.

4.3.3 PATHWAY BY AMBULANCE TO THE SECONDARY HOSPITAL

- The patient will be taken following the thick lined arrows on room 1 to the emergency room (ER) (Room No 11).
- An ambulance can access the ER from the front or the rear of the building.
- There is a computer (No. 12) for the patient record in the ER. A nurse collects the patient information electronically and the doctor will record the patient's symptoms and treatment
- All the information collected in out-patients at tables 1-5 is done for emergency admissions.

The remainder of the procedures are the same as those for a self admission patient except that the patient will be on a trolley and wheeled to the X-ray room.

4.4 DEVELOPMENT OF THE MODEL

4.4.1 THE PCP BEFORE THE INTRODUCTION OF TELERADIOLOGY

The detailed information was used to map the current patient “journey” through the system to form the PCP. A detailed PCP was completed for each of the three hospitals involved in the project.

Figure 7 shows the PCP for the entire system before the implementation of the teleradiology project. In addition to the elements of the pathway, the figure also highlights the perceived problems with the system, in particular the poor road infrastructure for travel and the lack of transfer of information between institutions. Any new PCP should address these issues.

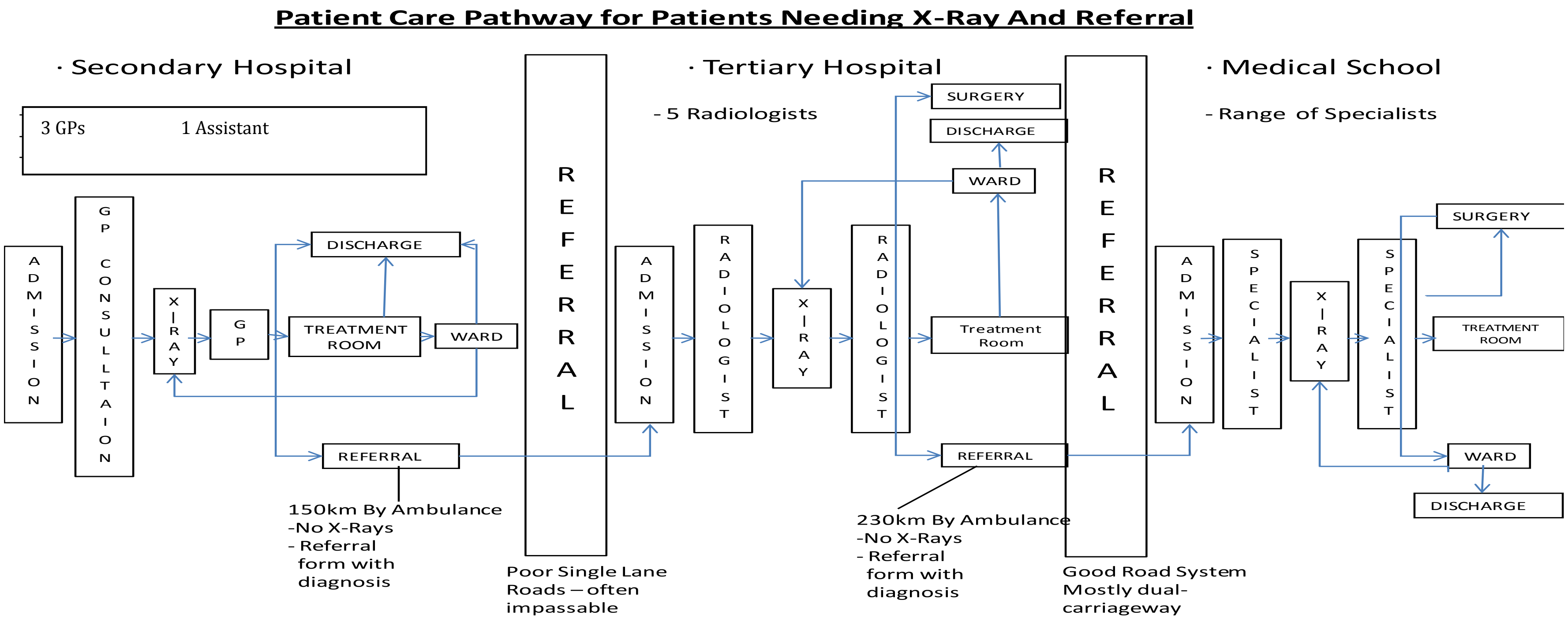

Figure 7: PCP of the entire system before implementation of Teleradiology

4.4.2 THE PCP PRE-IMPLEMENTATION OF TELERADIOLOGY

Figure 8 captures as a PCP the process of a consultation within the secondary care hospital that requires an X-ray to be taken and used. The top half of the diagram (white boxes) depicts the physical process for the patient.

The PCP also shows the information flows superimposed, and are shown in the coloured boxes. The boxes in the centre marked scanner and digitiser are used to depict devices that capture information in digital form, and the three boxes at the bottom of the diagram depict the ICT system comprising information management and communications.

In the secondary care hospital we see that the physical pathway for the patient has been modified, and this can be seen in the difference between Figure 7 and Figure 8. Figure 8 captures both the patient movement and the point at which the teleradiology would be introduced. The images and patient details stored in the central digital storage would be made available to other sites, specialists and anyone selected by the MoPH. This demonstrates the sharing of information and central storage and highlights the potential of moving information as opposed to patients.

Figure 9 shows the movement of patients between the secondary and tertiary hospital. The clear boxes across the top of the diagram depict the patient movement, whilst the boxes at the bottom illustrate the teleradiology and electronic storage and movement of information. On the right hand side are a series of potential options for the patient in terms of referral, , discharge or teleradiology consultation.

Figures 8 to 10 were combined to create the PCP depicting the entire system with the information flow added as shown in Figure 11. This shows the critical points in the system and not only illustrates the current system and also the schematic representation of introducing e-health. The diagrams were used to illustrate that the introduction of e-health would cause minimal disruption or deviation from current practices and captured the benefits of teleradiology by keeping the care local and avoiding unnecessary movement of patients and families.

Figure 10 and 11 are simplified figures extracted from 8 and 9, that serve to capture the teleradiology and not the patient movement, where figure 10 illustrates teleradiology between the secondary and the tertiary site, which would be the majority of consultations and figure 11 shows the teleconsultations with all three sites.

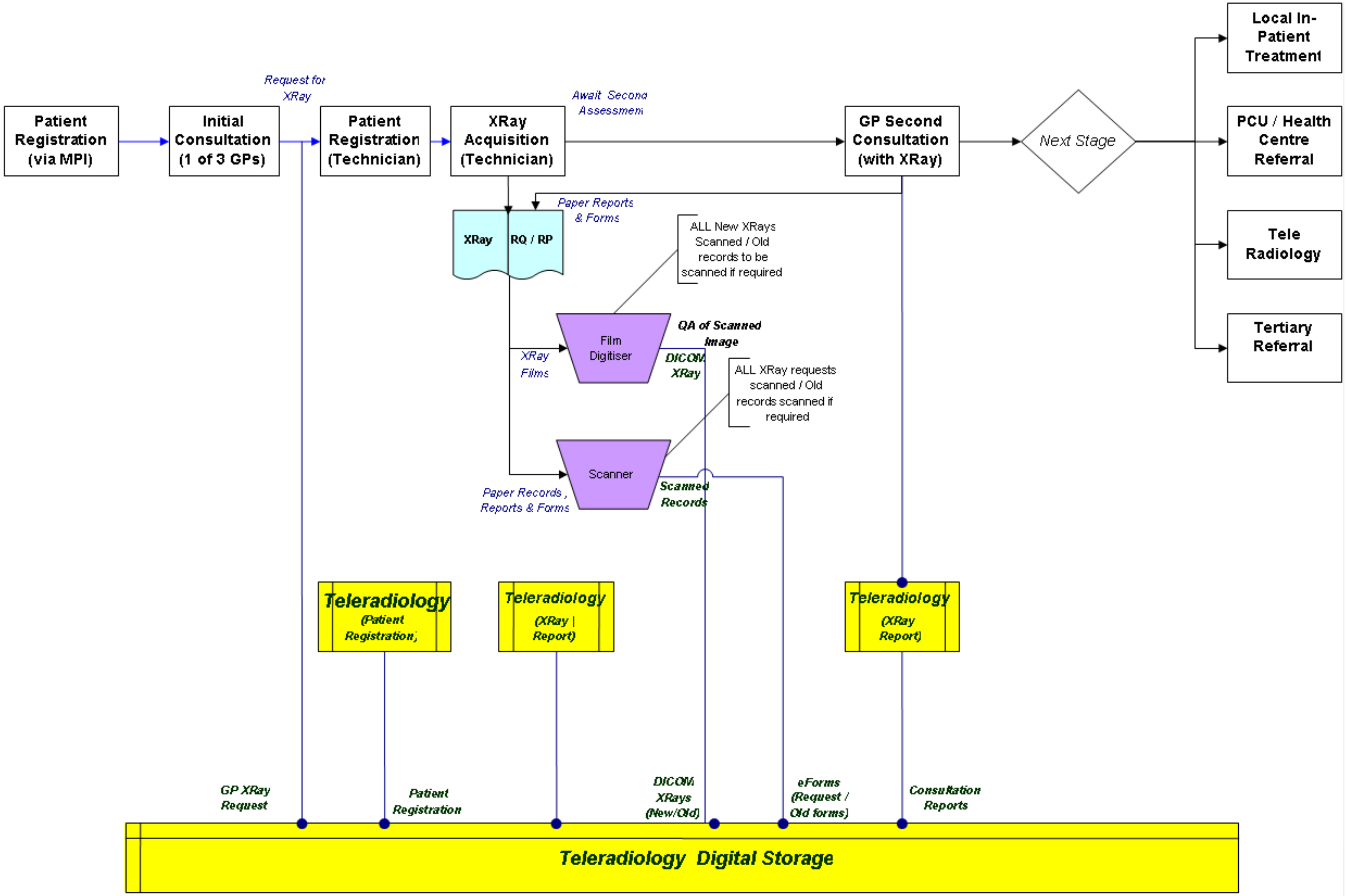

Figure 8: PCP of Consultation in Secondary Care Hospital

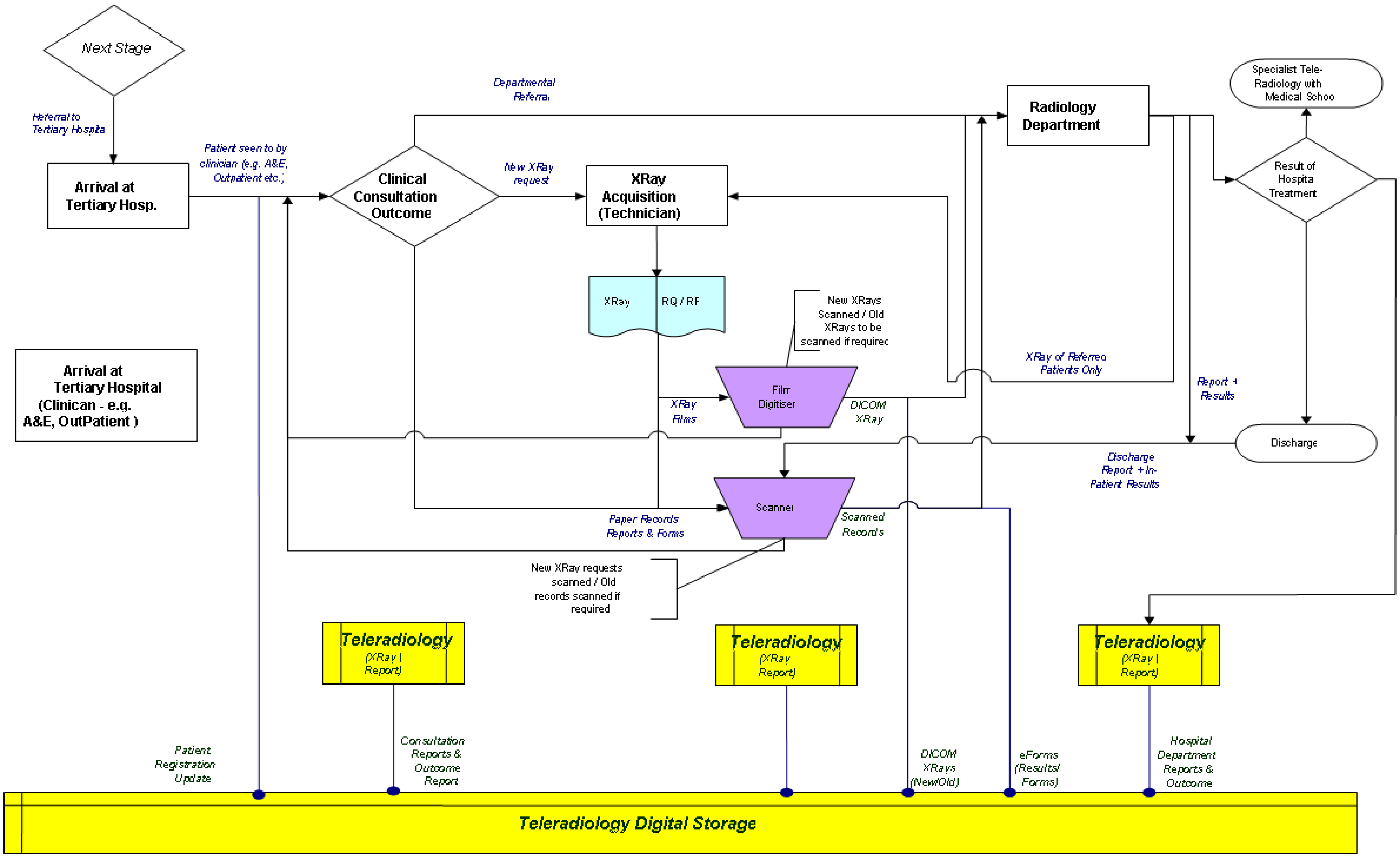

Figure 9: PCP of Referral from Secondary to Tertiary Care Hospital

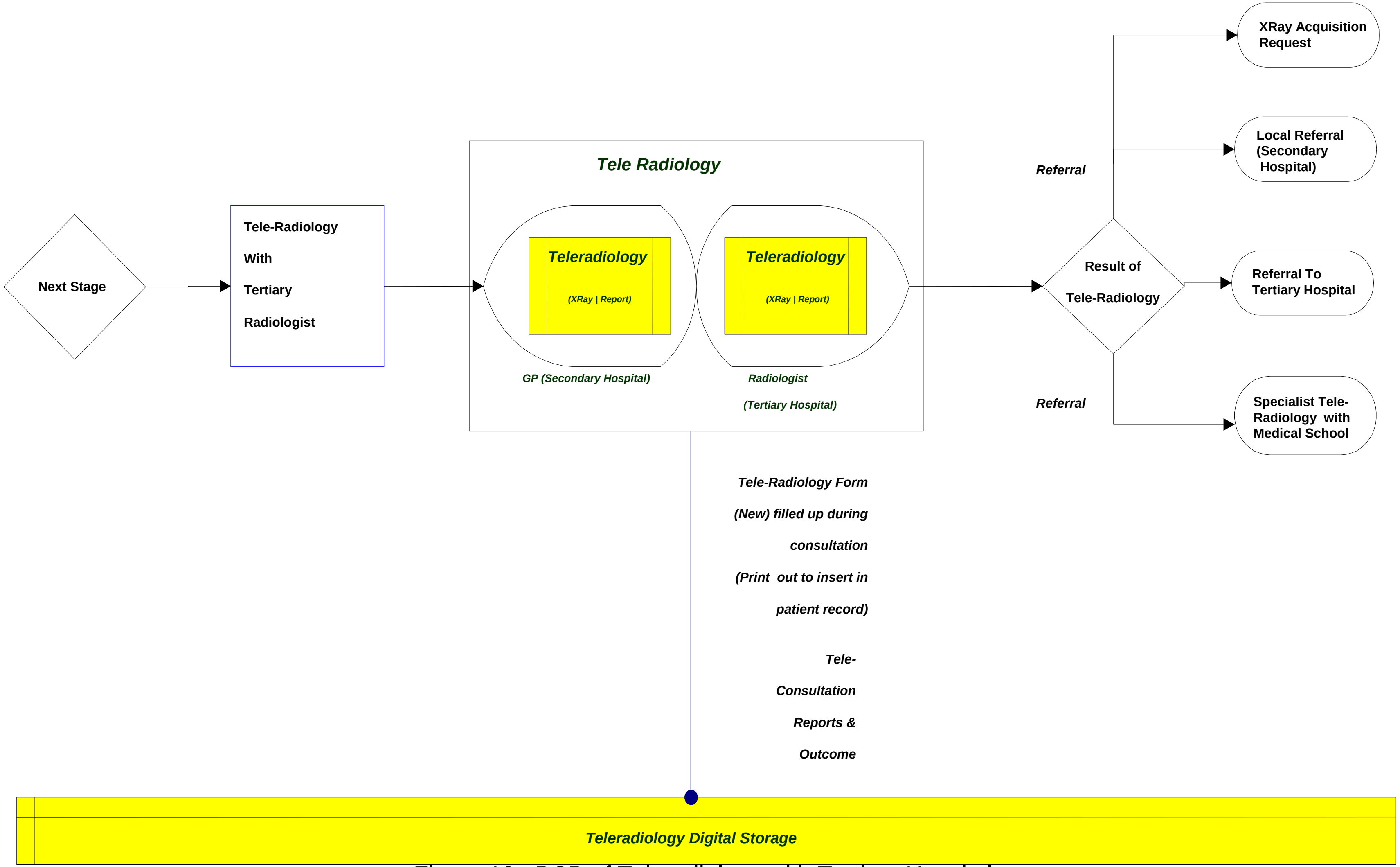

Figure 10: PCP of Teleradiology with Tertiary Hospital

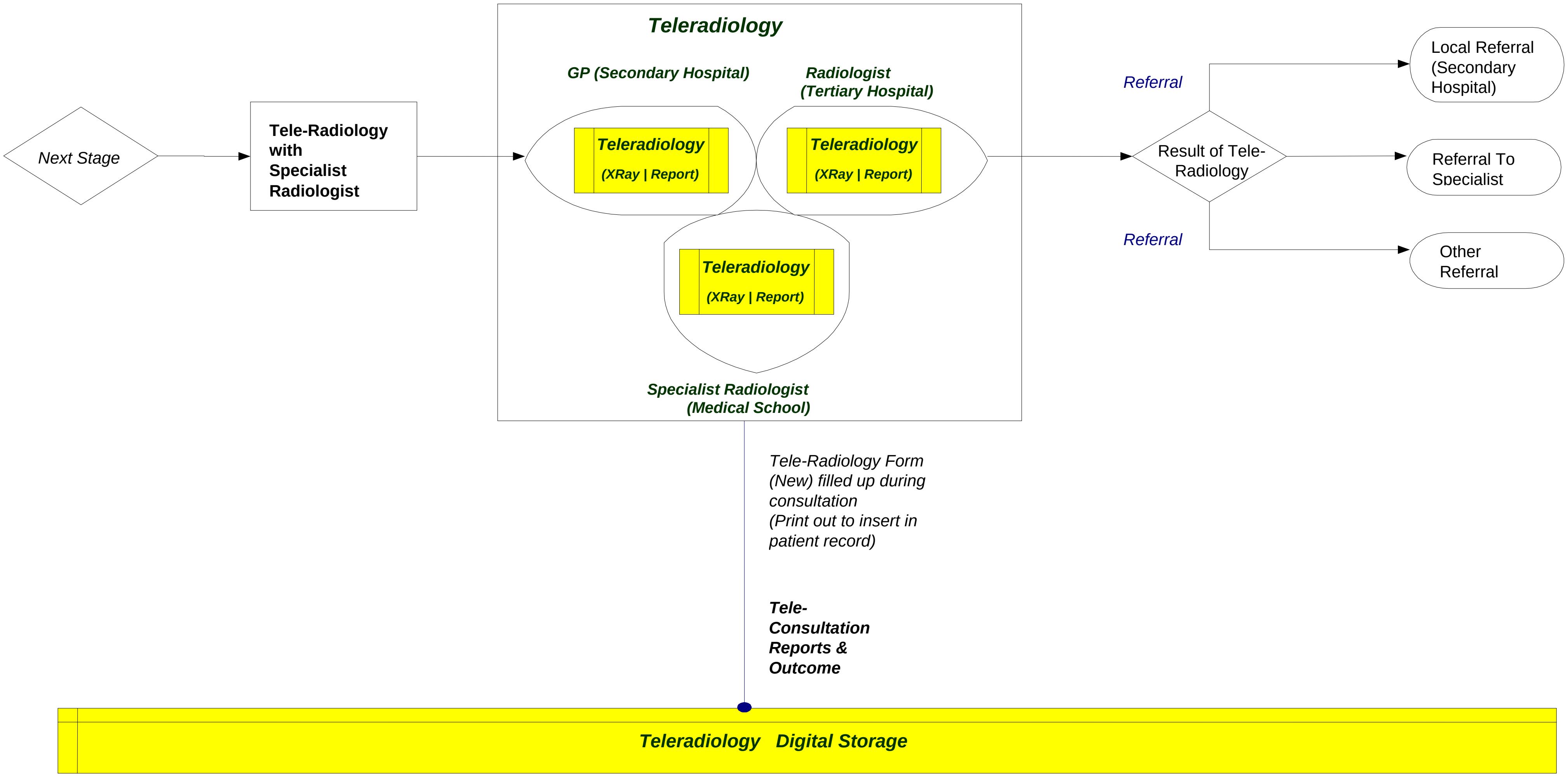

Figure 11: PCP of Teleradiology with Secondary, Tertiary and Specialist Hospital

4.4.3 THE PCP POST-IMPLEMENTATION OF TELERADIOLOGY

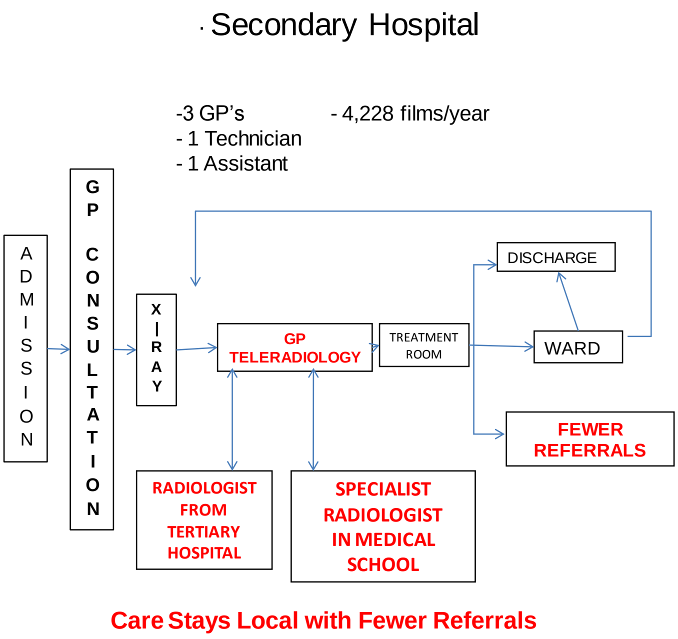

Figure 12: PCP Post-implementation of Teleradiology

The much simplified PCP in Figure 12 became the model that was used for comparison of the proposed system within the INCOSE systems analysis methodology.

The first three steps of the INCOSE life cycle are followed.

4.5 LIFE CYCLE DEVELOPMENT AND E-HEALTH

The first step of the INCOSE life cycle management was adopted for the pre-implementation phase.

This first step comprised the following Three Stages:

1) Concept Stage – Data collection for assessing preliminary requirements. This is where the stakeholder requirements are identified and clarified. The key objective is to provide confidence that the solution is achievable. The outcome of the first stage is a PCP that depicts each element of the system.
2) Development Stage - Development of a systems engineering framework capturing the representation of the entire system. Along with systems engineering thinking, the development phase is an evolving baseline that integrates the elements of the system components i.e. the amalgamation of the PCPs from individual hospitals to represent the entire system.
3) Production Stage - This stage is executed to produce a systems analysis model by comparison of pre- and post-implementation mapping of information flow that will result from the change to e-health.

Life cycle management allows a modular approach to be developed to include the full life cycle and evolve from the pre-implementation phase to full implementation and integration.

4.6 CONCLUSION

The development of the methodology provided two key advantages:

1) Understanding of the current system.

2) Understanding of the implications of introducing an e-health project.

By applying a methodology it became possible to manage the project in a structured, systematic and reproducible way. The methodology was simple, and readily understood and applied.

The methodology supports systems analysis and the means to consider the implications of introducing the teleradiology project before implementation. The following benefits of the teleradiology project were highlighted:

- Images and data were to be made accessible to medical staff throughout the health system so that case conferences using the teleconsultation facility could be scheduled eliminating the need for the patient to travel to the tertiary care centre.
- The system was to be made accessible by the secondary care health team so that management of the patient could be continuous across the separate health sectors.
- Patients could be returned to primary or secondary care much earlier.
- A greater level of shared care was encouraged.

Using the PCP gave the following advantages:

- Comparing the pre-implementation PCP with the proposed pathway using teleradiology identified critical points in the system and anticipated how the system would support the changes in clinical practice.
- Defining the PCP in terms of its processes and workflow allows information flow to be superimposed on the physical patient journey so that the full impact of the e-health and implications for the ICT can be considered.
- The inter-relationships between the hospitals are identified.
- Readily understood and accepted by the medical and political professionals.
- Ideal to convey concepts and practical aspects, especially to the non technical.
- The suggested systems analysis approach in this research potentially allows the sharing of information on design in a standard format, thereby, moving away from the duplication of work and managing the evidence locally, where traditionally little progress is made.

In conclusion, the modified PCP demonstrated that the e-health solution would support patients by keeping the care local, replacing the movement of patients to specialist centres by movement of information.

CHAPTER FIVE – DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

The final chapter considers the application of the research. It highlights the benefits of applying a formal methodology that includes a model that schematically captures and assesses the impact of introducing e-health.

The implications of the research are considered and a vision of its future is discussed.

The chapter develops the concept and concludes by reviewing the research objectives set in chapter one. Each objective is dealt with in turn and adopts the format of a discussion followed by a conclusion.

The main conclusion reviews and highlights the most important findings of the research.

The thesis closes with a critique and examines the limitations of the research.

5.2 APPLICATION OF THE RESEARCH

The methodology adopted to develop the model of this project has the benefit of being transferrable to other e-health projects and disciplines i.e. the model is not application specific. Whilst this research applied the proposed model to a teleradiology project, the model could similarly be applied to different applications and disciplines.

The advantage of the INCOSE lifecycle is that the framework can be applied from concept through to utilisation, support and retirement stage, therefore, the scope of the framework is not limited to the pre-implementation phase. Furthermore INCOSE underpins the life cycle management using a recognised and well established methodology.

The suggested e-health model can be scaled according to the requirement. However, a complex paper based modelling system will become cumbersome and difficult to work with, therefore, it must be acknowledged that there are some limitations with scale.

One of the innovations of this research is to adapt the existing PCP prior to implementation of a project with the objective of gaining full understanding the current system and the implications of introducing change.

Systems analysis enables the risk associated with the e-health project prior to implementation to be assessed.

In risk assessment three questions can be addressed: What can go wrong? What is the likelihood that it would go wrong? And, what are the consequences? Answers to these questions will help to identify, quantify, measure, and evaluate risks and their consequences and impacts.

To be effective and meaningful, risk management must be an integral part of the overall management of a system. This is particularly important in the management of technological systems, where the failure of the system can be caused by the failure of the hardware, the software, the organization, or the human element.

In adopting the PCP modelling methodology of this thesis, considering the entire system provides a much richer schematic representation of the patient journey, illustrating both the flow of patients and information flow.

Furthermore, examining the “whole system” emphasises the importance of, for example, team work within an organisation and that the successful e-health project cannot be driven by a small group or individual and that the actions of one element impacts on the wider delivery system.

This is relevant in terms of an application as this allows a common approach to a schematic representation of different e-health projects and coordinators to share and compare using a format that is readily understood.

Until the movement of information is captured, it becomes difficult to understand the full impact of e-health and the fundamental changes e-health brings to delivery of health care. Capturing the information flow is pivotal in understanding e-health and for this research, subsequent system analysis is key to the change management of the programme

There have been few reports of empirical studies that measure the organisational consequences of the introduction of e-health (Aas 2000) and to date, no formal methodology for systems analysis of e-health has been described or evaluated.

Two leading suppliers and partners in the medical devices, namely, Siemens Medical and AME International gave verbal reports in 2009 that they do not apply systems engineering or a formal framework for the pre-implementation phase of rural e-health projects. They did offer a fully integrated solution to hospitals and instead simply quoted their success in several large international investments in paperless hospitals.

If adopted the methodology in this research would encourage the sharing of best practice based on a readily understood and accepted model.

5.3 IMPLICATIONS OF THE WORK AND VISIONS OF THE FUTURE

The use of a systems approach to PCP within an e-health context provides a new methodology that combines with INCOSE to provide a standard methodology to approach, plan and manage the phases of an e-health project. The methodology would address the clear need articulated within the e-health community to provide organisational management of projects such as rural health (Whitten 2003).

Clearly the next step is to test the model. The methodology should be disseminated to the wider e-health community for full evaluation. Ideally the model would be tested in a rural setting and include a different application to test its suitability for a range of applications.

One of the implications of the “whole system” approach is that it highlights the cross boundary delivery of e-health. It further provides a focus on some of the problems associated with e-health, such as billing and accountability. By predicting the risks it then becomes possible to address these issues prior to implementation.

Furthermore the methodology provides an effective and readily understood communication tool that can be used to engage with all strata of personnel and encourages contribution. The literature has identified poor communication and engagement as a contributing factor towards the failure of e-health and its lack of integration. The PCP model can become an effective communication tool; therefore, the application of the proposed model has the capability of positively impacting on the success of e-health projects.

When the proposed PCP model was applied to the case study the measurable benefits to patients in terms of avoiding unnecessary travel were clearly demonstrated. The advantage of having a schematic representation of an e-health application that captures the benefits was found to be a valuable communication tool. The suggested model was found to be a clear and concise method of capturing the project in an easily understood and digestible format. It is recommended that this form of modelling can be used for communication by medical, non medical, administration and political personnel.

Application of the methodology can examine the “what if” scenarios. The PCP model provides a greater understanding of the issues involved in migrating from a traditional health care delivery system to e-health. Furthermore, it has long been established that one of the many general benefits of modelling is the ability to test a system before implementation i.e. to examine the outcome of various alternatives in a relatively low cost, low risk environment. This modelling approach of this research makes it possible to study systems before implementation and to consider outcomes and consequences of actions. The systems analysis approach gives a deeper insight into the properties of the teleradiology project.

Whilst the paper based model has been adequate for the purposes of this research it is recommended that the future of systems analysis based on the modified PCP for e-health could benefit from using an electronic and environment to develop electronic versions of the e-health models. Furthermore, capturing within an electronic tool could afford an integrated route to simulation.

From a system analysis perspective the electronic model would enhance the paper model and allow for ease of comparisons between different e-health applications. The electronic system would need to be built on standard definitions of semantics and pathway development. This would inform standard bodies and could result in standards and definitions.

It is recommended that future research might focus on identifying further industry tools that could be integrated to improve performance and functionality of the methodology.

It is clear that further research is necessary to evaluate the effectiveness of the proposed methodology and model when applied in other applications. Whilst it has not been possible to explore all the avenues that this research has exposed, it is hoped that the breadth of the work conducted during the course of this research will provide a solid foundation for further work.

5.4 DISCUSSION AND CONCLUSIONS OF EACH RESEARCH OBJECTIVE

5.4.1 PATIENT CARE PATHWAYS

1 An investigation of Patient Care Pathways as a formal methodology for schematically representing e-health projects.

This research presents a case that the fragmented approach to the development of e-health and the lack of formal methodology for systems analysis means that the full potential of e-health may not be realised.

In order to address this lack of organisational formal methodology and hence facilitate the adoption of e-health into the main stream delivery mechanism the research demonstrated the benefits of using a modified PCP as an e-health systems analysis model for schematically representing a teleradiology project in Thailand.

The PCP is commonly presented in a linear fashion, with a form similar to a flow chart; however, these pathways are primarily flow charts for clinical decision making and are not designed for systems analysis. This research served to evolve PCPs for the systems analysis of e-health.

To manage the pre-implementation phase of the teleradiology project in question firstly required the development of a traditional linear care pathway.

During this exercise a number of PCPs were mapped depicting each hospital and the various routes taken by the patients. The objective of understanding the current system and communicating the principles of PCP to all strata of medical and political professionals was achieved.

Secondly, a modified form of PCP was developed that captured the entire system and included the movement of information in addition to the traditional movement of patients. The objective was to adopt a systems approach and benefit from the documented benefits of examining the system as a whole. As a result, it becomes possible to depict and compare the delivery system pre and post e-health. In this way, the movement of information in the systems analysis is shown and this demonstrated the tangible benefits of e-health compared to the more traditional health care delivery mechanism. Neither cost analysis nor cost benefit is an objective of this study.

Applying the modified PCP model highlighted the following points;

- Analysis of the PCP revealed good professional relationships between the doctors in the hospitals and it was determined that the new teleradiology service would fit well into the existing pathway, result in minimal change management and potentially improve patient care.
- As a medium of communication, the PCPs were embraced by all strata of medical and political professionals and served to define the project in an easily assimilated form. Developing the PCP as an acceptable medium of communication was identified as being key to the scoping and acceptance of the teleradiology project.
- The model proved to be a robust method that was a valuable design tool allowing better understanding and thereby gave the ability to manage the implications of change prior to implementation of an e-health project.
- This research suggests that the use of the modified PCP to schematically represent e-health projects is an invaluable model for change management and implementation of e-health projects and provides a standard method worthy of application to extended applications of e-health.

In conclusion, the modified PCP was able to schematically represent the key advantages of e-health, that is, its ability to support patients by keeping the care local, and the movement of information to specialist centres as opposed to the movement of patients.

By comparing the PCP for patients entering the existing health care system with the proposed pathway using teleradiology a methodology was developed to identify critical points of the system and anticipate how the system sustains or supports variation in clinical practice.

This modified form of PCP allows the implications of introducing e-health and the interrelationship between the different systems and events to be considered and thereby demonstrate the potential implications of changing elements of the system and the effect this has.

5.4.2 SYSTEMS ENGINEERING

2 Identification of Systems Engineering tools that support and enhance the Patient Care Pathway and provide a holistic approach to systems analysis of e-health.

This research proposes the introduction of a systems approach to the analysis of e-health and the use of the PCP model.

The PCP provided the framework to depict information flow and systems engineering principles were applied to enhance the PCP in terms of:

a) Applying a recognised life cycle management tool.

b) Introducing the human factor element of Soft Systems Management.

System engineering principles provided by the International Council on Systems Engineering (INCOSE) were modified to incorporate the PCP as part of the methodology in a number of phases. This provides a validated framework for the model.

Key to this methodology is the systems approach which provides the opportunity for those with different perspectives and disciplines to contribute to the debate and ultimately increases the chances of success for e-health projects.

Structured, systematic change management approaches are required for changes in practice on the scale that the policy makers within e-health are predicting. It is suggested that this research makes a practical contribution to achieving the requirements of policy makers. To this end, the use of systems analysis in e-health could be argued is long overdue.

SSM has been used as the systems approach for this research. This methodology was chosen due to its suitability to human dominated systems problems. The choice of SSM was also supported by the e-health literature clearly stating that human factors are key to the successful implementation of e-health projects.

A systems engineering "tool" adopted by this research from SSM is the sensitivity to human factors coupled with the generic systems thinking of examining the system as a whole.

PCP mapping is generally taken to represent the progression of patients from one clinical process such as diagnostic tests or treatment to another. An important aspect of the research was to validate the framework and methodology through a case study of a teleradiology project in Thailand. This e-health model illustrates the benefits of e-health in the form of an information rich, boundary-less delivery system.

Systems' thinking considers that information flow from the surrounding environment is via a semi permeable membrane or boundary. Conversely, the whole system thinking and application in this research demonstrates the removal of traditional boundaries and the "freedom" of movement in terms of information flow. This information flow is pivotal in this research together with the application of the whole systems mapping based on PCP that encapsulated the systems analysis and benefits of this particular e-health project.

The suggested modelling approach within this research provides greater understanding of the issues involved in the migration from traditional health care delivery to an e-health system.

A PCP model is based on a consensus made up of many individual views and strengthens the degree of ownership and commitment for the project and the PCP. The SSM approach encourages engagement, coordination and identification of the stakeholders. These factors have been cited as an important criteria in the successful implementation of e-health and confirm the choice of the SSM management approach.

Several other management approaches were considered, such as Total Quality Management which is a customer driven SE approach to continuous quality improvement. This is viewed as a quality assurance style of management and is based on an authoritative style. This style is contrary to the recommendations in the literature that emphasises the importance of an open communication platform and avoidance of a top-down management style. Total Quality Management is considered by many to be more suitable for the manufacturing environment (Ghahrnani 2000).

Involvement of patients and professionals in the requirements analysis and the design process has been shown to be crucial in the success of previous e-health projects as this assists in planning to fit the e-health project into their daily work practices (Tinker 2005).

The final whole system PCP is a merging of the different elements of the system. This strengthens the degree of ownership and therefore, according to the literature, increases the likelihood of successful implementation of e-health.

One of the strengths of the PCP model was the way it identified the interrelationships between the hospitals with the whole systems approach providing a much richer picture, not only of the patient journey but more importantly the information flow.

In conclusion, systems thinking can be harnessed in the modification of the traditional PCP to produce a systems analysis tool able to be applied to other e-health projects.

The suggested systems analysis approach in this research potentially allows the sharing of information on design in a standard format, thereby, moving away from the duplication of work and managing the evidence locally, where traditionally little progress is made.

This research suggests that this approach is worthy of replication and transposing into different e-health applications for the purpose of systems analysis with the ultimate outcome of managing and predicting the impact of the introduction of e-health into the existing health care system.

5.4.3 CASE STUDY

3. The prospective application of the model for systems analysis to a pre-implementation phase of a teleradiology case study in Thailand and framework for its evaluation.

The teleradiology service was sited at the entry point of secondary care in order to be close to the patient and be sufficiently resourced. Images and data were to be made accessible to medical staff throughout the digital health network, and in this way case conferences using the teleconsulation facility were to be scheduled without need for the patient to travel to the tertiary care centre. Depending on the decision of the clinician, real time consultations could be arranged and scheduled via a telephone call, or alternatively could be based on the stored image, where the image and medical notes stored on the server were accessed as and when necessary.

The system was to be made accessible to the primary care health team, so that management of the patient could be continuous across all the separate health sectors.

This resulted in the change to the pathway whereby patients could be returned to primary or secondary care much earlier and by having the data, encouraged a greater level of shared care.

Creating the PCP for the teleradiology project involved physically following patients needing X-ray through all the various routes within each identified hospital. In addition, digital images were taken at each critical point and supported by documents detailing the events of each episode. From this information the entire process was represented schematically in a PCP.

The proposed model determined that the new teleradiology service would fit well into the existing pathway, result in minimal change and potentially improve patient care. When e-health is implemented organisational changes is inevitable, and in a study of 30 successful e-health sites in Norway, 97% reported at least one major organisational change (Aas 2001). It has been shown that the result of introducing technology is not a simple cause and effect relationship, rather that the effect of introducing technology to organisations will include not only the result of the technology itself, but also the characteristics of the organisation, human aspects, situation elements, review of processes and an interaction between all these factors (Kaplan 1997).

One can conclude that it is imperative to understand the dynamics of the organisation and this could be ameliorated by the adoption of the modified PCP methodology and its framework to predict the impact of e-health.

Systems analysis of the PCP model demonstrated that digital X-rays could be viewed at three hospitals and consulted by GP, radiologist and specialist radiologist without having to physically transfer the patient or hard copies of the X-rays. The modified PCP model clearly captured the process and illustrated the benefits of e-health to the patient and medical professionals.

The complexity of change management and peculiarities associated with e-health has been acknowledged and field work served to reinforce the literature and bring home the systems value that, “Whatever affects one thing directly, affects everything else indirectly” (Martin Luther King).

To illustrate this point, the project was to implement and evaluate pre- and post-implementation. However, a military coup in Thailand brought the project to a premature halt. There were Ministerial changes and a number of projects were stopped, this being one of them. This event was unpredictable and there were no ways to mitigate. The result was that political change prevented the implementation of the teleradiology project.

Prior to the military coup and subsequent changes within the Health Ministry, the project enjoyed the full support and commitment of the Thai Ministry of Health that was critical to the research. A significant proportion of the work undertaken throughout the course of this research involved the elicitation and analysis of the stakeholder requirements. In order to achieve this, it was necessary to investigate several aspects of the current health care delivery mechanism and obtain several viewpoints of what could be considered as the same aspect or requirements. This information was used in the first instance as the basis of the PCP and the resultant schematic representation are detailed in chapter four.

Time and financial commitment were made to the project and the investment made in building strong relationships was paramount to data collection and understanding. At each juncture, background information was systematically collated and cross checked with medical, administrative and political personnel.

In terms of taking digital images of patients, there were confidentiality issues raised by the tertiary hospitals and medical schools, therefore, images were limited to the primary care hospital. These images proved to be a valuable tool in the process of mapping the PCP, especially in light of working within different time zones and the significant distance between the UK and Thailand.

The PCP was built upon the systems engineering principle of clearly establishing the requirements and identifying real needs. Fundamental to this process was gaining an understanding of the human factors and introducing a system of regularly cross checking the accuracy of collated information with the medical professionals. These factors became pivotal in creating accurate and meaningful pathways.

By definition of a holistic approach the model design served to capture the entire process and included the emphasis of SSM being the human factors. This included a thorough understanding of the skills base of the medical professionals and the physical infrastructure of the buildings, equipment, IT and communications. Furthermore, sustainability of the project was established very early on and a financial commitment made and budgets allocated to ensure longevity of the programme.

The main challenge for e-health implementation is not only to address the domain specific issues but also to integrate the different related domains by inter-organisational collaboration (Broens 2007). This comment supports a more holistic approach adopted by this research. And the model serves to successfully capture and illustrate the multi stakeholder environment of e-health.

In conclusion, the chosen method proved to be robust and produced a valuable guideline to better understand and thereby manage the implications of change prior to implementation of an e-health project.

It was determined that the new teleradiology service would fit well into the existing pathway, was designed to have minimal change and potentially improve patient care.

5.5 MAIN CONCLUSIONS

The result of this study demonstrated that the proposed modified PCP can be applied as a pre-implementation framework to better understand the way a system actually operates. The model supports the understanding of the variables that can affect the system and inform decisions concerning the system and their possible consequences.

Developing the PCP for the existing teleradiology system proved invaluable in terms of gaining a comprehensive understanding of the current delivery mechanism. The purpose of the research was to develop and evaluate a methodology to determine the optimum way to migrate the current X-ray system to an e-health system and that would introduce minimal amount of change. The investment in this initial phase of the project was paramount in understanding the implications of change and how the changes may be minimised.

The proposed model provided a greater understanding of the issues involved in migrating from a traditional health care delivery system to e-health. Furthermore, it has long been established that one of the many general benefits of modelling is the ability to test a system before implementation i.e. to examine the outcome of various alternatives in a safe environment. Creating the PCP for the teleradiology project involved physically following patients needing an X-ray through all the various routes within each identified hospital. In addition, digital photos were taken at each critical point and supported by documents detailing the events of each episode. All this information was captured and the entire process represented schematically in a PCP.

Schematically capturing the whole delivery system for the e-health project allows systems analysis and demonstrated information flow between three hospitals in a border-less environment. This clearly demonstrated the benefits of introducing e-health using a formal methodology.

Ultimately, the adoption of the systems approach to the modified PCP allowing systems analysis of e-health could provide real benefit to clinical staff, patients, carers and policy makers in their desire to improve services.

5.6 LIMITATIONS AND CRITIQUE

Each piece of research has its limitations and this work is no exception.

The lack of operational and management standards or formal methodologies would indicate that the task of developing standards within e-health is not easy. The complexity of health care systems, and more specifically e-health, is often cited as cause, and neither can the methodology of this research be considered as a complete solution.

The methodology clearly illustrated the benefits of e-health in one particular context; however, the concept of comparing systems within different health care environments may not be feasible due to the wide ranging methods adopted by different health services i.e. locally driven health care.

Leadership has been demonstrated as a key element to the success of e-health projects and in a rural e-health project in Michigan the case study concludes that leadership was largely responsible for the success of the project (Whitten 2003).

One solution to have considered was to employ a radiologist in the secondary hospital thereby removing the requirement for teleradiology. However, Thailand has a severe shortage of radiologists and recruiting medical professionals to the rural area is a major problem. Teleradiology was investigated as a solution to the national shortage of radiologists.

Working on an International project brought its own obstacles in terms of working in different time zones and cultural differences, however, with the use of video conferencing and the support of the Thai Ministry of Health there were fewer challenges than anticipated. However, it must be recognised that the project would have been easier to manage and may have produced more data had the project been based locally.

Having the same person responsible to deliver the e-health project and evaluate the effectiveness of the methodology and outcome will result in bias. However, from a personal and research perspective, the research approach to the work benefited the outcome of the e-health project from the diversification of ideas and viewpoints that it introduced.

This research recommends that the PCP should be developed in computerised from. This would require common definitions to be adopted. However e-health may yet be too amorphous to conform to the rigors of computerisation, and naturally the process would be both time consuming and expensive.

There are inherent institutional management problems such as hierarchy that are issues common not just to change management within health care. However, the research poses that e-health is disruptive by its nature and challenges the core of the traditionally entrenched health care system, and therefore, working in e-health and introducing novel methods will take both time and tenacity.

Although the PCP represents well the technical design of the e-health system and identifies technical changes, that will indicate where data sharing may be required and can give insight into optimum design of the system, it cannot, however, solve organisational or human issues, for example, silos, power empires, personalities and much effort may be required overcoming such issues.

Clearly, for the “whole systems” PCP to be effective it should not be viewed as a prescriptive model since the proposed model is considered useful for the pre-implementation phase of e-health projects, it still must be owned and understood by the team involved in the implementation. The tasks of including all strata of personnel and gaining their co operation and understanding was feasible in this relatively contained project, however, it must be recognised that in a large scale project that this would be an issue that would demand different management techniques.

This research is intended to stimulate and promote an opportunity to debate the future of formal methodologies within e-health and specifically the application of PCP and systems analysis. The subject calls for a wider debate and hopefully a call to action within the community to better harness e-health to the benefit of all.

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APPENDIX A - SOFTWARE ARCHITECTURE

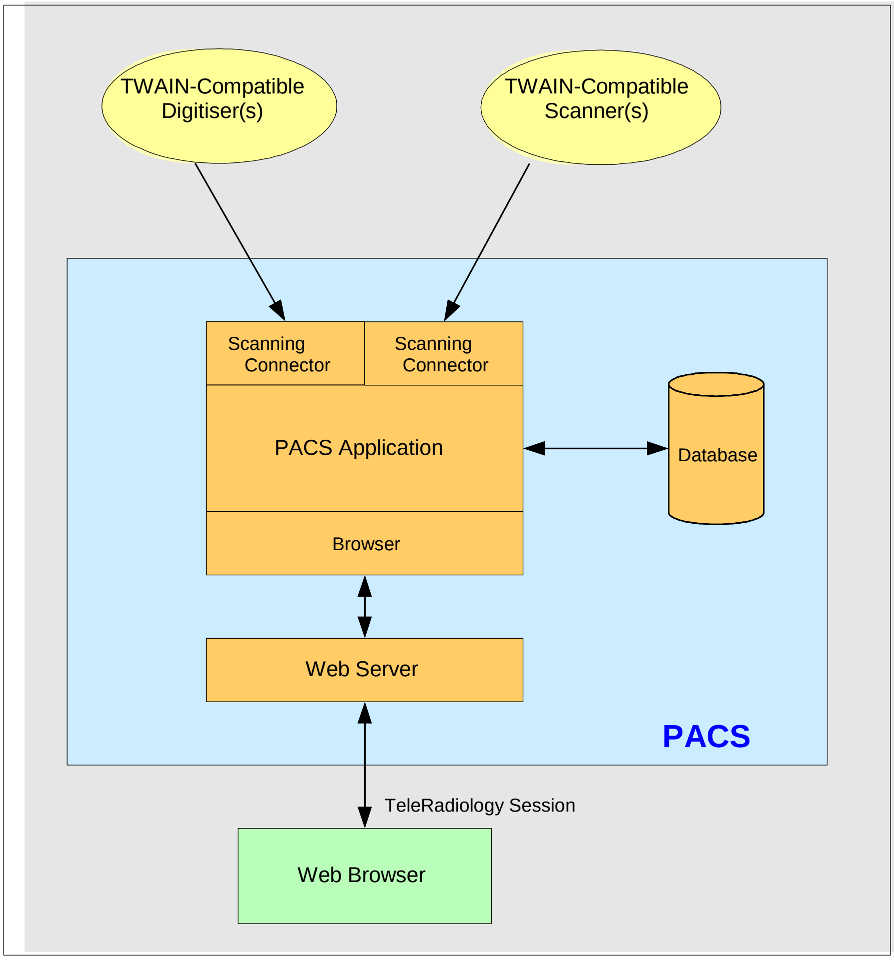

Figure 15: Software Architecture

PACS Application

The PACS application provides the core functionality of the teleradiology system, including access to the PACS database and communication with the web-server.

The PACS is a complete web-based solution. Authorised users carry out patient record related functions via a standard web browser that communicates with the PACS application through the web server.

Parts of the PACS User Interface such as colours/icons, folders, forms and leaflets can be customised and configured to meet specific customer requirements. Details of the customisations and configuration required for Thai Hospital will be included in the configuration

PACS connectors will be provided to transmit and receive data between the PACS and other hospital systems. For the Pilot phase two connectors are required:

Scanning Connector – to provide an interface between the compatible scanners/digitiser and PACS.

Oasis (ADT) Connector – to provide an interface between the database and PACS

APPENDIX B - HARDWARE/SOFTWARE REQUIREMENTS

The server hardware will typically be a multi-processor machine which will be used to process the incoming data from the various scanner(s)/digitiser(s) and be able to respond adequately to send images / reports to the various terminals around the networked hospitals.

Over the longer life of the system, data may be stored for example on near-line tape-libraries. The storage solutions used will depend on the data access requirements e.g. one year on-line storage with older data stored on near-line storage solutions.

A single server has been provided by MoPH to host the main database server and web server for PACS. The minimum server configuration includes:

- Hardware:
  - Dual processor, Intel Pentium III Xeon 900MHz with 2MB L2 cache
  - 2048 MB RAM
  - 18 GB hard disk (for the Operating System)
  - 40/80 GB DLT internal tape drive
  - CD-ROM
  - Integrated network card (Fast Ethernet 10/100)
- Storage:
  - Storage controller (Ultra2 SCSI adapter)
  - 10 x 36.4 GB SCSI hard drives
- Software:
  - Windows 2000 Server

- SQL Server 2000 (license for 1 processor only)
- VNC remote access software

The server needs to have a static IP address and be connected to the network.

Additional storage may be required based on statistics supplied by the Thai MoPH. The number and size of the storage solutions is dependent on the size of the installation; most specifically the number of modalities sending data to be stored on the system and the volume of images/scans taken by each is the defining factor.

The review stations are desktops or laptops that are used to access the PACS system. The review stations must be able to connect to the network.

The following minimum configuration for review stations was recommended:

- Processor – Pentium II
- Memory – 128MB RAM
- Operating system – Windows 98, 2000 or NT 4.0
- Web browser – Netscape Navigator 4.x or Internet Explorer 4.x

Note that, although Microsoft Windows based review stations are recommended, the PACS PIRILIS can be accessed from any web browser that supports HTML 4.0 or higher.

Scanners and PC's

The MoPH need to purchase the following scanners for loading the paper and film-based patient records:

- TWAIN compliant scanner e.g. Fujitsu M3096FX scanner (22 pages/min) or a Fujitsu M4097D duplex scanner (50 pages/min). Note any reasonably specified TWAIN compliant scanner can be used to scan forms/reports

- Film digitiser – such as the Vidar Sierra plus film digitiser

These scanners and digitisers are connected to dedicated PCs that will be used to control the scanning process. The Scanning Connector software will be installed on these PCs.

The PACS teleradiology solution was an “off the shelf” solution and, therefore, ready for delivery and installation. Prior to installation, the core PACS system would be available for basic customer specific configuration, if appropriate (see section on System Configuration). The project was to be delivered in a number of separate phases as the project progressed.

- The latest version of PACS, including the user interface would be installed. This would have been configured on site according to the basic configuration needs of the customers.

- A server would be put in place at the PACS hub located within the Pong Nam Ron Hospital

- The PACS system would be interfaced directly to the digitiser/scanner using the scanning connectors as defined below.

- The images and other relevant data would be collected in the central repository, which could then be accessed externally by users who wish to view the data using standard web-browsers.

- The teleconference can take place, with the relevant data accessed over a PC. If diagnostic quality is needed, then the local Image Viewer software will provide this.

Interfaces

It was proposed that a number of interfaces to existing systems and devises be developed to input the patient information at the user end. The PACS connected to these systems utilising industry standard hardware, systems software and interfaces, including XML, HL7, TWAIN and DICOM.

The software includes a number of connectors that enable standards-based devices and systems to be easily incorporated into the networked environment. This allows the appropriate clinical information to be captured from different sources and included in the patient record.

The PACS system would have been interfaced with the scanners/digitisers at the Pong Nam Ron Hospital. Additional interfaces to other systems, including additional imaging modalities can be added modularly in the future. There was a possibility of using the same system for teledermatology. The approach adopted by the personnel at Pong Nam Ron was that they have ownership of the system and develop and adapt the system to suit the individual configuration of the hospital and current work practices.

Where possible, the Teleradiology network would follow the current practices and avoid replication of activities or processes.

For the Pilot installation the PACS will include a one-way (incoming) interface to the scanners that will be used for loading paper-based patient information.

The scanning connector will:

- Allow TWAIN-compatible scanners/digitisers to interface with the PACS
- Enable users to import data (paper documents) and scanned images from the scanners/ digitisers into the system PACS.

- Include a user interface for controlling the scanning process and storing the scanned images in PACS.

- The scanner/digitiser will be attached to desktop review stations, which must be networked to enable communication with the server. Software will be provided for the for installation on the user PC, which will enable output from the document scanners to be up-loaded directly into the PACS system

Using this technique, the staff at the Pongnamron Hospital will be able to incorporate paper-based results such as archived ECG waveforms, blood test results, reports and correspondence etc. directly into patient records if appropriate.

APPENDIX C - NETWORKS REQUIRED AND CONFIGURATION

PACS acts essentially as a web server. It therefore requires a TCP/IP based network infrastructure to communicate with the rest of the clinical environment.

It was the responsibility of the MoPH to supply and support the network infrastructure.

The system essentially utilises standard networking hardware and associated communication technologies for the proposed deployment. The extensive communication linkages provided by the MoPH can be utilised for this project. By using standards-based technologies, PACS effectively leverages existing investments in communication technology made by the government of Thailand.

The proposed installation of 512 kbps communication link between the referral hospital and the tertiary hospital was required for the project. As agreed, the MoPH was due to supply a network that is compatible with the PACS prior to system installation.