DEVELOPING ECONOMIC MODEL FOR PICTURE ARCHIVING AND COMMUNICATION SYSTEMS INSTALLMENT DECISION MAKING

Mr.Thirapich Chuachantra

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การพัฒนาแบบจำลองทางเศรษฐศาสตร์สำหรับการตัดสินใจติดตั้งระบบการจัดเก็บและรับส่งข้อมูลภาพทางการแพทย์

นายถิรพิชญ์ เจือจันทร์

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คณะเภสัชศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

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การลงทุนสำหรับเทคโนโลยีสมัยใหม่ที่มีต้นทุนสูง เช่น ระบบการจัดเก็บและรับส่งข้อมูลภาพ ทางการแพทย์แบบดิจิตอลนั้นโรงพยาบาลที่มีวางแผนจะติดตั้งระบบดังกล่าวควรจะต้องมีข้อมูลต้นทุนผลได้และความคุ้มค่าของโรงพยาบาลนั้นๆ สนับสนุนการตัดสินใจด้วย อย่างไรก็ตามพบว่าหลายๆ โรงพยาบาลยังไม่มีการศึกษาแบบจำลองทางด้านเศรษฐศาสตร์ของการลงทุนระบบนี้อย่างจริงจัง ดังนั้นวัตถุประสงค์ของการศึกษานี้เพื่อพัฒนาแบบจำลองทางเศรษฐศาสตร์เพื่อวิเคราะห์ต้นทุนและต้นทุนที่สามารถประหยัดได้ของการได้มาของภาพถ่ายทางรังสี 3 ระบบ คือ ระบบการจัดเก็บและรับส่งข้อมูลภาพ ทางการแพทย์แบบดิจิตอล (PACS), ระบบการจัดเก็บและรับส่งข้อมูลภาพทางการแพทย์แบบไม่สมบูรณ์ร่วมกับระบบการใช้ฟิล์ม และระบบการใช้ฟิล์ม วัตถุประสงค์ต่อมาเพื่อวิเคราะห์ต้นทุน และต้นทุนที่ประหยัดได้ของการติดตั้งระบบของการได้มาของภาพถ่ายทางรังสีทั้ง 3 ระบบโดยใช้ข้อมูลตัวแทนของโรงพยาบาลขนาดเล็ก ขนาดกลาง และขนาดใหญ่ และวัตถุประสงค์สุดท้ายเพื่อหาจุดคุ้มทุนของการติดตั้งระบบ PACS ในโรงพยาบาลทั้ง 3 ขนาด โดยมีการวิเคราะห์ต้นทุนผลได้เป็นกรอบการศึกษาในการพัฒนาแบบจำลองทางเศรษฐศาสตร์นี้ รายการต้นทุนต่างๆ ถูกรวบรวมและนำมาสร้างแบบจำลองโดยการศึกษาการทำงานในสถานที่จริงการสัมภาษณ์ร่วมกับการทบทวนวรรณกรรม แล้วทำการวิเคราะห์ข้อมูลโดยใช้แบบจำลองนี้ โดยข้อมูลอัตราการใช้ทรัพยากร และต้นทุนของอุปกรณ์ของแต่ละระบบโดยรวบรวมจากงานวิจัยก่อนหน้า รายงานบัญชีต้นทุนอุปกรณ์ที่เกี่ยวข้อง รวมถึงสถิติต่างๆที่ได้เผยแพร่ไว้แล้วของหน่วยงานของรัฐ มูลค่าปัจจุบันถูกนำมาใช้ในการปรับค่าเงินตามเวลาที่เปลี่ยนไป หลังจากนั้นทำการแปลผลที่ได้จากแบบจำลองนี้โดยใช้การวิเคราะห์ต้นทุนส่วนต่าง และหาจุดเวลาคุ้มทุนของการลงทุนโดยใช้ค่าปัจจุบันสะสม การวิเคราะห์ความอ่อนไหวในการศึกษานี้ประกอบด้วยตัวแปร คือ เงินจัดซื้อระบบ PACS เริ่มต้น และ อัตราการใช้ทรัพยากร จากการทบทวนวรรณกรรมและศึกษาการทำงานในสถานที่จริงทำให้ได้แบบจำลองทางเศรษฐศาสตร์ ภายใต้มุมมองของผู้ให้บริการทางการแพทย์ ซึ่งประกอบด้วยต้นทุนทางตรง และต้นทุนทางอ้อม แบบจำลองนี้ตั้งสมมติฐานช่วงระยะเวลาการประเมินระบบ PACS ไว้ที่ 9 ปี, อัตราคิดลด 3 %, อัตราค่าจ้างเพิ่มขึ้น 5 % ต่อปี, ราคาแผ่นฟิล์มเพิ่มขึ้น 2 % ต่อปี, อัตราการใช้ทรัพยากรเพิ่มขึ้น 8 % ต่อปี และอุปกรณ์คอมพิวเตอร์จะถูกเปลี่ยนเมื่อใช้งานครบ 5 ปี ส่วนอุปกรณ์ไฟฟ้ากำหนดให้มีอายุการใช้งาน 10 ปี หลังจากทดสอบแบบจำลองแล้ว พบว่าระบบ partial PACS นั้นไม่มีความคุ้มค่าในการลงทุนในโรงพยาบาลทุกขนาด นอกจากนี้ยังพบว่าไม่มีจุดคุ้มทุนในการลงทุนระบบ PACS ของโรงพยาบาลขนาดเล็ก ในทางตรงกันข้ามมีความคุ้มค่าในการลงทุนของโรงพยาบาลขนาดกลาง และขนาดใหญ่ ซึ่งการติดตั้งระบบ PACS จะช่วยประหยัดต้นทุนได้ 24.5 และ 60.2 ล้านบาท สำหรับโรงพยาบาลขนาดกลาง และ ขนาดใหญ่ตามลำดับและมีจุดคุ้มทุนที่ปีลำดับที่ 4 ของการลงทุนของโรงพยาบาลทั้ง 2 ขนาด การวิเคราะห์ความอ่อนไหวแสดงให้เห็นว่า โรงพยาบาลขนาดเล็กจะคุ้มค่าต่อการลงทุนระบบ PACS ก็ต่อเมื่อลดเงินลงทุนเริ่มต้นลง 30% นอกจากนี้ถ้าโรงพยาบาลขนาดกลางมีอัตราการใช้ทรัพยากรไม่เปลี่ยนแปลงตลอดช่วงระยะเวลาการศึกษานี้ ก็จะไม่พบจุดคุ้มทุนในการลงทุนในระบบ PACS แบบจำลองทางเศรษฐศาสตร์ที่ถูกพัฒนาแล้วของการศึกษานี้อยู่ที่เวปไซต์ http://goo.gl/ljubyO โรงพยาบาลหรือสถานพยาบาลใดที่ต้องการข้อมูลต้นทุนผลได้ ความคุ้มค่า สนับสนุนการลงทุนในระบบ PACS สามารถเข้าไปดาวน์โหลดประยุกต์ใช้ได้โดยไม่มีค่าใช้จ่าย

ภาควิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่อนิสิต.....

สาขาวิชา เภสัชศาสตร์สังคมและบริหาร ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก.....

ปีการศึกษา ...2556..... ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม..... .....

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KEYWORDS: PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (PACS) / HEALTH TECHNOLOGY ASSESSMENT / ECONOMIC MODEL / DIFFERENTIAL COST ANALYSIS / NET PRESENT VALUE (NPV)

THIRAPICH CHUACHANTRA: DEVELOPING ECONOMIC MODEL FOR PICTURE ARCHIVING AND COMMUNICATION SYSTEMS INSTALLMENT DECISION MAKING. ADVISOR: ASST. PROF. PUREE ANANTACHOTI, Ph.D., CO-ADVISOR: ASST. PROF. PHANTIPA SAKTHONG, Ph.D., 110 pp.

A hospital needs cost-benefit evidence to support decision making to invest in high cost Picture Archiving and Communication System (PACS). However, not many hospitals are capable of conduct economic study. The first objective of the study was to develop economic cost models for installment of PACS, partial PACS and film-based system. The secondary objective was to analyze cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals. The last objective was to measure break even point of PACS of three size hospitals. Cost-benefit analysis was used as a study framework for develop economic cost models. Cost items came from work process study, interviewing head of radiology department and radiology technician and literature review. To test the models, utilization rate and cost were gathered from previous studies, reports, price list, and statistics and other available published data. Present value was used to adjust time value of money. Differential cost analysis was applied to interpret result of model testing. Accumulated present value was used to indicate break even point. Sensitivity analysis was also conducted. From literature review and work process study, economic models, developed from provider's perspective, were composed of direct cost and indirect cost items. The model assumed nine years PACS lifetime, three percent discount rate, five percent wage rate, five years replacement of PACS related hardware, and ten years replacement of other PACS and film-based items, two percent increase in film cost per year, and eight percent increase in service utilization rate. After testing the models, it was found that partial PACS was strongly not recommended in all hospital sizes. PACS showed no break even point for small size hospital, but worth investing for medium and large size hospitals. Implementing PACS would have saved 24.5 and 60.2 million baht for medium and large size hospitals, respectively. Break even point was recognized in 4th year for both medium and large size hospitals. Sensitivity analysis suggested that lowering initial cash flow in small size hospital by 30% would make PACS worth investment. Moreover, if service utilization rate remained unchanged, medium size hospital should not invest in PACS as there was no gain on investment in 10 year period. The economic cost model developed in this study was posted at http://goo.gl/ljubyO. Any hospitals that need cost-benefit evidence to support PACS investment can access and download freely for further use.

Department : Social and Administrative Pharmacy... Student's Signature .....

Field of Study : Social and Administrative Pharmacy Advisor's Signature .....

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LIST OF ABBREVIATIONS

APV	Accumulated Present Value
CBA	Cost-benefit Analysis
CEO	Chief Executive Officer
CR	Computed radiography
PACS	Picture Archiving and Communication System
PV	Present Value
NPV	Net Present Value

CHAPTER I
INTRODUCTION

Rational and Background

Medical image is important information that helps physicians make accurate diagnosis. Medical image was previously recorded on film; however, with progression of information technology, it is digitized and recorded in IT storage devices. Unlike film-based counterpart, Picture Archiving and Communication System (PACS) utilizes a lot less storage space. It frees radiology staffs from retrieving and returning film from and to storage room.

PACS is created to manage digital images. It has been widely implemented in many hospitals and healthcare institutes. PACS operates by acquiring medical images from various x-ray devices and storing them in a storage device. With PACS, digital images can be directly accessed by radiologists. Significant work process change has been made especially for a case that needs urgent interpretation. Radiologists can shortly provide their interpretation into the system. PACS allows authorized staffs to simultaneously retrieve medical images from multiple workstations. It enhance multidiscipline team discussion which results in accurate and faster diagnosis. Not only PACS allows comparison of images overtime on the same screen, it also provide tools for image adjustment e.g. lighten or darken of image. Once PACS is used, patients do not have to carry heavy stack of films from place to place [1-11].

PACS has been implemented in Thailand for approximately 10 years, mostly in big private and government hospitals. PACS is not widely used due to its high cost. To invest in PACS, cost benefit is a significant evidence to support hospital administrator's decision making [10, 12-14].

Previous cost-benefit studies of PACS showed inconsistent results. Fang et.al. conducted cost and cost saving analysis to compare full PACS implementation to existing film-based system. The study was done in the 500-bed public hospital in Taiwan[2]. They found that investment could be returned in 4^{th} year after a complete PACS installation. Van Gennip et. al. conducted two cost analysis to compare full

PACS implementation to film-based system. The study showed that PACS was worth investment and break even point was reached after 6th year [7, 12]. Two studies conducted by MacDonald et.al. and Alanen et.al., comparing cost of partial PACS and existing film-based system, found that partial PACS was not worth investment [1, 8]. Maass et.al. compared cost of film-based, partial PACS and PACS found that film-based was the cheapest system[15]. In Thailand, there was a study conducted by the Institute of Medical Research and Technology Assessment in two hospitals; Prasart Neurological Institute and Ubonratchathani Cancer Hospital. Partial PACS and film-based were existing system used in Neurological Institute and Cancer Hospital, respectively. The study found that PACS, in comparison with the existing system were worth investing. Investment for both hospitals could be returned within 2nd year[16].

It can be noted that factors affecting the cost and cost saving of PACS are study volume, the numbers of workstations, hospital size, software cost, maintenance cost, number of computed radiography (CR), and labor cost[1, 7, 8, 15].

Although many hospitals express their interest to implement PACS, but they have to demonstrate that it is worth investment. Not many hospitals in Thailand can conduct economic study by themselves. Also previous study use different cost structure and assumption. This study aimed to develop an economic model to analyze the costs and cost savings of PACS, partial PACS, and film-based system. Model testing was conducted using data that represent large, medium, and small size hospitals.

Objectives of the Study:

1. To develop economic cost model**s** for installment of PACS, partial PACS and film-based system.
2. To analyze cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals.
3. To measure break even point of PACS of three size hospitals.

Scope of study

The assessment time duration in this study was assumed 9-year, 2012-2021. All models were developed under providers' perspective

Expected Benefits:

1. Framework derivation in this study will be applicable for other hospital and health care institute to use as a model to support decision to adopt Picture Archiving and Communication Systems.

2. Costs and Benefits will be a solid evidence to support decision making for other hospital and health care institute to invest on full-scale Picture Archiving and Communication Systems.

Definition used in this study

1. **PACS** is management system for digitized medical image, implemented full-scale and hospital-wide.
2. **Partial PACS** is management system for medical image refers to use of both system; 100% film-based system and 50% of diagnostic viewing station and result viewing station of PACS system as the hospital cannot afford full capacity of radiologist and clinician workstation.
3. **Small hospital** is represented of Large Community hospital that has 90-150 beds. In this study we collected data from Ubonratchathani Cancer Hospital that served around 17 thousand patients in the year 2012.
4. **Medium hospital** is represented of General hospital is the hospital that has 150-500 beds. In this study we collected data from Prasat Neurology Institute, Bangkok that served around 30 thousand patients in the year 2012.
5. **Large hospital** is represented of Central hospital is the hospital that has more than 500 beds. Utilization data for a large size hospital was set as twice the medium size hospital.
6. **Direct costs** are the most obvious cost to measure which directs to the system or the investment for processing. It could be categorized in to two types are direct material cost and direct labor cost. For example, direct material cost of

PACS are purchasing cost for PACS hardware and software and film-based system are film, chemicals and space of operating a film-based system, etc.

7. **Indirect cost**s mean the cost arisen outside the system or the project and regarded as unintentional cost. It are related to the cost of maintenance, for instance air conditioning in the sever room and the machine room, CD to transfer medical image, film viewing lamp, etc.

CHAPTER II
LITERATURE REVIEW

This study was aimed to develop economic cost models for installment of PACS, partial PACS and film-based system under provider's perspective, to analyze cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals, and to measure break even point of PACS of three size hospitals. This literature review was undertaken by reviewing the relevant literature on the following 6 parts:

Part 2.1: Picture Archiving and Communication Systems

Part 2.2: Project analysis

Part 2.3: Economical project analysis

Part 2.4: Cost and benefit category of project assessment

Part 2.5: Cost items of PACS and film-based system

Part 2.6: Related PACS cost analysis study

Part 2.1: Picture Archiving and Communication Systems

PACS is a technology used to carry out digital medical imaging from the various modalities. PACS composes of several technologies such as computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, and digital projection radiography. The image data and pertinent information will be transmitted to other and possibly remote locations over networks. Those data will be displayed on computer workstations. Other than that soft copy of the data could be viewed in multiple locations and report at instant time from radiologists. However, data not only be secured and archived on digital media i.e. optical disks or tape, but also automatically retrieved as necessary. Close integration with the hospital information system (HIS) – radiology information system (RIS) is critical for system functionality. Medical image management systems are maturing and providing access outside of the radiology department to images through out the hospital via the Ethernet even in different hospitals or from a home workstation if teleradiology has been installed.

In film-based system, film serves to capture, display, transport, and store the image. This kind of technology has been used to improve the process of medical diagnosis since 1895, when Nobel Prize winner Roentgen discovered the first medical image radiograph. However, several factors have been concerned year by year, such as the high loss rate of film-based system (up to 20% of film cannot be found at the required time, creating a serious practical problem), limitation in viewing film at only one place at one time, and the time required to process images chemically. Transportation of radiographic films is very take time, and conventional film archives are tended to have a labor-intensive and unreliable. Even hospitals have a well-organized film library, a considerable amount of time in a radiology department is spent in process of searching for the previous films or arguing with physician about the location of films. Not only storage and retrieval of film, but also reporting of diagnostic information of radiologists, have become increasingly difficult using film-based system means [17].

Medical images on an X-ray film are stable, and the manipulation possible is only to adjust a brighter light. Once medical images are in digital format they can be manipulated for improve quality of viewing. Nevertheless, they may also be transported electronically, sorted, display, stored in an archive, retrieved when

needed, and called to any location within extended computer network, within the hospital or remotely to general practitioner or to other hospitals. When such a system is implemented throughout the hospital, the results will be performed as a filmless hospital environment. Even though there are hundreds of PACS implementations operating throughout the world, many are only exiguous, linking such as the intensive care unit with the radiology department, or networking a few workstations together, and there is a conflict that whether systems merit should be described as "PACS". There are few truly filmless hospitals in existence [9, 18].

In addition, from exploring medical image acquisition of hospitals in Thailand and from reviewing both domestic and international literatures found that there is implementing incomplete PACS or to be called that partial PACS. It is a result of the unavailability of hospital in both investment and lack of data to support the decision-maker to invest in full PACS. Partial PACS refers to use of both film-based system and PACS system as the hospital cannot afford full capacity of radiologist and clinician workstation.

Mini-PACS is a localized version of full-scale PACS. Generally, this system let users acquire images and distribute them rapidly. Also Mini- PACS let users store images for a short period of time, generally at the time point of using. Mini-PACS might be used in intensive care units where physicians need to keep study images on folder for several days. However, the primary long-term storage medium is still film.

Full-scale PACS are different from mini-PACS in two ways. First, full PACS supports long-term digital image storage – the electronic archiving of medical images. Second, PACS supports a more dexterous distribution of medical images. Hospital facilities may move above supporting specific departments to managing the flow of diagnostic images to a wider range of physicians. Full-scale PACS usually includes one or more teleradiology subsystems that might be used to communicate with central image archives.

Part 2.2: Project analysis

In the current economic situation of health care environment, reducing costs in health care is the one important objective for the hospital management. PACS implementations for health care systems need to use a lot of investment resources and each hospital have different environment such as number of patient, ward, required PACS work station, etc. therefore, the worth of PACS implementation would not have the same result for each hospital.

PACS has been implemented in Thailand for approximately 10 years, mostly in big private and government hospitals. PACS is not widely used due to its high cost. To invest in PACS, cost benefit is a significant evidence to support hospital administrator's decision making of every hospital and health care institute, require to implement that it has suitability and worth for installation this system [9, 10, 18, 19].

Background and importance of the project analysis [11, 20, 21]

Concepts of cost and benefit analysis of the project that was occurred for long time ago which had been begun in the U.S.A. for the first time in early 20th century. The federal of the U.S.A. issued law about "The River and Harbor Act" in the Year 1902. This law specified that Harbor and river projects including related projects that must be prepared a report about the commercial benefit and cost. Based on mentioned law, it is arisen the development of techniques for assessing tangible costs and benefits of the project.

The word "Project" that may mean the investment activities that was analyzed properly that is able to solve existing problems or to achieve the desired objectives under the prescribed period. Therefore, it requires studies and researches for relevant entities should know that how to prepare and how much resource to invest.

Until the 1930s the concept about the cost-benefit analysis had been expanded from the commerce to a social and economic. When World War 2 ended, various relevant entities also extend the scope of the analysis to include indirect and intangible of costs and benefits.

Although, the analysis of the project according to the principle of cost and benefit is an important tool, and has been applied for analysis for long time ago, but utilization of this tool is still very new in Thailand. Nevertheless, the analysis of cost

and benefits are not only limited to government projects and state enterprise but it is also involved of investment by the private sector. For example, the investment of a full PACS system of the Neurological Institute this system is relatively new in Thailand. Thus, an investment in such systems there are the cost is quite high and the benefit was not very high due to this institute is a health service agency of government. But many institutions or entities would desire the highest profits by using the limited resources, therefore, before decision-maker of each institute decide to invest in any project that it is essential to analyze the project first for assist to know an opportunity to achieve in the project and whether should invest in this project. [20-22]

The advantages of operation in the project format

The proposals about the investment or development issues should be performed in the form of projects because there are many advantages as follows

1. The project format provides a framework for involved expert from various departments in order to decide and perform systematically.
2. The project format could be framework to be able to collect and analyze information from various sources.
3. The resources supplier can use information outcome in planning of responsibilities functions of themselves due to this format can express the total and an annual expenditure.
4. The operation in project format can lead to analyze and evaluate the impact of the project or investment to the participants, whether participants would be anyone such as provider, patient or societal.
5. The investment proposal in a project format is able to help decisions about issues of the organization form and manage easier and better.
6. The project format will provide protocol of following and evaluating performance for managers and planners, for example; operations are meet requirements or not.
7. The project format can help encourage systematically and seriously in the analysis and review alternative projects. This process will lead to be the best choice.

From such advantages that not only investment activities or development which can estimate cost and benefit easily in monetary term that would be performed in projects format. But the other investment which cannot or difficult to estimate, such as education, research, loans, and medical which these investments should be also performed in project format. Because it can provide framework for cooperation of various experts in preparing the project, costs estimation including providing appropriate management.

The limitations of operation in the project format

Although there are several the advantages of performance in project format but also have limitations as follows

1. The quality of project analysis is based on the quality of data including estimates of costs and benefits will be occurred in the future. For example, if we add inappropriate or different assumption from reality too much in the analysis, it affects project analysis and planning incorrect.
2. The difficulty of valuation cost and benefit in monetary terms. For the project that can estimate costs and benefits in monetary terms easily. The cost benefit analysis can assess properly including analysis for comparing alternative project for better project also. But the project that cannot or difficult to estimate costs and benefits, the cost –minimization will be applied in this case.
3. Cannot replace political decision. Although the project was planned and executed under political conditions but political benefits and financial and economic benefits of the project may not be the same. Especially political leaders must respond to many group which gained benefits and pressure that occur. The considering the pros and cons may lead to conclusion not be the same as the result of project analysis. The project analysis would not replace the political decision-making. It is only a tool that assists to consider and decide in order to reduce errors minimized.

The feasibility study of project

Each country on the earth, whether developed or developing or undeveloped countries and whether it is socialist or capitalist are also faced with limited resources are used for well livelihood of people in the country. Therefore, public and private sector have to decide to adopt own resources in activities that meet maximum needs. And every time when decide to choose the choice, it mean that must be lose something. These are opportunity costs. In order to use efficiently the resources, it is essential to study the project feasibility. The feasibility study must be studied and documented that comprised of information about justification and soundness of project for investment in the best project. Therefore, the feasibility study has the same meaning with project analysis. The project will be evaluated advantage and disadvantage or benefits and cost. The analysis emphasize the evaluation of project worth which will have the worth when benefit greater than cost. So, prior to invest in each project that have to have process in considering carefully by considering alternative project for comparison in order to efficiently use the resources and maximum benefit.

For the scope of the study will be different for each project depending on the characteristic, type and category of project. The characteristic of project may mean a new investment project or expansion of existing project or just modify machine or tool only. Type of project may mean its field such as energy, industry, agriculture, education or medicine. And the project was categorized as public or private. These differences of each project affect that have no the certainty structure for analysis that what feasibility of the project should be analyzed. However, generally, the analysis of the project will consist of these feasibilities as follow.

Technical feasibility

Due to the project that may has a variety of techniques or methods used for implementation whether it is equipment, quantity or quality. These will affect to the cost of production. Therefore, it is necessary to consider the pros and cons of each the technique of implementing project, then select the most appropriate way. This feasibility analysis focuses on the choices formulation and selection of the best techniques to the project. However, technical issues will vary according to location. Appropriate techniques for the one place may not be suitable for another location. In

addition, a technique that uses cost-minimized, it is not always necessary to allow the project to be most effective due to the different techniques may yield different. Comparison between costs and benefits of each alternative is to make that what technique is the best technique.

Financial feasibility

The analysis of financial feasibility is the investment and income analysis of the project in private sector that is profit in monetary term mainly. Moreover , this feasibility include the suitable financial planning for project to ensure that if the project start and continue that will not have any problem in each process of project . This feasibility also analyzes monetary profit of co-worker and co-project such as physician, radiologist, pharmacist, nurse and the other assistant to ensure that there are profits sufficient to attract theses person join the project together.

Analysts are required to prepare various financial statements such as the income statement, balance statement and cash flows statement to determine whether the project will have sufficient funds to operate in the future or not, to define rate of financial return of the project, to assess liquidity and the ability to repay debt. In general, the instrument used to measure the operation is ratio analysis.

Moreover, there is important a method used in the analysis is discount cash flow method. According to this method would be require the project's cash flows, the discounted cash flow, the calculating net present value (NPV) and internal rate of return (IRR).

Social and political feasibility

Many projects may pass the other feasibility analysis. But those projects may not be possible in the social and political feasibility. For example, Improvement of traffic project by prohibiting the sale on the sidewalk across Bangkok city. The project may not be implemented for reasons of social only, it seems the government bullies people who are poor and trying to earn a living honestly. If the government does not allow these people continue to sell on the sidewalk. These people may turn to a dishonest career. Or they may fear the government political parties will lose the popular of the people who are in trouble; so, not daring to do such a project. Not only the such government project but in the public health organizations also; for example, the introduction of modern technology such as Picture Archiving and Communication

Systems (PACS) into the Prasat Neurological Institute that must consider the satisfaction of medical personnel to use this new technology. Because the modern technology may make some personnel who cannot adapt themselves follow technology that are be complicated in performance and resist system soon. Not physician, radiologist, radiology technician, nurse only but all personnel who involve this system. The satisfaction may be convenient, accuracy, saving time and resource and friendly user more than conventional system. The new system should be introduced and instruct for involved personal which may reduce resistant new system.

Managerial feasibility

It is considered that if the project is implemented, how various managements are. This feasibility must be considered since the project has not yet been decided to implement, is not the project have been implemented and then would be consider managerial feasibility, because different management approach that affect the costs and benefits of projects differ also. If the project has not been carefully considered from the beginning, it may cause problems later, and projects that was anticipate would be good at the beginning become a fail project later.

For example, the second stage expressway project that there was the conflict between the Expressway Authority and concessionaire. In agreement that which is organization would collect the toll. This issue make such project was disrupt period of time, etc. In the case of cost benefit analysis of the PACS in Prasat Neurological Institute. The Institute has implemented the partial system. The researcher hope that this study will be helpful to other healthcare institutions that have not already been implemented PACS use these information for the investment decision.

Economic feasibility

This feasibility is often less attended than should be from the almost private sector because the analysis of this feasibility does not focus on monetary profit. But the analysis of this feasibility that there are very important for the government's project itself or the project that government encourages the private sector do. It is estimated that the resources used in a project that will give benefit how to society and It is used as efficiently as possible to society or not.

Part 2.3: Economical Project Analysis [11, 20, 21]

For private businesses, the goal of investing is to make a monetary profit. Private investors are interested in how much money the project will be need to invest and how much get it back. But the government's project that the almost project purpose is not only monetary profit and the large number of projects are not manufactured to put money into the project, some projects may yield a trade, but the government is provides free or collect a little money. And some projects may yield a non-negotiable. In private sector's perspective this projects that have to lost private sector would not invest. If the government is interested in only monetary profit like private sector, government just will not invest also. If the benefits is provided to the social or public are worthwhile for used resource. In the economic, government should consider to implement this project.

The main difference of the evaluation of economic and financial is goal and standpoint of evaluation. Standpoint of economic evaluation is in the social. In analysis that the analyst must compile that the project's implement what and how much social's resources are used and what a whole society will return. However, the used social's resources are interested by economists such as national resources, labor and capital and other production factors. The return is the satisfaction, well-being of people in society non-monetary terms only. However, the profit evaluate based on the concept of the economic evaluation is required the unit of money as the unit count in order to compare the resources to spend in project with the satisfaction of the society will be return from that project . This analysis may be called "Social Cost-Benefit Analysis" or "Social Project Evaluation" in order to emphasize that this evaluation determine the net benefit (profit) of the societal perspective. But the money unit is used as unit count makes many people misunderstand that money is the goal of economic analysis. If it is happens like that, this assessment is not different from the finance assessment or private evaluation in any way.

Assessment of public health project according to economics principle

Evaluation of project activities under the guidance of economic have been increasingly recognized and applied. Beginning at the project can be simply applied as irrigation projects. Up to The project that has been complicated to estimate as

transportation projects. Until The project that has the tangible less such as environmental, education and health projects. The evaluation of public health is complicated both the costs and benefits. The estimated cost, there are the problems about the join cost and difficulty of finding shadow prices of some costs. In particular, the shadow prices of the medical staff of various departments. However, assessing the benefits of the project even more difficult because need to convert the benefits into the monetary term due to the benefits that there are wide variety of produce such as services, prevention, treatment and promotion.

The evaluation project based on the economic has been attempted to apply to the public health project immensely because this evaluation could answer many questions. It also can be included in the decision to use public resources to be effective.

The Application of project analysis based on the principles of economics to make decisions on public health issue that can assist decision-maker decision two levels are

1. Planning public health policy level

To provide resources of a country that is allocated to be used in ways to maximize the benefits. for example, which model of organization is most effective such as the budget allocation to health care institute provide medical image service with film-based system or picture archiving and communication system (PACS) which services will be more effective or which diseases that the state should focus on prevention or which kind of treatment or services that the state should provide for people, etc.

2. Institute policy level

To help decide in question is more specific, such as in the treatment of a diseases should use any treatments to be effectively and economically as possible or the detection of a cause of illness should use any tool or method is the most economical and the least error .

It can be seen that the evaluation of the costs and the benefits based on economic approach can solve the problem to the medical personnel in various field for the most effective management and utilization of resources under the control of themselves. All countries are faced with the overwhelming demand for medical

services and public health but the resources of each country's government can be allocated that has very limited.

Although there are many difficulties in assessing the benefits but the economists and medical personnel accept increasingly that the decision to select or not select any project based on the assessment is not perfect that is better than decision by without any assessment. And because of the difficulty to convert the benefits into the monetary term in the evaluation of public health project, in some cases, cost-effectiveness analysis or cost-utility analysis thus will be evaluate instead of cost- benefit analysis**.**

Type of assessment of public health project economically viable

Although the basic principles and analysis based on economic approach is the same whether applied to any kind project. The need to identify the types of costs and benefits then calculate the value of costs and benefits in monetary term.

However application of the above principles to the different kind projects, such as education, healthcare, industrial, agricultural projects naturally have differences in the characteristics of both the cost and benefit. Thus, the measurement and calculating values of costs and benefits have different methods. Some project simple measures such as quantity and value of industrial products. And it is difficult to measure production from the field of public healthcare or education project, etc. In particular, public healthcare project measurement and calculating value of the benefits of the project is very difficult. therefore, analytical model of public healthcare project have been developed from Cost-Benefit Analysis, which is the basic model to varies analytical model are Cost-Minimization analysis (CMA), Cost-Effectiveness analysis (CEA), Cost-Utility analysis (CUA). However, choosing any models of analysis was based on a question or a problem of analyzing. The pros and cons and detailed of the four models are as follows.

1. Cost-Minimization analysis

It is analysis to compare various alternatives will lead to identical outcome in order to select whether any alternatives would be the lowest cost. If all alternatives could be achieved the same in all respects the alternative which is spent the lowest cost that would be the best choice.

For example, the considering two program that relates with the surgery in adults such as hemorrhoid surgery the surgery and the outcome of surgery of these two programs are identical. Both programs are difference that is one program the patients was admitted at the hospital after surgery, at least one night. While another program the patient returned to treatment at home. If the effectiveness of a treatment are identical the program that is the lowest cost would be save for society. Cost-minimization analysis has both advantages and disadvantages. An important advantage is that the analysis does not evaluate the benefits of the project because all program are identical benefits, compare only the costs. Due to the evaluation benefits of the public health care projects are difficult more than the costs. The difficulty excluding in evaluating the benefits that contributes for easier analysis. The disadvantage of this model is if these projects is taken into consideration the benefits that different or are not equal, then the analysis in this model is not appropriate and to ensure that the benefits of each alternative projects will be identical in all respects have to prove and tested, so this model is limited in its use.

2. Cost-Effectiveness analysis

In the case of there are many options and all options have the same goal (Single common effect) which are different only the effectiveness of outcome each option. Therefore, cost analysis alone is not sufficient need to bring the effectiveness of each option was determined by comparison with the costs.

For example, kidney failure disease may be treated in several ways, such as dialysis or kidney transplant. These alternative methods must be the same goal to extend the life to patients. However, the options' effectiveness in prolonging the life is different. The cost of implementing each option is different also, so one of the methods could not be decide to choose just because of the lowest cost. The method which has a higher cost may be effective to extend more the life of patients, so the comparison between the various alternatives, In this case, must compare the cost per a unit of the goal. (E.g. cost per 1 extend life-year of patient) or compare the goal per a unit of cost. (E.g. time that will be extended per 1 baht each option). Comparison the goal per a unit of cost (such as 1 baht) is a very useful way when making decisions under conditions of limited budgets and the scale of each alternatives are not much different.

In addition, the cost - effectiveness analysis can also be used to choose between projects with a common goal in a manner broader. For example, Comparison of a kidney transplant with a heart transplant. The both surgery is a common goal to extend the life of patients, but in this case the patient has a different cause of illness, or even in comparison the cholera vaccine program with health education programs if both program have a common goal is to reduce the number of sick days of the population or a target group. The limitation of CEA is the projects that were analyzed by comparing CEA have to be a single common effect, and have no side effects. The single common effect of the project must be identified and measured such as the duration that be extend the life of patients, number of deaths decreased, or the number of sick days reduced etc.

However, CEA has the advantage that is reduce the limitations of CMA is the compare projects no need to have identical outcome, but the outcome that only be single common effect. Although the analysis will be measured and calculated the outcome of each project into consideration but it is the only data in the manner of measurement by appropriate metric units. (such as day, month, year or the number of life), which the analysis does not attempt to change that outcome into the monetary term which the calculation that is the most difficult to find a method to change that is generally accepted.

3. Cost-Benefit analysis

It is a comparative analysis of the project by both the cost and benefit of the project is calculated in units of money in order to compare benefits and costs of a project or between projects together. This method is suitable to be used on projects that have various benefits or used in the comparison between the project that its benefits may be similar but not identical, both in quantity and / or quality and may also have side effects are different. This method can be analyzed due to both the cost and benefit will be converted into the same unit is the unit of money.

In a comparative analysis between various projects, we often find that the outcome of each project may not be identical despite of the same goal. In other words, each projects which be compared, not only have intended benefits which is the primary goal together, but It also have different unintended benefits (multiple effects). For example, the government aims to reduce the rate of births with contraception.

This may choose a method of contraception in many ways, such as medication, the use of condoms, injections and other methods which is Temporary contraception until to preventing pregnancy is relatively permanent, such as sterilization, which is also available alternative to female or males. The government should campaign to encourage people for birth control what methods are the most economically efficient because a cost and performance of each method of contraception are different. In addition, each method also have varies side effects. In the CBA analysis of each method, both of intended benefits (lower birth rate) and unintended benefits (side effect) will be included in the analysis.

The CBA for a project which will provide relatively complete information to decision-makers were aware that the project will require how many resources and will lead to how many benefits. Finally, the project will yield a worthwhile investment or not. In addition, the CBA comparison of various projects is to provide relative information to decision makers in the selection process in any project that will (if need to choose). Because the CBA can provide a relatively complete for the decision and also can be used in comparative analysis between the various alternatives are widely is the advantages of the CBA, similarly with other analytical model advantages often lead to disadvantages as well. The CBA is applicable to all projects must be based on the assumption that the costs and benefits of each project can be calculated as monetary term. For some projects, the cost and benefit calculations are not difficult to do but some projects such as public health programs these calculations in many cases still is a controversial in theory or concept, and although some concept are accepted but difficulty in practice is still very high such as measurement and calculation value of pain, human life, acquisition a new or loss of any part of the body organs, etc. In addition, the calculation the value of life or an organ in to monetary term that many people attacked those economists who do it as cold-blooded, and no spirit.

4. Cost-Utility analysis

CUA was analyzed by the same principles as CBA, but the method of calculating the value of benefits instead of calculating the value of money, which is where many people are not satisfied. Therefore there are calculating methods the value of benefits (particularly in public health project which relate to human life is

important) in units of utility or satisfaction. It is a measure the benefits of the public health project in the form of satisfaction to program or compare with other program that is increased or decreased when changes in level of health status. For example, suppose there is a pair of twins is identical, but there is occupations difference only. One is an advertise drawing, while another one as a writer. If they are lost right arm in the same way and then measured in terms of changes in health status of both are identical in all respects that become the disabled have no right arm. If we let them express feelings to their health status by scaling with the scale 0 to1, 0 if die and 1 if completely healthy in all respects. Disability of his right arm, each person will value how many scale between 0 and 1. It was found that although the two are twins, which is identical may scale to the disability of amputated right very different because the need to use right arms and hand of both are not equal. In this case, because the occupations are different, the writers may turn to use something else to write instead of to the right hand such as a tape recorder. But an advertise drawing is hard to find something else to replace the use of his right hand. Thus, satisfaction to lose (or regret) on the right arm, both of them are not equal. That is the feeling loss of the two do not equal in spite of the loss of their right arm same.

Although CUA is a relatively new when compared with other methods mentioned above. But for public health project, analysts believed that if this method is improved to continue, it may be the most satisfy model because CUA is the only model to be able to incorporate changes in quality of life in the analysis. Moreover, It also can be used common measured units as a central unit to compare the costs and effects or benefits between different projects is a choice in deciding which common measured units is often in units of number of days with good health (Healthy days) or an equivalent number of years in perfect health (Quality - Adjusted life - years: QALY) The results of analysis by the CUA is usually outlined in terms of cost per healthy day or QALY resulting from the implementation of a project. Analysts who are in field of public health project are satisfied and accept the common measure units rather than the measurement of monetary units. However, the disadvantage of CUA at the present is the difficulty of converting the benefits of the project into terms of quality units and Also need to be improved much further.

The selection of any method of analysis will happen after the study of problems or questions that need answers, study on the nature of the project, answer issue which the decision-maker would like to know and the analysis must include an understanding of the different analytical methods, including the limitations of each method in order to be able to choose appropriately. But whether choose any assessment model the cost assessment of project is unavoidable.

The form of project selection and criterion for decision making of project assessment

Generally, decision-makers will be faced with the problem of selecting a project in three form consist of

1. The project's acceptance or unacceptance

In case of, there are quite a lot of resources for the implementation project. Although there are many independent projects for consideration, the decision- maker that only compare the benefits and cost of each project that which project is the most benefit after implementation can be approved.

2. The project selection among projects which are independent

The independent project refers to the many projects which can not be replaced with the other projects and the goal of each projects are difference such as fundamental public health care project, flood protection projects of Bangkok inner area, dam construction project , public park projects, reforestation projects, etc. These projects can be considered that each project has specific goals for different projects. The governments of all countries usually acquire these independent projects from all ministries for country development. But the government can not implement all projects that has the analyzed outcomes are reasonably due to the government budget is not enough to do all the projects, and although it can be take on a loan but it is still limited. In such cases, these independent programs must be ranked prior to be selected. Which project's goal that meet the greatest need of the society will be ranked as the first. The other projects that meet the needs less than that will be ranked as less important projects respectively. In this case, the decision to choose which independent project is the best that decisions-makers have to have a tool or criteria to assist in

ranking the projects in order To achieve the goal of a society or country as much as possible and use the limited resources (budget) most efficiently.

3. The project selection among projects that can be substituted (Mutually exclusive)

If one project is implemented, other projects those lead to the same goal, no need to be done. Usually, planners will need to explore many opportunities and projects which are expected to lead to the desired goal in order to be studied in detail for the decision to choose which project is the best. After the project was selected and implemented, other projects are out of necessary. In short that it is the project selection among projects that can be replaced. For example, the goal of a project is to provide fresh water to a community for the consumption. This supplying may be performed the tap water project from surface water sources or from groundwater sources. Whether any project is implemented, the tap water will be enough for the needs of the community, no need to implement both projects together. Both projects were analyzed in order to be compared that which project would be better or may be a selection between a different size projects. For example, dam construction project for irrigation in any location, may be divided into a A project that the height of dam is 25 meters, and a B project has a dam height is 15 meters which a water storage is less than the A project, but there are people who are suffered less than due to their agricultural areas and housing are in a catchment's area was less. In some cases it may be the choosing the location of a project such as the selection construction a dam at the upstream or at the middle of the river. If the dam is selected to construct at one point, the other point may not be constructed so some point must be selected. In addition, a special case of projects with a mutually - exclusive category is the time selection for implementation. A project may be considered as the appropriated project, but are not sure what should be implemented at the present or should be implemented next 5 years or 10 years, if a particular time is chosen other times are not a necessity for considering.

When any projects have to be decided for implementation whether independent project or mutually exclusive project, in some case, the selection program from consideration Net Present Value only that the results may be not satisfied. Therefore, the other criterion may assist for decision to select project. There

are various criteria start with a simple decision criterion up to Net Present Value (NPV), Internal Rate of Return (IRR), Benefit – Cost Ratio (B/C), and the last Net Benefit – Investment Ratio (N/K).

These criteria which will be discussed next part that there are various different pros and cons. And whether any criteria would be selected who select have to be realized that these criteria are just a tool. The decision- maker must be combined with other information for decision to implement.

1. The simple criteria for determination

Assuming that the decision maker must select the most appropriate and right project from 4 projects with the concern of cost and benefit information in each year as shown in this table

Table 2.1: Represents the net benefit of the project in each year

year / project	1	2	3	4	5
A_1	-100	115	0	0	0
A_2	-100	20	30	50	170
A_3	-100	100	110	-50	0
A_4	-100	80	110	-50	-10

1. Selection by Ranking by inspection.

As seen above, the decision maker can immediately realize that the project A_4 is less better than the project A_3 by way of net benefit per annum comparison; therefore, if the project A_3 is in the list of inspection, there is no certainly need to consider the project A_4.

However, this method cannot indicate which ones, among the projects A_1 A_2 and A_3, are better. It is, thus, required to seek for other measures for determination. Note that this above method can, at least, sift out some unpleasant choices at the first place.

2. Selection by Cut – off period

This selection is regarded as an inexact selective method or project priority but well-known adopted for investment. This shall provide the certain periods of payback. For example, in case where the decision maker provides that the chosen project shall pay back within 3 years from the project commencement. If this measure is strictly applied, the project A_2 shall be deselected. Only the project A_1 and A_3 can be determined in mind.

The weakness of this above method is the project A_2 shall gain more profit after 3 years. However, the profit gain in year 4 and 5 will not be determined according to this method. It is therefore favorable for any projects that pay back in the beginning and well known adopted for the high risk uncertain projects, uncertainty in profit in particular.

3. Selection by Payback period

The payback period is the period started from the date of commencement until the net benefit of the project combined altogether in each year is worth compared with the expenses of investment. The investor may prioritize the projects based on payback period of each project. From above example, the project A_1 and A_3 will pay back within 2 years from the project commencement while the project A_2 will take 4 years for payback. Therefore, the project A_1 and A_3 are better than A_2 according to this method.

The weakness of this method is as similar as the 2^{nd} method in term of favoring with any projects that pay back in the beginning.

4. Selection by Average rate of return

The rate of return shall be calculated by way of adding altogether with the net benefit in the positive year, divided by the number of years. The outcome, then, shall be calculated in percentage of the cost of investment in the first year. For the example;

The rate of return in the project $A_2 = \left[\frac{20+30+50+170}{\frac{4}{100}} \right] \times 100 = 67.5\%$

The said calculation can be applied directly with the project A_1 and A_2. However, the project A_3 in which the value is negative does not indicate how to apply for calculation. This is therefore weakness of this method.

5. Selection by Net Average of return

This method was modified and upgraded from the 4th method by adding the net of profit gain of every year after ceasing investment, subtracted by the cost of investment, divided by the number of years after ceasing investment. The outcome, then, shall be calculated in percentage of the cost of investment in the first year. For the example, the project A_3;

$$\text{The Net Average of return} = \left| \frac{(100+110-50)-100}{\frac{3}{100}} \right| \times 100 = 20\%$$

Among other methods, this method is better because the formula requires the information or the net benefit for a whole period of the project. Note that this method is still full of weakness such as which starting year and ending year should be started to calculate in term of the number of years that would bring to divide?

Although all said methods are inexact measures focusing mostly on certain periods of payback, they do not distinguish the monetary value either taken place or paid in different periods. Therefore the value of cost and benefit taken place in different periods shall be added-subtracted-multiplied-divided directly. And even though all methods can be applied in any certain circumstances, they cannot be applied in general, especially the selection between the vast numbers of projects being complicated in size, age and the trend of cost and benefit. The next chapter will be given more complicated and elaborating in investment measures. It is noted that all methods in the next chapter is based on the theory that the value of each baht in different periods shall be unequal.

2. The criteria for measuring the monetary value in different periods

The requirements will be measured the benefit or cost each baht in different periods; namely, the cost or benefit valued of 1 baht that would occur in next year shall be less than 1 baht in the present. The measure on assessing the project which does not alter the timing has mostly weakness in the sense of the disregard of **the time value of money** because this measure believes that the amount of money both in the future and in the present is similar although the similar amount of money in the future

has, in fact, more value in the future. The grounds of measuring differently each year may be clarified by 2 features as follows;

1. The present consumption shall satisfy more than the future consumption. For the example, Mr. A lends Mr. B 100 baht for 1 year. Once the period is due, Mr. B repays 110 baht meaning that Mr. A is not able to spend his own money for self-consumptions. He has to wait until Mr. B is capable of repaying the debt. Such loans cause the partial loss of Mr. A's satisfaction for self-consumption. Therefore, Mr. A will only allow Mr. B borrows money if he will repay the principal (100 baht) plus the partial tranche (10 baht as referred to the interest) in order to redeem for Mr. A's loss. Gaining 110 baht in return could imply the satisfaction of Mr. A's loss as equivalent to the consumes 100 baht today. Or alternatively, the value of 110 baht within 1 year shall be as same as 100 baht today. This is why the valued of 1 baht that would occur in next year shall be less than 1baht in the present.

2. The profit gain is much more than the loss. According to the above example, if Mr. B bring this loan for investment and it is worth more than the previous loan lent by Mr. A within 1 year, Mr. B shall compensate to Mr. A due to the loss of profit gain. Mr. A can earn profit from the investment likewise if she does not lend to Mr. B.

Based on the fundamental of the different money value according to such period of time, it is unable to integrate the cost and benefit arisen in certain years directly for comparing each other or finding the net benefit. Hence, in order to compare the cost and the benefit in the future, there is necessary to convert and decrease the value of the cost and the benefit into the present value. In other word, it should be based on the similar period of time in the present. The process of decreasing the value of the cost and benefit has criterion to apply for decreasing called "discount rate" which is normally shown in percentage.

Discount rate selection

The discount rate shall select the appropriate rate because the high rate shall not affect much on the analysis of the project or vice versa. Therefore it is questionable what rate is appropriate to select for discount.

The developing countries generally assumed discount rate of 8-15%, UK 6%, but often selected for Thailand of 12%. Office of the National Economic and Social Development Board in Thailand recommended that to use of 12%, the study and analysis of the World Bank into Thailand B.E.2521 was 15% based on the uncertainty of the acquired and method, but by international principle of medicine and health related equipment recommended for discount rate of 3-6%. It recommends that should provide by the sensitivity in this section.

From above concept, the value of 1 baht gained or paid in different periods shall be unequal. Hence, we shall compare the value of 1 baht in different periods in the future and convert to the present. The example represents that the deposit of P_0 in the bank account can be risen up to P_1 within 1 year as equivalent to $P_0(1+r)$. If we keep depositing for 1 more year, we will receive, at the end of 2nd year, totally;

$$P_2 = P_0(1+r)(1+r)$$
$$= P_0(1+r)^2$$

That is $P_0(1+r) = P_1$ or $P_0 = P_1 \times \frac{1}{(1+r)}$

$$P_0(1+r)^2 = P_2 \text{ or } P_0 = P_2 \times \frac{1}{(1+r)^2}$$

therefore $P_0(1+r)^t = P_t$ or $P_0 = P_t \times \frac{1}{(1+r)^t}$

The multiplied by $\frac{1}{(1+r)^t}$ with the *t* stands for the numbers of following years in the future while *r* stands for discount rate which is the minimum acceptable rate of return for the present investment and the future self-consumption. In other word, *r* represents the rate of satisfaction for not consuming 1 year. According to the above example, the discount rate is equal to 10% as equivalent to 0.1 converted in discount factor. This convert is regarded as future value discount become to the present value. The said rate of discount in this example is obviously 10%. However, in order to analyze certain projects, which rate of discount shall be applied appropriately is still controversial among the scholars considerably. Moreover, it is noted that either

approve or dismiss the project or accept many projects shall be determined based on discount rate.

1. Net Present Value: NPV

It means the calculation of the present value of the net benefit of the project. The formula of NPV can be calculated as follow;

$$NPV = (B_0 - C_0) + \frac{B_1 - C_1}{(1+r)} + \frac{B_2 - C_2}{(1+r)^2} + \cdots + \frac{B_n - C_n}{(1+r)^n}$$

or

$$\boldsymbol{NPV} = \sum_{\boldsymbol{t=0}}^{\boldsymbol{n}} \frac{B_t - C_t}{(1+r)^t}$$

When

B_t = the value of the benefits of the project that occurred in the year *t*.

C_t = the value of the costs of the project that occurred in the year *t*.

r = discount rate

n = life of the project or the end of the project.

While B_t - C_t is the net benefit of the project occurred in the year (t). Once the future value discount is converted by multiply with $\frac{1}{(1+r)^t}$ (or the so-called "discount factor"), then the outcome will be the net benefit in the year (t). The present value shall be added up altogether in case where the project taken many years and the outcome will be the net benefit of the throughout its life.

Table 2.2: Show an example of calculating the net present value any project with the 10% of the discount rate (Unit : THB million)

Year	Year No. (t)	Costs C_t	Benefits B_t	B_t - C_t	$\frac{1}{(1+r)^t}$	$\frac{B_t - C_t}{(1+r)^t}$
2551	1	7.5	0	-7.5	0.909	-6.817
2552	2	6.0	0	-6.0	0.826	-4.956
2553	3	1.3	3.0	1.7	0.751	1.276
2554	4	1.3	4.0	2.7	0.683	1.844
2555	5	1.3	6.0	4.7	0.621	2.918
2556	6	1.3	7.0	5.7	0.564	3.214
2557	7	1.3	7.0	5.7	0.513	2.924
2558	8	1.3	7.0	5.7	0.467	2.661
2559	9	1.3	7.0	5.7	0.424	2.416
2560	10	-	0.3	0.3	0.386	0.115
					NPV	= 5.595

Note that *t* in the table starts from the 1st year until the 10th year which is the last year of the project's life. However, if we go back to the previous formula, the 1st years will be begun at the 0 year and n which is the last year of the project's life will be terminated at the 9th year. This shows that project's year counting is different into 2 categories. The first one will start to count the 1st year at 1 as the 1st year of investment is implemented at the end of the year (regarded as the 1st year). Therefore, the present information at the 1st year in terms of expenses occurred in the end of the 1st year shall be discounted for calculation. In contrast, the latter one believes that the expenses occurred in the 1st years commenced at the beginning of the year (regarded as the 0 year). Therefore it is no need to discount to convert into the present value again. Both ideas are not the perfect solution because the 1st year of investment may implement at the beginning until the end of the year and we prefer set a year for discount rate calculation (rather than either month or day basis). There is, thus, possibility for variability. It is difficult to seek for an answer which one between year counted from 0 or 1 is right. However, it is certain that the outcome of the NPV

calculation shall be unequal because the cost and benefit, counted from year 0, will be discounted less than the counted from year 1.

The other remarkable point dealt with period of time is *n* which con note for the date of project termination. The date of project termination will be determined by the Economic life which is needed to consider the certain end of lives. Alternatively, it shall consider once the project is implemented at any period of time, the components of the project are still worth to buy or build rather than to repair. For the instance, the said reservoir may have the end of life, as opined by the engineer, for 50 years under the assumption of frequent maintenance basis. However, it is well-known that this reservoir may benefit only for 10 years. Also the benefit in the last year shall be regarded as Scrap value of the remnant from the project which is, to some extent, likely usable. Therefore, to determine the Economic life shall consider based on condition, maintenance and sources from other relevant projects. Moreover, the Economic life, in practical, will be determined approximately not exceeding than 30 years because either cost or any benefits taken place after 30 years calculated by the discount rate at 5% will be regarded as a few value.

For determining certain projects, the decision maker only wishes to know whether the project will lead to the acceptable economic result. NPV plays a significant role to help the decision maker's determination as follow; if the value of NPV is more zero, it means that the project is fruitful and acceptable for economy. But if not, the project is unacceptable. However, there is a chance where the value of NPV is equal to zero and it means that either approval or dismissal the project will not affect the economic system.

If such economic system has a lot of capital, it shall proceed all projects that the value of NPV is more than zero so that the economic system shall gain the maximum net profit gain. In contrast where the economic system has limited resources, the decision maker shall have to consider the project selection among projects which are independent. This selection concentrates on management in limited resources and prioritizes the best social based projects. Priority is inevitable while applying NPV is unlikely useful for assisting project priority. The example in Table 2.3 may clarify well why we cannot apply NPV to prioritize the projects.

Table 2.3: Show project ranking by descending NPV

Project	PV(C)	PV(B)	NPV	Rank
X	100	200	100	1
Y	50	110	60	3
Z	50	120	70	2

If we prioritize the projects based on NPV, we will prioritize projects X Z and Y respectively. Assuming the economic system has limited recourses only 100 units, it means that society is not capable of implementing all those projects despite the fact that their NPV values are higher than zero. It is, therefore, acceptable for implementing some prioritized projects which is, in this scenario, the X project only. However it is clear that the combination between Y and Z project will gain the value of NPV more than the X project under the same amount capital put down. This is why applying NPV to prioritize the projects is not recognized for project priority.

In case we need to select among the projects regarded as mutually exclusive, the decision maker may adhere the general principle that go for the maximum NPV's value. In addition, it must be based on the condition that the selected project is completely mutually exclusive; namely, the X and Y are the choices to select which is able to meet satisfaction. They are, however, often synergy. As such, the choices would not be limited only X and Y but (3/4) X+1/2(Y) etc. After we get more choices, then determine which choice will be the highest value of NPV.

However, there are many study of PACS cost-benefit analysis focus on cost only, thus NPV formula could be applied as follow;

$$\boldsymbol{NPV} = \sum_{\boldsymbol{t=0}}^{\boldsymbol{n}} \frac{C_t}{(1+r)^t}$$

When

C_t = the value of the costs of the project that occurred in the year *t*.

r = discount rate

n = life of the project or the end of the project.

The NPV in this case, a project which has the lowest cost would be selected to invest[2].

2. Internal Rate of Return : IRR

The Internal Rate of Return: IRR is the maximum rate of interest (or the discount rate) that the project could pay for certain resources and once it is paid up, the benefit of the project is still equal to the cost of the project. IRR shall be calculated by seeking the discount rate that could equate between the present value of cost and the present value of benefit or alternatively follow this equation as follow;

$$\sum_{t=0}^{n} \frac{C_t}{(1+i)^t} = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t}$$

or

$$\boldsymbol{NPV} = \sum_{\boldsymbol{t=0}}^{\boldsymbol{n}} \frac{B_t - C_t}{(1+i)^t} = \mathbf{0}$$

When

B_t = the value of the benefits of the project that occurred in the year *t*.

C_t = the value of the costs of the project that occurred in the year *t*.

i = internal rate of return

n = life of the project or the end of the project

In order to seek the value of *i*, it shall need to calculate by ongoing change of the *i* value. The *i* value could substitute the above equation; for instance, assumingly that i is equal to 0.05 or 5% and if either the value of PV(C) is less than PV (B) in the 1st equation or the value of NPV is more than zero in the 2nd equation, it means that the applicable value of *i* is too low and it is needed to substitute with the high value of *i* continuously until the value of *i* that could affect the value of NPV closer to zero maximally. According to the scenario, if we substitute *i* as 8%, the value of NPV is still positive closer to zero while it is negative when the value of *i* is 9%. So we could

find out that the rate of *i* value that could affect the value of NPV closer to zero maximally is between 8% and 9% by applying the rule of three.

Once we know the IRR in any projects, the decision to approve or dismiss the projects will be based on the value of *i* compared with the discount rate (*r*). As mentioned previously, *r* is the rate of return or the minimum rate of remedy that is acceptable for society to suspend the present consumption. Moreover *r* is needed to be calculated in order to know the value of NPV. Any projects where there is *i* value more than *r* value will be regarded as acceptable project because the rate of return of the project is more than the minimum rate of remedy that is acceptable for society. As such, the society would increase its satisfaction. Note that the projects will be vice versa if the rate of return of the project is so low that the society could accept.

In order to determine any projects if the economic result is acceptable. It is needed to consider IRR which is always applicable method adopted by the World Bank and the international financial institutions. Although it is well-known to apply for prioritizing among the projects either independent or non-independent project, there is several weaknesses as follows;

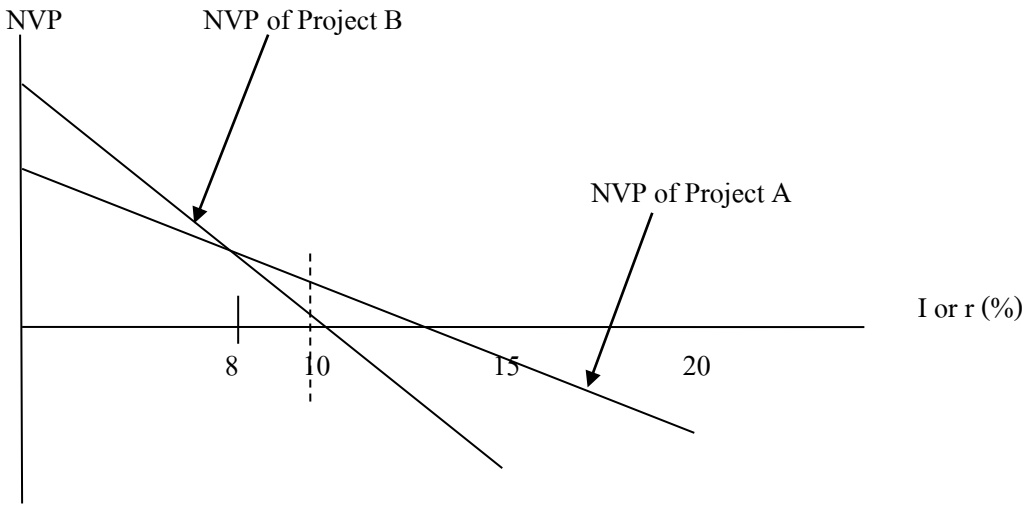
1. The rate of return within certain projects may be gained more than one value. According to the IRR formula, it is seemed to be as polynomial; then, it is likely that the *i* value could not only affect the value of NPV as equivalent as 0 but also could gain more than one value. In case where the value could be gained more than one value, which values shall be applied for determination although all values are acceptable value for prioritizing projects.

Note that those who regard IRR is preferable formula rebut that the *i* value could be gained more than one value when the net benefit of the project ($B_t - C_t$), since the beginning of the project until the end, It is possible that it has been changed between positive and negative value more than one time. The value of $B_t - C_t$ is, in fact, always subtractive in the beginning of the project because the benefit does not exist but investment. Once the period of investment has been passed, the value of $B_t - C_t$ will be additive and ongoing until the end of project. This change is just only happened one time. If the *i* value shall gain more than one value, it means that the value is rebounded to be subtractive again. This rebound could happen when

the capital of the project is quite massive budget periodically. For the example, the irrigative project with the water pump which its life will be longed for certain years; say 5 years. Once it is needed to replace the expired pump, the cost of the project will be added from time to time. In same issue, a PACS system, this system is related to medical radiation image, the almost system consisting of computer system and electrical tool which its life will be longed for certain years; 5 years or 10 years. It is also needed to replace the expired equipments. Although this case is rare to happen, this is regarded as the weakness of IRR for determination.

2. The internal rate of return is highly sensitive with the cost and the benefit of the project. If there are any comparisons between the independent projects with the different economic lives determined by the IRR value, the short-life project or the projects that the benefit are existed at the beginning are more favorable indicated by the IRR value while the IRR value in the long-life projects or the gestation period projects is lower. Note that the high value of IRR shall not mean it is always better than the other. This issue can be clarified by the picture below.

Figure 2.1: Graph demonstrate NPV of project A compared with project B



Suppose the vertical graph represents the present value of net benifit while the horizontal represent the discount rate. The graph A will represent a change of NPV form the project A when the discount rate is changed while the graph B will represent

a change of NPV from the project B when the discount rate is change at different level of rates. Note that project A and B can be either independent project or mutually exclusive project where the size of investment is equal. the difference between both A and B graphs is based on the different timing where the cost and benefit are existed. It can forsee that if the applied discount rate for NPV appraisement is lower than 10%, the value of NPV of the project B will be higher than the project A meaning that the project B provide profit gain more than the project A. In contrast, the project A is better than the project B if the applied discount rate is higher than 10%.

According to the IRR appraisement, IRR is the maximum rate of discount that could affect the value of NPV as equate to 0. The IRR from the project A is, as shown in the picture, equal to 0.2 or 20% while the project B is equal to 0.15 or 15%. At this stage we still cannot conclude immediately that the project A is better than the project B.

It is important to bear on mind that the IRR appraisement cannot be applied alone for determination. It is needed to compare with the social discount rate as well. The social discount rate will be the key to determine which projects are acceptable or dismissal. If the social discount rate is assumable equal to 0.08 or 8% per annum, the economic outcome of both project A and B in the previous chart are acceptable. And if the decision maker has to select between both projects based on this rate of social discount, the value of NPV in the project B is more than the project A. This could affect the project priority which is totally different compared and determined the IRR appraisement alone. As a result, we cannot ensure that the IRR appraisement alone can fulfill the society's goal maximally as target.

Determination based on the IRR seems to be simple for the analyst at the beginning because the analyst does not even try to seek and apply the social discount rate for appraisement like NPV appraisement or any other measures that is going to mention later on. Although it is simple at the beginning, at the end the anylyst still needs to analyze if the projects are acceptable. The social discount rate is, therefore, inevitable for determination. Moreover, IRR is roughly regarded as the well helpful tool for selection or project priority even though it may be not really satisfaction when

it is needed to determine profoundly. That is why, as mentioned above, the IRR is not acceptable tool for selection or project priority.

3. Benefit – Cost Ratio: B/C

B/C means the ratio between the present value of benefit and the present value of the whole cost as represented in the following formula;

$$\frac{B}{C} = \frac{B_0 + \frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + \ldots + \frac{B_n}{(1+r)^n}}{C_0 + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^n}}$$

The project, which is acceptable under this approach, is the project has a present value of benefits over costs. That is the value of B/C is greater than one.

This formula is well known and extensively applied in the U.S. because it used to apply the beginning phase of water resource project for appraisement and project priority. The value after calculation is the present value of benefit per 1 baht of the present value of cost. This eliminates the comparison of the different sizes of projects where it is regarded as challenges for applying NPV. However this famous trend is strating to way down because the minuend is the present value of the benefit before discounting the cost while what we are interested is the net benefit rather than the benefit prior to the cost discount. Moreover, the divisor is the whole cost including the cost at the beginning phase of the project and the cost of maintenances and other services. The underlying necessity of project priority is because of the limitation in investment significantly. Therefore, the divisor shall be the cost, in term of investment, at the beginning only excluding the cost of maintenances and other services.

Furthermore, the another significant weakness of this formula is able to lead to the practical problem; namely, the analyst has no idea which item shall either take side in the part of benefit or subtract in the part of cost instead. For the examples, the new road could reduce the cost of the old style traffic. The decreasing cost is a result of the new road. Then, should this cost be added together with the other benefits due

to the new road or deducted from the cost of the new road? Alternatively, the cost and the benefit appraisement from the agricultural project, the cost of dam construction, the cost of maintenance and the cost of implementation will be listed down as the cost of the project. Should, the cost of agricultural plantation in the project area be, however, either added in this cost and combined the net value of agricultural products in the part of benefit or deducted from the value of product first until the net profit is extracted and added in the part of benefit later on? These above case studies are not problems if we apply the NPV or IRR formulas because either way can get the similar value of $B_t - C_t$. However, taking side in the part of benefit or subtracting in the part of cost would affect the value of B/C. Thus, this could be hesitant for determination. In the worse case, if the analysts are needed to compare between the independent projects which are different and analyzed with different team, the practical analysis would be ambiguous and dissimilar. This is why it cannot be comparable.

As seen, the B/C is way down to apply for selection or project priority due to the failure of the formula itself and other reasons; it is, therefore, necessary to adjust for the new acceptable formula.

4. Net Benefit Investment Ratio: N/K.

N/K means the ratio between the present value of the net benefit (subtracting the cost) per the present value of the investment cost as represented in the following formula;

$$\frac{N}{K} = \frac{\frac{B_t - C_t}{(1+r)^t} + \frac{B_{t+1} - C_{t+1}}{(1+r)^{t+1}} + \ldots + \frac{B_n - C_n}{(1+r)^n}}{K}$$

When

N represents the present value of the net profit calculated at the year of t which is the starting year of benefits gain and the end of the cost of investment. Therefore, the value of $C_1,\ldots,C_n$ shall combine only the cost existed annually such as the repairing cost, management cost, etc.

K represents the present value of resources used for investment which exists at the beginning phase of the project, say 1-5 years. In addition, it depends on category and size of the project.

The value of N/K representing the net benefit per 1 baht of the investment cost shall be an acceptable economic result once its value is more than or equal to 1.

The outstanding formula is to enable to prioritize many independent projects. This formula, nowadays, is the only one that is acceptable for independent project priority due to the adjustment based on the 3 formulas above. It was created for strengthening the weakness of each formulas, the inappropriateness of project priority in particular. To clarify, the NPV formula cannot apply for project priority because of several different sizes of projects. Applying NPV formula in the small project is clearly unfair for comparison while applying N/K is to resize for equal comparison which is the value of the net benefit per capital 1 baht. The significant weakness of B/C formula is that B is the benefit before discounting the cost. In practical will, however, be problematic which item shall be added for the benefit or deducted for the cost. Fortunately, N/K could resolve this problem by net benefit calculation. Moreover, N/K is a formula that could calculate the present value at the social discount rate for project priority or comparison. Repeatedly, the formula is useful for project priority based on applying the social discount rate which is better than prioritized by IRR formula

From such information, we can conclude and compare the measures as shown in the table below. This table has categorized the priority of the project under the 3 circumstances which are the independent project with infinite budget, the independent project with a limited budget and mutually exclusive projects.

Table 2.4: summarize the comparison between the criteria on assessing the project which alter the timing

List	NPV	IRR	B/C	N/K
1. selection or priority of the project:				
(a) Independent project:				
1 infinite budget	NPV>0 non priority	IRR>1 non priority	B/C>1 non priority	N/K>1 non priority
2 limited budget	Not appropriate to priority	Is likely to priority incorrectly	Is likely to priority incorrectly	Is for prioritizing the project until the budget is run out
(b) Mutually exclusive projects	Select the project whose has the maximum of the value of NPV	Is likely to get the result incorrectly	Is likely to get the result incorrectly	Generally do not apply directly
2. Discount rate	Inappropriate discount rate setting	Set the cost of opportunity loss in order to apply cut off rate	Appropriate discount rate setting	Appropriate discount rate setting

The table 2.4 shows the comparison between the criteria on assessing the project which alter the timing. If the project is independent and has no limit of budget, the four criteria can be applied for selection or denial. However, in the case of limited budget, the appropriate measure for prioritizing the project is N/K ratio while mutually exclusive projects shall apply NPV for prioritizing appropriately and correctly.

However, almost study of PACS cost-benefit analysis focus on cost, NPV interpretation what worth project for investment has to sort NPV by ascending order. The lowest NPV of any project would be interpreted that this project should be recommended to investment [1, 2, 7, 8, 12, 15].

Part 2.4: Cost and benefit category of project assessment

Costs [11, 20, 21]

Cost category of project means the value of the factors of production or resources used in the project which is the whole amount of money paid up for supplying the factors of production.

Direct cost means the cost directs to the system or the project for processing such as in the PACS and film-based system systems. The direct cost composes of any resources which are such as capital cost, operating cost and maintenance cost.

Indirect cost means the cost arisen outside the system or the project and regarded as unintentional cost. The estimation of the indirect cost is approximately 10-30% of the beginning investment per year. [2, 9].

Cost in accordance with the economic notion differs from the business cost. The business cost means any cost paid by monetary in actual while the economics cost have a wider definition and scope; namely, apart from the business cost, it shall include unclear and non monetary paid. For the instance, the owner of the project take pleasure using his/her workplace and workforce without paid for the rent and labor. To clarify, the business cost will not cover these costs while they are needed to include for calculating the economics cost as an actual cost of the project because they are deemed as resources or factors of production which can be usable in any project.

Moreover, the economics cost may include the indirect costs due to the post project which are such as electricity bill, water bill, personnel training, the cost of the electricity lamp for the film viewing box, the cost of CD for the patient when needs to relocate to other hospitals. Such indirect costs shall be deemed as the cost of the project as similar as the direct cost

The cost of the project composes of the explicit cost and actual pay in the form of cash and the implicit cost or pay in the form of non cash. The economics cost is then wider meaning that that is the whole cost of the project regardless the indirect or direct cost and pay with cash.

The cost of the project shall be divided as 2 features which are tangible costs which is able to value; and intangible costs which is unable to value or appraisal. However, the latter is the cost actually existed by the system such as the comfort and satisfaction. Therefore the solution is to identify what certain projects or systems are

unable to value without calculation so that those who have power to make a decision can know such results. [21].

The cost of the project is the resources and service management in certain kinds needed to add or use for production which is the medical images. In order to identify completely the costs from the PACS and film-based system, the division of cost category, i.e. direct cost and indirect cost, may be helpful for the analyst to collect all certain costs comprehensively.

What kind of resources should be used for the direct cost until the analytic year end shall be gained the data from preparatory team and study the possibility of the project in advance or work in association with all the relevant technical teams for processing. Alternatively, in the case where the said budget for running the capital, operation and maintenance have been made, we may take this as a base in identifying the cost of the project in each year.

In order to select the costs for analyzing, we will integrate only the costs arisen in certain projects or systems. Especially any other costs in the past shall not be integrated for analysis. These costs in the part is called ―sunk cost" which means the resources used for any kind of activities in the past (before assessment) and such resources cannot be renewed. Therefore, they do not relate to the decision making in the present. This issue should bear in mind when the cost of the project needs to clarify, the expanding or developing projects in particular. For the example, the cost of darkroom for film processing with the film-base system will not integrate the previous cost from the beginning of the room building as a cost for analysis. Once the analysis of the cost by the PACS system is made and has compared with the film-based system, we will find that the store area for the film is the sunk cost. The devices are needed to consider since when they are bought and how much the cost still remains in the present; then, we can add them for analysis. [1, 2].

Furthermore, there are costs which are not the economics cost. They shall not be added for analysis such as tax, the loan's interest and depreciation because tax and the loan's interest are just to transfer the money from the project to the government or the creditors respectively while the depreciation is just the accounting method. In case of annual depreciation, it actually seems to be repeated integration because the cost of hard ware is counted as the cost of the system at the beginning of system purchase.

Benefits

Direct benefit means the aimed benefit or goals of the projects or systems. Hence, the direct benefit of the PACS are the film cost saving and labor cost saving. These are the direct benefit of the project which is not only based on financial benefit.

Indirect benefit means the benefit which is not arisen directly from the systems or the projects; then, in the PACS system, the indirect benefits consist in the income based on the increasing store area for the film due to the non storage, the rate of decreasing film loss and the rate of film loss due to the decreasing printing process [4, 5, 11, 20, 21].

Part 2.5: Cost items of PACS and film-based system

The cost item of PACS and film-based system was collected from studying work process and interviewing head of radiology department and radiology technician from two practice setting are Ubonratchathani Cancer Hospital and Prasat Neurological Institute, and from reviewing both domestic and international literatures. There was a different of cost item depending on analyzed hospitals.

Cost items of PACS

The cost items of any PACS system comprise of the image acquisition equipments, a system for storage and retrieval of data, workstations for the display and interpretation of medical images, and a computer networking system over which to transmit information.

Modality clusters was not taken into account for every study, because film-based system need to use these items like PACS. Whether for CT, MRI, nuclear medicine, and sonography, typically are homogeneous groupings of equipment connected to share printing, soft copy viewing and storage resources.

From information of several study, cost items have different depend on environment of each hospitals whether PACS or film-based system. The main cost items usually found in each study comprised of work station and hardware, software, server, storage (whether redundant array of independent disk or optic disk etc.), networking system, maintenance, IT staff, and general staff. Moreover, some studies

also included CR, CR cassettes, web server and licenses, electricity of running PACS, data network rent and space for archive also[1, 2, 7, 12, 15, 16, 18]. These costs are direct cost of PACS. Indirect cost usually was neglected to take in to account in cost analyzing [5, 23]. De Backer found that estimation of the indirect cost is approximately 10-30% of the beginning investment per year [9]. Therefore, indirect costs, whether PACS or film-based system, would be include in this study.

Cost items of film-based system

The main cost items of film-based system comprised of film, film processors, film printer, film envelope, viewboxes, office tool, maintenance, developer, electricity, space of operating system and personnel[1, 2, 7, 12, 15, 16, 18]. Maass et al. categorized personnel into four types are darkroom technologists, file room secretaries, office secretaries, and digital archive personnel[15].

In addition, some study also include paper-related expense, multiformat cameras, alternators, quality control devices, folder, and teaching files, film jackets, and disposal of waste. These cost items has difference items depend on environment of each hospitals.

Part 2.6: Related PACS cost analysis study

This study reviewed domestic and international literatures to collect cost items, assumptions of PACS and film-based system. Each literature was found that cost items and assumptions have the different depended on situation, environment or size of hospitals. Sizes of hospitals were found since 150 beds to 1,000 beds. The propose of these study is to analyze cost of PACS compared with other system, but the results of previous study showed inconsistent results.

A study by Fang et. al. aimed to analyze the differential cost between film-based system and a full-scale of PACS implemented all at once. The study was done in the 500-bed and 100 physicians public hospital in Taiwan. The radiology department performed 150,000 studies in 2002. There was a 10% annual increase in utilization of the radiology department between 1997 and 2002. There were 12 assumptions in this study comprised of 1) duration of study is an 8-year time horizon,

2) a discount rate of 3% is assumed, 3) the number of examined images increases by 5% per year, with 2002 as the reference year, 4) if PACS were not installed, the hospital would have to purchase three film processors at years 0, 4, and 8, 5) The PACS short-term storage holds one year of recent images, and the long-term images are stored in redundant array of independent disks (RAID) arrays, purchased annually according to the amount of image files, 6) backup tapes for disaster recovery are purchased constantly every year during the estimation period, 7) The annual maintenance cost of PACS is estimated at 5% of the initial purchase cost, 8) The hardware of PACS work stations used by clinicians and radiologists can last for four years and will be replaced in the fifth year, 9) The upgrade costs of software PACS are included in the maintenance cost, 10) Both CR and conventional film cassettes are replaced at a similar rate and similar prices; it is assumed that there is no significant price difference between them, 11) The concurrent web viewing for multi-users can cover the increasing demand for viewing images, 12) The price of computer-related hardware remains the same during the estimation period. The cash flow and running costs of film-based system and PACS were measured over an eight-year time horizon. When PACS was implemented over a short period, there was instant conversion into digital image and archives. The NPV for PACS is US $1,598,698, whereas the NPV for film-based system is US $2,083,856, indicating a net cost saving of US $485,157. The break even point, was measured by accumulated net present value (APV), is fourth years. The costs of CR and image plates account for 40% of the initial capital expenditure in PACS implementation, followed by computer hardware (30%) and software (9%) costs. The result shows that implementation of PACS all at once can produce cost savings[2].

Likewise, Van Gennip et. al. conducted two cost analysis to compare full PACS implementation to film-based system. These studies suggested that assumption should be comprised of 1) an interest rate of 3% (corrected for inflation) is assumed, 2) lifespan of 5 years and cost 5% of the purchase price per year on maintenance, 3) optical disk drives and jukeboxes have a lifespan of 5 years and cost 10% of the purchase price per year on maintenance, 4) All computer hardware prices are assumed to drop by 10% per year (corrected for inflation), with inaccuracy up and down leading to minimal 0% and maximal 15% price drop per year, 5) lightboxes and

alternators have a lifespan of 10 years and cost annually 5% of their purchase price on maintenance, 6) for all types of personnel an increase in wages of 2% per year is assumed (corrected for inflation), 7) for the expected time savings of all personnel an inaccuracy of ±25% is assumed, 8) film prices are assumed to increase by 2% per year (corrected for inflation). The results revealed that the extra costs of a hospital wide PACS would amount to 3.2% of the total hospital budget. it mean that PACS was worth investment and break even point was reached after 6^{th} year [7, 12].

Clouse et. al. analyzed cost of film-based and PACS and measured provider satisfaction. In this study, the annual operating cost of PACS for year 1 amount to US$ 2,485,924.80 and ranges from US$ 2,774,724.80 to US$ 1,812,861.80 for year 2 through 8. Whereas, the annual operating cost of film-based system is US$ 913,665.97. The result showed that film-based system was worth investment; however, economic analysis approach was not applied for this study [18].

MacDonald et. al. evaluated the Implementation of PACS. The setting for the study was the Western Health Authority which serves a population of approximately 80,000. The duration of this study is 6-year since 2003 to 2008. An inflation rate of 3% and depreciation cost of 15% for all hardware were assumed. The cost analysis results of this study were showed in term of cost/exams. The results found that cost of film-based system is lowest cost following by PACS. The highest cost system is partial PACS [1]

Maass et. al. conducted a cost analysis of film-based system, partial PACS, and full PACS in Turku University Central Hospital (TUCH) during 1998. Definition of full PACS in this study mean that 10% of film-based system was used in PACS also. All equipment items were assumed the life time of 10 years. The results showed that the cost of film-based system is the lowest cost following by full PACS. The highest cost system is partial PACS which is 21% increase of film-based system[15].

Alanen et. al. analyzed the costs of partial PACS and compared these costs with conventional analogue radiography using activity-based accounting (ABC). Assumptions of this study consisted of the maintenance and updating costs of programs used in the digital equipment were included in the annual operating costs. Acquisition costs were distributed over the period 1983-1993. The partial PACS, the CT scanner, and film-based system equipment were all purchased in 1993. The capital

investment depreciation was calculated in equal installments. The lifetime of all radiography machines was 15 years, except for the roentgen tubes for which it was 3 years. In the baseline calculations, the lifetime of the partial PACS was set at 10 years and the interest rate for invested capital was assumed as 0%. The result showed that partial PACS has total costs were 9% higher than those of film-based system. An interest rate of 4% and 8% resulted in a 12% and 15% difference between partial PACS and film-based system[8].

In Thailand, there was a study conducted by the Institute of Medical Research and Technology Assessment in two hospitals; Prasart Neurological Institute and Ubonratchathani Cancer Hospital. Partial PACS and film-based were existing system used in Neurological Institute and Cancer Hospital, respectively. In this study, assumptions comprised of 1) duration of study is an 9-year time horizon, 2) a discount rate of 3% is assumed, 3) lifetime of CR and computer hardware of 10 year and 5 year were assumed, respectively. The study found that PACS, in comparison with the existing system were worth investing. Investment for both hospitals could be returned within 2nd year [16].

CHAPTER III
METHODOLOGY

There are two objectives of this study which are; 1.) to develop economic cost model**s** for installment of PACS, partial PACS and film-based system, 2) to analyze cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals, and 3) to measure break even point of PACS of three size hospitals. Therefore, Material and method was divided into three parts according to the study objectives as follow;

Part 3.1: Development of economic cost models for installment of PACS, partial PACS and film-based system

Part 3.2: Analyzing cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals

Part 3.3: Measuring break even point of PACS of three size hospitals.

Part 3.1: Development of economic cost models for installment of PACS, partial PACS and film-based system

Study design

Cost-benefit analysis was applied as a study framework. Three economic models using provider's perspective for PACS, partial PACS and film-based system were developed in three size hospitals. Duration of assessment is a nine-year time horizon since 2012 to 2021.

Data collection

Cost items and assumptions used in three economic models were derived from studying work process and interviewing head of radiology department and radiology technician from two practice setting are Ubonratchathani Cancer Hospital and Prasat Neurological Institute, and from reviewing both domestic and international literatures. All cost items were categorized into two categories which are 1.) Direct costs consist of direct material cost and direct labor cost and, 2.) Indirect cost. Each cost items were considered whether it should be based on its assumption of use rate or price increasing or not by reviewing literatures and interviewing the head of radiology department. The results of this objective is economic cost model consist of cost item and assumptions. Economic cost model of small size hospital was developed from data of Ubonratchathani Cancer Hospital and economic cost model of medium size hospital was developed from data of Prasat Neurological Institute. For the part of economic cost model of large hospital, cost item and assumption was assumed like medium size hospital. At the end of process, economic cost model would be develop 3 model PACS, partial PACS และ film-based system for three size hospitals.

Part 3.2: Analyzing cost saving of installment of three systems by using data that represented large, medium, and small sized hospitals

Three economic models were tested by using data that representing three size hospitals; large, medium, and small to measure NPV and analyze differential cost to find what the system is economic worth to installment. Year zero for measuring NPV of this study is year 2012.

Data collection

Data collections in this part consist of data of utilization data and cost data of each cost item in economic cost models.

Utilization data; such as examination volume, number of imaging devices and radiographic imaging convention equipments, number of personnel, and the numbers of workstations, came from Institute of Medical Research and Technology Assessment study. Data from Ubonratchathani Cancer Hospital and Prasat Neurological Institute represented small and medium size hospital, respectively. Utilization data for a large size hospital was set as twice the medium size hospital[16].

Cost data came from various sources such as studies done by Institute of Medical Research and Technology Assessment[16], medical equipment items and price list 2012 [24], drug price and co-medical supplies price survey 2009 and 2013[25, 26], Mahasarakam hospital's term of reference document[27]. Costs were varied by specification and quality of product, purchasing volume and purchasing year. Thus, in this study, lowest cost for the same item specification was chosen.

Chosen cost data would be calculated and considered in conjunction with utilization data and their assumptions then would be filled out in economic cost model to analyze cost and cost saving.

Cost and cost saving analysis

Net Present Value

When the financial impact of a investment is assessed, after identification of all annual cost, in this study only cost would be analyzed thus, NPV is estimated according to the following formula:

$$\boldsymbol{NPV} = \sum_{\boldsymbol{t=0}}^{\boldsymbol{n}} \frac{C_t}{(1+r)^t}$$

where C_t is cost at time t,

r is the discount rate, and

N is the lifetime of the project

NPVs were calculated according to the discount rate of 3%. Then take the NPV of each system to sort ascending. NPV of what system is lowest value it means that the cost is use for that system as the amount is minimal. The model that provided lowest cost would be recommended for hospital[2].

Differential cost analysis

This analysis approach was used for decision making after calculation NPV. The out come of this approach is cost saving of two compared systems which cost saving are in term of NPV. The calculated value from differential cost analysis could be both of negative or positive value depending on setting denomination and subtrahend. Cost savings of two compared systems for each size hospital were PACS – film-based system, PACS - partial PACS, and partial PACS – film-based system [1, 2, 11].

Part 3.3: Measuring break even point of PACS of three size hospitals.

Measurement break even point of this study is compartment APV of PACS with another system whether partial PACS or film-based system in duration year 2012-2021. The lower cost system was chosen to compare with PACS, which would be known after analyzing NPV.

Accumulated present value

Accumulated present value was used to specify when hospital will regain from investment by using below formula[2];

$$\boldsymbol{AVP} = \sum_{\boldsymbol{i=0}}^{\boldsymbol{n}} (\boldsymbol{PVL_i} - \boldsymbol{PVH_i})$$

$\boldsymbol{n}$ is the project lifetime

$\boldsymbol{PVL_i}$ is PV of lower initial investment system (year 0) at i^{th} year

$\boldsymbol{PVH_i}$ is PV of higher initial investment system (year 0) at i^{th} year

The payback period is the time when PACS produces cost savings compared with another system [2, 8, 11, 28-31].

Sensitivity analysis

Type of sensitivity analysis of this study is One-way Sensitivity Analysis. This approach will assess changed value of individual variable. Variable for sensitivity analysis in this study consists of 2 variables are initial purchase cost of PACS and film utilization rate.

Initial purchase cost was selected because it was one of the major cost for system implementation. Initial purchase cost items would be revealed after economic cost model developed NPVs were recalculated for initial purchase cost of PACS of 70%, 100% and 130%

Film utilization rate was another parameter selected for sensitivity analysis because it affected many cost items. In this study, film utilization rate not mean only item in film-based system, but include PACS cost item utilized increase depending on patient increase every year also such as CR cassette or number of film. Film utilization rate of 0%, 8% and 10%, to compare with the NPV for base-case assumption[2, 32].

The study (protocol number 13-33-010) was approved by the ethics committee of the Faculty of Pharmaceutical Sciences, Chulalongkorn University in March, 2013

CHAPTER IV

RESULTS

The result of this study is divided into four parts as follow;

Part 4.1: Economic cost models and assumptions of three systems

Part 4.2: NPVs and cost savings of installment of three systems by using data that represented large, medium, and small sized hospitals

Part 4.3: Break even point of PACS of three size hospitals

Part 4.4: Sensitivity analysis

Part 4.1: Economic cost models and assumptions of three systems

Studying work process and interviewing head of radiology department and radiology technician from two hospitals and reviewing domestic and international literatures, a set of cost items from provider's perspective and model assumption were proposed[1, 2, 7, 8, 12, 16, 18]. All cost items were evaluated and confirmed by two experienced radiologists. Table 4.1 summarizes cost structure of the 3 models; PACS, partial PACS, and film-based system.

General assumptions for three cost models were summarized as follows:

1. PACS lifetime:

   In previous studies, PACS lifetime were assumed differently e.g. five years in one study, eight years in two studies, nine years in two studies, and10 years in two studies[1, 2, 7, 8, 12, 16, 18]. Technology obsolete was raised as an important issue that affects PACS lifetime.

   For this study, two expert radiologists were consulted. Both of them unanimously selected nine years lifetime since year 2012 to 2021. This is because PACS was highly expensive and it was near impossible to re-invest a newer system in short time period. In addition, they both believed that an upgraded version may not provide significant change compared to huge investment.
2. Lifetime of PACS related hardware and CR reader:

   Most of PACS related hardware (e.g. workstations for radiologists, workstations for clinicians, and severs) were assumed to have four years lifetime. These items were assumed to be replaced in 5^{th} year. Only CR item was assumed to have nine years lifetime and replaced in 10^{th} year. Depreciation rate was applied for all items according to lifetime assumption[33].

Table 4.1: Cost structure for PACS, partial PACS and film-based models

Cost structure	PACS	Partial PACS	Film
Direct cost			
A) Direct material cost			
1. Computed radiography (CR)	✓	✓	
2. CR cassettes	✓	✓	
3. Server	✓	✓	
4. Diagnostic viewing station	✓	✓	
5. Result viewing station	✓	✓	
6. PACS and RIS software	✓	✓	
7. Redundant array of independent disks (RAID)	✓	✓	
8. Network	✓	✓	
9. Electricity for running PACS (e.g. sever and viewing stations, etc)	✓	✓	
10. PACS maintenance cost	✓	✓	
11. Film		✓	✓
12. Film cassettes with screen			✓
13. Film processor		✓	✓
14. Film printer		✓	✓
15. Film envelope		✓	✓
16. Color sticker		✓	✓
17. Office tool of film-based system		✓	✓
18. Film processor's maintenance cost		✓	✓
19. Film printer's maintenance cost		✓	✓
20. Film developer		✓	✓
21. Film storage room		✓	✓
22. Film print process room		✓	✓
23. Electricity for film printer and film processor		✓	✓
B) Direct labor cost	✓	✓	✓
Indirect cost			
1. Electricity for things other than PACS or film-based system			
1.1 air-conditioner of server room	✓	✓	
1.2 air-conditioner of film storage room		✓	✓
1.3 film viewing lamp		✓	✓
2. Office tool of PACS	✓	✓	
3. CD to transfer medical image	✓	✓	
4. Lost film		✓	✓
5. Damaged film		✓	✓
6. Film viewing lamp		✓	✓

3. Financial value adjustment:

   Since the study assumed nine year lifetime, value of cost incurred during this time period should be adjusted. It was found that six studies took into account time value of money [1, 2, 7, 8, 12, 16]. Only one study did not adjust financial value[18]. Net Present Value (NPV) and 3% discount rate were frequently specified in previously studies [2, 7, 11, 12, 16, 29]. For this particular study, NPV and 3% discount rate was assumed.

4. Film utilization rate:

   Statistics from Cluster for Health Information Development showed that service utilization rate increased approximately 8% annually[32]. CR cassette, storage, PACS related office supply, film, film cassettes, film envelope, colored sticker, office tool of film-based system were adjusted annually base on 8% film utilization rate.

Other than general assumptions, some cost items have their specific assumptions as follows;

1. Software upgrading is assumed to be included in maintenance cost [2, 16].
2. PACS maintenance cost is assumed to be 8% of initial purchase cost (given that initial purchase cost are sum of direct cost item number 1 to 8) [2, 16].
3. Film price was assumed to increase approximately 2% per year (price of other items is defined as a constant during the estimate period) [12].
4. Film processor's maintenance is assumed to be estimated at 5% of the initial purchase cost[16].
5. Wage rate for all relevant personals is assumed to be estimated to increase 5% annually (based on government wage adjustment)[34].
6. Lost film and damaged film is assumed to be 1.5% and 1.7% of film cost each year [16].

Further assumption will be report and discuss in part 4.2.1.

Part 4.2: NPVs and cost savings of installment of three systems by using data that represented large, medium, and small sized hospitals

From the results of this study found that cost and qualification data of each cost items are difference depended on vender company and purchase department of each hospital. In order to know derivation approach of cost and qualification data that represented in developed cost model, this part will be divided into two sections as follows;

4.2.1 Derivation of cost data and qualification of each items that represented in developed cost model

4.2.2 Analyzing NPVs and cost savings of installment of three systems

4.2.1 Derivation of cost data and qualification of each cost items that represented in developed cost model

Cost data came from various sources such as studies done by Institute of Medical Research and Technology Assessment[16], medical equipment items and price list 2012 [24], drug price and co-medical supplies price survey 2009 and 2013[25, 26], Mahasarakam hospital's term of reference document[27]. Costs were varied by specification and quality of product, purchasing volume and purchasing year. Thus, in this study, lowest cost for the same item specification was chosen.

PACS cost model

Direct cost

Direct material cost

CR

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and medical equipment items and price list[16, 24]. The study found that CR has variety of pricing based on its specification. CR was selected price follow suggestion of radiology technician of Prasart Neurology Institute and term of reference for computed radiography and

diagnostic workstation of Mahasarakam hospital[27]. The price of multi-load CR and supported mammography is 2,700,000 baht.

CR cassette

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and medical equipment items and price list[16, 24]. The study found that CR cassette has variety of pricing based on its specification. CR cassette was selected price follow often used size is 14*17 inch. The price of cassette sizes is 35,000 baht. It was assumed that

- Each cassette could be used approximately 20,000 times
- Cassette would be purchase every year depend on film utilization rate
- The start number of study per year, start at 15,144 and 32,791 studies per year for small and medium hospital, respectively by 2012 as the reference year
- The start number of study per year of large hospital was assumed that as twice time of medium hospital is 65,582 studies per year

Image and database server

From the results of interviewing radiology technician of two size hospitals revealed that the price from the previous research was calculated using rate reserved for the future and depend on required option of each hospital. Therefore, this price was take into account follow previous study[16]. From verifying data found that price sever of small in previous study differ from medical equipment items and price list about 60,000 baht, but for medium hospital that differ quite dramatically[24]. For large hospital was assumed that this cost as twice time of medium hospital.

Diagnostic viewing station

From the results of interviewing radiology technician and suggestion of term of reference of Mahasarakam hospital suggested that qualification of diagnostic viewing station has to have two monitor and number of pixel not less than 3 million pixels[27]. From survey cost data found that 900,000 baht is the lowest price. The number of using diagnostic viewing station was assumed; based on study of Institute of Medical Research and Technology Assessment which depend on the number of

radiologist and had one public workstation. This cost for large hospital was assumed that as twice time of medium hospital [16, 24].

Result viewing station

From the results of interviewing radiology technician and suggestion of term of reference of Mahasarakam hospital suggested that qualification of result viewing station has to have two monitor and not less than 23 inches 2 million pixels[27].The lowest price is 39,000 baht. The number of using result viewing station was assumed based on study of Institute of Medical Research and Technology Assessment which depend on the number of radiologist. This cost for large hospital was assumed that as twice time of medium hospital [16, 24].

PACS and RIS software

Form verifying data found that the price of software is difference because this cost is depending on the number of studies and radiologists of each hospital. This price was assumed based on; cost data of medical equipment items and price list; and number of studies and radiologists of study of Institute of Medical Research and Technology Assessment. At 2012, the small and medium hospital have; 15,144 and 32,791 studies per year; and three and seven diagnostic workstation, therefore price of software for small hospital and medium hospital are 3,000,000 and 3,500,000 baht, respectively. This cost for large hospitals was assumed equal as medium hospital [16, 24].

Redundant array of independent disks (RAID)

From result of previous study found that RAID was purchased annually according to the amount of image files[2]. It was assumed that;

- The started number of memory unit per year, start at 150 and 1,155 GB per year for small and medium hospital, respectively by 2012 as the reference year[16].
- The start number of memory unit per year of large hospital was assumed that as twice time of medium hospital is 8,894 GB per year

Network

From interviewing vender company and radiology technician found that this cost has to assess at real situation of each hospital. Therefore, this price was take into account follow previous study[16]. This cost for large hospital was assumed that as twice time of medium hospital.

Electricity charge of database sever and all viewing stations

This cost was derived from calculation formula each equipment as follow[35];

$$\text{unit} = \frac{\text{Watt} \times \text{No.of equipment} \times \text{No.of use hour in 1 day}}{1000} \quad (1)$$

Electricity charge for 1 year (not include vat) = unit x Float time (FT) x 365 (2)

Finally, Vat 7% was added in (2).

Maintenance cost

This cost was derived form reviewing literature and interviewing radiology technician. It found that the annual maintenance cost of PACS and partial PACS is estimated at 8% of the initial purchase cost (initial purchase costs are direct cost item number 1 to 8)[2, 16].

Direct labor cost

From studying real work process of acquisition medical image and interviewing of two hospitals and reviewing literature. The result found that labor cost of PACS consists of receptionist, information technology staff. This cost was assumed that the wage rate for all type personal an increase is estimated at 5% per year and the number of the radiologist and radiology technician is not foreseen to change, and therefore these personnel costs were not taken into account. This cost for large hospital was assumed that as twice time of medium hospital [2, 12, 15, 16].

Indirect cost

Electricity charge of air-conditioner of server room

This cost data was derived from average data of previous study due to each size hospital have only two air-conditioner in equal area[16].

Office tool of PACS, CD charge for moving patients to another hospital

This cost data was derived from previous study. Every cost in this section depended on film utilization rate of 8% per year. Except CD charge used constant cost due to CD would be provide in case of only moving patients to another hospital[16].

Film-Based Cost Model

Direct cost

Direct material cost

Film

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and drug price and co-medical supplies price survey 2013[16, 26]. The study found that film has variety of pricing and size. Film was selected price follow often used size is 14*17 inch. The lowest price of a film is 29 baht. The start cost of film was start at 1,091,590 and 4,539,443 baht per year for small and medium hospital, respectively by 2012 as the reference year. The start cost of film of large hospital was assumed that as twice time of medium hospital is 9,078,886 baht per year[16].

Film cassettes with screen

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and drug price and co-medical supplies price survey 2009 [16, 25]. The study found that film cassettes with screen have variety of pricing based on its specification. Film cassettes with screen was selected price follow often used size is 14*17 inch. The price of cassette sizes is 13,500 baht. It was assumed that

- Each cassette could be used approximately 20,000 times

- Cassette would be purchase every year depend on film utilization rate
- The start number of study per year, start at 15,144 and 32,791 studies per year for small and medium hospital, respectively by 2012 as the reference year
- The start number of study per year of large hospital was assumed that as twice time of medium hospital is 65,582 studies per year

Film processor

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and medical equipment items and price list. This cost was found only in small size hospital in study of Institute of Medical Research and Technology Assessment. Verifying cost data found that film processor have variety of price and size. The medium size and lowest price was selected that has price is 450,000 baht. Number of film processor is two equal as requirement of small hospital of previous study [16, 24]. It was assumed that

- The lifetime of film processor was assumed to have four years lifetime. The hospital would have to purchase film processors, if PACS were not installed completely, at years 0 and 5.
- The price of film processor remains the same during the estimation period.

Film processor's maintenance

From research data of Institute of Medical Research and Technology Assessment found that this cost was estimated about 5% per year.

Film printer

From cost and qualification data was found in two sources; research of Institute of Medical Research and Technology Assessment and medical equipment items and price list. This cost was found in both size of small and medium size hospital in study of Institute of Medical Research and Technology Assessment. Verifying cost data found that film printer have variety of price and size. The medium

size and lowest price was selected that has price is 900,000 baht. Number of film printer is one and three machine equal as requirement of small and medium size hospital of previous study, respectively [16, 24]. This cost for large hospital was assumed that as twice time of medium hospital. It was assumed that

- The lifetime of film printer was assumed to have four years lifetime. The hospital would have to purchase film printer, if PACS were not installed completely, at years 0 and 5.
- The price of film printer remains the same during the estimation period.

Film printer's maintenance

From research data of Institute of Medical Research and Technology Assessment found that this cost was estimated about 5% per year.

Film envelope, Color sticker and Office tool of film-based system

This cost data was derived from data at the zero- year of previous study, cost of next year in this study depend on film utilization rate. This cost for large hospital was assumed that as twice time of medium hospital[16].

Film developer and Electricity charge of film printer and film processor

This cost data was derived from data of previous study. The result from reviewing found that film developer and electricity charge of film processor was found only in small size hospital[16]

Film storage room and Film print process room

From interviewing radiology to assess cost of film storage room found that have 72 m^2 and 36 m^2 of small and medium size hospital, respectively.

In part of film print process room of small and medium size hospital was found that has film processors and film printer have same amount in same amount area is 12 m^2.

It was made profit proximally 1,000 baht/ m^2/year. These cost for large hospital was assumed that as twice time of medium hospital[16].

Direct labor cost

From studying real work process of acquisition medical image and interviewing of two hospitals and reviewing literature. The result found that labor cost of film-based system consists of receptionist, film room personnel, film carrier. This cost was assumed that the wage rate for all type personal an increase is estimated at 5% per year and the number of the radiologist and radiology technician is not foreseen to change, and therefore these personnel costs were not taken into account. This cost for large hospital was assumed that as twice time of medium hospital [2, 12, 15, 16].

Indirect cost

Electricity charge of air-conditioner of film storage room and lamp for the film viewing box

These cost data was derived from previous study. This cost for large hospital was assumed that as twice time of medium hospital[16].

Lost film and Damaged film

These cost were derived from previous study. Lost film and damaged film was assumed to be 1.5% and 1.7% of film cost each year, respectively [16].

Lamp for the film viewing box

This cost data was derived from previous study. This cost depends on lifetime of lamp. This study assumed lifetime of Lamp for the film viewing box about 20,000 hour per 1 lamp[16].

Partial-PACS Cost Model

From cost data of research of Institute of Medical Research and Technology Assessment found that all cost data of partial PACS is not differs from PACS and film-based system. In this study assumed that partial PACS are 100% film-based system and 50% of diagnostic viewing station and result viewing station of PACS system. Note that reducing number of work station if there is a fraction would be round up to the integer.

4.2.2 Analyzing NPVs and cost savings of installment of three systems

Three developed models; film-based vs. partial PACS vs. PACS, were tested using data that represented small, medium and large size hospitals. In this result section consist of 2 sections are 4.2.2.1) the result analyzing NPV and 4.2.2.2) the result of analyzing cost savings of installment of three systems

4.2.2.1 The result of analyzing NPV

Information from Table 4.2, Table 4.3, and Table 4.4 showed that initial capital expenditure at year zero for PACS, film-based system, and partial PACS were 14.03, 3.94, and 16.32 million baht for small size hospital, respectively. For all system, there would be a cost surge in 5^{th} year as many items; e.g. server and workstation related hardware for PACS and film processor and film printer for film-based system, needed to be replaced. NPV for PACS and film-based system were 34.16 and 29.73 million baht, thus NPV for partial PACS was 58.51 million baht. All systems of small size hospital were sort NPV in ascending order is film-based system < PACS < partial PACS.

The NPV results of PACS, film-based system and partial PACS for medium size hospitals was show in Table 4.5, Table 4.6, and Table 4.7, respectively. The study result showed that initial capital expenditure at zero years for PACS, film-based system, and partial PACS were 25.47, 9.05, and 30.06 million baht for medium size hospital, respectively. All system, there would be a cost surge in 5^{th} year as many items; e.g. server and workstation related hardware for PACS and film processor and film printer for film-based system, needed to be replaced. NPV for PACS and film-

based system were 64.18 and 88.70 million baht, thus NPV for partial PACS was 140.13 million baht. All systems of medium size hospital were sort NPV in ascending order is PACS < film-based system < partial PACS

For large size hospital, the NPV results of PACS, film-based system, and partial PACS were showed in Table 4.8, Table 4.9, and Table 4.10. Information showed that initial capital expenditure at zero years for PACS, film-based system and partial PACS were 45.86, 18.10, and 55.08 million baht for large size hospital, respectively. For all systems, there would be a cost surge in 5^{th} year as many items; e.g. server and workstation related hardware for PACS and film processor and film printer for film-based system, needed to be replaced. NPV for PACS and film-based system were 117.16 and 177.40 million baht, thus NPV for partial PACS was 269.47 million baht. All systems of large size hospital were sort NPV in ascending order is PACS < film-based system < partial PACS.

Table 4. 2: Cost of implement PACS assume nine years lifetime of small hospital

Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct material cost										
1. CR (1)	2,700,000									
2. CR cassettes	26,502	28,622	30,912	33,385	36,056	38,940	42,055	45,420	49,053	52,978
3. Server (2)	1,300,000					1,300,000				
4. Diagnostic viewing station (3)	2,700,000					2,700,000				
5. Result viewing station (24)	936,000					936,000				
6. PACS and RIS software	3,000,000									
7. RAID	26,650	28,782	31,085	33,571	36,257	39,158	42,290	45,673	49,327	53,273
8. Networking system	1,500,000									
9. Electricity for running PACS (e.g.sever and viewing stations, etc)	427,521	427,521	427,521	427,521	427,521	427,521	427,521	427,521	427,521	427,521
10. PACS maintenance cost	975,132	975,132	975,132	975,132	975,132	975,132	975,132	975,132	975,132	975,132
Direct labor cost										
1. Information technology staff (1)	300,000	315,000	330,750	347,288	364,652	382,884	402,029	422,130	443,237	465,398
2. Receptionist (1)	112,620	118,251	124,164	130,372	136,890	143,735	150,922	158,468	166,391	174,711
Indirect cost										
1. Electricity for things other than PACS										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
2. Office tool of PACS	3,650	3,942	4,257	4,598	4,966	5,363	5,792	6,255	6,756	7,296
3. CD to transfer medical image	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Annual Cost	14,034,315	1,923,490	1,950,061	1,978,107	2,007,714	6,974,973	2,071,981	2,106,840	2,143,657	2,182,550
Present Value	14,034,315	1,867,466	1,838,119	1,810,248	1,783,828	6,016,673	1,735,252	1,713,053	1,692,223	1,672,743
Net Present Value	34,163,920									

Note: A number of each cost item is shown in parenthesis.

Table 4.3: Cost of film-based system assume nine years lifetime of small hospital

Film - Based System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. Film	5,000,650	5,508,716	6,068,402	6,684,952	7,364,143	8,112,340	8,936,553	9,844,507	10,844,709	11,946,532
2. Film cassettes with screen	22,134	23,905	25,817	27,882	30,113	32,522	35,124	37,934	40,968	44,246
3. Film printer (3)	2,700,000					2,700,000				
4. Film envelope	85,640	92,491	99,890	107,882	116,512	125,833	135,900	146,772	158,514	171,195
5. Color sticker	40,500	43,740	47,239	51,018	55,100	59,508	64,268	69,410	74,963	80,960
6. Office tool of film-based system	33,184	35,839	38,706	41,802	45,146	48,758	52,659	56,872	61,421	66,335
7. Film printer's maintenance cost (3)	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000
8. Film storage room (72 m^2)	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
9. Film print process room (12 m^2)	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
10. Electricity for film printer	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901
Direct labor cost										
1. Receptionist (2)	225,240	236,502	248,327	260,743	273,781	287,470	301,843	316,935	332,782	349,421
2. Film room personel (4)	292,160	306,768	322,106	338,212	355,122	372,878	391,522	411,098	431,653	453,236
3. Film carrier (2)	146,080	153,384	161,053	169,106	177,561	186,439	195,761	205,549	215,827	226,618
Indirect cost										
1. Electricity for things other than film-based system										
1.1 air-conditioner of film storage room (2)	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700
1.2 film viewing lamp	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538
2. Lost film	75,010	82,631	91,026	100,274	110,462	121,685	134,048	147,668	162,671	179,198
3. Damaged film	85,011	93,648	103,163	113,644	125,190	137,910	151,921	167,357	184,360	203,091
4. Film viewing lamp	3,000						3,000			
	9,051,748	6,920,763	7,548,869	8,238,655	8,996,270	12,528,482	10,745,739	11,747,240	12,851,007	14,063,970
Present Value	9,051,748	6,719,187	7,115,533	7,539,536	7,993,069	10,807,178	8,999,388	9,551,581	10,144,703	10,778,862
Net Present Value	88,700,786									

Table 4.4: Cost of partial PACS assume nine years lifetime of small hospital

Partial - Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct material cost										
1. CR (1)	2,700,000									
2. CR cassettes	26,502	28,622	30,912	33,385	36,056	38,940	42,055	45,420	49,053	52,978
3. Server (2)	1,300,000					1,300,000				
4. Diagnostic viewing station (2)	1,800,000					1,800,000				
5. Result viewing station (12)	468,000					468,000				
6. PACS and RIS software	3,000,000									
7. RAID	26,650	28,782	31,085	33,571	36,257	39,158	42,290	45,673	49,327	53,273
8. Networking system	1,500,000									
9. Electricity for running PACS (e.g.sever and viewing stations, etc)	368,189	368,189	368,189	368,189	368,189	368,189	368,189	368,189	368,189	368,189
10. PACS maintenance cost	865,692	865,692	865,692	865,692	865,692	865,692	865,692	865,692	865,692	865,692
11. Film	1,202,496	1,324,669	1,459,255	1,607,516	1,770,839	1,950,757	2,148,954	2,367,287	2,607,804	2,872,757
12. Film processor (2)	900,000					900,000				
13. Film printer (1)	900,000					900,000				
14. Film envelope	40,730	43,988	47,507	51,308	55,413	59,846	64,633	69,804	75,388	81,419
15. Color sticker	13,577	14,663	15,836	17,103	18,471	19,949	21,545	23,269	25,130	27,140
16. Office tool of film-based system	4,800	5,184	5,599	6,047	6,530	7,053	7,617	8,226	8,884	9,595
17. Film processor's maintenance cost (2)	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
18. Film printer's maintenance cost (1)	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
19. Film developer	105,840	105,840	105,840	105,840	105,840	105,840	105,840	105,840	105,840	105,840
20. Film storage room (36 m^2)	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
21. Film print process room (12 m^2)	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
22. Electricity for film printer and film processor	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
Direct labor cost										
1. Information technology staff (1)	300,000	315,000	330,750	347,288	364,652	382,884	402,029	422,130	443,237	465,398
2. Receptionist (2)	225,240	236,502	248,327	260,743	273,781	287,470	301,843	316,935	332,782	349,421
3. Film room personnel (3)	219,120	230,076	241,580	253,659	266,342	279,659	293,642	308,324	323,740	339,927
4. Film carrier (1)	73,040	76,692	80,527	84,553	88,781	93,220	97,881	102,775	107,913	113,309

Table 4.4: Cost of partial PACS assume nine years lifetime of small hospital (con.)

Cost	year 0	1	2	3	4	5	6	7	8	9
Indirect cost										
1. Electricity for things other than PACS and film-based system										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
1.2 air-conditioner of film storage room (1)	14,850	14,850	14,850	14,850	14,850	14,850	14,850	14,850	14,850	14,850
1.3 film viewing lamp	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
2. Office tool of PACS	3,650	3,942	4,257	4,598	4,966	5,363	5,792	6,255	6,756	7,296
3. CD to transfer medical image	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
4. Lost film	18,037	19,870	21,889	24,113	26,563	29,261	32,234	35,509	39,117	43,091
5. Damaged film	20,442	22,519	24,807	27,328	30,104	33,163	36,532	40,244	44,333	48,837
6. Film viewing lamp	2,000						2,000			
Annual Cost	16,318,295	3,924,521	4,116,342	4,325,222	4,552,765	10,168,733	5,073,058	5,365,863	5,687,476	6,038,454
Present Value	16,318,295	3,810,215	3,880,047	3,958,191	4,045,073	8,771,638	4,248,606	4,362,938	4,489,746	4,627,972
Net Present Value	58,512,721									

Note: A number of each cost item is shown in parenthesis.

Table 4.5: Cost of implement PACS assume nine years lifetime of medium hospital

Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. CR (1)	2,700,000									
2. CR cassettes	57,384	61,975	66,933	72,288	78,071	84,316	91,061	98,346	106,214	114,711
3. Server (2)	5,761,038					5,761,038				
4. Diagnostic viewing station (7)	6,300,000					6,300,000				
5. Result viewing station (60)	2,340,000					2,340,000				
6. PACS and RIS software	3,500,000									
7. RAID	205,277	221,699	239,435	258,590	279,277	301,619	325,749	351,809	379,954	410,350
8. Networking system	1,737,450									
9. Electricity for running PACS (e.g.sever and viewing stations, etc)	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082
10. PACS maintenance cost	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092	1,808,092
Direct labor cost										
1. Information technology staff (1)	300,000	315,000	330,750	347,288	364,652	382,884	402,029	422,130	443,237	465,398
2. Receptionist (1)	112,620	118,251	124,164	130,372	136,890	143,735	150,922	158,468	166,391	174,711
Indirect cost										
1. Electricity for things other than PACS										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
2. Office tool of PACS	10,000	10,800	11,664	12,597	13,605	14,693	15,869	17,138	18,509	19,990
3. CD to transfer medical image	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Annual Cost	25,472,083	3,176,039	3,221,259	3,269,448	3,320,809	17,776,600	3,433,943	3,496,205	3,562,618	3,633,474
Present Value	25,472,083	3,083,533	3,036,346	2,992,008	2,950,495	15,334,252	2,875,873	2,842,735	2,812,364	2,784,755
Net Present Value	64,184,444									

Note: A number of each cost item is shown in parenthesis.

Table 4.6: Cost of film-based system assume nine years lifetime of medium hospital

Film - Based System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. Film	5,000,650	5,508,716	6,068,402	6,684,952	7,364,143	8,112,340	8,936,553	9,844,507	10,844,709	11,946,532
2. Film cassettes with screen	22,134	23,905	25,817	27,882	30,113	32,522	35,124	37,934	40,968	44,246
3. Film printer (3)	2,700,000					2,700,000				
4. Film envelope	85,640	92,491	99,890	107,882	116,512	125,833	135,900	146,772	158,514	171,195
5. Color sticker	40,500	43,740	47,239	51,018	55,100	59,508	64,268	69,410	74,963	80,960
6. Office tool of film-based system	33,184	35,839	38,706	41,802	45,146	48,758	52,659	56,872	61,421	66,335
7. Film printer's maintenance cost (3)	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000
8. Film storage room (72 m^2)	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
9. Film print process room (12 m^2)	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
10. Electricity for film printer	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901
Direct labor cost										
1. Receptionist (2)	225,240	236,502	248,327	260,743	273,781	287,470	301,843	316,935	332,782	349,421
2. Film room personel (4)	292,160	306,768	322,106	338,212	355,122	372,878	391,522	411,098	431,653	453,236
3. Film carrier (2)	146,080	153,384	161,053	169,106	177,561	186,439	195,761	205,549	215,827	226,618
Indirect cost										
1. Electricity for things other than film-based system										
1.1 air-conditioner of film storage room (2)	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700
1.2 film viewing lamp	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538
2. Lost film	75,010	82,631	91,026	100,274	110,462	121,685	134,048	147,668	162,671	179,198
3. Damaged film	85,011	93,648	103,163	113,644	125,190	137,910	151,921	167,357	184,360	203,091
4. Film viewing lamp	3,000						3,000			
	9,051,748	6,920,763	7,548,869	8,238,655	8,996,270	12,528,482	10,745,739	11,747,240	12,851,007	14,063,970
Present Value	9,051,748	6,719,187	7,115,533	7,539,536	7,993,069	10,807,178	8,999,388	9,551,581	10,144,703	10,778,862
Net Present Value	88,700,786									

Note: A number of each cost item is shown in parenthesis.

Table 4.7: Cost of partial PACS assume nine years lifetime of medium hospital

Partial - Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. CR (1)	2,700,000									
2. CR cassettes	57,384	61,975	66,933	72,288	78,071	84,316	91,061	98,346	106,214	114,711
3. Server (2)	5,761,038					5,761,038				
4. Diagnostic viewing station (4)	3,600,000					3,600,000				
5. Result viewing station (30)	1,170,000					1,170,000				
6. PACS and RIS software	3,500,000									
7. RAID	205,277	221,699	239,435	258,590	279,277	301,619	325,749	351,809	379,954	410,350
8. Networking system	1,737,450									
9. Electricity for running PACS (e.g.sever and viewing stations, et	459,469	459,469	459,469	459,469	459,469	459,469	459,469	459,469	459,469	459,469
10. PACS maintenance cost	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492	1,498,492
11. Film	5,000,650	5,508,716	6,068,402	6,684,952	7,364,143	8,112,340	8,936,553	9,844,507	10,844,709	11,946,532
12. Film printer (3)	2,700,000					2,700,000				
13. Film envelope	85,640	92,491	99,890	107,882	116,512	125,833	135,900	146,772	158,514	171,195
14. Color sticker	40,500	43,740	47,239	51,018	55,100	59,508	64,268	69,410	74,963	80,960
15. Office tool of film-based system	33,184	35,839	38,706	41,802	45,146	48,758	52,659	56,872	61,421	66,335
16. Film printer's maintenance cost (3)	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000	135,000
17. Film storage room (72 m^2)	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
18. Film print process room (12 m^2)	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
19. Electricity for film printer	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901	73,901
Direct labor cost										
1. Information Technology staff (1)	300,000	315,000	330,750	347,288	364,652	382,884	402,029	422,130	443,237	465,398
2. Receptionist (2)	225,240	236,502	248,327	260,743	273,781	287,470	301,843	316,935	332,782	349,421
3. Film room personel (4)	292,160	306,768	322,106	338,212	355,122	372,878	391,522	411,098	431,653	453,236
4. Film carrier (2)	146,080	153,384	161,053	169,106	177,561	186,439	195,761	205,549	215,827	226,618

Table 4.7: Cost of partial PACS assume nine years lifetime of medium hospital (con.)

Cost	year 0	1	2	3	4	5	6	7	8	9
Indirect cost										
1. Electricity for things other than PACS and film-based system										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
1.2 air-conditioner of film storage room (2)	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700	29,700
1.3 film viewing lamp	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538	20,538
2. Office tool of PACS	10,000	10,800	11,664	12,597	13,605	14,693	15,869	17,138	18,509	19,990
3. CD to transfer medical image	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
4. Lost film	75,010	82,631	91,026	100,274	110,462	121,685	134,048	147,668	162,671	179,198
5. Damaged film	85,011	93,648	103,163	113,644	125,190	137,910	151,921	167,357	184,360	203,091
6. Film viewing lamp	3,000						3,000			
Annual Cost	30,058,865	9,494,433	10,159,935	10,889,636	11,689,862	25,798,613	13,533,425	14,586,831	15,746,053	17,018,275
Present Value	30,058,865	9,217,896	9,576,713	9,965,559	10,386,291	22,254,110	11,334,030	11,860,429	12,430,080	13,043,091
Net Present Value	140,127,064									

Table 4.8: Cost of implement PACS assume nine years lifetime of large hospital

Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	year 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. CR (2)	5,400,000									
2. CR cassettes	114,768	123,950	133,866	144,575	156,141	168,632	182,123	196,693	212,428	229,422
3. Server (2)	11,522,077					11,522,077				
4. Diagnostic viewing station (13)	11,700,000					11,700,000				
5. Result viewing station (120)	4,680,000					4,680,000				
6. PACS and RIS software	3,500,000									
7. RAID	410,410	443,243	478,702	516,998	558,358	603,027	651,269	703,371	759,640	820,411
8. Networking system	3,474,901									
9. Electricity for running PACS (e.g.sever and viewing stations, etc)	911,307	911,307	911,307	911,307	911,307	911,307	911,307	911,307	911,307	911,307
10. PACS maintenance cost	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172	3,264,172
Direct labor cost										
1. Information technology staff (2)	600,000	630,000	661,500	694,575	729,304	765,769	804,057	844,260	886,473	930,797
2. Receptionist (2)	225,240	236,502	248,327	260,743	273,781	287,470	301,843	316,935	332,782	349,421
Indirect cost										
1. Electricity for things other than PACS										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
2. Office tool of PACS	20,000	21,600	23,328	25,194	27,210	29,387	31,737	34,276	37,019	39,980
3. CD to transfer medical image	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Annual Cost	45,858,016	5,665,914	5,756,343	5,852,706	5,955,413	33,966,981	6,181,650	6,306,155	6,438,962	6,580,652
Present Value	45,858,016	5,500,888	5,425,905	5,356,055	5,291,308	29,300,216	5,177,034	5,127,481	5,082,976	5,043,522
Net Present Value	117,163,401									

Note: A number of each cost item is shown in parenthesis.

Table 4.9: Cost of film-based system assume nine years lifetime of large hospital

Film - Based System's Cost : Year 2012 - 2021

Cost	ปีที่ 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. Film	10,001,301	11,017,433	12,136,804	13,369,903	14,728,286	16,224,679	17,873,107	19,689,015	21,689,418	23,893,063
2. Film cassettes with screen	44,268	47,809	51,634	55,765	60,226	65,044	70,247	75,867	81,937	88,492
3. Film printer (6)	5,400,000					5,400,000				
4. Film envelope	171,280	184,982	199,781	215,763	233,025	251,667	271,800	293,544	317,027	342,390
5. Color sticker	81,000	87,480	94,478	102,037	110,200	119,016	128,537	138,820	149,925	161,919
6. Office tool of film-based system	66,368	71,677	77,412	83,605	90,293	97,516	105,318	113,743	122,843	132,670
7. Film printer's maintenance cost (6)	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000
8. Film storage room (144 m^2)	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000
9. Film print process room (24 m^2)	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
10. Electricity for film printer	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801
Direct labor cost										
1. Receptionist (4)	450,480	473,004	496,654	521,487	547,561	574,939	603,686	633,871	665,564	698,842
2. Film room personel (8)	584,320	613,536	644,213	676,423	710,245	745,757	783,045	822,197	863,307	906,472
3. Film carrier (4)	292,160	306,768	322,106	338,212	355,122	372,878	391,522	411,098	431,653	453,236
Indirect cost										
1. Electricity for things other than film-based system										
1.1 air-conditioner of film storage room (4)	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400
1.2 film viewing lamp	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076
4. Lost film	150,020	165,261	182,052	200,549	220,924	243,370	268,097	295,335	325,341	358,396
5. Damaged film	170,022	187,296	206,326	227,288	250,381	275,820	303,843	334,713	368,720	406,182
6. film viewing lamp	6,000						6,000			
Annual Cost	18,103,496	13,841,525	15,097,738	16,477,309	17,992,539	25,056,964	21,491,479	23,494,480	25,702,013	28,127,940
Present Value	18,103,496	13,438,374	14,231,066	15,079,072	15,986,138	21,614,357	17,998,775	19,103,163	20,289,407	21,557,724
Net Present Value	177,401,571									

Note: A number of each cost item is shown in parenthesis.

Table 4.10: Cost of partial PACS assume nine years lifetime of large hospital

Partial - Picture Archiving and Communication System's Cost : Year 2012 - 2021

Cost	ปีที่ 0	1	2	3	4	5	6	7	8	9
Direct cost										
Direct materials cost										
1. CR (2)	5,400,000									
2. CR cassettes	114,768	123,950	133,866	144,575	156,141	168,632	182,123	196,693	212,428	229,422
3. Server (2)	11,522,077					11,522,077				
4. Diagnostic viewing station (7)	6,300,000					6,300,000				
5. Result viewing station (60)	2,340,000					2,340,000				
6. PACS and RIS software	3,500,000									
7. RAID	410,410	443,243	478,702	516,998	558,358	603,027	651,269	703,371	759,640	820,411
8. Networking system	3,474,901									
9. Electricity for running PACS (e.g.sever and viewing stations, etc)	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082	610,082
10. PACS maintenance cost	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972	2,644,972
11. Film	10,001,301	11,017,433	12,136,804	13,369,903	14,728,286	16,224,679	17,873,107	19,689,015	21,689,418	23,893,063
12. Film printer (6)	5,400,000					5,400,000				
13. Film envelope	171,280	184,982	199,781	215,763	233,025	251,667	271,800	293,544	317,027	342,390
14. Color sticker	81,000	87,480	94,478	102,037	110,200	119,016	128,537	138,820	149,925	161,919
15. Office tool of film-based system	66,368	71,677	77,412	83,605	90,293	97,516	105,318	113,743	122,843	132,670
16. Film printer's maintenance cost (6)	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000	270,000
17. Film storage room (144 m^2)	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000
18. Film print process room (72 m^2)	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
19. Electricity for film printer	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801	147,801
Direct labor cost										
1. Information Technology staff (2)	600,000	630,000	661,500	694,575	729,304	765,769	804,057	844,260	886,473	930,797
2. Receptionist (4)	450,480	473,004	496,654	521,487	547,561	574,939	603,686	633,871	665,564	698,842
3. Film room personel (8)	584,320	613,536	644,213	676,423	710,245	745,757	783,045	822,197	863,307	906,472
4. Film carrier (4)	292,160	306,768	322,106	338,212	355,122	372,878	391,522	411,098	431,653	453,236

Table 4.10: Cost of partial PACS assume nine years lifetime of large hospital (con.)

Cost	ปีที่ 0	1	2	3	4	5	6	7	8	9
Indirect cost										
1. Electricity for things other than PACS and film-based system										
1.1 air-conditioner of server room (2)	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140	25,140
1.2 air-conditioner of film storage room (4)	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400	59,400
1.3 film viewing lamp	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076	41,076
2. Office tool of PACS	20,000	21,600	23,328	25,194	27,210	29,387	31,737	34,276	37,019	39,980
3. CD to transfer medical image	10,000	10,000	FALSE	10,000	10,000	10,000	10,000	10,000	10,000	10,000
4. Lost film	150,020	165,261	182,052	200,549	220,924	243,370	268,097	295,335	325,341	358,396
5. Damaged film	170,022	187,296	206,326	227,288	250,381	275,820	303,843	334,713	368,720	406,182
6. film viewing lamp	6,000						6,000			
Annual Cost	55,079,578	18,350,703	19,671,694	21,141,082	22,741,521	50,059,006	26,428,613	28,535,408	30,853,832	33,398,254
Present Value	55,079,578	17,816,217	18,542,458	19,347,085	20,205,547	43,181,338	22,133,547	23,201,898	24,356,300	25,596,980
Net Present Value	269,460,947									

Note: A number of each cost item is shown in parenthesis.

Table 4.11 summarized NPV of PACS, partial PACS and film-based system for three sizes.

Table 4.11: NPV for film-based, partial PACS and PACS models for three size hospitals

NPV for	**Hospital size**		
	Small	Medium	Large
PACS	34,163,920	64,184,444	117,163,401
Partial PACS	58,512,721	140,127,064	269,470,373
Film	29,737,283	88,700,786	177,401,571

Results from NPV analyzing showed that PACS was worth investment in medium and large size hospitals as their NPV were smallest followed by film-based system. On the contrary, for small size hospital, NPV of PACS was more than film-based system. It is worth noted that NPV of partial PACS are larger than NPV from the other two models in all hospital sizes. Three systems for each size hospitals could be sort in ascending NPV as follow;

Small size hospital: film-based system < PACS < partial PACS

Medium size hospital: PACS < film-based system < partial PACS

Large size hospital: PACS < film-based system < partial PACS

4.2.2.2 The result of analyzing cost savings

Table 4.12 summarized cost savings of two compared systems. Implementing PACS would save approximately 24.5 and 60.2 million baht compared to film-based system in medium and large size hospital.

Table 4.12: Differential cost analysis for film-based, partial PACS and PACS models for three size hospitals

Cost saving of differential system	**Hospital size**		
	Small	Medium	Large
PACS-Film	4,426,637	24,516,342	60,238,170
Partial PACS- Film	28,775,438	51,426,278	92,068,802
Partial PACS- PACS	24,348,801	75,942,620	152,306,972

Conversely, PACS for small size hospital as it was considered more expensive than film-based system by approximately 4.4 million baht. The information suggested that partial PACSs were most expensive for all hospital sizes.

Part 4.3: Break even point of PACS of three size hospitals

Accumulated Present Value

From the result of analyzing NPV and cost saving of PACS and film-based system found that partial PACSs were most expensive. It means that partial PACSs were strongly not recommended for all hospital sizes. In this study, Film- based system was selected to compare with PACS to measure break even point if these systems were installed at the same time.

Accumulated Present Value (APV) for PACS compared to film-based system was calculated using the below formula[2].

$$\boldsymbol{AVP} = \sum_{\boldsymbol{i=0}}^{\boldsymbol{n}} (\boldsymbol{PVF_i} - \boldsymbol{PVP_i})$$

$\boldsymbol{n}$ is the project lifetime

$\boldsymbol{PVF_i}$ is present value of film-based system at i^{th} year

$\boldsymbol{PVP_i}$ is present value of PACS at i^{th} year

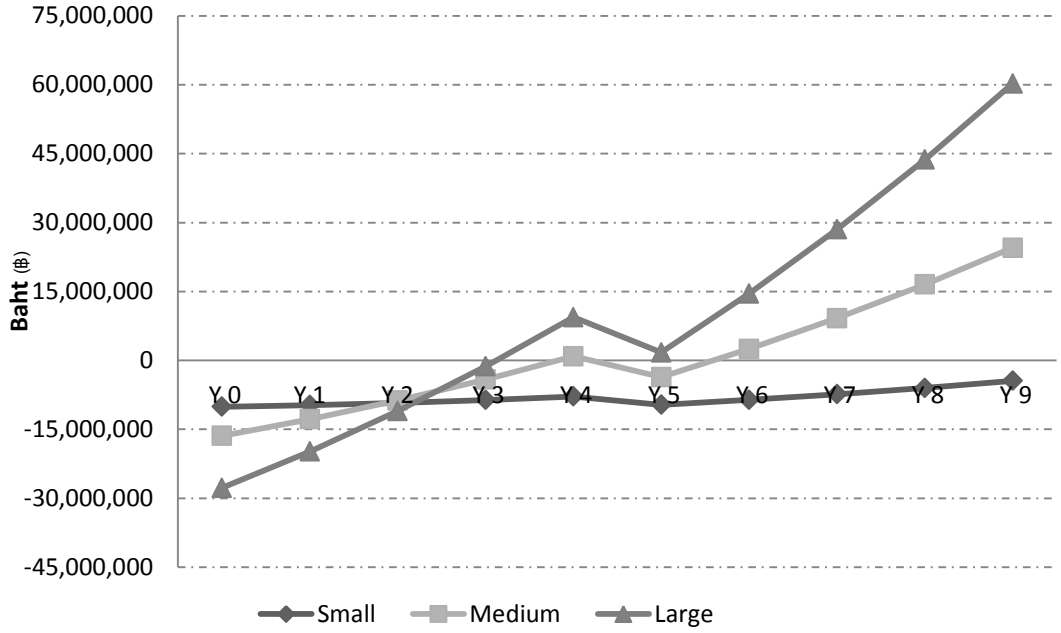


Figure 4.1: Accumulated Present Value of all size hospitals in three cost models

Figure 4.1 showed that, over 10 year study period, APV of medium and large size hospital appeared above zero line, while APV of small size hospital did not reach zero line. It could be interpreted that PACS was worth implementing in medium and large size hospital, but not recommended for small size hospital. Break even point is the first time that APV reach zero line for both medium and large size hospitals was at 4^{th} year. The negative slope of APV in5^{th} year was a result of replacing items such as workstation hardware and server.

Part 4.4: Sensitivity analysis

Type of sensitivity analysis of this study is One-way sensitivity analysis. This approach will assess changed value of individual variable. From data of development economic cost model and reviewing literatures, sensitivity analysis was also conducted on two variable; initial purchase cost and film utilization rate.

Initial purchase cost was selected because it was one of the major cost for system implementation. Hospital with limited budget could choose a lighter PACS

package, or reduce the numbers of workstations to lower initial investment; on the other hand, hospital with adequate budget could select best possible options. In this study, initial purchase cost consists of CR, CR cassettes, server, diagnostic viewing station, result viewing station, PACS and RIS software, RAID, and networking system which ±30% change in initial purchase cost was analyzed with 100% was based case.

Film utilization rate was another parameter selected for sensitivity analysis because it affected many cost items such as CR cassette or number of film. In this study, film utilization rate consists of CR cassette, RAID, office tool of PACS, film, film cassettes with screen, film envelope, color sticker, and office tool of film-based system. Film utilization rate 0% and 10% were analyzed with 8% as a base case.

The sensitivity result of initial purchase cost was shown in Figure 4.2 and film utilization rate was shown in Figure 4.3.

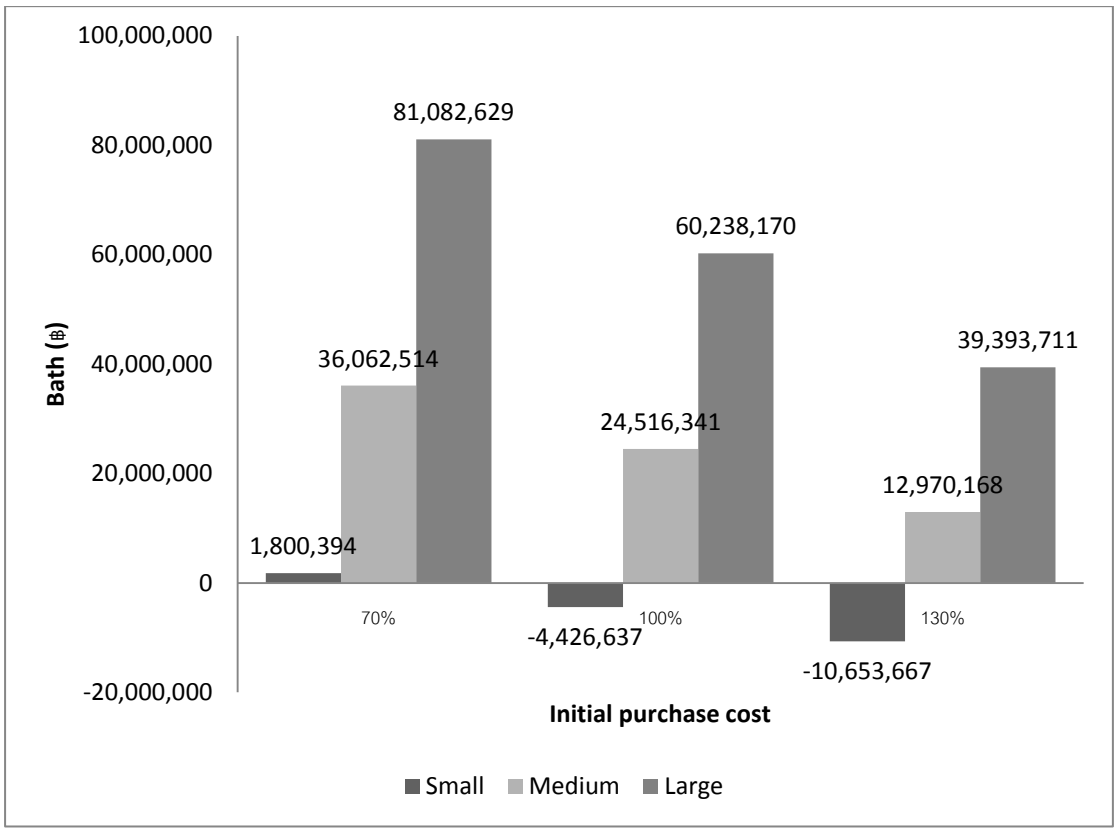


Figure 4.2: Sensitivity analysis of initial purchase cost

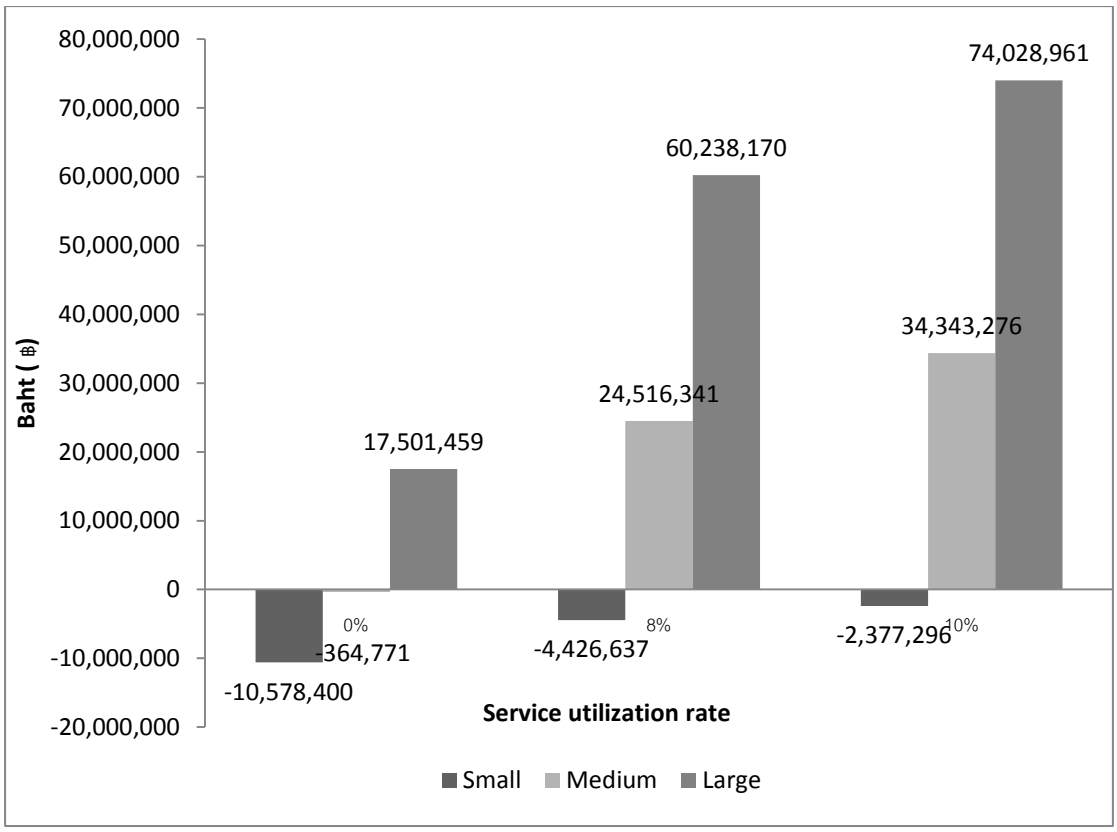


Figure 4.3: Sensitivity analysis of film utilization rate

Result from sensitivity analysis suggested that lowering initial purchase cost affected small size hospital's decision, and lessening film utilization rate could alter medium size hospital's decision. It means that if small size hospital invests on PACS at 70% of base case, it would have saved 1.8 million baht. Also, if service utilization rate remained unchanged, medium size hospital should not invest in PACS as there was no gain on investment in 10-year period.

CHAPTER V
DISCUSSION AND CONCLUSION

This chapter comprise of the topics as follow;

Part 5.1: Discussion

Part 5.2: Conclusion

Part 5.3: Limitation

Part 5.4: Policy recommendation

Part 5.5: Recommendation for further study

Discussion

This study focused on cost model development for PACS, partial PACS and film-based system. Not only this study, but the study of MacDonald et. al., Alanen et. al., and Maass et. al. also analyzed cost of partial PACS with other system. Partial PACS model was a combined model of PACS and film-based system. Without doubt, partial PACS model produced highest cost among the three models. [1, 8, 15]

Cost models were developed based on providers' perspective. Costs or benefits incurred from other perspectives were not included. Examples of benefit and cost from patient's perspective were benefit from satisfaction not to carry heavy load of film, or cost of retaking image when lost film. Examples of costs from a societal perspective were costs to dispose contrast media, film, and electronic device garbage [5, 36]. These costs were not included in this study as they were too difficult to measure.

All cost items in the three developed models were tangible costs. Intangible cost item such as reduced cost from faster diagnosis and accurate treatment, benefit from medical staffs' and patients' satisfaction with PACS, and benefits from better organization image were not taken into account[5, 37]. It was found in various literatures that most studies not included these cost in to account, however they recommended list intangible costs and benefits should not be ignored [11, 20, 21].

The average lifetime of x-ray equipment (e.g. CR) is estimated to be ten years. However, hardware computers are usually less durable than x-ray equipment. This means that in the fifth year of the project analysis, work station and computer hardware will need to be replaced. Although most companies replace computers equipments every three years, some replace computers at a longer period for cost saving. This study counted on using this computer hardware for PACS, film processor, and film printer for four years and then purchasing new materials in the fifth year. This factor was not considered in most of the existing articles on financial evaluation of PACS or the costs were probably included in maintenance costs [1, 2, 7, 33].

Despite the fact that data from specialized hospitals were used in this study, cost items in the model were not affected. NPV were largely affected by the number of radiologists and clinicians in a hospital. MacDonald et.al., Van Gennip et. al., and Fang et. al showed cost of work station about 58%, 53% and 29%, respectively. These numbers are highly related to the numbers of workstations which is the major cost item in the model [1, 2, 7].

Although PACS is a digital image management system, PACS alone is not efficient enough. Integrating PACS with Hospital Information System (HIS) make fragmented medical information easier to access and enhance continuity of care. HIS will provide personalized information e.g. gender, date of birth, health insurance coverage, and medical history. With better information system, linking PACS with HIS put more cost on hospital.

Limitation

1. There are many cost related assumptions in this study which might affect the result. For example, this study assumes unchanged cost of CR, workstation, sever, film developer which actually change overtime. This in fact may result in decision bias to implanted PACS.
2. Information and data that represent large size hospital whether cost items, cost data or number of each items. It was assumed as twice from information and data of medium size hospitals which was found in previous study. Due to cost analysis information of PACS in Thailand are limited. To demonstrate cost saving roughly, also this study conduct economic cost model for large hospital.
3. In this study set, all items in three alternative; PACS, film-based system or partial PACS, start simultaneously at year 0. In fact, each hospital has had any existing system whether film-based system or partial PACS. Therefore, this study might not nearby real situation of many hospitals. The results of this study assist decision making roughly for implements PACS.
4. This study only focuses only on tangible cost only. Intangible cost and benefit are excluded. Comprehensive analysis framework is suggested for better answer.

Conclusion

Cost models for PACS, partial PACS and film-based system was developed and tested. Partial PACS implementation is strongly not recommended for all hospital sizes. PACS is not recommended for small size hospital, while recommended for medium and large size hospitals.

Since each hospital is unique. To reach a conclusion whether or not PACS should be implemented, a particular hospital should use its own data to run the model. Cost model is publicly posted and can be accessed online at http://goo.gl/ljubyO

Policy recommendation

1. Based on result of this study, it is recommended that each hospital should use its own data to analyze the cost due to internal factor of each hospital are difference.
2. The decision to implement PACS in small sized hospital might be positive if the number of diagnostic viewing station decrease. Sharing work station might be a good choice to enhance cost effectiveness.
3. cost effectiveness ratio is important for decision making, however, small sized hospital should be considered number of radiologists and radiology technicians.

Recommendation for further study

1. One of the factor driving to achievement is the personnel in certain organizations. Therefore, once the PACS is studied, it should be recorded the user's satisfaction and recommendations in particular system.
2. Further study should be included intangible cost and benefit due to comprehensive analysis result in better answer and reliability.

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Appendices

Appendix A

Protocol Review No. 13-33-010

Study Protocol Approval

The Ethics Committee of The Faculty of Pharmaceutical Sciences, Chulalongkorn University, Bangkok, Thailand has approved the following study to be carried out according to the protocol dated and/ or amended as follows:

Study Title: Developing economic model for picture archiving and communication systems installment decision making

Study Code: -

Centre: CHULALONGKORN UNIVERSITY

Principal Investigator : Thirapich Chuachan

A list of the Ethics Committee members and positions present at the Ethics Committee meeting on the date of approval of this study has been attached.

This Study Protocol Approval Form will be forwarded to the Principal Investigator.

Chairman of Ethics Committee: .....

(Narueporn Sutanthavibul, Ph.D.)

Secretary of Ethics Committee: Suyanee Pongthananikorn .....

(Suyanee Pongthananikorn, Ph.D.)

Date of Approval: March 1, 2013

Date of Approval Expiration: March 1, 2014

Appendix B

Specification of PACS

ร่างขอบเขตของงาน (Term of Reference : TOR) เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์ให้เป็นดิจิตอล พร้อมชุดคอมพิวเตอร์ประมวลผลการถ่ายภาพ โรงพยาบาลมหาสารคาม

คุณลักษณะเฉพาะ
เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์ให้เป็นดิจิตอล
พร้อมชุดคอมพิวเตอร์ประมวลผลการถ่ายภาพ

1. คุณสมบัติทั่วไป

1.1 เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์ให้เป็นดิจิตอล (Computed Radiography) พร้อมชุดคอมพิวเตอร์ประมวลผลการถ่ายภาพ

1.2 เครื่องคอมพิวเตอร์แม่ข่ายสำหรับจัดเก็บและเรียกดูภาพเอกซเรย์ (PACS Server) และเครื่องคอมพิวเตอร์พร้อมจอภาพความละเอียดสูงเพื่อใช้ในการวินิจฉัยภาพเอกซเรย์ (Diagnostic Workstation) พร้อมโปรแกรมการเรียกดูภาพตามมาตรฐาน DICOM 3.0

2. คุณสมบัติเฉพาะ

2.1 เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์ให้เป็นดิจิตอล (Computed Radiography) พร้อมชุดคอมพิวเตอร์ควบคุมคุณภาพและรับส่งภาพถ่ายทางรังสีวิทยา

2.1.1 เครื่องอ่านและแปลงสัญญาณภาพเอกซเรย์ให้เป็นดิจิตอล (Computed Radiography)
แบบใส่คาสเซทได้ครั้งละมากกว่าหนึ่งคาสเซท (Multi-Loader) จำนวน 1 เครื่อง ดังนี้

2.1.1.1 สามารถสแกนแผ่นรับภาพ (Image Plate) ในคาสเซทชนิดพิเศษและทำการแปลงสัญญาณภาพที่ได้เป็นข้อมูลแบบดิจิตอลและเก็บเข้าระบบคอมพิวเตอร์เพื่อทำ การประมวลภาพและ ตกแต่งภาพได้

2.1.1.2 มีที่รับคาสเซทเข้าได้ครั้งละ 10 แผ่น และ สามารถใช้ได้กับคาสเซทขนาดตั้งแต่ 8 x 10 นิ้ว จนถึง 14 x 17 นิ้ว

2.1.1.3 มีความสามารถในการอ่านในอัตราไม่น้อยกว่า 100 แผ่นต่อชั่วโมง ที่ขนาดของแผ่น รับภาพแบบผสมกันและที่ความละเอียดตามมาตรฐาน

2.1.1.4 มีค่า Gray Scale สูงสุดไม่น้อยกว่า 12 Bit/ Pixel และให้ค่าความละเอียดของภาพที่แสดงสูงสุดไม่น้อยกว่า 20 Pixel/ mm. สำหรับภาพถ่ายเอกซเรย์เต้านม

2.1.1.5 แผ่นรับภาพยังคงสามารถเก็บพลังงานไว้ได้เกินกว่า 70% หลังจากผ่านการถ่ายภาพเอกซเรย์และยังไม่ได้เข้าเครื่องอ่านและแปลงสัญญาณประมาณ 2 ชั่วโมง

2.1.1.7 สามารถใช้กับแผ่นรับภาพพิเศษสำหรับถ่ายเอกซเรย์เต้านมได้

2.1.2 ชุดคอมพิวเตอร์ควบคุมคุณภาพและรับส่งภาพถ่ายทางรังสีวิทยา (NX Station) พร้อมทั้งซอฟท์แวร์ ประกอบด้วย

2.1.2.1 NX Workstation for General X-Ray 1 ชุด

2.1.2.1.1 จอแสดงภาพแบบ LCD ความละเอียดสูงขนาดไม่น้อยกว่า 19 นิ้ว หน่วยประมวลผลกลางแบบ Xeon ความเร็วในการประมวลผลไม่น้อยกว่า 2.4 GHz. หรือดีกว่า

2.1.2.1.2 หน่วยความจำหลัก 2 GB RAM หรือดีกว่า

2.1.2.1.3 Hard Disk ความจุไม่น้อยกว่า 36 GB หรือมากกว่า

2.1.2.1.4 ระบบต้องง่ายต่อการเรียกภาพถ่ายเอกซเรย์ขึ้นมาแสดงและแก้ไขก่อนส่งให้รังสีแพทย์ โดยสามารถเลือกและค้นหาภาพถ่ายเอกซเรย์ได้โดยใช้ชื่อคนไข้ หรือข้อมูลอื่นๆ ที่เกี่ยวข้อง

2.1.2.1.5 ระบบต้องสามารถประมวลผลและสามารถแสดงภาพถ่ายเอกซเรย์ได้อย่างรวดเร็ว

2.1.2.1.6 มีระบบการใส่ข้อมูลคนไข้ลงบนคาสเซท

2.1.2.1.7 มีซอฟท์แวร์ที่ใช้ปรับแต่งภาพและมีความสามารถดังนี้

2.1.2.1.7.1 สามารถปรับ Window Level ของภาพได้ ทั้งแบบ Automaticc และ Manual

2.1.2.1.7.2 สามารถปรับค่า Gray Scale ได้

2.1.2.1.7.3 สามารถขยายภาพเพื่อดูรายละเอียดของภาพได้ (Magnify)

2.1.2.1.7.4 สามารถ Zoom and Roam ภาพถ่ายทางรังสีได้

2.1.2.1.7.5 สามารถหมุนภาพและพลิกกลับภาพได้

2.1.2.1.7.6 สามารถลดการรบกวนของภาพได้ (Noise Reduction)

2.1.2.1.7.7 สามารถจัดแสดงภาพได้หลายแบบ (Multi-Format Display)

2.1.2.1.7.8 มีฟังก์ชั่น Automatic Grid-Line Artifact Suppression

2.1.2.1.7.9 มีระบบการสร้างขอบภาพสีดำเพื่อความสบายตาของรังสีแพทย์ที่ดูภาพเอกซเรย์ได้ (Electronic Shutter)

2.1.2.1.7.10 สามารถปรับความคมชัดของขอบอวัยวะได้ (Edge Enhancement)

2.1.2.1.7.11 สามารถส่งภาพในระบบ DICOM 3.0 ได้

2.1.2.2 NX Workstation for General X-Ray and Mammogram 1 ชุด

2.1.2.2.1 จอแสดงภาพแบบ LCD ความละเอียดสูงขนาดไม่น้อยกว่า 19 นิ้ว หน่วยประมวลผลกลางแบบ Xeon ความเร็วในการประมวลผลไม่น้อยกว่า 2.4 GHz. หรือดีกว่า

2.1.2.2.2 หน่วยความจำหลัก 2 GB RAM หรือดีกว่า

2.1.2.2.3 Hard Disk ความจุไม่น้อยกว่า 36 GB หรือมากกว่า

2.1.2.2.4 ระบบต้องง่ายต่อการเรียกภาพถ่ายเอกซเรย์ขึ้นมาแสดงและแก้ไขก่อนส่งให้รังสีแพทย์ โดยสามารถเลือกและค้นหาภาพถ่ายเอกซเรย์ได้โดยใช้ชื่อคนไข้ หรือข้อมูลอื่นๆ ที่เกี่ยวข้อง

2.1.2.2.5 ระบบต้องสามารถประมวลผลและสามารถแสดงภาพถ่ายเอกซเรย์ได้อย่างรวดเร็ว

2.1.2.2.6 มีระบบการใส่ข้อมูลคนไข้ลงบนคาสเซท

2.1.2.2.7 มีซอฟท์แวร์ที่ใช้ปรับแต่งภาพและมีความสามารถดังนี้

2.1.2.2.7.1 สามารถปรับ Window Level ของภาพได้ ทั้งแบบ Automaticc และ Manual

2.1.2.2.7.2 สามารถปรับค่า Gray Scale ได้

2.1.2.2.7.3 สามารถขยายภาพเพื่อดูรายละเอียดของภาพได้ (Magnify)

2.1.2.2.7.4 สามารถ Zoom and Roam ภาพถ่ายทางรังสีได้

2.1.2.2.7.5 สามารถหมุนภาพและพลิกกลับภาพได้

2.1.2.2.7.6 สามารถลดการรบกวนของภาพได้ (Noise Reduction)

2.1.2.2.7.7 สามารถจัดแสดงภาพได้หลายแบบ (Multi-Format Display)

2.1.2.2.7.8 มีฟังก์ชั่น Automatic Grid-Line Artifact Suppression

2.1.2.2.7.9 มีระบบการสร้างขอบภาพสีดำเพื่อความสบายตาของรังสีแพทย์ที่ดูภาพเอกซเรย์ได้ (Electronic Shutter)

2.1.2.2.7.10 สามารถปรับความคมชัดของขอบอวัยวะได้ (Edge Enhancement)

2.1.2.2.7.11 สามารถส่งภาพในระบบ DICOM 3.0 ได้

2.1.2.2.8 มีฟังก์ชั่นรองรับการถ่ายภาพแมมโมแกรมได้

2.2 เครื่องคอมพิวเตอร์แม่ข่ายสำหรับจัดเก็บและเรียกดูภาพเอกซเรย์ (PACS Server) และเครื่องคอมพิวเตอร์พร้อมจอภาพความละเอียดสูงเพื่อใช้ในการวินิจฉัยภาพเอกซเรย์ (Diagnostic Workstation) พร้อมโปรแกรมการเรียกดูภาพตามมาตรฐาน DICOM 3.0

ระบบการจัดเก็บและรับส่งภาพทางการแพทย์ (PACS) โดยระบบดังกล่าวจะต้องมีคุณสมบัติทางเทคนิคอย่างน้อยดังนี้

2.2.1 ซอฟท์แวร์ระบบการจัดเก็บและรับส่งภาพทางการแพทย์ (PACS)

2.2.1.1 สามารถจัดการระบบจัดเก็บข้อมูลภาพซึ่งได้มาตรฐาน DICOM 3.0

2.2.1.2 มีฟังก์ชันการทำงานแบบ DICOM Modality Worklist Server

2.2.1.3 รองรับ ActiveX technology

2.2.1.4 รองรับรองรับ 168 Bits Triple DES Encryption

2.2.1.5 รองรับระบบการเรียกดูภาพเอกซเรย์ของรังสีแพทย์ แพทย์นอกแผนกเอกซเรย์ และ การเรียกดูภาพจากภายนอก โรงพยาบาล ได้โดยใช้ Microsoft Internet Explorer และ แบบ Client/Server

2.2.1.6 มี Module การทำงานแยกเป็น DICOM Server, Database Server, Internet Information Server โดย Module ต่างๆ สามารถทำงานอยู่บน Server เครื่องเดียวกัน หรือ กระจายการทำงานอยู่บน Server หลายๆตัวได้ โดย Module การรับส่งภาพต่างๆ สามารถเพิ่มมากกว่า 1 ชุดได้เมื่อมีความหนาแน่น ของข้อมูลเพิ่มขึ้น อีกทั้งรองรับการทำงานแบบ Clustering และ Network Loading balance

2.2.1.7 ผู้ดูแลระบบสามารถบริหารจัดการระบบ PACS ผ่านทาง Microsoft Internet Explorer ได้ ซึ่งทำให้ผู้ดูแลระบบ สามารถจัดการระบบจากเครื่องคอมพิวเตอร์ใดๆก็ได้ซึ่งอยู่ในระบบเดียวกัน โดยต้องสามารถจัดกลุ่มผู้ใช้งานได้อย่างน้อย 32 กลุ่ม

2.2.1.8 สามารถใช้ Microsoft Internet Explorer เพื่อเปิดดูภาพ DICOM 3.0 Format จากจุดใดก็ได้ ซึ่งสามารถเชื่อมต่อ เครือข่ายของระบบทั้งจากภายใน และ ภายนอกโรงพยาบาล โดยต้องรองรับจำนวนผู้ใช้งานพร้อมๆกัน เช่น รังสีแพทย์ และ แพทย์ทั่วไป ได้ไม่น้อยกว่า 20 คน โดยต้องรองรับการ Conference ภาพกันได้แบบ Real-time

2.2.1.9 สามารถรองรับ DICOM PDF, DICOM Waveform และ WADO (Web access to DICOM Objects)

2.2.1.10 Software สำหรับ การแสดงผล

2.2.1.10.1 สามารถแสดงภาพ Grayscale และ สี ทั้งแบบภาพนิ่ง และภาพเคลื่อนไหว (Cine) ได้

2.2.1.10.2 สามารถปรับเปลี่ยนรูปแบบ Layout ในการแสดงภาพได้ตามต้องการ พร้อมทั้งสามารถเปิดภาพ และใช้งานหลายหน้าต่างพร้อมๆกันได้

2.2.1.10.3 สามารถแสดง Reference Line ในภาพ CT และ MR ได้

2.2.1.10.4 สามารถเปรียบเทียบภาพของคนไข้คนเดียวกัน หรือ หลายคนในจอภาพเดียวกันได้ โดยวิธีการเลือกภาพผ่านทางการคลิกเมาส์ขวา

2.2.1.10.5 สามารถปรับความขาว/ดำ, ขยาย-ย่อขนาดภาพ, วัดระยะ, วัดมุม และ วัดขนาดได้

2.2.1.11 ระบบ PACS จะต้องใช้งานร่วมกับระบบบริหารงานโรงพยาบาลได้อย่างมีประสิทธิภาพ โดยต้องมีความสามารถอย่างน้อยดังนี้

2.2.1.11.1 สามารถเชื่อมโยงรายการสั่งตรวจเอกซเรย์จากระบบบริหารงานโรงพยาบาลเข้ากับระบบ PACS เพื่อให้เครื่องมือที่รองรับมาตรฐาน DICOM Work List หรือระบบ RIS นำไปใช้งานได้

2.2.1.11.2 รองรับการเปิดภาพจากระบบ PACS ผ่านทางโปรแกรมของระบบบริหารงานโรงพยาบาลได้โดยตรง ทั้งในส่วน ของรังสีแพทย์ และ แพทย์ผู้ส่งตรวจ

2.2.1.11.3 หากมีการเปลี่ยนแปลงข้อมูลผู้ป่วยในระบบบริหารงานโรงพยาบาล ข้อมูลผู้ป่วยในระบบฐานข้อมูลของระบบ PACS ต้องสามารถเปลี่ยนแปลงได้โดยอัตโนมัติ

2.2.2 เครื่องคอมพิวเตอร์พร้อมจอชนิดความละเอียดสูงไม่น้อยกว่า 3 ล้านพิกเซล แบบจอคู่ จำนวน 1 ชุด

2.2.2.1 มีหน่วยประมวลผลกลาง (CPU) ชนิด ประสิทธิภาพโดยรวมไม่ต่ำกว่า Core 2 Duo มีความเร็วไม่น้อยกว่า 2.83 GHz (E8300) หรือดีกว่า มี Cache Memory ไม่น้อยกว่า 6 MB

2.2.2.2 มีหน่วยความจำหลัก (RAM) ไม่น้อยกว่า 2GB แบบ DDR2 RAM หรือดีกว่า

2.2.2.3 มี Hard Disk เป็นแบบ Serial ATA หรือดีกว่า ความเร็วรอบไม่น้อยกว่า 7200 rpm และมีความจุไม่น้อยกว่า 80 GB (Unformatted) จำนวน 2 หน่วย

2.2.2.4 มี DVD Drive สามารถอ่านและเขียนแผ่น CD-R CD-RW และ DVD หรือดีกว่า จำนวน 1 หน่วย

2.2.2.5 มี Ethernet Port แบบ 10/100/1000 Base-TX หรือดีกว่า 1 พอร์ต

2.2.2.6 มีจอภาพชนิด TFT Monochrome LCD ขนาดไม่น้อยกว่า 20 นิ้ว จำนวน 1 ชุด ซึ่งมี ความละเอียดสูงไม่น้อยกว่า 3 ล้านพิกเซล พร้อมการ์ดแสดงผล

2.2.2.7 มีจอภาพชนิด TFT Color LCD ขนาดไม่น้อยกว่า 19 นิ้ว มี Resolution ไม่น้อยกว่า 1280 x 1024 Pixels

2.2.2.8 มีแป้นพิมพ์ (Keyboard) และ Optical Mouse

2.2.2.9 มีโปรแกรมระบบปฏิบัติการ Microsoft Windows XP Professional หรือรุ่นล่าสุด ที่มีลิขสิทธิ์ถูกต้องตามกฎหมาย

2.2.2.10 มีโปรแกรม Anti Virus สำหรับป้องกันเครื่องคอมพิวเตอร์

2.2.2.11 ผู้ขายต้องทำการติดตั้งซอฟท์แวร์ PACS ให้สามารถใช้งานได้อย่างสมบูรณ์ และ สามารถใช้งานร่วมกับโปรแกรม บริหารงานโรงพยาบาลได้อย่างมีประสิทธิภาพ

2.2.3 เครื่องคอมพิวเตอร์พร้อมจอชนิดความละเอียดสูงไม่น้อยกว่า 5 ล้านพิกเซล แบบจอคู่ จำนวน 1 ชุด

2.2.3.1 มีหน่วยประมวลผลกลาง (CPU) ชนิด ประสิทธิภาพโดยรวมไม่ต่ำกว่า Core 2 Duo มีความเร็วไม่น้อยกว่า 2.83 GHz (E8300) หรือดีกว่า มี Cache Memory ไม่น้อยกว่า 6 MB

2.2.3.2 มีหน่วยความจำหลัก (RAM) ไม่น้อยกว่า 2GB แบบ DDR2 RAM หรือดีกว่า

2.2.3.3 มี Hard Disk เป็นแบบ Serial ATA หรือดีกว่า ความเร็วรอบไม่น้อยกว่า 7200 rpm และมีความจุไม่น้อยกว่า 80 GB (Unformatted) จำนวน 2 หน่วย

2.2.3.4 มี DVD Drive สามารถอ่านและเขียนแผ่น CD-R CD-RW และ DVD หรือดีกว่า จำนวน 1 หน่วย

2.2.3.5 มี Ethernet Port แบบ 10/100/1000 Base-TX หรือดีกว่า 1 พอร์ต

2.2.3.6 มีจอภาพชนิด TFT Monochrome LCD ขนาดไม่น้อยกว่า 20 นิ้ว จำนวน 1 ชุด ซึ่งมี ความละเอียดสูงไม่น้อยกว่า 5 ล้านพิกเซล พร้อมการ์ดแสดงผล

2.2.3.7 มีจอภาพชนิด TFT Color LCD ขนาดไม่น้อยกว่า 19 นิ้ว มี Resolution ไม่น้อยกว่า 1280 x 1024 Pixels

2.2.3.8 มีแป้นพิมพ์ (Keyboard) และ Optical Mouse

2.2.3.9 มีโปรแกรมระบบปฏิบัติการ Microsoft Windows XP Professional หรือรุ่นล่าสุด ที่มีลิขสิทธิ์ถูกต้องตามกฎหมาย

2.2.3.10 มีโปรแกรม Anti Virus สำหรับป้องกันเครื่องคอมพิวเตอร์

2.2.3.11 ผู้ขายต้องทำการติดตั้งซอฟท์แวร์ PACS ให้สามารถใช้งานได้อย่างสมบูรณ์ และ สามารถใช้งานร่วมกับโปรแกรม บริหารงานโรงพยาบาลได้อย่างมีประสิทธิภาพ

2.2.4 เครื่องคอมพิวเตอร์แม่ข่ายหลักสำหรับจัดเก็บและเรียกดูภาพเอกซเรย์ (PACS Main Server)จำนวน 1 เครื่อง รายละเอียดดังนี้

2.2.4.1 หน่วยประมวลผลกลาง (CPU) Intel Xeon Quad Core ทำงานที่ความเร็วของสัญญาณ นาฬิกา 2.33 GHz.หรือดีกว่า

2.2.4.2 หน่วยความจำหลัก (RAM) ไม่น้อยกว่า 4 GB

2.2.4.3 มีหน่วยเก็บข้อมูล Hard disk แบบ SATA หรือ SAS ที่มีความจุรวมไม่น้อยกว่า 1.5 TB After RAID 5

2.2.4.4 มี LAN Port สำหรับการต่อเชื่อมเครือข่ายที่ความเร็ว 10/100/1000 แบบ copper port (RJ-45) ติดตั้งภายในเครื่องไม่น้อยกว่า 2 Port

2.2.4.5 มีจอภาพสี LCD ขนาด 17” จำนวน 1 จอ

2.2.4.6 ติดตั้ง Power Supply แบบ Hot Plug จำนวน 2 ตัว

2.2.4.7 ติดตั้งระบบปฏิบัติการ Window Server 2003 Std edition

2.2.4.8 ติดตั้ง MS SQL Server 2000 หรือ 2005 Standard Edition

2.2.4.9 UPS 3.0 KVA จำนวน 1 หน่วย

2.2.5 เครื่องคอมพิวเตอร์แม่ข่ายสำรองข้อมูลสำหรับจัดเก็บและเรียกดูภาพเอกซเรย์ (PACS Backup Server) จำนวน 1 เครื่อง รายละเอียดดังนี้

2.2.5.1 หน่วยประมวลผลกลาง (CPU) Intel Xeon Quad Core ทำงานที่ความเร็วของสัญญาณนาฬิกา 2.33 GHz. หรือดีกว่า

2.2.5.2 หน่วยความจำหลัก (RAM) ไม่น้อยกว่า 4 GB

2.2.5.3 มีหน่วยเก็บข้อมูล Hard disk แบบ SATA หรือ SAS ที่มีความจุรวมไม่น้อยกว่า 500 GB After RAID 5

2.2.5.4 มี LAN Port สำหรับการต่อเชื่อมเครือข่ายที่ความเร็ว 10/100/1000 แบบ copper port (RJ-45) ติดตั้งภายในเครื่องไม่น้อยกว่า 2 Port

2.2.5.5 ติดตั้ง Power Supply แบบ Hot Plug จำนวน 2 ตัว

2.2.5.6 ติดตั้งระบบปฏิบัติการ Window Server 2003 Std edition

2.2.5.7 ติดตั้ง MS SQL Server 2000 หรือ 2005 Standard Edition

2.2.6 เครื่องคอมพิวเตอร์สำหรับสำรองข้อมูลภาพแบบ Off-Line (Backup Workstation) จำนวน 1 ชุดประกอบด้วย

2.2.6.1 หน่วยประมวลผลกลาง (CPU) Intel Core2 Duo ทำงานที่ความเร็วของสัญญาณนาฬิกา 2.0 GHz. หรือดีกว่า

2.2.6.2 หน่วยความจำหลัก (RAM) ไม่น้อยกว่า 1 GB

2.2.6.3 หน่วยข้อมูล Hard disk ที่มีความจุไม่น้อยกว่า 80 GB 7200 rpm

2.2.6.4 DVD+/-RW Drive

2.2.6.5 LAN Port สำหรับการต่อเชื่อมเครือข่ายที่ความเร็ว 10/100/1000 แบบ copper port (RJ-45) ติดตั้งภายในเครื่องไม่น้อยกว่า 1 Port

2.2.6.6 มีจอภาพสี LCD ขนาด 17” จำนวน 1 จอ

2.2.7 เครื่องคอมพิวเตอร์สำหรับใช้ในการบริการตรวจเช็คระบบจากภายนอกโรงพยาบาล (Remote Workstation) จำนวน 1 ชุด ประกอบด้วย

2.2.7.1 หน่วยประมวลผลกลาง (CPU) Intel Core2 Duo ทำงานที่ความเร็วของสัญญาณนาฬิกา 2.0 GHz. หรือดีกว่า

2.2.7.2 หน่วยความจำหลัก (RAM) ไม่น้อยกว่า 1 GB

2.2.7.3 หน่วยเก็บข้อมูล Hard disk ที่มีความจุไม่น้อยกว่า 80 GB 7200 rpm

2.2.7.4 มี LAN Port สำหรับการต่อเชื่อมเครือข่ายที่ความเร็ว 10/100/1000 แบบ copper port (RJ-45) ติดตั้งภายในเครื่องไม่น้อยกว่า 2 Port

2.2.7.5 มีจอภาพสี LCD ขนาด 17” จำนวน 1 จอ

3. อุปกรณ์ประกอบเครื่อง

3.1 คาสเซทสำหรับเอกซเรย์ เป็นแบบมี Memory Chip

3.1.1 ขนาด 8 x 10 นิ้ว จำนวน 5 อัน

3.1.2 ขนาด 10 x 12 นิ้ว จำนวน 5 อัน

3.1.3 ขนาด 14 x 17 นิ้ว จำนวน 7 อัน

3.2 คาสเซทสำหรับเอกซเรย์เต้านม เป็นแบบมี Memory Chip

3.2.1 ขนาด 8 x 10 นิ้ว จำนวน 4 อัน

3.3 เครื่องพิมพ์ภาพเอกซเรย์ลงบนฟิล์ม (Dry Printer) จำนวน 1 เครื่อง

Appendix C
Data cost

ผลการสืบราคายาและเวชภัณฑ์ร่วม(วัสดุรังสีการแพทย์)สำนักงานสาธารณสุขจังหวัดเชียงใหม่ ประจำปี 2556

ลำดับ	รายการ	ขนาด	ลำดับที่1	ราคา	ลำดับที่2	ราคา
1	ฟิล์ม(Flim) 14" x 17" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,900	บ.อีคอนเทคซัพพลายจก.	3,250
2	ฟิล์ม(Flim) 14" x 14" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,500	บ.อีคอนเทคซัพพลายจก.	2,680
3	ฟิล์ม(Flim) 12" x 15" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,350	บ.อีคอนเทคซัพพลายจก.	2,570
4	ฟิล์ม(Flim) 11" x 14" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,050	บ.อีคอนเทคซัพพลายจก.	2,200
5	ฟิล์ม(Flim) 10" x 12" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,550	บ.อีคอนเทคซัพพลายจก.	1,670
6	ฟิล์ม(Flim) 8" x 10" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,050	บ.อีคอนเทคซัพพลายจก.	1,160
7	ฟิล์ม(Flim) 7" x 17" Blue	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,600	บ.อีคอนเทคซัพพลายจก.	1,710
8	ฟิล์ม(Flim) 14" x 17" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,900	บ.อีคอนเทคซัพพลายจก.	2,950
9	ฟิล์ม(Flim) 14" x 14" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,500	บ.อีคอนเทคซัพพลายจก.	2,510
10	ฟิล์ม(Flim) 12" x 15" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,350	บ.อีคอนเทคซัพพลายจก.	2,390
11	ฟิล์ม(Flim) 12" x 16" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,450	บ.อีคอนเทคซัพพลายจก.	2,470
12	ฟิล์ม(Flim) 11" x 14" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	2,050	บ.อีคอนเทคซัพพลายจก.	2,070
13	ฟิล์ม(Flim) 10" x 12" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,550	บ.อีคอนเทคซัพพลายจก.	1,595
14	ฟิล์ม(Flim) 8" x 10" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,050	บ.อีคอนเทคซัพพลายจก.	1,095
15	ฟิล์ม(Flim) 7" x 17" Green	กล่อง	บ.แอลเอฟเอเชีย(ปท)จก.	1,600	บ.อีคอนเทคซัพพลายจก.	1,635
16	ฟิล์มฟันผู้ใหญ่ (Dental Film)	กล่อง	บ.อีคอนเทคซัพพลายจก.	1,200	บ.โอเร็กซ์เทรดดิ้ง จก.	2,300
17	ฟิล์มฟันเด็ก (Dental Film)	กล่อง	บ.อีคอนเทคซัพพลายจก.	950	บ.โอเร็กซ์เทรดดิ้ง จก.	2,000
18	Developer แบบล้างมือ	แกลลอน	บ.แอลเอฟเอเชีย(ปท)จก.	650	-	-
19	Fixer แบบล้างมือ	แกลลอน	บ.แอลเอฟเอเชีย(ปท)จก.	500	-	-
20	Developer แบบล้างเครื่องอัตโนมัติ	แกลลอน	บ.แอลเอฟเอเชีย(ปท)จก.	1,500	บ.อีคอนเทคซัพพลายจก.	1,750
21	Fixer แบบล้างเครื่องอัตโนมัติ	แกลลอน	บ.แอลเอฟเอเชีย(ปท)จก.	800	บ.อีคอนเทคซัพพลายจก.	1,450

ผลการสืบราคายาและเวชภัณฑ์ร่วม(วัสดุรังสีการแพทย์) สำนักงานสาธารณสุขจังหวัดเชียงใหม่ 1/4

อันดับที่	บริษัท	ขนาดบรรจุ	ราคาต่อหน่วย	หมายเหตุ
รายการลำดับที่ 1 Film X-Ray ชนิด Blue ขนาด 14 x 17 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	2,300.00	FUJI
รายการลำดับที่ 2 Film X-Ray ชนิด Green ขนาด 14 x 17 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	2,230.00	FUJI
2	ไอเร็กซ์ เทรดดิ้ง จำกัด	100 แผ่น/กล่อง	2,239.00	KODAK MX - G
3	เบอร์ลี่ ยุคเกอร์ จำกัด	100 แผ่น/กล่อง	2,240.00	AGFA
รายการลำดับที่ 3 Film X-Ray ชนิด Blue ขนาด 14 x 14 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,960.00	FUJI
รายการลำดับที่ 4 Film X-Ray ชนิด Green ขนาด 14 x 14 นิ้ว				
1	ไอเร็กซ์ เทรดดิ้ง จำกัด	100 แผ่น/กล่อง	1,833.00	KODAK MX - G
2	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,855.00	FUJI
3	เบอร์ลี่ ยุคเกอร์ จำกัด	100 แผ่น/กล่อง	2,100.00	AGFA
รายการลำดับที่ 5 Film X-Ray ชนิด Blue ขนาด 12 x 15 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,800.00	FUJI
รายการลำดับที่ 6 Film X-Ray ชนิด Green ขนาด 12 x 15 นิ้ว				
1	ไอเร็กซ์ เทรดดิ้ง จำกัด	100 แผ่น/กล่อง	1,748.00	KODAK MX - G
2	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,755.00	FUJI
3	เบอร์ลี่ ยุคเกอร์ จำกัด	100 แผ่น/กล่อง	1,860.00	AGFA
รายการลำดับที่ 7 Film X-Ray ชนิด Blue ขนาด 11 x 14 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,550.00	FUJI
รายการลำดับที่ 8 Film X-Ray ชนิด Green ขนาด 11 x 14 นิ้ว				
1	ไอเร็กซ์ เทรดดิ้ง จำกัด	100 แผ่น/กล่อง	1,486.00	KODAK MX - G
2	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,490.00	FUJI
3	เบอร์ลี่ ยุคเกอร์ จำกัด	100 แผ่น/กล่อง	1,580.00	AGFA
รายการลำดับที่ 9 Film X-Ray ชนิด Blue ขนาด 10 x 12 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,200.00	FUJI
รายการลำดับที่ 10 Film X-Ray ชนิด Green ขนาด 10 x 12 นิ้ว				
1	ไอ ดี เอส มาร์เก็ตติ้ง จำกัด	100 แผ่น/กล่อง	1,150.00	FUJI
2	ไอเร็กซ์ เทรดดิ้ง จำกัด	100 แผ่น/กล่อง	1,152.00	KODAK MX - G
3	เบอร์ลี่ ยุคเกอร์ จำกัด	100 แผ่น/กล่อง	1,180.00	AGFA

บัญชีรายการและราคาครุภัณฑ์ทางการแพทย์ โดยคณะกรรมการพิจารณารายการครุภัณฑ์ สำนักงานปลัดการะทรวงสาธารณะสุข

ชื่อรายการ	ชื่อย่อ	ประมาณการราคา
1.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิด 1 loader รองรับเมมโมแกรม	cr/ssm 1 slot	2,500,000
2.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิด 1 loader ไม่รองรับเมมโมแกรม	cr/ssnm 1 slot	2,200,000
3.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 2 loader รองรับเมมโมแกรม	cr/msm 2 slot	2,800,000
4.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 2 loader ไม่รองรับเมมโมแกรม	cr/msnm 2 slot	2,500,000
5.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 4 loader รองรับเมมโมแกรม	cr/msm 4 slot	3,300,000
6.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 4 loader ไม่รองรับเมมโมแกรม	cr/msnm 4 slot	3,000,000
7.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 8 loader รองรับเมมโมแกรม	cr/msm 8 slot	3,800,000
8.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 8 loader ไม่รองรับเมมโมแกรม	cr/msnm 8 slot	3,500,000
9.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 10 loader รองรับเมมโมแกรม	cr/msm 10 slot	4,000,000
10.เครื่องแปลงสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอล ชนิดไม่น้อยกว่า 10 loader ไม่รองรับเมมโมแกรม	cr/msnm 10 slot	3,800,000
11.คาสเซ็ทรับภาพดิจิตัลขนาด 15*30 ซม.สำหรับทันตกรรม	Cassette แผ่นละ	20,000
12.คาสเซ็ทรับภาพดิจิตัลขนาด 18*24 ซม.สำหรับเมมโมแกรม	Cassette แผ่นละ	25,000
13.คาสเซ็ทรับภาพดิจิตัลขนาด 8*10 นิ้ว	Cassette แผ่นละ	30,000
14.คาสเซ็ทรับภาพดิจิตัลขนาด 10*12 นิ้ว	Cassette แผ่นละ	30,000
15.คาสเซ็ทรับภาพดิจิตัลขนาด 14*17 นิ้ว	Cassette แผ่นละ	35,000

บัญชีรายการและราคาครุภัณฑ์ทางการแพทย์ โดยคณะกรรมการพิจารณารายการครุภัณฑ์ สำนักงานปลัดการะทรวงสาธารณะสุข			
ชื่อรายการ	ชื่อย่อ	ประมาณการราคา	
16.คาสเซ็ทรับภาพดิจิตัลขนาด 18*24 นิ้ว	Cassette แผ่นละ	40,000	
17.คาสเซ็ทรับภาพดิจิตัลขนาด 14*51 นิ้ว	Cassette แผ่นละ	50,000	
18.เครื่องรับสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอลชนิดชุดรับภาพซีซีดี	dr/ccd	3,000,000	
19.เครื่องรับสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอลชนิดชุดรับภาพแฟลตพาแนลมีสาย	dr/fp,มีสาย	4,000,000	ราคากลางไอซีทีปี2554
20.เครื่องรับสัญญาณภาพ เอกซ์เรย์ เป็นดิจิตอลชนิดชุดรับภาพแฟลตพาแนลไร้สาย	dr/fp ไร้สาย	4,500,000	ราคากลางไอซีทีปี2554
21.ชุดคอมพิวเตอร์แม่ข่ายหลักตามมาตรฐานแบบที่1	ไม่น้อยกว่า4core 2.4ghz , ram4gb,hd 140 gb 2 หน่วย	120,000	ราคากลางไอซีทีปี2554
22.ชุดคอมพิวเตอร์แม่ข่ายหลักตามมาตรฐานแบบที่2	ไม่น้อยกว่า4core 2.66ghz2หน่วย ,ram 16 gb,hd 300gb 4หน่วย	320,000	ราคากลางไอซีทีปี2554
23.ชุดคอมพิวเตอร์แม่ข่ายหลักตามมาตรฐานแบบที่3	ไม่น้อยกว่าriscหรือepic ,ram 4gb hd 140 gb 2 หน่วย	620,000	ราคากลางไอซีทีปี2554
24.ชุดคอมพิวเตอร์แม่ข่ายรองตามมาตรฐานแบบที่1	ไม่น้อยกว่า4core 2.4ghz , ram4gb,hd 140 gb 2 หน่วย	120,000	ราคากลางไอซีทีปี2554
25.ชุดคอมพิวเตอร์แม่ข่ายรองตามมาตรฐานแบบที่2	ไม่น้อยกว่า4core 2.66ghz2หน่วย ,ram 16 gb,hd 300gb 4หน่วย	320,000	ราคากลางไอซีทีปี2555
26.ชุดคอมพิวเตอร์แม่ข่ายรองตามมาตรฐานแบบที่3	ไม่น้อยกว่าriscหรือepic ,ram 4gb hd 140 gb 2 หน่วย	620,000	ราคากลางไอซีทีปี2556
27.ชุดคอมพิวเตอร์เก็บ สำรองข้อมูลขนาดความจุไม่น้อยกว่า 2tb	Storage 2T	30,000	ราคากลางไอซีทีปี2557
28.ชุดคอมพิวเตอร์เก็บ สำรองข้อมูลขนาดความจุไม่น้อยกว่า 4 tb	Storage 4T	35,000	ราคากลางไอซีทีปี2558

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ชื่อรายการ	ชื่อย่อ	ประมาณการราคา
29.ชุดคอมพิวเตอร์เก็บ สำรองข้อมูลขนาดความจุไม่น้อยกว่า 6tb	Storage 6T	45,000
30.ชุดคอมพิวเตอร์เก็บ สำรองข้อมูลขนาดความจุไม่น้อยกว่า 8 tb	Storage 8T	55,000
31.โปรแกรมจัดเก็บ ประมวลผล รับส่งข้อมูลไม่น้อยกว่า25000ภาพต่อปี(pacs/ris)	Pacs 25,000 Studies & 1 Radiologist	2,000,000
32.โปรแกรมจัดเก็บ ประมวลผล รับส่งข้อมูลไม่น้อยกว่า50000ภาพต่อปี(pacs/ris)	Pacs 50,000 Studies & 2 Radiologist	2,500,000
33.โปรแกรมจัดเก็บ ประมวลผล รับส่งข้อมูลไม่น้อยกว่า100000ภาพต่อปี(pacs/ris)	Pacs 100,000 Studies & 4 Radiologist	3,000,000
34.โปรแกรมจัดเก็บ ประมวลผล รับส่งข้อมูลไม่น้อยกว่า100000ภาพต่อปี(pacs/ris)ไม่จำกัด	Pacs 100,000 Studies & 4 Radiologist unlimit	3,500,000
35.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 3 ล้านพิกเซล จอเดี่ยว	lcd 3 mp เดี่ยว	500,000
36.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 3 ล้านพิกเซล จอคู่	lcd 3 mp คู่	900,000
37.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 5 ล้านพิกเซล จอเดี่ยว	lcd 5 mp เดี่ยว	800,000

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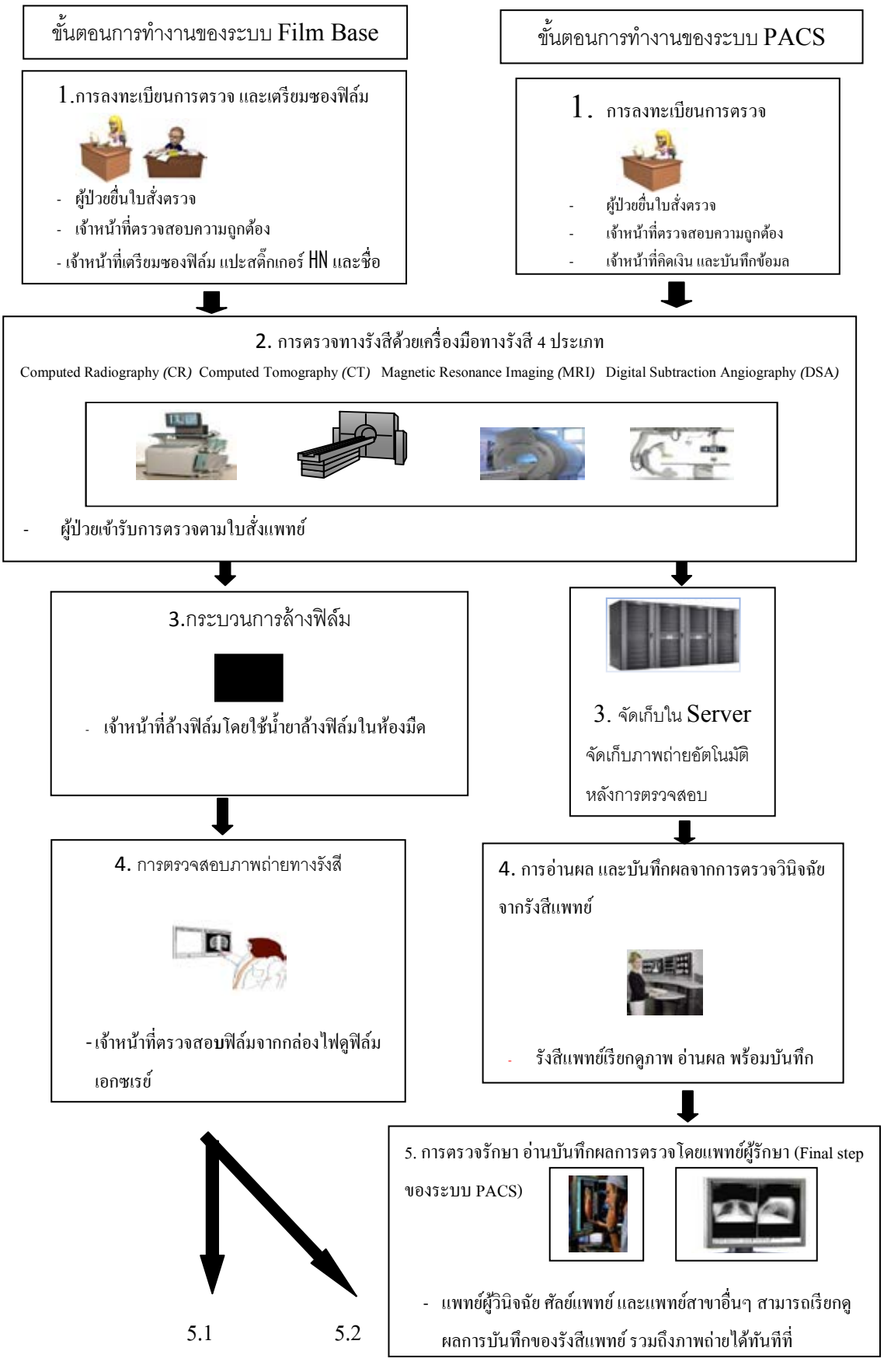
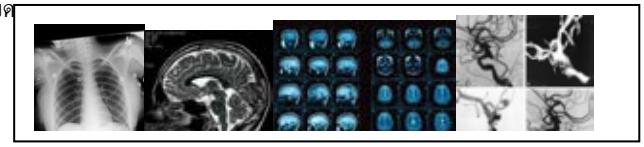
ชื่อรายการ	ชื่อย่อ	ประมาณการราคา
38.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 5 ล้านพิกเซล จอคู่	lcd 5 mp คู่	1,500,000
39.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 6 ล้านพิกเซล จอเดี่ยว	lcd 6 mp เดี่ยว	900,000
40.ชุดคอมพิวเตอร์พร้อมจออ่านภาพเอกซ์เรย์ดิจิตัลขนาดไม่น้อยกว่า 6 ล้านพิกเซล จอคู่	lcd 6 mp คู่	1,800,000
41.จอภาพแสดงผลเอกซ์เรย์แนวตั้งขนาดไม่น้อยกว่า23นิ้ว 2ล้านพิกเซล	lcd vertical 23 นิ้ว 2 mp	9,000
42.เครื่องพิมพ์ภาพเอกซ์เรย์ลงบนแผ่นฟิล์มไม่รองรับเมมโมแกรม	dry laser printer ไม่รองรับเมมโม	600,000
43.เครื่องพิมพ์ภาพเอกซ์เรย์ลงบนแผ่นฟิล์มรองรับเมมโมแกรม	dry laser printer รองรับเมมโม	1,000,000
44.เครื่องสแกนแผ่นฟิล์มเอกซ์เรย์ไม่รองรับเมมโมแกรม	film scanner	800,000
45.ชุดคอมพิวเตอร์สำหรับผู้ใช้งานจอไม่น้อยกว่า23นิ้ว 2ล้านพิกเซล	computer user	30,000
หมายเหตุ		
ราคาเครื่องแปลงสัญญาณภาพเอกซ์เรย์เป็นดิจิตัลรวมคอนโทรล		
ราคาเครื่องรับสัญาณภาพเอกซ์เรย์เป็นดิจิตัลรวมคอนโทรล		
ราคาโปรแกรมจัดเก็บภาพรวมโปรแกรมระบบเชื่อมต่อระบบฐานข้อมูลโรงพยาบาล		
ราคาค่าดำเนินการติดตั้งรวมอยู่ในระบบขึ้นอยู่กับการต่อรองกำหนดราคากลางของโรงพยาบาล		
ราคาคาสเซ็ทเป็นราคาโดยประมาณสามารถถัวเฉลี่ยและรวมในราคาเครื่องแปลงสัณญาณภาพแล้ว		
ถ้าโรงพยาบาลมีระบบเครือข่ายอยู่แล้วสามารถเชื่อมต่อได้เลย		
โปรแกรมต้านไวรัส ตู้เก็บเซอฟเวอร์ เครื่องสำรองไฟอยู่ในรายการชุดเครื่องมือแล้ว		

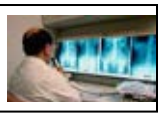
Appendix D: Work process



5.1 การเตรียมฟิล์มให้รังสีแพทย์อ่านผล โดยเจ้าหน้าที่แผนกรังสี (Film 50% ของทั้งหมด



6. การอ่านผล และบันทึกผลจากการตรวจวินิจฉัยจากรังสีแพทย์



- รังสีแพทย์อ่านผลจากกล่องไฟดูฟิล์มเอกซเรย์ แล้วบันทึกผลที่ได้ลงในกระดาษแนบกับ

5.2 คนไข้รอยืมฟิล์มเพื่อนำไปให้แพทย์ผู้วินิจฉัยด้วยตัวเอง (Film 50% ของทั้งหม

- คนไข้ยืนรอรับด้วยตัวเองฟิล์มเมื่อตรวจด้วยเครื่องมือทางรังสีเสร็จแล้ว เพื่อนำไปให้แพทย์ผู้รักษา

7. การนำส่งฟิล์ม และบันทึกผลการตรวจจากรังสีแพทย์ ให้แพทย์ผู้รักษา

- เจ้าหน้าที่นำฟิล์ม และบันทึกผลที่รังสีแพทย์

8. การตรวจรักษา อ่านบันทึกผลการตรวจโดยแพทย์ผู้รักษา

- แพทย์ผู้วินิจฉัย ศัลย์แพทย์ และแพทย์สาขาอื่นๆ ดูผลฟิล์มจากกล่องไฟดูฟิล์มเอกซเรย์ตามห้องตรวจต่างๆ

9. การตรวจรับฟิล์มจากการยืมไป และการเก็บรักษาฟิล์ม (Final step ของระบบ Film Base)

ห้องเก็บภาพถ่ายทางรังสี

- เจ้าหน้าที่รับคืนฟิล์มจากแหล่งต่างๆ ของโรงพยาบาล เช่น หอผู้ป่วย ห้องตรวจผู้ป่วยนอก ห้องประชุม เป็นต้น
- เจ้าหน้าที่ลงทะเบียน ตรวจนับ ฟิล์มที่ได้รับคืนมา (หากไม่ครบจำนวน หรือผิดจากเดิมที่รับไป เจ้าหน้าที่จะส่งคืนแหล่งที่มานั้นๆ หรือถ้าไม่สามารถหาคืนได้ แล้วต้องมีการสั่งตรวจซ้ำ จะต้องเขียนรายงานทุกครั้ง)
- เจ้าหน้าที่นำฟิล์มไปเก็บในห้องเก็บฟิล์ม

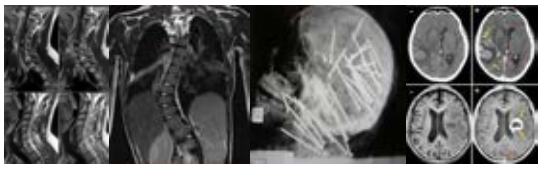
กรณีผู้ป่วยขอฟิล์ม หรือภาพถ่ายทางรังสีไปใช้ที่สถานพยาบาลอื่นๆ

ขั้นตอนการทำงานของระบบ Film Base

1. เจ้าหน้าที่รับแจ้งความประสงค์นำฟิล์มออกจากโรงพยาบาล

2. เจ้าหน้าที่ค้นหาฟิล์มของผู้ป่วยที่ต้องการ

3. เจ้าหน้าที่ลงทะเบียนว่าผู้ป่วยได้รับฟิล์มไปแล้ว



ฟิล์ม

ทั้งกระบวนการใช้เจ้าหน้าที่ 1 คน ใช้ระยะเวลาทั้งหมด 15 นาที

ขั้นตอนการทำงานของระบบ PACS

1. เจ้าหน้าที่รับแจ้งความประสงค์นำภาพถ่ายทางรังสีออกจากโรงพยาบาล

- เจ้าหน้าที่รับแจ้งความประสงค์ของผู้ป่วย
- เจ้าหน้าที่นำภาพถ่ายทางรังสีของผู้ป่วยบันทึกลงในแผ่น CD ส่งมอบให้แก่ผู้ป่วย
- บันทึกข้อมูล

CD

ทั้งกระบวนการใช้เจ้าหน้าที่ 1 คน ใช้ระยะเวลาทั้งหมด 5 นาที

BIOGRAPHY

Thirapich Chuachantra was born in Nakornratchasima, Thailand, on August 2, 1983. He graduated from Princess Chulabhorn Collage, Nakornsithammarat in 2001and received his Bachelor of Pharmacy degree in Pharmacy from Silpakorn University in February 2006. Thirpich has worked in Bhumibol Adulyadej Hospital from 2006 to present (2013), in the position of pharmacist. He entered the degree of Master of Science in Social and Administrative Pharmacy Program, Faculty of Pharmaceutical Science at Chulalogkorn University in 2009