An Analysis of Barcode and RFID using Analytical Hierarchy Process (AHP)
Case Study: The Bangkok Christian Hospital

by
Mr. Sarawut Alongkornsopit

A Final Report of the Six Credit Course
SCM 2202 Graduate Project

Submitted in Partial Fulfillment
Of the Requirement for the Degree of Master of Science
in Supply Chain Management
Assumption University

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Academic Year	November 2007

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ABSTRACT

The Bangkok Christian Hospital is one of the hospitals that is studying technology to decrease the working lead time and also prevent medical error in giving medical treatment to the wrong patient. There are two technologies that they are considering. Those technologies are RFID and Barcode.

In this paper, the analytic hierarchy process (AHP) is used as technique for analyzing information systems implementation decisions. Expert Choice is used to implement the AHP. There are 10 main factors with 26 criteria to be considered. Sourcing of the factors is from expert comments and published articles. Explanation of each calculation step of Expert Choice is also provided.

The study results show that implementation of Barcode seems to be the best option. Barcode is stronger than RFID on the following points; Limitation of the system, Uncertainty of the system, Compatibility of software, Compatibility of hardware, Resource requirement, Easy to implement, Reliability, Number of vendors available for installation, System maintenance, Number. of vendors available in term of back-up service, Cost of Tag, Cost of Reader, Cost of Implementation and Cost of Application. These factors are considered as the direct factors which mostly affect the result of the decision to identity the better identification technology.

Within two years, barcode is the better technology to use and implement. In the long term, RFID experts believe that RFID will replace barcode technology. So, the hospital should prepare their system to support expansion of RFID in the future.

The result of this study could be an example for other hospitals interested in implementing RFID or Bar code and also using the Analytical Hierarchy Process (AHP) in identification technology selection.

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CHAPTER 1 INTRODUCTION

When people talk about Radio frequency Identification (RFID) and Barcode, they always think about an inventory management system, a warehouse management system and Logistics activity. Only a few people think about how to use these two technologies to increase efficiency of activity in a Hospital by decreasing the happening of errors and eliminating waste in the working process of the healthcare industry.

There are cases in Thailand about giving medical treatment to the wrong patient. The root cause is that the nurse received the wrong patient profile from the officer. Then the doctor / nurse did not cross-check again whether the patient profile in their hand belonged to the patient in front of them or not.

Bar code and RFID are both identification technologies that hold data that is accessed by some type of reader. Practically, they complement each other very well and can be used effectively side by side in many applications. Bar code is an optical technology, and RFID is a radio technology. The way these technologies exchange data account for most of the differences between RFID and bar code and help determine where each identification technology is best put to use

Some of hospitals in America are using RFID and Barcode to prevent wrong identification of their patients. For example, St. Clair Hospital, a 331-bed hospital based in Pittsburgh, USA was keen to improve patient safety by employing IT to prevent errors in medication administration. In 2004, the hospital introduced a medication verification system. The nurses would use the PDAs to scan bar codes located on: (a) patient wristbands, (b) medications and (c) their name/identification cards in order to cross-check whether the patient profile or the medicine in their hand belonged to the patient in front of them or not (Schuerenberg, 2005).

However, the use of bar codes mean that the nurses had to position the PDA near a patient's bar coded wristband to scan it, and as their and/or patients wristbands became worn out it would take the nurses several attempts before they could get a good scan on older bar coded wristbands (Schuerenberg, 2005). To resolve this problem, the hospital administrators replaced the bar coded patient wristbands and clinical identification badges with RFID tags, and the scanning devices that would fit into the PC card slot on the PDAs with a RFID tag. The introduction of RFID tags significantly reduced the time spent by the nurses on medication administration whilst also ensuring that medication errors were reduced. In addition, as RFID devices can exchange information without the need for direct device to device contact, as is the case for bar coded wristbands, the patient would not have to be disturbed during the process, which was a regular occurrence when the bar coded wrist band was attached to the patient's arm (Schuerenberg, 2005)

In Thailand, most of the hospitals are studying how they can use identification technology to prevent medical errors that might be happen and also how identity identification technology could improve their efficiency by reducing lead time per transaction in the outpatient department (OPD).

The Bangkok Christian Hospital is one hospital which is studying technology to decrease the working lead time and also prevent medical error in giving medical treatment to the wrong patient. There are two technologies that they are thinking about. One technology is RFID and another technology is Barcode. The challenge is which technology is suitable for their organization and what is the factor(s) / decision method that they should use in technology selection.

1.1 Objectives

This paper intends to focus on a comparison of IT selection criteria between Bar Code and RFID technology by using the Analytical Hierarchy Process.

Specific Objectives are

- To identify factor(s) to be considered in "Barcode and RFID"
- To study the Analytical Hierarchy Process (AHP)
- To recommend identity identification technology which will be use in the Bangkok Christian Hospital

1.2 SCOPE

This project aims to study identity identification technology justification method and compare the benefits of implementing Barcode or RFID. Due to the limitation of time and availability of sharing information, The Bangkok Christian Hospital was selected for this project.

1.3 METHODOLOGY

Because the information in the healthcare industry is quite specific and confidential, the case study approach is suitable for its flexibility in question forming and information gathering style. The information in this project was mainly collected by face to face interviews. All considered factors will be compared by using the Analytical Hierarchy Process (AHP)

1.4 PROJECT STRUCTURE

This project is structured in the following order. Chapter 2 is the Literature Review, which will present tools for identity identification technology justification. Chapter 3 presents the justification method by using the Analytical Hierarchy Process (AHP). Chapter 4 uses the result of AHP to compare two alternatives (RFID vs Barcode) step by step, and factor by factor. Chapter 5 presents recommendations based on the result of AHP, limitations of this study, and further research.

Chapter 1 Introduction

Emphasizes the importance of technology which can be helpful to the healthcare industry especially in a Hospital

Chapter 2 Literature Review

Document Logistics, RFID, Bar code, and illustrates some methods of technology justification

Chapter 3 Methodology

Factor(s) to be considered, Study of AHP and Demonstration of the Analytical Hierarchy Process (AHP)

Chapter 4 Comparison and Analytical

Comparison of two alternatives (RFID and Bar Code) step by step / factor bv factor

Chapter 5 Conclusion and Recommendations

Achievement of objective(s), Recommendations, Limitations and Future Research

Figure 1-1Structure of the study

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

Hospitals have been faced with a competitive environment which has resulted in the need for increasingly high levels of capital investment to support facilities and equipment. Growth of service economies world-wide and the vast amount of revenue they generate have undoubtedly contributed to the subsequent increase in scholarly and practitioner interest regarding services, service quality, failure and recovery. There has never been a more opportune time to pursue the notion of excellence in service quality by whichever means possible, to enhance service delivery and outputs. The following discussion deals with such efforts within a supply chain context and "progressive" technology.

2.2 Summary and limitations of AHP

Table 2-1 Summary and limitations of AHP

Author	Summary	Limitation
Banuelas and Antony, 2007	Analytic hierarchy process (AHP) has emerged as a successful and practical multi-criteria decision analysis (MCDA) technique applied in a variety of areas. Its successful application to a wide range of unstructured and complex problems is largely published in the literature AHP dictated the incorporation of uncertainty in pair-wise comparisons and managerial aspects, in order to apply this technique successfully for the selection of design concepts. A simulation approach was recommended to incorporate	1. AHP is a hard operational research technique, which has a dominant tendency to look for technical solutions to well-structured problems in which desirable ends can be easily stated. However, interventions such as the design concept selection, involve relationships between people and their differential willingness and ability to adjust to the changed circumstances of the desired state of the problem. In addition, different people and various departmental factions can have their own conceptions of what is the problem. Each of these can

	uncertainty in the AHP. It generates probabilistic rankings, which were treated using statistical tools and techniques (eg. ANOVA, MSD, confidence intervals, sensitivity charts).	affect the capability of reaching consensus and converging judgments into a Likert scale, in order to describe the pairwise comparisons of objectives and alternatives required in the AHP. 2. It is hard to reach consensus in the pairwise comparison required in AHP. That is, decision-makers need to clearly state their preferences on criteria-by-criterion basis and translate that preference into a numeric scale (Likert scale). It is assumed that all decision makers agree with that preference. However, in practice, this is not always the case and it is difficult to reach consensus. Researchers have dealt with this problem by using probabilistic judgments, fuzzy sets and intervals. 3. AHP provides decision-makers a score of the expected utilities of each alternative. The alternative with the highest weight should be selected over the others. Sometimes a clear apparent winner among alternatives will emerge. However, the alternatives' weights are just used as a general guide in the selection of a particular alternative, and a small difference in the alternatives' weight is not to be taken as definitive evidence that one alternative is preferable to another. In addition, AHP does not allow decision-makers to draw any statistical conclusion about the difference between alternatives weight. If two alternatives

		have scores that are quite close, it is unclear whether there is a statistical significant difference between the alternatives.
Coyle, 2004	The Analytic hierarchy process (AHP) is a useful technique for discriminating between competing options in the light of a range of objectives to be met. The calculations are not complex, while the AHP relies on what might be seen as a mathematical trick.	1. AHP only works because the matrices are all of the same mathematical form – known as a positive reciprocal matrix.
Warren, 2004	The feature of The Analytic hierarchy process (AHP) that initially sparked many investigations was rank reversal and this caused much discussion about whether it was legitimate or not. Regardless of whether it can occur with real world decision makers, it has been convincingly shown to be a function of normalization. Consequently, it is considered to be a secondary category problem. In contrast, the more fundamental primary category of problems has been defined and the problems identified within this category are: scale misinterpretation, comparison matrix eigenvalue evaluation, and multiple normalizations in hierarchical aggregation of priorities. Moreover, it has been shown that the axiomatic foundations of AHP are also questionable. In general, it is not possible to validate decision analysis techniques based on subjective scoring such as the AHP when they are applied to strategic decisions with abstract criteria. This fact has resulted in the AHP being used in a wide variety of	1. **Top-down Rating of the Relative Importance of Criteria**: It is difficult to know what .relative importance of criteria means, when comparing two heterogeneous concepts without explicit units of measure in top-down criteria comparisons, and without knowledge of what contributions the respective sub-criteria make. 2. **The Pairwise Comparison Rating Scale is Ordinal**: The ratio comparisons seem to impute a ratio scale to the ratings and produce absolute measures by canceling out units for criteria. However, this is not the case since the linguistic or numerical measures applied are on ordinal scales. So A/B = 5 cannot mean A = 5B unless units are assigned. Thus, any numbers assigned are necessarily ordinal measures, and this implies that the eigenvalue polynomial computation is inadmissible. 3. **The Eigenvalue Method for Determining Priorities**: There seems to be no valid reason why the right eigenvector method does balance out

	applications, which in turn has established the method with a sort of de facto credibility. In their enthusiasm to apply the AHP with its very user-friendly software, analysts not infrequently construct models that also violate the most basic constraint of independence of criteria or factors. The increased complexity of procedures for aggregating inter-dependent information may be partially responsible for this, plus the fact that such methods are scarce. However, Saaty has proposed another technique, called the Analytic Network Process to be applied when independence of criteria does not exist. Unfortunately the scale misinterpretation problem is again present so its results also are very questionable. And besides that there are further higher-level assumptions and procedures that are also questionable. It is curious that the large amount of literature focusing on comparing different AHP computational mechanisms is largely inconclusive, and all tacitly seem to accept that the input ratings are actually ratio scale measures that allow complicated algebraic operations to be validly performed. Despite numerous claims by the AHP school that the method gains it rigor because it uses ratio scale measures, it is obvious that there is a fundamental misunderstanding in what the different types of scale mean. This is a common problem in scientific literature because it has primarily been concerned with matters of the physical realm.	inconsistent ratings, especially since left and right eigenvectors may yield different results. This uncertainty is in addition to whether or not the eigenvalue computation is admissible by scale type limitations. 4. **The Normalization Problem**: Normalization of the weight and alternative preference vectors causes anomalies in both single level and multi-level hierarchical aggregation of priorities, and is one of the reasons for rank reversal. 5. **Additive Aggregation of Priorities:** For additive aggregation all criteria must be independent and not inter-related, which is often not the case.

	And because no bells and whistles sound when inadmissible operations are performed on measures, sophisticated computational mechanisms can effortlessly be applied which convinces others of the methods validity by virtue of their sophistication. The unfortunate conclusion is that the many simulations of computational AHP refinements are all meaningless because they also perform inadmissible operations. Although some comparisons of quantitative factors may invoke a quasi-ratio scale rating of some measurable property, The proposed scale is not a true ratio scale because of its lower and upper limits, and the absence of an absolute zero. And needless to say, comparisons of qualitative factors cannot yield ratio scale measures. Overall, even without the ordinal scale problem, there are enough questionable features in the AHP to severely doubt the validity of the output priorities. With this in mind, the method should be applied with great caution. It should also be noted that it is not only the AHP that is subject to some of these criticisms and several other techniques in the field of multi-criteria or multi-attribute decision analysis also have similar limitations. At the present time we are examining several other decision analytic techniques that have been proposed recently and which attempt to avoid the pitfalls described. Needless to say, if decision analytic methods are being applied to make important Defense decisions, the method	

	applied should be theoretically sound. Only then can there be confidence in the analytical results.	
Davies, 2001	The Analytic hierarchy process (AHP) can be used whenever a decision problem can be represented by a hierarchy, or cluster of hierarchies, resting on the assumption of an overriding objective or goal. When faced with a vast range of alternatives under time pressure and without resort to appropriate decision-support systems, management is likely to make intuitive decisions involving cognitive leaps; and unlikely to consider the range of choices thoroughly. The foundation for AHP is in simplifying the cognitive demands placed on decision makers by restricting the simultaneity of choosing from numerous options to pairwise comparisons Several software packages now incorporate AHP which fulfill the requirements of a decision support system (DSS). These are techniques that can assist management in the gathering, structuring and interpreting of all relevant information to improve their decision making. Typically, these packages involve: • Criteria and alternatives specified by the users, i.e. model structures are user driven rather than system driven; • weights allocated to each objective or criterion; • The user(s) evaluating each alternative against each criterion;	1. When the system is user driven, the question of validity rests with the user. There may be difficulties with understanding, using, and interpreting the system, possibly leading to the wrong variation of an AHP model being adopted, and reluctance to follow through any recommendations from the system output. 2. Since AHP is generally used to solve specific problems, it was not possible to offer a statistical analysis of applications used.

	• A summary calculation that indicates the best alternative based upon the criterion weights and alternative priorities. When AHP is used as a stand-alone technique, or combined with other software, Expert Choice (EC) is the only software reported. The popularity of Expert Choice may be attributable to its being the first software specializing in AHP.	
Millet, 1998	The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty. It has been used extensively by government and business organizations. Expert Choice, Inc. (1995), one of the vendors of AHP software, reports thousands of installations of its namesake product on PC around the globe. The step of using the AHP are as following:- 1. **Constructing a hierarchy of criteria**: This hierarchical structure offers a natural way to divide and conquer the complexity of multiple ethical principles; without it, decision makers may simply be overwhelmed. The AHP is very flexible in modeling decision hierarchies. User can grow the hierarchy to lower and lower levels of sub-criteria. In general, as the complexity and importance of the decision increases, user will tend to use deeper hierarchies. 2. **Allocating weights to the criteria**: The second step in applying the AHP involves allocating weights to each	1. **Theoretical underpinning**: At the heart of the controversy surrounding the Analytic Hierarchy Process lays the thorny issue of rank reversal. The original computational method of the AHP has been criticized for allowing the introduction of a new alternative, even an irrelevant one, to cause the rankings of the previous alternatives to be reversed. The debate has been deadlocked since each side could present convincing examples for and against rank reversals. 2. **Subjectivity:** The subjective nature of the modeling process in the AHP is a clear limitation, but it cannot be avoided. This means that the methodology cannot guarantee "correct" decisions or even agreement among multiple decision makers. At best, it can only help our chances to make better decisions and to reach a consensus. 3. **Time and effort:** Beyond the time and effort required to structure the AHP model, the number of pairwise comparisons increases rapidly as the number of nodes in the hierarchy increases.

	criterion and splitting that weight among the sub-criteria below each criterion. A pairwise comparison process improves the accuracy of these eights since it allows managers to focus on a series of relatively simple questions. This pairwise comparison process also allows the methodology to raise an alarm when the decision maker was inconsistent. Software implementations of the AHP, such as Expert Choice (1995), provide a variety of verbal, numeric, and graphical comparison methods. In situations where the decision maker can directly attach a numerical value to each of the compared elements, these values can be used to directly compute weights. 3. **Evaluating the alternatives:** The alternatives are evaluated in light of each of the lowest-level criteria. 4. **Integrating judgments into final scores**: Under each sub-criterion, the most preferred alternative receives the full weight of that criterion. The other alternatives receive lower weights in proportion to how well they compared to the most preferred one.	

2.3 DOCUMENT MANAGEMENT AND LOGISTICS

Document Logistics covers all the processes in transporting, storing (saving, filing, archiving), handling and converting (printing, copying, scanning) from the creation to the usage and storage of paper-based or electronic documents.

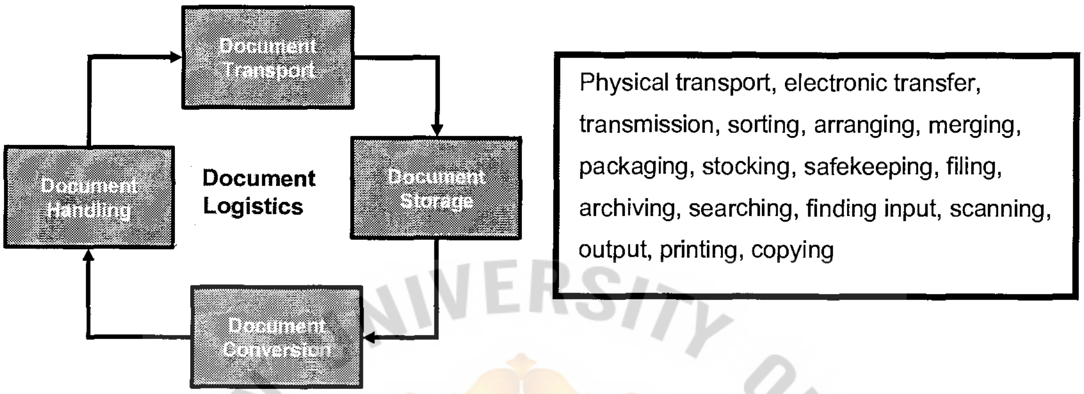


Figure 2-1 Document Logistics Flow

The management of documents in the industry is challenging. The basic theory of managing documents is not unlike managing books in a library. The documents need a safe and secure place to keep them when they are not being used, they need to have the capability to check them out and check them in to meet user demands, and there is a need to know where each one is at any given time. This venue creates unique challenges that are not easily met, and if mismanaged, could lead to project overruns, increased maintenance costs, and overall increased cost of doing business.

Patient records management has been highlighted by the Government as a key area in order to assist in the reduction of waiting times and to reduce administration costs. Records are a valuable resource because of the information they contain. That information is only usable if it is correctly recorded in the first place, is regularly up-dated, and is easily accessible when it is needed.
Information is essential to the delivery of high quality evidence-based health care on a day-to-day basis and an effective records management service ensures that such information is properly managed and is available:

- to support patient care and continuity of care

- to support sound administrative and managerial decision making,
- as part of the knowledge base for NHS services
- to meet legal requirements, including requests from patients under access-to- health- records legislation

Electronic product code

EPC is the next generation of product identification. The EPC adopts the basic structures of the global trade item number (GTIN), an umbrella group under which all existing bar codes fall, which is supported by EAN International and the Uniform Code Council, Inc. (UCC). EAN International and the UCC were chosen as implementation partners because of their many years of experience in developing and managing global standards.

Like the UPC (Universal Product Code) or bar code, the EPC is divided into numbers that identify the manufacturer, product, version and serial number (see Figure 2-2).

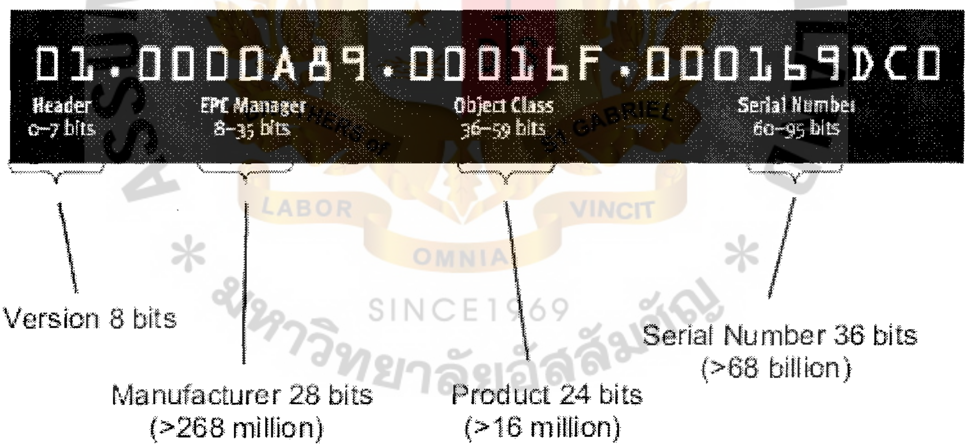


Figure 2-2 The electronic product code

As shown in the figure 3, EPC has a header and three sets of data. The header identifies the EPC's version number this allows for different lengths or types of EPC later on. The second part of the number identifies the EPC manager, most likely the manufacturer of the product the EPC is attached to, for example "The Coca-Cola Company." The third, called object class, refers to the exact type of product, most often the stock-keeping unit (SKU), for example "Diet Coke 330 ml can, U.S. version." The fourth is a serial number, unique to the item, that tells us exactly which 330-ml can of Diet Coke we are referring to. This makes it possible, for example, to quickly find products that might be nearing their expiration date.

Table 2-2 EPC tag classes

EPC tag Class	Tag Class capabilities
0	EPC number is factory programmed onto tag and is read-only
1	Read/write-once tags are manufactured without the EPC number (under programmable)
2	Class 1, plus larger memory, encryption and read/write capabilities
3	Class 2, capabilities, plus a power source to provide increased range and/or advanced functionality (such as sensing capability)
4	Class 3 capabilities, plus an active transmitter and sensing
5	Class 4 capabilities, plus the ability to communicate with passive tags (essentially a reader)

EPC global Network

Leveraging existing RFID and Internet technologies, the EPC global Network will convey real time data about individual items as they move through the supply chain. Information can be collected, utilized, and communicated across supply chains, across industry and around the world. In that way, the EPC global Network will make an organization more effective by enabling true visibility of information about items in the supply chain. The EPC global Network is comprised of the following five fundamental elements:

EPC: Unique number that identifies a specific object in motion in the supply chain.

id System: The id system consists of EPC tags and EPC readers.

Object Name Service (ONS): ONS is similar to the domain name service (DNS) in the computer network. It provides the network address service of product information.

Physical Markup Language (PML): A common language in the EPC global Network to define data on physical objects.

Savant: The savant sends a query over the Internet to the object name service (ONS), which acts like a yellow page directory, to retrieve the network address of the product information. The program can run on different computers distributed throughout an organization. It is a software technology that acts as the central nervous system of the EPC global Network.

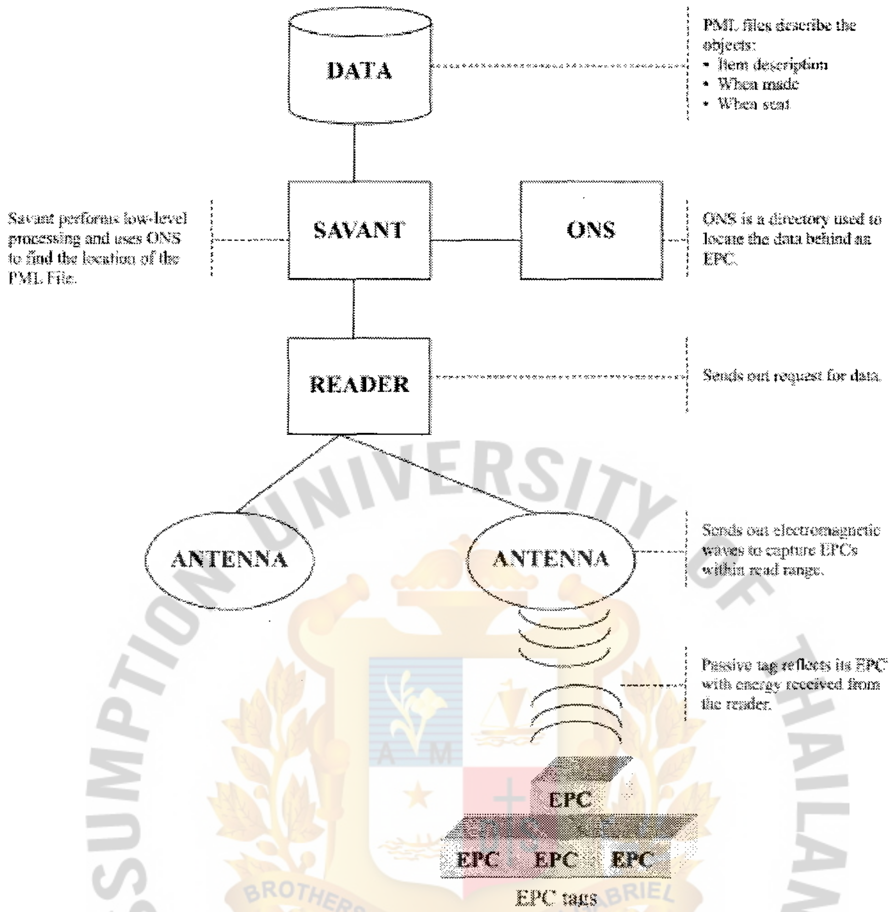


Figure 2-3 RFID system

2.4 RFID TECHNOLOGY

RFID stands for Radio Frequency Identification. It is an electronic method of exchanging data over radio frequency waves. An RFID system consists of three main components:

1. **RFID "tag" or "transponder"**

   is a tiny microchip for information storage. A tag is attached to an object

2. **RFID "reader" or "transceiver"**

   reads the information on the tag from distance ranging.

3. Antenna or coil

communicates the information via radio waves. The antenna in an RFID tag is a conductive element that permits the tag to exchange data with the reader.

The RFID system enables an antenna to emit radio signals to activate the tag, and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. The transceiver receives the data from the antenna or transmits data to antenna.

2.4.1 The roots of RFID

Auto-id, represents a broad category of technologies that are used to help machines identify objects, humans, or animals. As such, it is often referred to as automatic data capture, as auto-id is a means of identifying items and gathering data on them without human intervention or data entry. As can be seen in Figure 1, the omnipresent bar code is itself a form of auto-id technology. RFID is also a type of auto-id technology.

Sometimes referred to as dedicated short-range communication, RFID is ‘‘a wireless link to identify people or objects’’. RFID is, in reality, a subset of the larger Radio frequency (RF) market, with the wider market encompassing an array of RF technologies, including: cellular phones, digital radio, the global positioning system (GPS), high-definition television, and wireless networks.

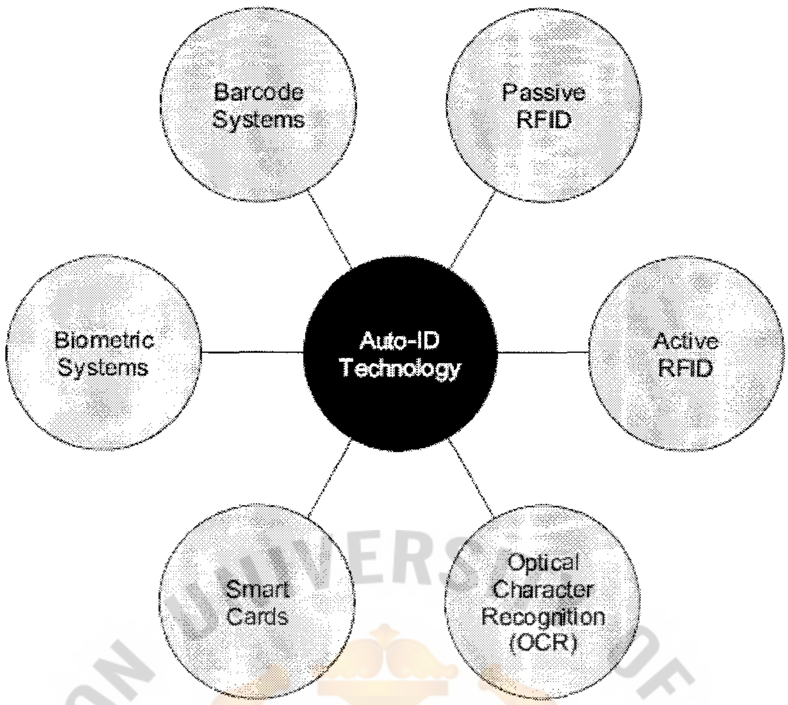


Figure 2-4 The family of auto-id technologies

2.4.2 Two types of RFID tags

Passive RFID tags operate without a separate external power source and obtain operating power generated from the reader. Passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade off is that they have shorter read ranges than active tags and require a higher-powered reader. Read-only tags are typically passive and are programmed with a unique set of data (usually 32 to 128 bits) that cannot be modified. Read-only tags most often operate as a license plate into a database, in the same way as linear barcodes reference a database containing modifiable product-specific information.

Active RFID tags are powered by an internal battery and are typically read/write, i.e., tag data can be rewritten and/or modified. An active tag's memory size varies according to application requirements; some systems operate with up to 1MB of memory. In a typical read/write RFID work-in-process system, a tag might give a machine a set of instructions, and the machine would then report its performance to the tag. This encoded data would then become part of the tagged part's history. The battery-supplied power of an active tag generally gives it a longer read range. The trade off is greater size, greater cost, and a limited operational life (which may yield a maximum of 10 years, depending upon operating temperatures and battery type).

Table 2-3 Differentiating passive and active RFID tags

Passive tags	Active tags
Operate without a battery	Powered by an internal battery
Less expensive	More expensive
Unlimited life (because of no battery)	Finite lifetime (because of battery)
Less weight (because of no battery)	Greater weight (because of battery)
Lesser range (up to 3-5m, usually less)	Greater range (up to 100m)
Subject to noise	Better noise immunity
Derive power from the electromagnetic field generated by the reader	Internal power to transmit signal to the readers
Require more powerful readers	Can be effective with less powerful reader
Lower data transmission rates	Higher data transmission rates
Less tags can be read simultaneously	More tags can be read simultaneously
Greater orientation sensitivity	Less orientation sensitivity

2.4.3 RFID System Frequency Ranges

There are 4 different frequency ranges that RFID systems operate at. As a rule of thumb, low-frequency systems are distinguished by short reading ranges, slow read speeds, and lower cost. Higher-frequency RFID systems are used where longer read ranges and fast reading speeds are required.

Table 2-4 Frequency Range

Frequency	Range	Applications
Low-frequency 125 - 148 KHz	3 feet	Animal identification; automobile key-and-lock
High-frequency 13.56 MHz	3 feet	Library book identification; airline baggage tracking; smart cards
Ultra-high frequency 868 - 956 MHz	25 feet	Supply chain tracking: Box, pallet, container, trailer tracking
Microwave 2.45 GHz	100 feet	Highway toll collection; vehicle fleet identification

2.5 BAR CODE

Bar coding is widely acknowledged as one of the strongest and most cost-effective methods for improving patient safety. But many healthcare organizations are reluctant to implement bar coding because of their misperceptions about integration challenges and supporting system requirements. In reality, bar coding offers the benefits of flexible, open-system technology that can improve patient safety through standalone applications, integrate with legacy healthcare IT systems, and provide a migration path to future system upgrades.

Hospital IT personnel can prepare their organizations to benefit from bar code patient safety systems by dispelling the misperceptions and setting the foundation for adoption. Establishing bar code standards and policies is the starting point that will help multiple departments implement applications that can leverage legacy systems, and provide a migration path to maximize the return on bar code investments.

Bar coding does not need to be proprietary. Most bar codes simply act as a shortcut for entering a string of data or looking up a database record. Bar code scanning replaces keyboard or manual data entry on the front end of a system. Legacy systems may not require much modification to accept bar code data entry.

Effective bar code applications for patient safety can be implemented without a computerized physician order entry (CPOE) or electronic medical record (EMR) infrastructure. Medication administration is probably the most important and effective use of bar coding to improve patient safety, and does not require a CPOE or EMR system in place. The FDA estimates that bar code applications would prevent 50 percent of medication administration errors, but actual users have reported more than 80 percent reductions. Medication administration impacts many operations, because it requires bar-coded patient wristbands, unit-dose labels with bar codes, bedside scanning equipment, and the software application to confirm the drug administration. Packaged solutions are available and cost less than more far-reaching EMR and CPOE systems. Cost-effective bar code applications can also be implemented for identifying and managing specimens, blood products, medical equipment, files and records, and more. Bar code investments will be leveraged if CPOE or EMR systems are implemented later, because the bar code system can remain in place and be integrated to complement the new applications.

Every hospital with a bar code medication administration system has overcome the obstacle of ensuring medications have a bar code label. (And, as noted previously, approximately 30 percent of adopters have less than 150 beds). To date, they have had to mark most of their own medications. The FDA rule will greatly reduce self-labeling requirements and costs. Bar code printing is especially cost-effective for hospitals that will be implementing systems

2.6 RFID VS Barcode

It is important to understand the significant differences between RFID and bar code to appreciate the benefits RFID can provide. Bar code and RFID are both identification technologies that hold data that is accessed by some type of reader. In actuality, they complement each other very well and can be used effectively side by side in many applications. Bar code is an optical technology, and RFID is a radio technology. The ways these technologies exchange data account for most of the differences between RFID and bar code and help determine where each identification technology is best put to use.

One of the key differences between RFID and bar code technology is that RFID eliminates the need for line-of-sight reading that bar coding depends on. Also, RFID scanning can be done at greater distances than bar code scanning. High frequency RFID systems (850 MHz to 950 MHz and 2.4 GHz to 2.5 GHz) offer transmission ranges of more than 90 feet, although wavelengths in the 2.4 GHz range are absorbed by water (the human body) and therefore has limitations.

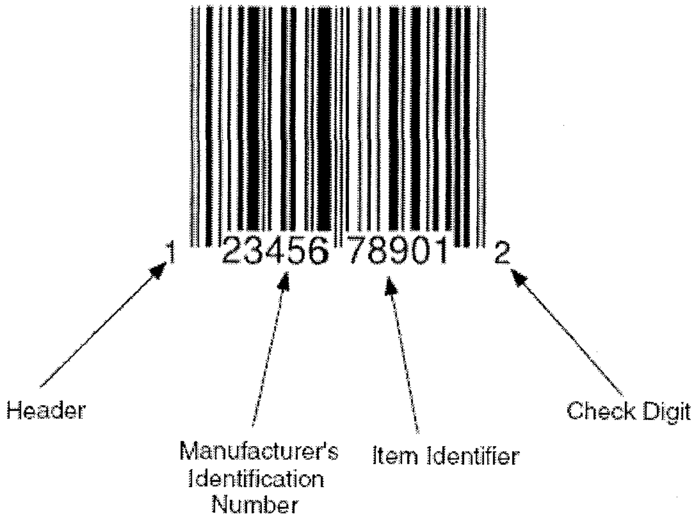


Figure 2-5 Anatomy of a bar code

There are five primary advantages that RFID has over bar codes. These are:

(1) Each RFID tag can have a unique code that ultimately allows every tagged item to be individually accounted for,

(2) RFID allows for information to be read by radio waves from a tag, without requiring line of sight scanning or human intervention,

(3) RFID allows for virtually simultaneous and instantaneous reading of multiple tags,

(4) RFID tags can hold far greater amounts of information, which can be updated, and

(5) RFID tags are far more durable.

Table 2-5 RFID and bar codes compared

Bar code	RFID
Bar codes require line of sight to be read	RFID tags can be read or updated without line of sight
Bar codes can only be read individually	Multiple RFID tags can be read simultaneously
Bar codes cannot be read if they become dirty or damaged	RFID tags are able to cope with harsh and dirty environments
Bar codes must be visible to logged	RFID tags are ultra thin and can be printed on label and they can be read even when concealed within an item
Bar codes can only identify the type of item	RFID tags can identify a specific item
Bar code information cannot be updated	Electronic information can be over - written repeatedly on RFID tags
Barcodes must be manually tracked for item identification, making human error an issue	RFID tags can be automatically tracked, eliminating human error

One of the principal advantages that RFID tags have for identifying products, items, and equipment is the fact that the tags are far more durable than bar codes. If a bar code label is covered with grease, grime or mud, it is unreadable. If a bar code is torn, smudged, or disfigured, it can no longer function as an identifier. However, RFID tags are highly durable, and so long as they are not destroyed (either physically or with an electromagnetic pulse of sufficient strength to do so), passive tags will be ready to transmit indefinitely. RFID tags and labels can work effectively, even in harsh environments with excessive dirt, dust, moisture, and in temperature extremes. They can function in both extreme heat and cold, with a functional temperature range between - 25 and 70C. Some tags specifically designed for industrial applications can function well beyond the boiling point – up to 250 C. Most tags can withstand the high power pasteurization process and X-rays. The only caveat to the latter would be that most silicon-based electronic circuits are erased by the gamma radiation commonly used for sterilization

It is also important to bear in mind the fundamental temporal differences between bar codes and RFID. With bar code technology, information on the item is obtained only when someone takes the action of scanning the bar code label with a reader – and only that particular reader. In contrast, an item tagged with RFID is always turned on and available to be read – and perhaps by multiple readers at the same time. Thus, while a bar code labeled item can only be read discretely, an RFID-tagged item can be read or monitored continuously. In practical terms, a bar code can only tell you where an item of a particular class was when it was last scanned, while RFID can tell you precisely where a particular item is presently.

2.7 RFID APPLICATION IN HOSPITALS

It is not difficult to conclude that RFID technology should become a critical success factor for the medical centers of the 21st century in terms of both improved patient safety and improved hospital savings. It can enable the average hospital to *save more than $2 million per year* (*The Joint Commission on Accreditation of Healthcare Organizations (JCAHO)-Michael Powell, 2005*)

The most significant factor that results in medical errors and serious hurt is the provision of medicine in inpatient healthcare. We fulfill the system analysis and design for the pharmaceutics operations in inpatient nursing. This system associated with RFID tags can automatically identify the patient identity, compare the drugs he takes and then synchronize the registration in the Electronic Healthcare Record (EHR). With this system, a mismatch, over-dosage, or drug–error can trigger an alert and eliminate the problem. In addition, with the RFID tag, the modified flow of the standard of operation (SOP) to keep the drug safely can be more reliable (*The Application of RFID on Drug Safety of Inpatient Nursing Healthcare - Fan Wu Dept. Management of Information Systems, Chung-Cheng University Taiwan, China, 2005*)

RFID technology is already being deployed across the pharmaceutical industry to combat drug counterfeiting. The next frontier is the patient care center, in which the technology will be used to identify patients and track the location of doctors, nurses and equipment in real time as well as control the inventory of pharmaceuticals and medical equipment. In our research, we will focus on patient identification and tracking assets.

RFID technology is growing in popularity in the healthcare industry. Hospitals have been trying to move away from the standard patient blue card for years. One option is a wristband with a bar code on it. A more recent trend is to use wristbands with embedded RFID tags. The RFID system represents the next advanced step in patient identification technology. The data is stored on the wristband and remains securely with the patient.

2.7.1 **RFID wristband for patients:**

1. It contains the patient's name, social security number, birthday, sex, blood type, allergies, physician, admission date, contact person and phone number, and ailment
2. It can be read through the body and clothing
3. Fluids do not interfere with it
4. It will not interfere with other medical equipment
5. It contains a 13.56 MHz RFID chip and antenna that together offer a read range of approximately 3 feet

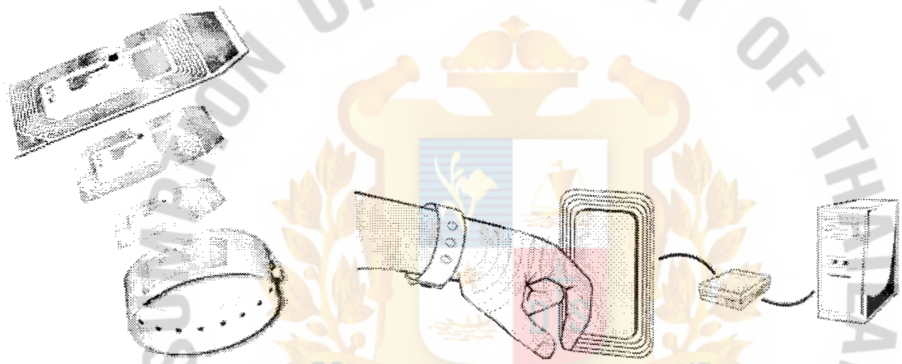


Figure 2-6 RFID wristband for patient

The principles upon which RFID is based are quite straightforward, even though the technology and the way it operates can be quite sophisticated. Just as one does not need to understand the technicalities of a mobile phone or PC to use them, the same holds true of RFID. Here is a basic overview of an RFID System in action:

1. RFID wristband enters the radio frequency field of an RFID scanner.
2. Radio frequency signal powers RFID inlet in wristband.
3. RFID wristband transmits data to reader/writer.
4. Reader/writer sends data to computer.
5. Computer determines action and sends data to reader/writer.
6. Reader/writer updates or modify RFID wristband.

2.7.2 Patient identification

The patient will be given a RFID bracelet. Each bracelet contains a unique patient number assigned during the admission process. When used for patient ID purposes, the RFID chips are typically embedded in plastic wristbands. The chips can also be attached to plastic or paper tags. Each RFID chip stores about 2 KB of information about a tagged object or individual — allergies, blood type, medications, and so on. The chips transmit data wirelessly to an RFID reader, without having to come into direct physical contact with — or even immediate proximity to — the reader. The bracelet is scanned using an RFID scanner attached which a nurse typically rolls in on a cart and places within several feet of the patient. Only authorized users have access to the specific information they need to care for each specific patient.

When the patients check out from the hospital, they need to return the RFID wristband. The hospitals can reuse the RFID chips.

Table 2-6 RFID technical challenges and corresponding strategies (Suhong Li, 2006)

	Technical challenges	Corresponding strategies
Cost	Passive tag price ranges from 20 cents to 1 dollar Major retailers will have to invest $400,000 at each distribution center, $100,000 at each store to read and manage the data, and $35-40 million to integrate the RFID system into existing information systems	The price of the tag and reader will continue dropping Conduct a ROI analysis using ROI calculator by Auto-ID center Phase-in approach of the implementation
Standards	No general accepted standard ISO 11785 for 125 KHz, ISO 15693 for 13.56 MHz, and ISO 18000-6 for 860-930 MHz ISO 15693 for passive, read-write tags which operate at 13.56 MHz 915 MHz UHF frequency by The American National Standards Institute	UHF is considered the standard frequency for the retail industry supply chain
Tag and reader selection	Tag frequency Reader antenna shape Tag antenna design Read rate Read reliability	Use a circular polarized reader antenna if the tag orientation within the radio frequency field is unknown; use a linear polarized reader antenna for greater frequency penetration and longer read ranges A multi-directional tag antenna (double dipole) is less orientation specific and performs better than a single-directional antenna Tags should be slightly offset from metal containers and from items containing liquid or attached to a teflon bracket A signal light system (poka-yoke)
Data management	The quality and synchronization of the data generated by RFID devices False read and multiple reads of tags Noise and "dirty" data The effective use of the massive amount of data generated	Application of a RFID middleware to process the data and to filter out redundant and unneeded information
System integration	Integration of RFID systems and the data they generate with other functional databases and applications	Data synchronization Many software developers have focused on the integration issue of RFID technology such as SAP, Oracle, and Microsoft
Security	Eavesdropping Tracking attacks Fraudulent tags and readers Physical tamper attacks Denial of service (DoS) attacks	For eavesdropping, "silent" or "blinded" tree-walking algorithm (MIT) and the pseudonym scheme (RSA Laboratories) For tracking attack, the randomized hash lock method and the application of a selective blocking tag For fraudulent tags/readers, low-cost one-way hash function methods For physical tamper attacks, tamper resistance hardware For DoS attack, special reader

2.8 BENEFITS OF USING RFID SYSTEM FOR PATIENT IDENTIFICATION:

1. Continuously track each patient's location
2. Track the location of doctors and nurses in the hospital
3. Track the location of expensive and critical instruments and equipment
4. Restrict access to drugs, pediatrics, and other high-threat areas to authorized staff
5. Monitor and track unauthorized persons who are loitering around high-threat areas
6. Facilitate triage processes by restricting access to authorized staff and "approved" patients during medical emergencies, epidemics, terrorist threats, and other times when demands could threaten the hospital's ability to effectively deliver services
7. Use the patient's RFID tag to access patient information for review and update through a hand-held computer

2.8.1 Opportunity to improve efficiency:

1. Provide non-transferable Positive Patient identification which can help save lives and money through reducing medical errors
2. Allow healthcare personnel to instantly and accurately capture and verify data for medication administration, point-of-care-testing (POCT), transfusion, specimen collection/tracking, surgical site safety, and patient charging. RFID wristbands are designed to meet the commonly referenced Five Rights of Medical Safety: the Right Patient, Right Drug, Right Dose, Right Route, and Right Time. For instance, in a transfusion check in the operating room, an alarm blares or a warning message is shown on the monitor if a nurse tries to carry into the operating room the wrong blood type for the patient. The patient chip does not match the one on the blood tag. Everyone knows. A simplified view of the system (a design showing reader input to LCD monitor) is shown below:

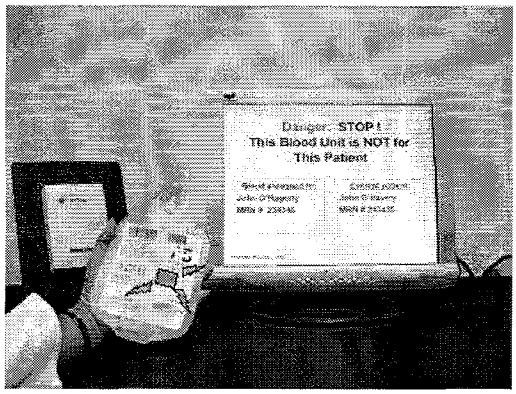


Figure 2-7 A design showing reader input to LCD monitor

3. Time saving: Doctors and nurses are able to view any patient's complete record whenever they need to, rather than having to repeatedly walk to a central filing area to retrieve records between seeing patients. That could mean saving each doctor or nurse 3 minutes for each patient seen in a day.
4. Unlike a barcode, RFID system allows information to be read by radio waves from a tag with non-line-of- sight technology. This would reduce medical errors because before healthcare workers often fail to scan the patient's barcode or must wake the patient to do so. That means the staff members often choose to either bypass the required barcode scan or verify a patient by sight and scan a copy of the patient's barcode on their clipboard instead.
5. Speed up treatment: For example, in 2003 Boston Marathon, the runners were required to wear RFID wristbands during the race. If the runner needed to be taken to a hospital, he or she can get treatment very quickly because the emergency staff can read from his RFID tag.
6. Read/write electronic storage technology allows for data transfer to and from host systems and data storage (e.g. blood type, allergic reaction warning, instructions/DNR, surgery site)
7. RFID yields larger memory capacities, wider reading ranges, and faster processing than bar codes
8. RFID wristbands are hard to damage due to protection against ripping
9. RFID wristbands are reusable

2.9 THE CHALLENGE OF APPLYING RFID IN HOSPITALS

2.9.1 Hard to maintain the Five Rights of Patient Care:

The five rights of patient care are often given as right patient, right drug, right dose, right route and right time. By further integrating the digital and healthcare worlds, radio frequency identification (RFID) offers a way to maintain those five rights and to join-up care and processes. But all too often, the five rights check is flawed because it fails to guarantee the right patient. Approximately 5% of patient wristbands are erroneous or missing altogether. Missing, poor quality and incorrect wristbands are a major contributing factor to many adverse events. Figure (1) depicts the stages of medication management during which errors typically occur and can be prevented. Medical errors are the eighth leading cause of death for Americans — more than motor vehicle accidents, breast cancer or AidS.

2.9.2 Problems of two major tools for patient identification:

Bar Code

A bar-coded wristband is not easy to read if the patient gets it wet or is sleeping on top of that arm. It is even harder when the patient is on an emergency room gurney or operating table -- busy times when mistakes in medication or blood transfusion can be easy to make. Because the reading of bar codes needs a line of sight between the patient's ID tag and a bar code and scanner, healthcare workers often fail to scan the patient's ID bracelet's bar code or must wake the patient to do so. That means that staff members often choose to either bypass the required bar code scan or verify a patient by sight and scan a copy of the patient's bar code on their clipboard instead.

Physical Order Entry

Physical Order Entry is the most common and traditional way on patient identification. Mis-keying and misreading of information is always happening. When the nurses are very busy, they have the chance to key in the medical records to wrong patients. Shortage of nurses is a critical issue in hospital but they still need to spend their valuable time to input patients' medical records.

2.9.3 Expensive Cost of Medical Errors

Adverse drug events alone cost U.S. hospitals billions annually, while errors lead to an increase in hospital stays of 4.6 days and an incremental cost of $4,700 per admission. Medication errors may occur at any point in the medication process. Medication errors cost the nation more than $2 billion annually in terms of lost income, lost household production, disability, and healthcare expenditures. Individual hospitals may expend as much as $5.6 million annually to treat the effects of these medication mistakes.

2.10 CHALLENGING IN ADOPTING RFID

It is more challenging to install an RFID system in a hospital than in a warehouse because of its special characteristics.

2.10.1 Hardware:

2.10.1.1 Material matters

Radio waves bounce off metal and are absorbed by water at ultra-high frequencies. Metal causes eddy currents in the vicinity of the RFID reader antennae, which absorb RF energy. Metal can also detune both reader and tag antennae, creating interference between the tag and reader, thus reducing the overall effectiveness.

2.10.1.2 Electro-Magnetic Wave Interference.

Other electrical magnetic device, wireless LAN, cellular phone can interfere in the data exchange between the tag and the reader.

2.10.1.3 Medical equipment requirement.

Some medical equipment is radiosensitive. RFID system operating in the low frequency (13.56MHz) and ultra-high frequency (915MHz) use the same spectrum as the medical telemetric equipments.

2.10.1.4 **Multiple floors.**

Unlike the warehouse and the retailer store, the building in the hospital has multi-floors. One floor could be reading another floor's data, causing the data redundancy and inaccuracy.

2.10.1.5 **Limited patient room.**

Patient rooms are small, which can be a drawback when using 900 MHz products.

2.10.2 Software

2.10.2.1 **Established system incompatibility**

Established a numbering system in which the hospital may have sunk large investments may be incompatible with EPC encoded system, requiring extensive reworking of existing systems, and additional translation schemes.

2.10.2.2 **Large dynamic data flow**

Tags on a patient, on the staff, or on medical equipment are always moving, from one place to another. This will generate a large quantity of dynamic data. Unlike the data that are intentionally input by people or by a barcode-reader, this data flow is totally uncontrollable, un-predictable. This needs a real-time database, or a strategy to process the data flow.

2.10.2.3 **Data Integration with Patient Management System**

Generally, the management system in a hospital has already been established. The RFID process has to be integrated with an already running system. The most important function of the new system is to establish RFID regulation, which means, the right person, (or the right device in an asset management) will appear at a right place on a right time. If anything conflicting with the regulation happens, the system will give an alarm.

2.10.2.4 Data Integration with Asset Management Systems;

One solution for the interference and reflection problem is to install more than one tag on one object to be traced. Besides the consideration in the Patient care system, the new system also needs to handle multi-tags attached in the same device.

2.10.2.5 Data Sharing with Other Systems

Healthcare has many management systems such as lab test, pharmacy, and medical supply. RFID can be used in the whole supply chain system. One problem is whether all these partners are welling and ready to adopt RFID? If, not, there is a kind of waste of such resource. If, yes, the other problem is how to share the RFID data as well as how to share the benefit and the cost, because the downside will inherit the benefit from the upside, if the upsides use the RFID system.

2.10.3 Cost

2.10.3.1 Tight budgets

Hospitals sometime need financial support from government, but government budgets are also tight. A lot of hospitals lose money on patient care, due to the government's failure to pay the full cost of treating Medicaid and Medicare patients and a growing number of uninsured people. The HealthCare industry is different from other industries. Companies in other industries can choose not to do business with the bad credit company, but, hospitals cannot choose their customers.

2.10.3.2 High initial investment

Hardware, software, installations are very expensive. Also, compared with bar-code, the price of tags is much higher. Silicon chips currently represent 60%-80% of the total cost of RFID tags. Reducing the silicon chip cost is not easy. It depends on the semiconductor technology. Now, although producing chipless (different material) RFID tags is the way to reduce the cost, this tag does not perform as well as the tag with silicon chip.

2.10.4 Others

2.10.4.1 Varied RF frequencies

Existing RFID or other auto-id systems may use different RF frequencies in the same application system. Different countries may assign different parts of the radio spectrum for short-range RF transmissions. This means RF reconciliation will be needed in the whole supply chain.

2.10.4.2 Security concern.

The communication between the tag and the receiver is an open-loop, the radio signal can be received by other unauthorized receivers.

2.10.4.3 Process redesign

RFID is the same as every other technology investment, it requires process flow and physical asset changes. But in reality, people don't intend to change their routine process.

2.10.4.4 Repack problems

Drugs are usually packed in a bottle or other containers. In order to satisfy the five rights, RFID tags needs to be attached on the unit dose drugs. This requires not only a large number of tags but also additional time and work to affix medications with RF tags, and the smaller size of the RFID tag is preferred. This point does suggest that the hospital pharmacy must be intimately involved in the planning and implementation of the RFID utilization system for medication administration.

2.10.4.5 The emergence of other technologies----QR code and other 2-D code, may slow the speed of RFID application

QR code was developed and first released in 1994 by a Japanese company. Now, it has been used in manufacturing and Logistics. QR code is a 2-D Code, which can store data horizontally and vertically, while bar code can store data horizontally. Compared with a conventional bar code, which can store maximum 20 digits, QR code can handle several dozen to several hundred times more information than the conventional bar code does. It is capable of handling all types of data. Data can be read from any direction. Carrying the same amount of data, QR code uses approximately one-tenth the space of a traditional bar code. QR code has error correction capability. Data can be restored even if the symbol is partially dirty or damaged.

Although QR code needs the line-of-sight, this flaw can be compensated by the ease of use and the lower costs. Because of the technology of the RFID product (using antenna to transfer data), it is hard to reduce the size of the tag. The smaller the size, the shorter transmission distance.

Present Application Status

- Asset Management (real time locating)
- Hospital staff Management (real time tracking)
- Patient Care
- Medicine dispense control
- Lab Test Process Control
- Other, and baby matching

2.10.5 Technology Implementation considerations

Many approaches to technology adoption and implementation can be found in recentacademic and practitioner literature (Angeles, 2005; Curtin et al., 2007; Quaddus and Xu, 2005; del Aguila-Obra and Padilla-Mele´ndez, 2006; Hong and Zhu, 2006). In many respects, RFID adoption is very much like any other technology adoption (before RFID). The manager must align the technology requirements with the business requirements, but in the case of RFID this may mean that the business processes may have to be changed drastically to adapt to the technology. These are some of the same issues that organizations are facing when adopting ERP, integrated software systems, electronic data interchange, and e-commerce. Business processes have to be examined in light of the technology and its capabilities.

Table 2-7 Contributing factors for Technology adoption

Theory	Factors
IT adoption (Beatty et al, 2001)	- Perceived benefits - Complexity - Organizational compatibility - Top Management support
Innovation theory (Beatty et al, 2001)	- Entry timing - Organization readiness - External factors
Technology, organization, environment (TOE) (Zhu et al., 2003)	- Technology competence - Firm scope - size - Consumer readiness - Competitive pressure
Industrial organizational (Porter, 1981)	- Firm performance is enabled to constrained by industrial structure
Resource-bases view (Barney, 1991)	- Presence of resources that meet certain conditions such as value, rarity, imperfect imitabilility and lack of substitutability

To determine whether adopting RFID will be beneficial to an organization or one of its processing applications, a manager must follow a procedure that is conducive to the organization's business plan and objectives. Clearly, the first step is to achieve an understanding of what RFID can and cannot do. Then the process for building the ROI business case should begin with the firm, and then the other aspects of the supply chain delivery system. In this case, the RFID application must be implemented to meet organizational business goals. If, for example, the business goal is to improve customer service through more accurate/timely order delivery, the manager must analyze the business processes presently in place and determine which processes need to be changed to fully utilize the RFID technology. Moreover, performance metrics should be aligned with the firm's objectives and reflect such topics as improved cash-to-cash cycles, leaner inventories, reduced stock outs, and more accurate data (Spekman and Sweeny, 2006).

CHAPTER 3 METHODOLOGY

To propose alternative technology which will be applied to a Hospital, the comparison between barcode and RFID has to be agreed on. A case study approach is good for delivering new ideas, getting feedback, and providing flexibility to collect information.

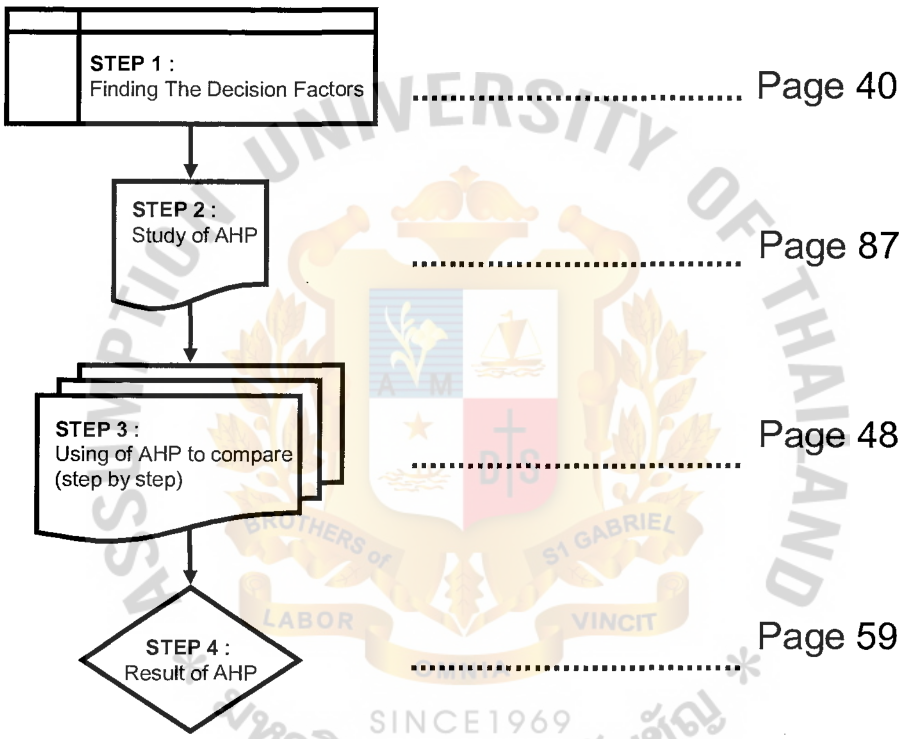


Figure 3-1 four steps in the selection of Technology for BCH

Figure 3-1 illustrates 4 steps of the selection of technology for the Bangkok Christian Hospital. The 4 steps are as following:-

1. Finding the decision factors
2. Study of AHP
3. Using AHP to compare (step by step)
4. Result of AHP

Figure 3-2 exhibits the step of getting factors to be considered. The factors used in this study come from four articles and expert comments. After that all the factors are presented to the IT managers of 3 hospitals to make sure that everybody agrees to use these factors to consider new technology to be applied in the Hospital.

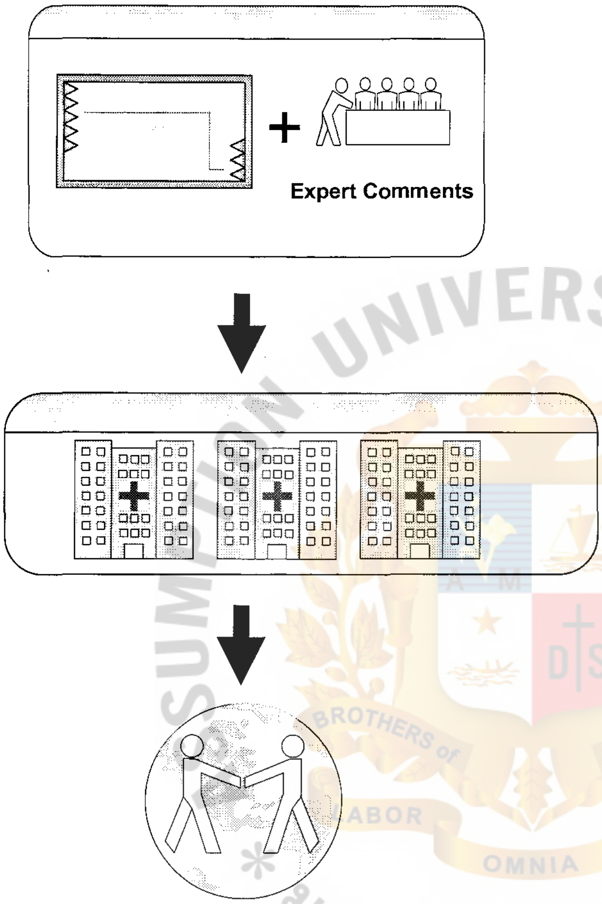


Figure 3-2 Step of getting factors to be considered

3.1 Finding Decision Factors

Referring to Table 2-7 Contributing factors for Technology adoption and interviews with the IT managers of The Bangkok Christian Hospital, Viphavadee Hospital and Bumrungrad Hospital. There are 10 groups of factors which should be considered, as follows:-

Table 3-1 Criteria for the selection of Technology for BCH

Factors	Details	Explanations
1.Technical	- Limitation of System	- Can be use in or cannot be use in
	- Uncertainty of System	- Number of error happening after implement technology
2. Effect to Employee	- Learning curve	- Spending time in order to learn how to use the technology
	- User friendly	- Easy or difficult to used the system
	- User readiness	- Scale for employee know-how
3. Effect to Organization	- Organization readiness	- Scale for organization know-how
4. Effect to Customer	- Customer readiness	- Scale for customer know-how
	- Image from using new technology	- Attitude of the customer after implement technology
5. Effect to Partner	- Partner readiness	- Scale for partner know-how
6. Effect from others	- Image from using new technology	- Attitude of the other hospital or concern people
	- Competitive Pressure	- Where the hospital is while the other hospitals are using the technology
7. System and Technology	- Compatibility of Software	- Suitable for the current system or not
	- Compatibility of Hardware	- Suitable for the current system or not
	- Accuracy of the data	- No. of error from the system.
	- Access to the information	- Able to track the information
	- Future of technology	- How long of the technology can be use in the organization or up to date technology?

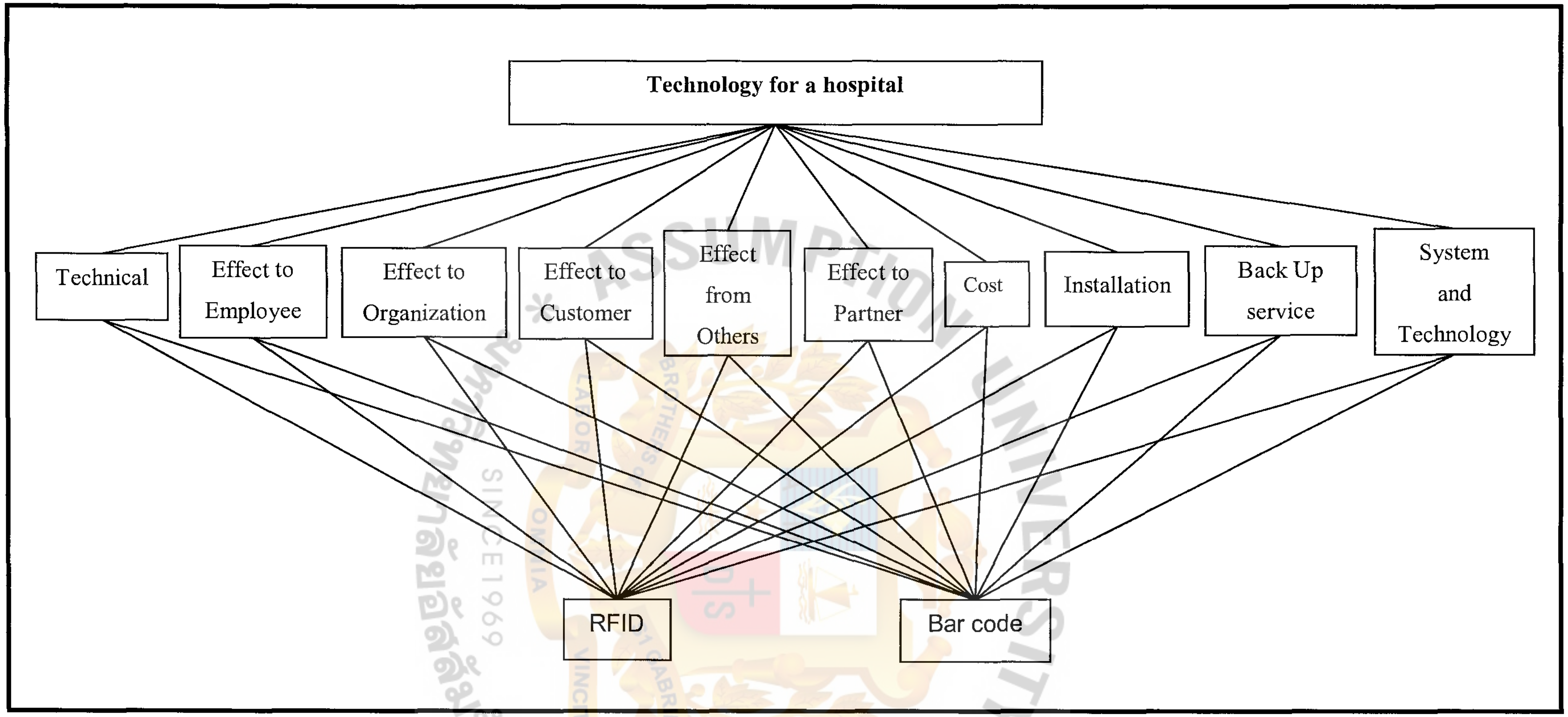
Factors	Details	Explanations
8. Installation	- Resource requirement	- The current resource for each technology compare with resource need for implement technology
	- Easy to implement	- Time line for implement technology from the beginning until the system is stable
	- Reliability	- The technology is trustable or not
	- No. of vendor available	- No. of supplier to install the system
9. Back Up service	- System Maintenance	- Have spare parts of the equipment or not
	- No. of vendor available	- No. of supplier available in market to service for maintenance of the system
10. Cost	- Tag	- Cost of Tag
	- Reader	- Cost of Reader
	- Implementation	- Cost of Implementation such as Training of the technology to users
	- Application / Software	- Cost of copyright for Software

Table 3-1 exhibits the factors to be considered when the hospital would like to select a technology to be used in the hospital. In the interviews, interviewees commented that Groups. 2 to 7 are considered as indirect factors. Groups 1, 8, 9 and 10 are considered as direct factors.

Table 3-2 Origin of Criteria for the selection of Technology for BCH

Factors	Details	Expert Comment	Breen, 2003	Beatty et al, 2001	Zhu et al, 2003	Reyes,2007
1.Technical	- Limitation of System	X		X		
	- Uncertainty of System	X		X		
2. Effect to Employee	- Learning curve	X				
	- User friendly				X	
	- User readiness				X	

Factors	Details	Expert Comment	Breen, 2003	Beatty et al. 2001	Zhu et al. 2003	Reyes.2007
3. Effect to Organization	- Organization readiness				X	X
4. Effect to Customer	- Customer readiness				X	X
	- Image from using new technology	X				
5. Effect to Partner	- Partner readiness				X	X
6. Effect from others	- Image from using new technology	X				
	- Competitive Pressure		X		X	X
7. System and Technology	- Compatibility of Software	X		X		X
	- Compatibility of Hardware	X		X		X
	- Accuracy of the data	X				X
	- Access to the information		X			
	- Future of technology	X				
8. Installation	- Resource requirement	X				
	- Easy to implement	X				
	- Reliability	X				
	- No. of vendor available	X				
9. Back Up service	- System Maintenance	X				
	- No. of vendor available	X				
10. Cost	- Tag	X				X
	- Reader	X				X
	- Implementation	X				X
	- Application / Software	X				X


Technology for a hospital
Technical
Effect to Employee
Effect to Organization
Effect to Customer
Effect from Others
Effect to Partner
Cost
Installation
Back Up service
System and Technology
RFID
Bar code

3.2 Study of the Analytic Hierarchy Process (AHP)

The AHP is a mathematically based, multi objective decision-making tool. It uses the pair-wise comparison method to rank-order alternatives of a problem that are formulated and solved in a hierarchical structure. The technique has the advantage of being simple and thorough in handling difficult real-life problems. It provides greater utility in applications where information is either incomplete or not available. The AHP approach has been adopted in many applications including resource allocation business performance evaluation project selection and auditing. Additional application areas include problems in public policy, marketing, procurement, health care, corporate planning, transportation planning and many other areas The AHP requires a problem be decomposed into levels, each of which is comprised of elements or factors. The elements of a given level are mutually independent, but comparable to the elements of the same level. The structure presupposes that elements of any given level are influenced by elements at the level immediately above them. The process of AHP comprises the following steps:

1. Structure a problem with a model that shows the problem's key elements and their relationships.
2. Elicit judgments that reflect knowledge, feelings, or emotions.
3. Represent those judgments with meaningful numbers.
4. Use these numbers to calculate the priorities of the elements of the hierarchy.
5. Synthesize these results to determine an overall outcome.
6. Analyze sensitivity to changes in judgment.

For more details, please see Appendix A (p.88)

3.3 Comparison of each factor by using Analytic Hierarchy Process (AHP) – Step by step

Table 3-3 Weight each factors (Rating by IT manager of Bumrungrad, Viphavadi and the Bangkok Christian Hospital)

Criteria	Weight
1.Limitation of System	8
2.Uncertainty of System	8
3. Learning curve	6
4. User friendly	6
5. User readiness	4
6. Organization readiness	4
7. Customer readiness	4
8. Image from using new technology	2
9. Partner readiness	4
10. Image from using new technology	2
11. Competitive Pressure	3
12. Compatibility of Software	5
13. Compatibility of Hardware	5
14. Accuracy of the data	8
15. Access to the information	7
16. Future of technology	4
17. Resource requirement	8
18. Easy to implement	5
19. Reliability	7
20. No. of vendor available	8
21. System Maintenance	8
22. No. of vendor available	7
23. Cost of Tag	8
24. Cost of Reader	8
25. Cost of Implementation	8
26. Cost of Application / Software	8

Remark: 8= Main criteria for technology justification

A score is rated ranging from 1 to 9. The meaning of each score refer to table 3-3

Table 3-4 A common scale will be using to help judgment and rating the scale.

Intensity of importance	Definition	Explanation
1	Equal importance (Equally preferred)	Two factors contribute equally to the objective
3	Somewhat more important (Moderately preferred)	Experience and judgment slightly favour one over the other.
5	Much more important (Strongly preferred)	Experience and judgment strongly favour one over the other.
7	Very much more important (Very strongly preferred)	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important (Extremely preferred)	The evidence favouring one over the other is of the highest possibility validity.
2,4,6,8	Intermediate values	When compromise is needed

3.3.1 Demonstration in technology selection by using AHP

Step 1 Specify the criteria for evaluating the technology

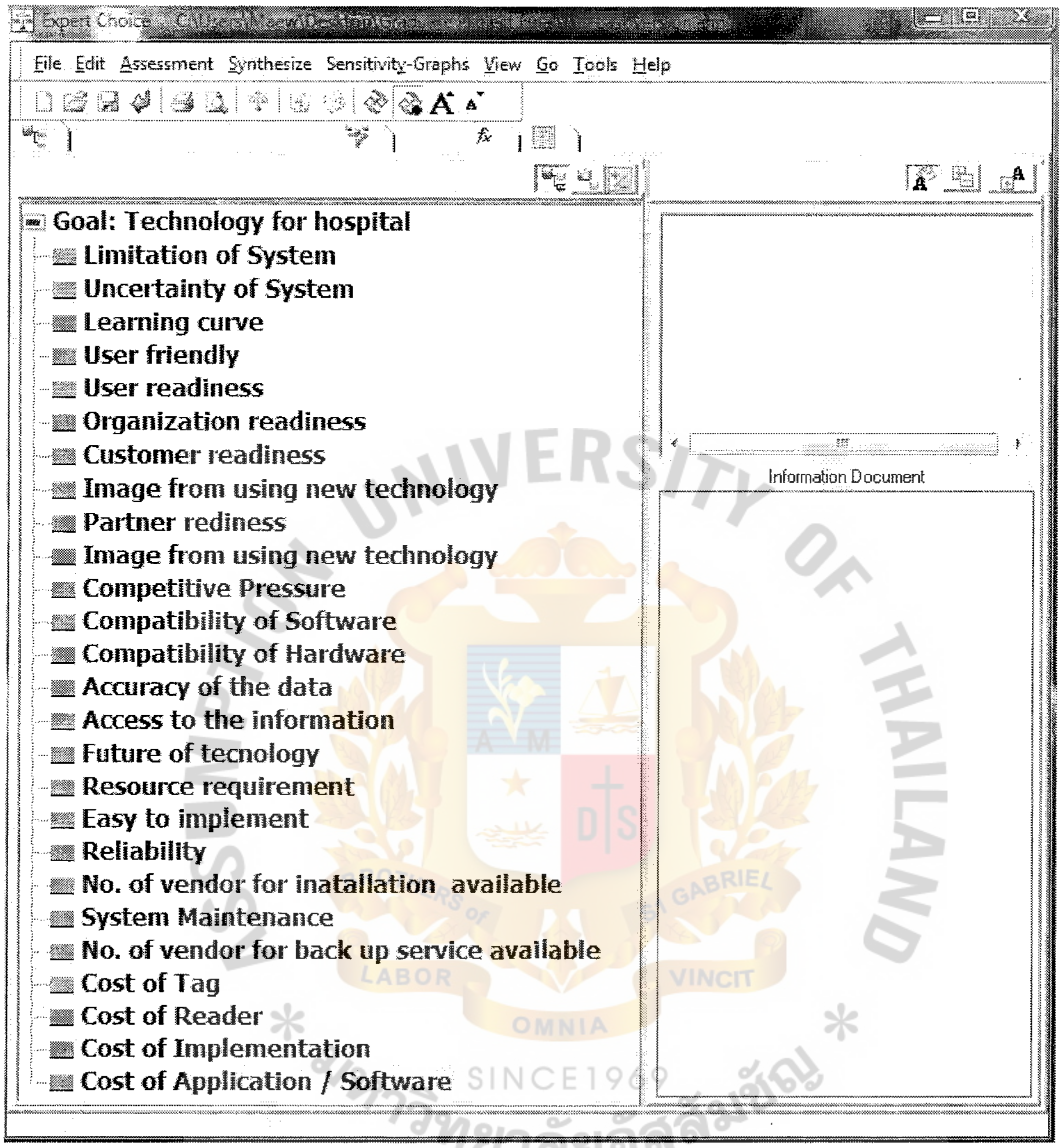
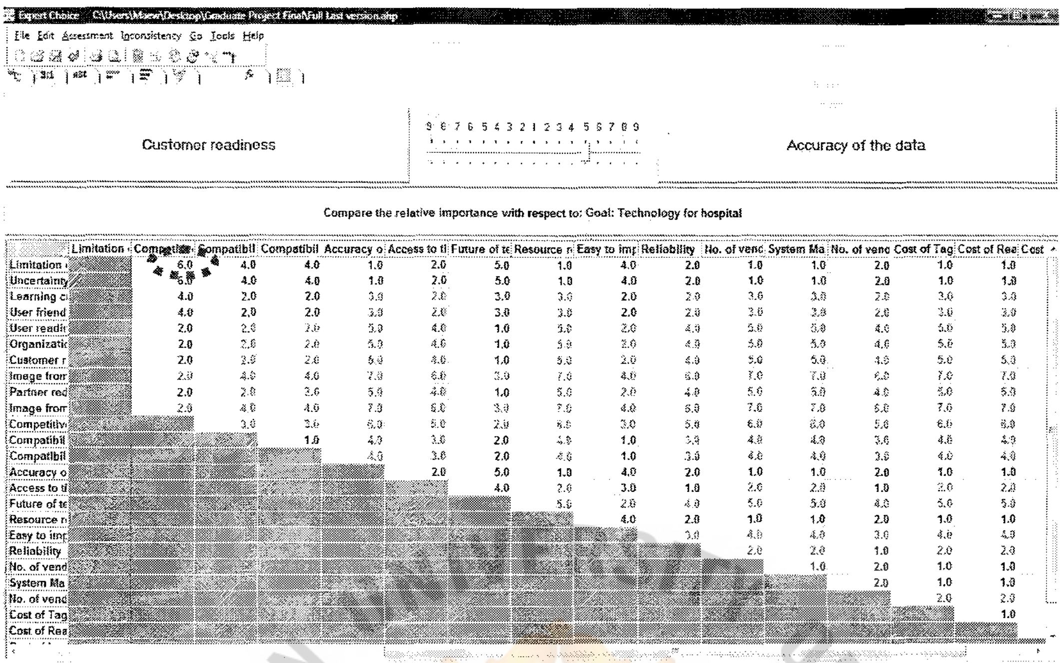


Figure 3-4 AHP: Criteria for evaluating the technology

Step 2 Obtain the pair wise comparisons of the relative importance of the criteria



	Limitation	Competitive	Compatibil	Compatibil	Accuracy o	Access to t	Future of te	Resource r	Easy to imp	Reliability	No. of venc	System Ma	No. of venc	Cost of Tag	Cost of Rea	Cost
Limitation		6.0	4.0	4.0	1.0	2.0	5.0	1.0	4.0	2.0	1.0	1.0	2.0	1.0	1.0	
Uncertainty		6.0	4.0	4.0	1.0	2.0	5.0	1.0	4.0	2.0	1.0	1.0	2.0	1.0	1.0	
Learning c		4.0	2.0	2.0	3.0	2.0	3.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0	3.0	
User friend		4.0	2.0	2.0	3.0	2.0	3.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0	3.0	
User readi		2.0	2.0	2.0	5.0	4.0	1.0	5.0	2.0	4.0	5.0	5.0	4.0	5.0	5.0	
Organizati		2.0	2.0	2.0	5.0	4.0	1.0	5.0	2.0	4.0	5.0	5.0	4.0	5.0	5.0	
Customer r		2.0	2.0	2.0	5.0	4.0	1.0	5.0	2.0	4.0	5.0	5.0	4.0	5.0	5.0	
Image from		2.0	4.0	4.0	7.0	6.0	3.0	7.0	4.0	6.0	7.0	7.0	6.0	7.0	7.0	
Partner rea		2.0	2.0	3.0	5.0	4.0	1.0	5.0	2.0	4.0	5.0	5.0	4.0	5.0	5.0	
Image from		2.0	4.0	4.0	7.0	6.0	3.0	7.0	4.0	6.0	7.0	7.0	6.0	7.0	7.0	
Competitiv			3.0	3.0	6.0	5.0	2.0	6.0	3.0	5.0	6.0	6.0	5.0	6.0	6.0	
Compatibil				1.0	4.0	3.0	2.0	4.0	1.0	3.0	4.0	4.0	3.0	4.0	4.0	
Compatibil					4.0	3.0	2.0	4.0	1.0	3.0	4.0	4.0	3.0	4.0	4.0	
Accuracy o						2.0	5.0	1.0	4.0	2.0	1.0	1.0	2.0	1.0	1.0	
Access to t							4.0	2.0	3.0	1.0	2.0	2.0	1.0	2.0	2.0	
Future of te								5.0	2.0	4.0	5.0	5.0	4.0	5.0	5.0	
Resource r									4.0	2.0	1.0	1.0	2.0	1.0	1.0	
Easy to imp										3.0	4.0	4.0	3.0	4.0	4.0	
Reliability											2.0	2.0	1.0	2.0	2.0	
No. of vend												1.0	2.0	1.0	1.0	
System Ma													2.0	1.0	1.0	
No. of vend														2.0	2.0	
Cost of Tag															1.0	
Cost of Rea																

Figure 3-5 pair wise comparisons of the relative importance of the criteria

In order to explain how the score in each cell come out, the step of calculation in AHP program are as following:-

1. Use rating score from
2. Table 3-1 to calculate difference between score of each criterion.
3. After the result comes out then plus one.

For example:

From table 3-1, under factor Technical, there are 2 items which are Limitation of system and Uncertainty of system. And under factor Effect from others, there are 2 items which are Image from using new technology and competitive pressure.

Weight for Limitation of System is 8.

Weight for Competitive Pressure is 3.

Calculation: $(8 - 3) + 1 = 6$

- Black color of a number in the table means criteria in roll is more important than criteria in column.
- Red color of number in the table mean criteria in column is more important than criteria in roll.

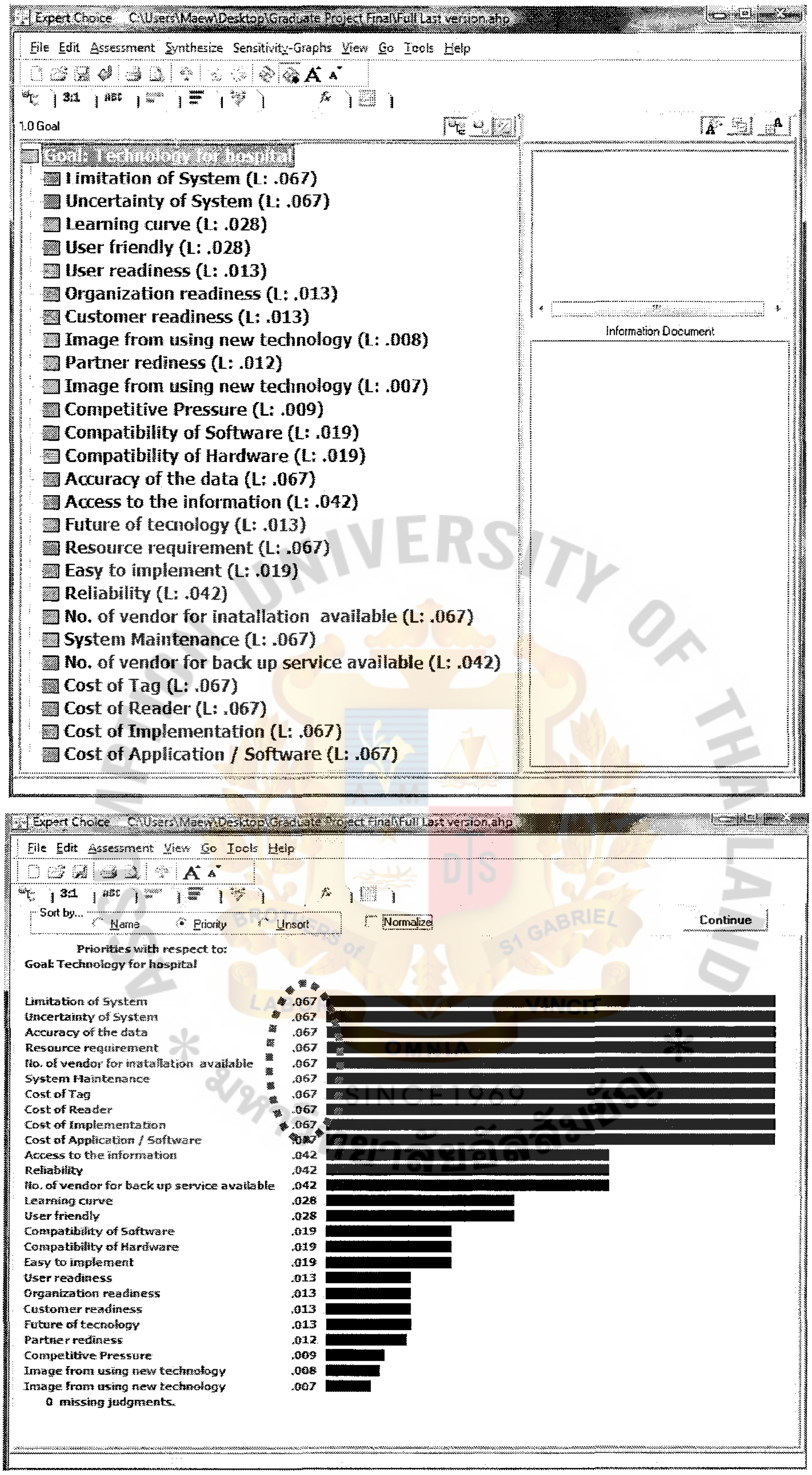


Figure 3-6 AHP: Weight of each criterion for the technology evaluation

In order to explain how the score in each cell come out, the step of calculation in AHP program are as following:-

Referring to the data from Figure 3-7 to calculate main criteria

1. Comparing one by one in each criteria.

Table 3-5 Example: Calculation step of criteria score I

	1.Limitation of System	Calculation
1.Limitation of System	1.00	(8-8)+1
2.Uncertainty of System	1.00	(8-8)+1
3. Learning curve	0.33	1/(8-6)+1
4. User friendly	0.33	1/(8-6)+1
5. User readiness	0.20	1/(8-4)+1
6. Organization readiness	0.20	1/(8-4)+1
7. Customer readiness	0.20	1/(8-4)+1
8. Image from using new technology	0.14	1/(8-2)+1
9. Partner readiness	0.20	1/(8-4)+1
10. Image from using new technology	0.14	1/(8-2)+1
11. Competitive Pressure	0.17	1/(8-3)+1
12. Compatibility of Software	0.25	1/(8-5)+1
13. Compatibility of Hardware	0.25	1/(8-5)+1
14. Accuracy of the data	1.00	(8-8)+1
15. Access to the information	0.50	1/(8-7)+1
16. Future of technology	0.20	1/(8-4)+1
17. Resource requirement	1.00	(8-8)+1
18. Easy to implement	0.25	1/(8-5)+1
19. Reliability	0.50	1/(8-7)+1
20. No. of vendor available	1.00	(8-8)+1
21. System Maintenance	1.00	(8-8)+1
22. No. of vendor available	0.50	1/(8-7)+1
23. Cost of Tag	1.00	(8-8)+1
24. Cost of Reader	1.00	(8-8)+1
25. Cost of Implementation	1.00	(8-8)+1
26. Cost of Application / Software	1.00	(8-8)+1
Total	**14.37**	

2. Convert the total score to be 1.00 then distribute to all the score.

Table 3-6 Example: Calculation step of criteria score II

Criteria	1.Limitation of System	Calculation
1.Limitation of System	0.070	1/14.37
2.Uncertainty of System	0.070	1/14.37
3. Learning curve	0.023	0.33/14.37
4. User friendly	0.023	0.33/14.37
5. User readiness	0.014	0.20/14.37
6. Organization readiness	0.014	0.20/14.37
7. Customer readiness	0.014	0.20/14.37
8. Image from using new technology	0.010	0.14/14.37
9. Partner readiness	0.014	0.20/14.37
10. Image from using new technology	0.010	0.14/14.37
11. Competitive Pressure	0.012	0.17/14.37
12. Compatibility of Software	0.017	0.25/14.37
13. Compatibility of Hardware	0.017	0.25/14.37
14. Accuracy of the data	0.070	1/14.37
15. Access to the information	0.035	0.5/14.37
16. Future of technology	0.014	0.20/14.37
17. Resource requirement	0.070	1/14.37
18. Easy to implement	0.017	0.25/14.37
19. Reliability	0.035	0.5/14.37
20. No. of vendor available	0.070	1/14.37
21. System Maintenance	0.070	1/14.37
22. No. of vendor available	0.035	0.5/14.37
23. Cost of Tag	0.070	1/14.37
24. Cost of Reader	0.070	1/14.37
25. Cost of Implementation	0.070	1/14.37
26. Cost of Application / Software	0.070	1/14.37
Total	**1.00**	

3. Find the ratio of Criteria by using summary of the score in horizontal of each criteria then divide by number of criteria used.

Example: **Limitation of System criteria**

(0.07 + 0.07 + 0.07 + 0.07 + 0.06 + 0.06 + 0.05 + 0.06 + 0.06 + 0.06 + 0.07 + 0.07 + 0.07 + 0.07 + 0.06 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07 + 0.07) / 26

= 0.067

Remark: Sum of weight of each factor will be equal to 1.00

Table 3-7 calculation of weight for each criterion

Criteria	Weight
1.Limitation of System	0.067
2.Uncertainty of System	0.067
3. Learning curve	0.029
4. User friendly	0.029
5. User readiness	0.013
6. Organization readiness	0.013
7. Customer readiness	0.013
8. Image from using new technology	0.007
9. Partner readiness	0.013
10. Image from using new technology	0.007
11. Competitive Pressure	0.009
12. Compatibility of Software	0.019
13. Compatibility of Hardware	0.019
14. Accuracy of the data	0.067
15. Access to the information	0.042
16. Future of technology	0.013
17. Resource requirement	0.067
18. Easy to implement	0.019
19. Reliability	0.042
20. No. of vendor available	0.067
21. System Maintenance	0.067
22. No. of vendor available	0.042
23. Cost of Tag	0.067
24. Cost of Reader	0.067
25. Cost of Implementation	0.067
26. Cost of Application / Software	0.066
Total	**1.000**

Step 3 Obtain measures to each technology

For Example: Limitation of System

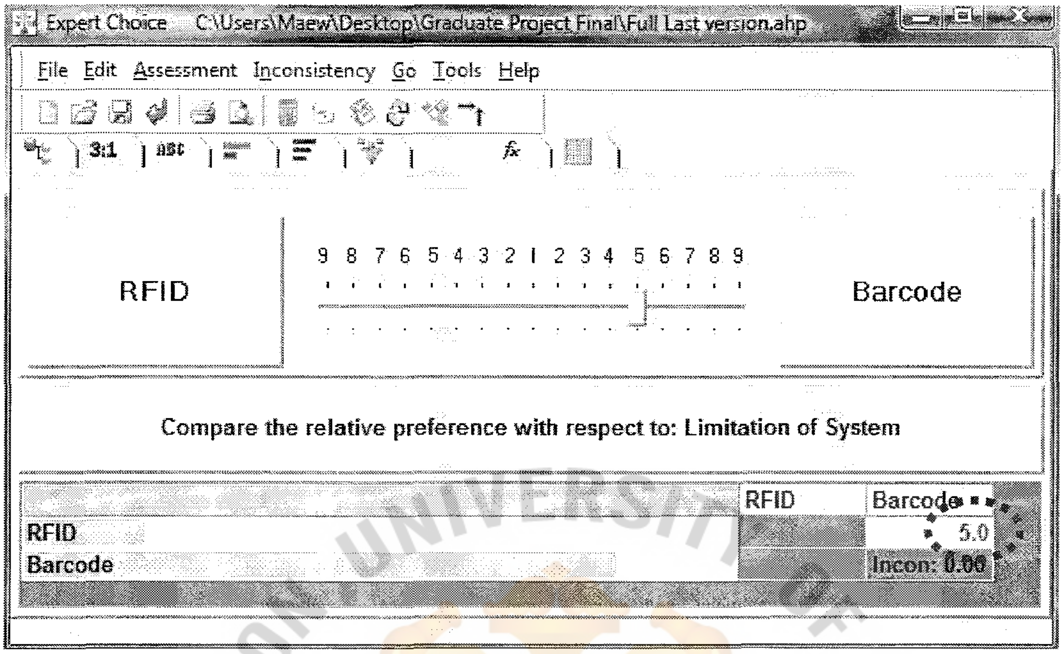


Figure 3-7 AHP: Pair-wise comparisons of Limitation of System criteria and its result

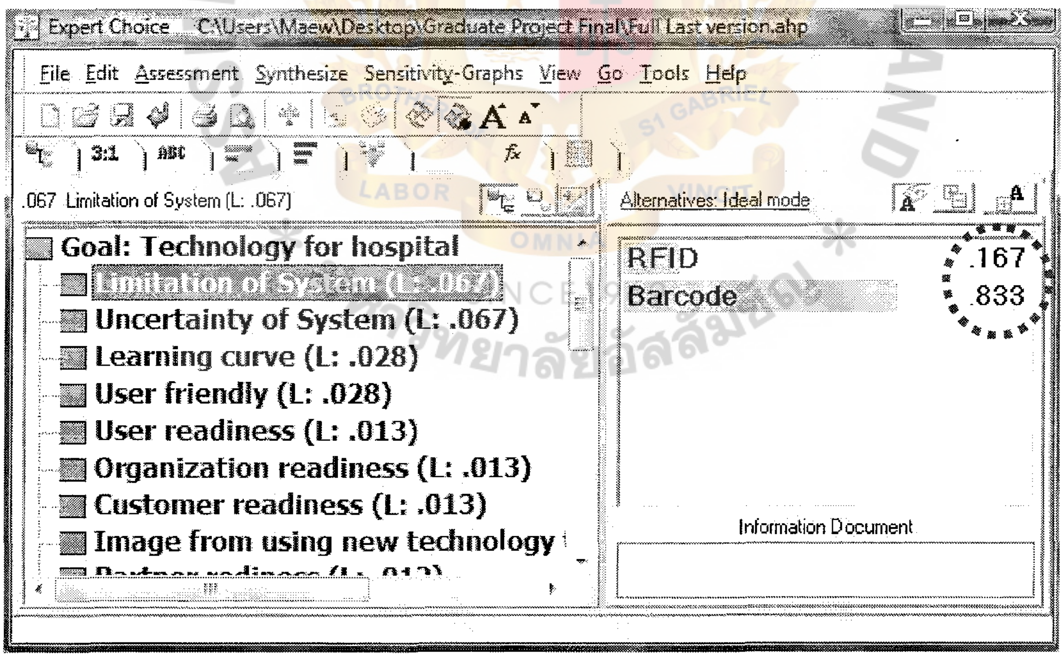


Figure 3-8 AHP: Pair-wise comparisons of Limitation of System criteria and its result

In order to explain how the score in each cell come out, the step of calculation in AHP program are as following:-

Referring to Figure 3-7, use the data in each cell to calculate the rating for RFID and Barcode

For Example:

Data for Limitation of System criteria:

1. Voting score given by interviewees between RFID and Barcode is 5.
2. Score of Barcode is 5 times of RFID (Bar Code : RFID is 5:1)
3. Full score is 6 (come from 5 +1)
4. Rating for RFID is 1/6 = 0.167 and rating for Barcode is 5/6 = 0.833.

Table 3-8 Rating for RFID and Barcode Technology

Criteria	RFID	Barcode
1.Limitation of System	0.167	0.833
2.Uncertainty of System	0.167	0.833
3. Learning curve	0.500	0.500
4. User friendly	0.500	0.500
5. User readiness	0.500	0.500
6. Organization readiness	0.500	0.500
7. Customer readiness	0.500	0.500
8. Image from using new technology	0.875	0.125
9. Partner readiness	0.500	0.500
10. Image from using new technology	0.875	0.125
11. Competitive Pressure	0.750	0.250
12. Compatibility of Software	0.250	0.750
13. Compatibility of Hardware	0.250	0.750
14. Accuracy of the data	0.500	0.500
15. Access to the information	0.500	0.500
16. Future of technology	0.900	0.100
17. Resource requirement	0.167	0.833
18. Easy to implement	0.167	0.833
19. Reliability	0.250	0.750
20. No. of vendor available	0.250	0.750
21. System Maintenance	0.250	0.750
22. No. of vendor available	0.250	0.750
23. Cost of Tag	0.250	0.750
24. Cost of Reader	0.250	0.750
25. Cost of Implementation	0.250	0.750
26. Cost of Application / Software	0.250	0.750

Step4 – Summarize the result

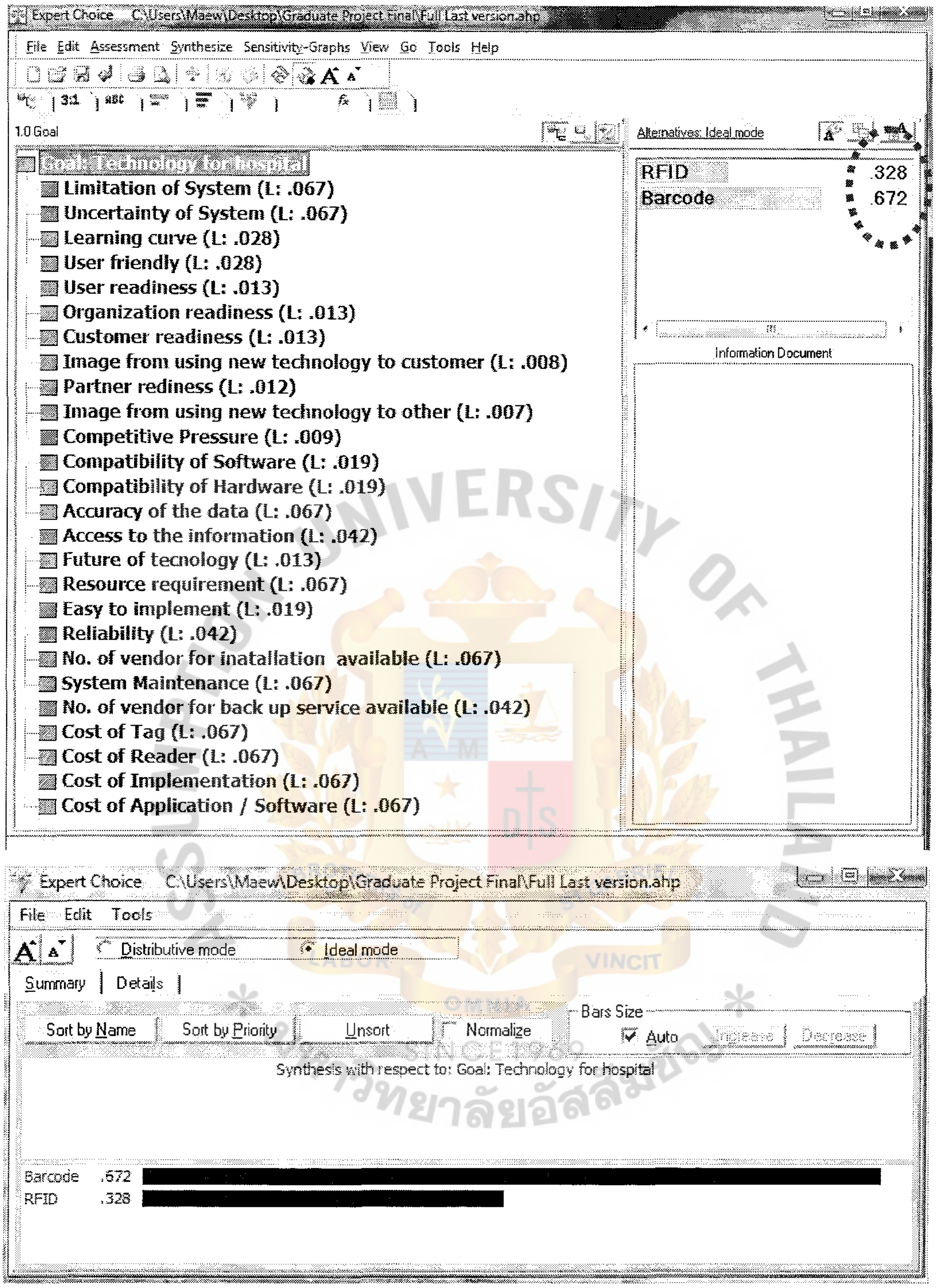


Figure 3-9 AHP: Summary of the result of technology selection

Referring to the data from Figure 3-5 and Figure 3-6, the result of AHP come from the summary of multiple between weight of each criterion from Table 3-7 and number of rating of each alternative from Table 3-8 Rating for RFID and Barcode Technology

Table 3-9 Calculation for RFID and Barcode Technology

Criteria	Weight criteria of RFID(WC)	Weight (W)	RFID	Calculation
1.Limitation of System	0.167	0.067	0.011	0.167 x 0.067
2.Uncertainty of System	0.167	0.067	0.011	0.167 x 0.067
3. Learning curve	0.500	0.029	0.014	0.500 x 0.029
4. User friendly	0.500	0.029	0.014	0.500 x 0.029
5. User readiness	0.500	0.013	0.006	0.500 x 0.013
6. Organization readiness	0.500	0.013	0.006	0.500 x 0.013
7. Customer readiness	0.500	0.013	0.006	0.500 x 0.013
8. Image from using new technology	0.875	0.007	0.006	0.875 x 0.007
9. Partner readiness	0.500	0.013	0.006	0.500 x 0.013
10. Image from using new technology	0.875	0.007	0.006	0.875 x 0.007
11. Competitive Pressure	0.750	0.009	0.007	0.750 x 0.009
12. Compatibility of Software	0.250	0.019	0.005	0.250 x 0.019
13. Compatibility of Hardware	0.250	0.019	0.005	0.250 x 0.019
14. Accuracy of the data	0.500	0.067	0.034	0.500 x 0.067
15. Access to the information	0.500	0.042	0.021	0.500 x 0.042
16. Future of technology	0.900	0.013	0.012	0.900 x 0.013
17. Resource requirement	0.167	0.067	0.011	0.167 x 0.067
18. Easy to implement	0.167	0.019	0.003	0.167 x 0.019
19. Reliability	0.250	0.042	0.011	0.250 x 0.042
20. No. of vendor available	0.250	0.067	0.017	0.250 x 0.067
21. System Maintenance	0.250	0.067	0.017	0.250 x 0.067
22. No. of vendor available	0.250	0.042	0.011	0.250 x 0.067
23. Cost of Tag	0.250	0.067	0.017	0.250 x 0.067
24. Cost of Reader	0.250	0.067	0.017	0.250 x 0.067
25. Cost of Implementation	0.250	0.067	0.017	0.250 x 0.067
26. Cost of Application / Software	0.250	0.067	0.017	0.250 x 0.067
Total			0.328	

Formula for AHP score = $(WC_1 \times W_1) + ((WC_2 \times W_2) + \ldots (WC_x \times W_x)$

Then AHP score of RIFD = (0.167 x 0.067) + (0.167 x 0.067) + (0.5 x 0.029) + (0.5 x 0.029) + (0.5 x 0.013) + (0.5 x 0.013) + (0.5 x 0.013) + (0.875 x 0.007) + (0.5 x 0.013) + (0.875 x 0.007) (0.75 x 0.009) + (0.25 x 0.019) + (0.25 x 0.019) + (0.5 x 0.067) + (0.5 x 0.042) + (0.9 x 0.013) + (0.167 x 0.067) + (0.167 x 0.019) + (0.25 x 0.042) + (0.25 x 0.067) + (0.25 x 0.067) + (0.25 x 0.042) + (0.25 x 0.067) + (0.25 x 0.067) + (0.25 x 0.067) + (0.25 x 0.067) = 0.328

3.4 Comparing results by using Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) result shows that Bar code is the most suitable technology for the hospital with a score of 0.672 while the score of RFID is 0.328.

CHAPTER 4 PRESENTATION OF DATA AND CRITICAL DISCUSSION OF RESULTS

This Chapter will analyze what is/are the factor(s) which affect decision making, what is the main factor that makes the result emerge as Barcode, and the trend of the technology to be selected if some factors change.

Figure 3-9 shows that Barcode is the technology that The Bangkok Christian Hospital should select in order to improve their service in the hospital, with a score at 0.672 while the score of RFID is 0.328

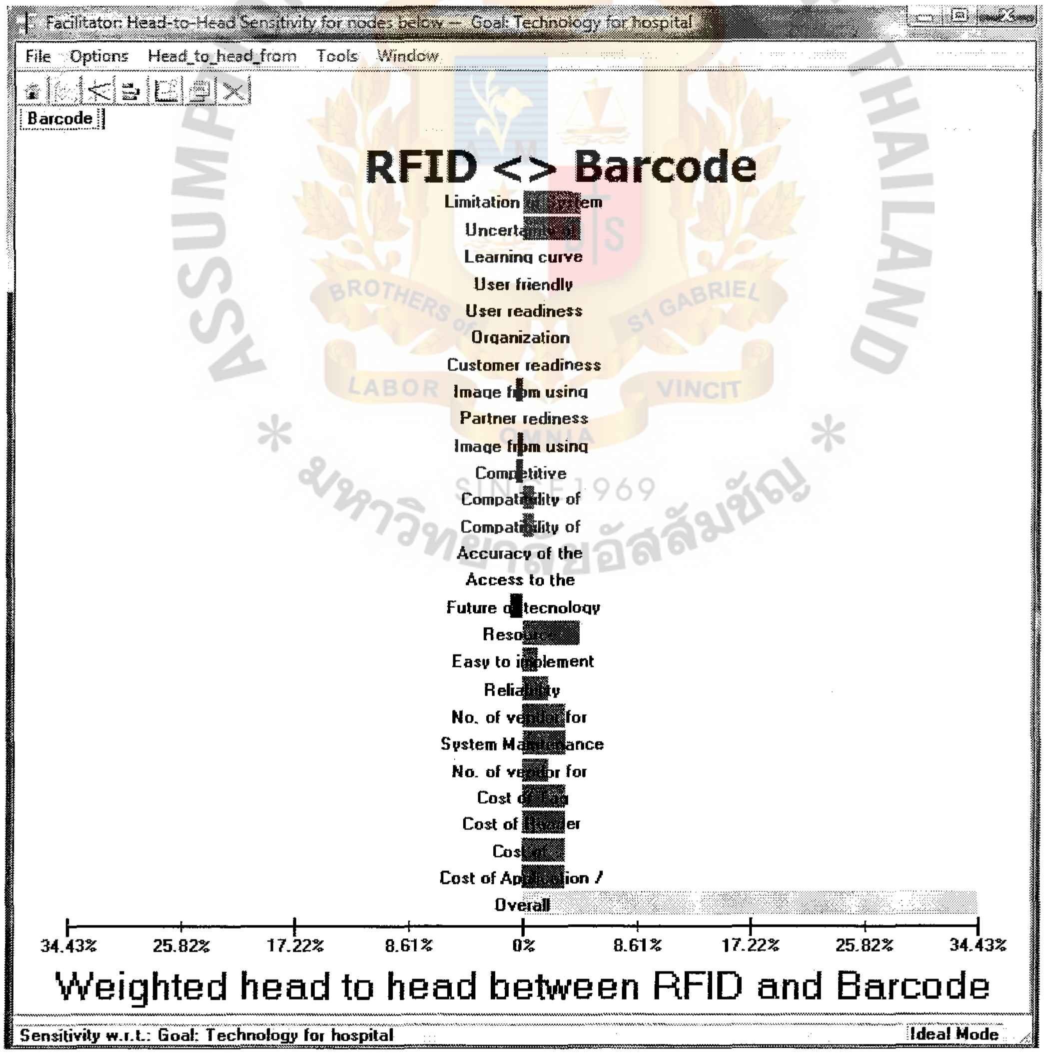


Figure 4-1 AHP: Weighted head to head between RFID and Bar code

From Figure 4-1, This figure shows that Barcode is stronger than RFID on the following points:-

1. Limitation of the system
2. Uncertainty of the system
3. Compatibility of software
4. Compatibility of hardware
5. Resource requirement
6. Easy to implement
7. Reliability
8. Number of vendors available for installation
9. System maintenance
10. Number of vendors available in term of back up service
11. Cost of Tags
12. Cost of Readers
13. Cost of Implementation
14. Cost of Application

From an overall point of view, Barcode is better than RFID by around 34.43% (resulting from Barcode score: 0.672 minus RFID score: 0.328 = 0.344).

Since RFID is a new technology, users still have some doubts about its performance. With limitation of system and uncertainty of performance, users may still not feel confident in using of RFID technology.

However, there are some factors that show RFID is better than Barcode as follows:-

1. Image from using new technology to customer
2. Image from using new technology to other
3. Competitive Pressure
4. Future of technology

From these 4 factors, the RFID rating is higher than Barcode showing that IT people in the hospital prefer to use RFID more than Barcode. All IT managers would like to try the technology which is considered as new and advanced technology.

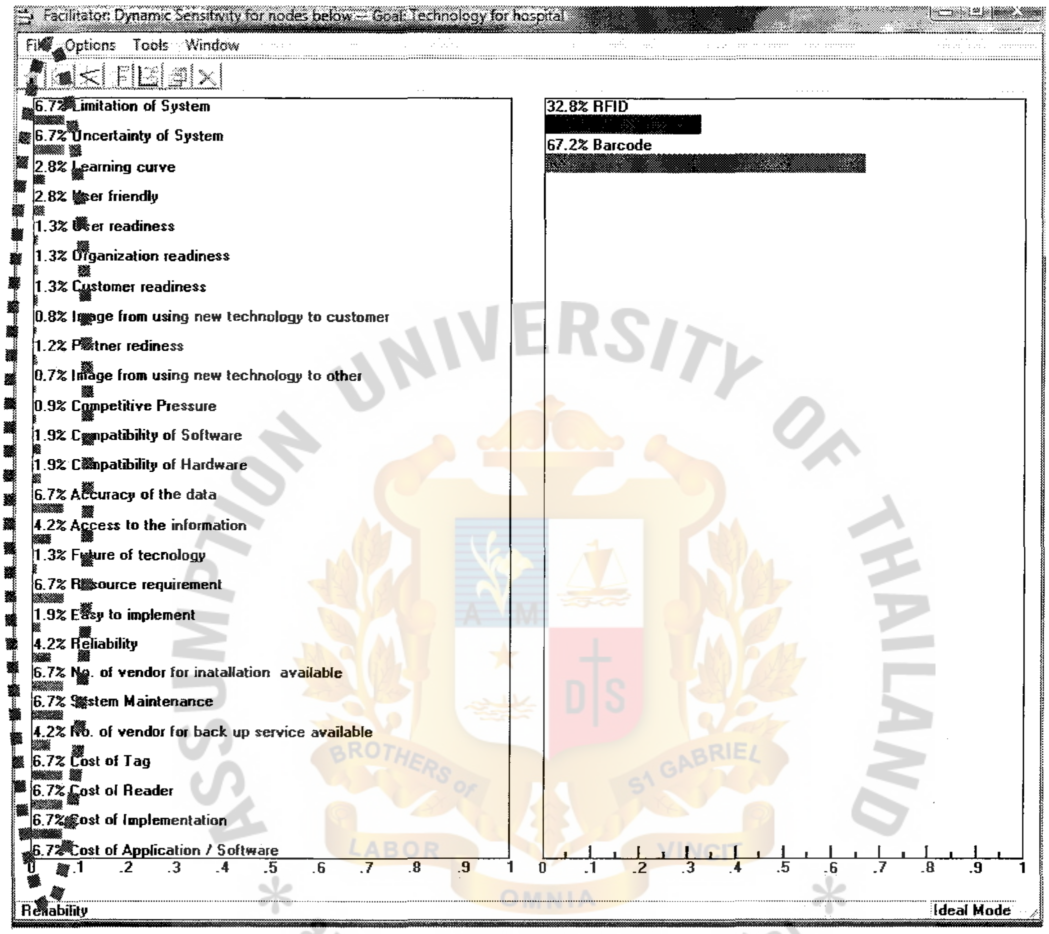


Figure 4-2 AHP: Dynamic Sensitivity of technology selection

Figure 4-2 exhibits the effect of each factor on the decision making, result in the following percentages.

1. Technical

- Limitation of System 6.70%
- Uncertainty of System 6.70%

2. Effect on Employees

- Learning curve	2.80%
- User friendly	2.80%
- User readiness	1.30%

3. Effect on the Organization

- Organization readiness	1.30%

4. Effect on Customers

- Customer readiness	1.30%
- Image from using new technology	0.80%

5. Effect on Partners

- Partner readiness	1.20%

6. Effect from others

- Image from using new technology	0.70%
- Competitive Pressure	0.90%

7. System and Technology

- Compatibility of Software	1.90%
- Compatibility of Hardware	1.90%
- Accuracy of the data	6.70%
- Access to the information	4.20%
- Future of technology	1.30%

8. Installation

- Resource requirement	6.70%
- Easy to implement	1.90%
- Reliability	4.20%
- No. of vendor available	6.70%

9. Back-Up service

- System Maintenance	6.70%
- Number of vendors available	4.20%

10. Cost

- Tag	6.70%
- Reader	6.70%
- Implementation	6.70%
- Application / Software	6.70%

Total	**100.00%**

From the study, the main factors which effect to the result of study are

1) Technical- Limitation of System
2) Technical- Uncertainty of System
3) System and technology – Accuracy of data
4) Installation - Resource requirement
5) Installation - No. of vendors available
6) Back Up service- System Maintenance
7) Cost- Tag
8) Cost- Reader
9) Cost – Implementation
10) Cost - Application / Software

The next step in this study will prove that all 14 factors which make Barcode stronger than RFID have an effect on the result of AHP, by removing the 14 factors and then re-running the AHP.

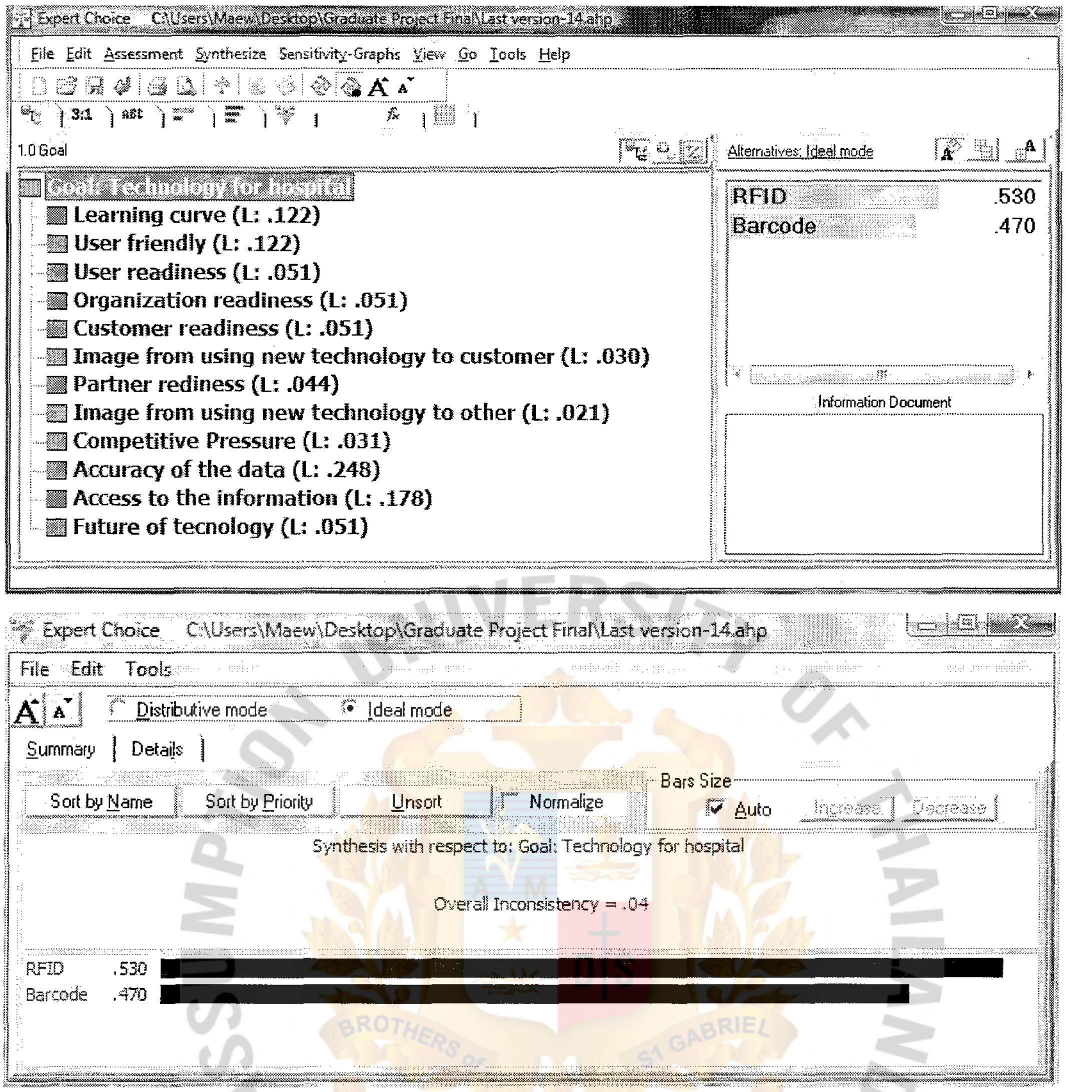


Figure 4-3 AHP: Summary of the result of technology selection after removing the 14 criteria

Figure 4-3 shows the result after removing all 14 factors. It means that the study will focus only on the factors that make RFID stronger than Barcode. The factors used to calculate this are:-

1. Learning Curve
2. User friendly
3. User readiness
4. Organization readiness
5. Customer readiness
6. Image from using new technology (Customer Point of view)
7. Competitive Pressure
8. Partner readiness

9. Accuracy of the data
10. Access to the information
11. Future of technology
12. Image from using new technology (from others)

After re-running of AHP, the result changes to be RFID with a score of 0.530 while the Barcode score is 0.470.

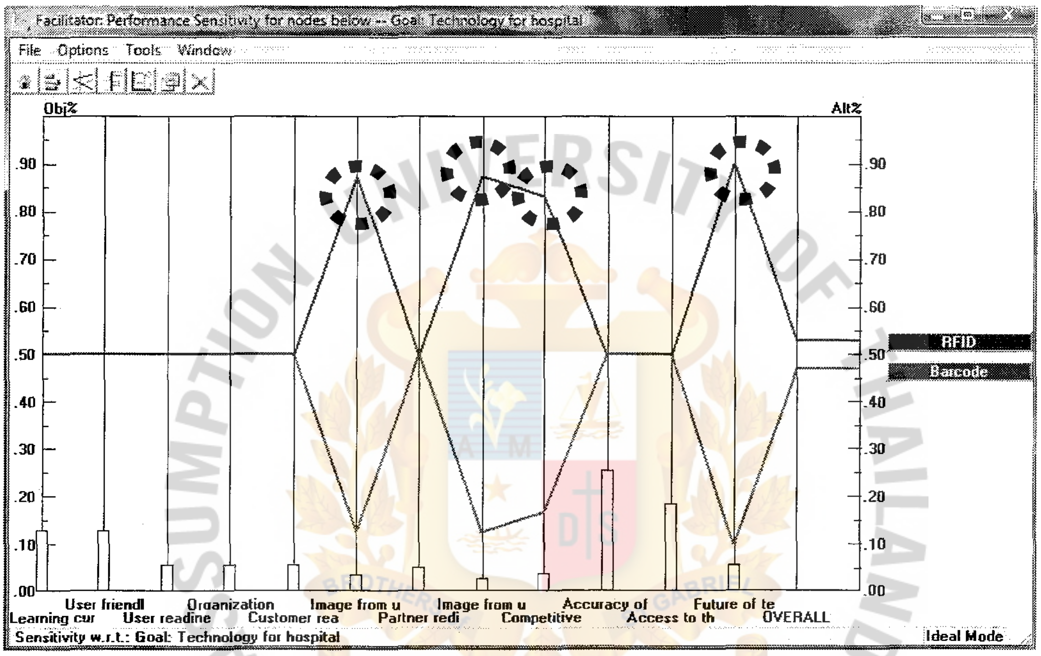


Figure 4-4 AHP: Performance sensitivity of technology selection after removing the 14 criteria

From Figure 4-4, it illustrated the factors that RFID better than Barcode by using line graph. All these factors are

1. Image from using new technology to customer
2. Image from using new technology to other
3. Competitive Pressure
4. Future of technology

From the result of AHP, these 4 factors are considered as strong points of RFID which is voted and rated by IT managers of 3 selected “grade A” hospital.

Figure 4-5 AHP: Dynamic Sensitivity of technology selection after removing the 14 criteria,

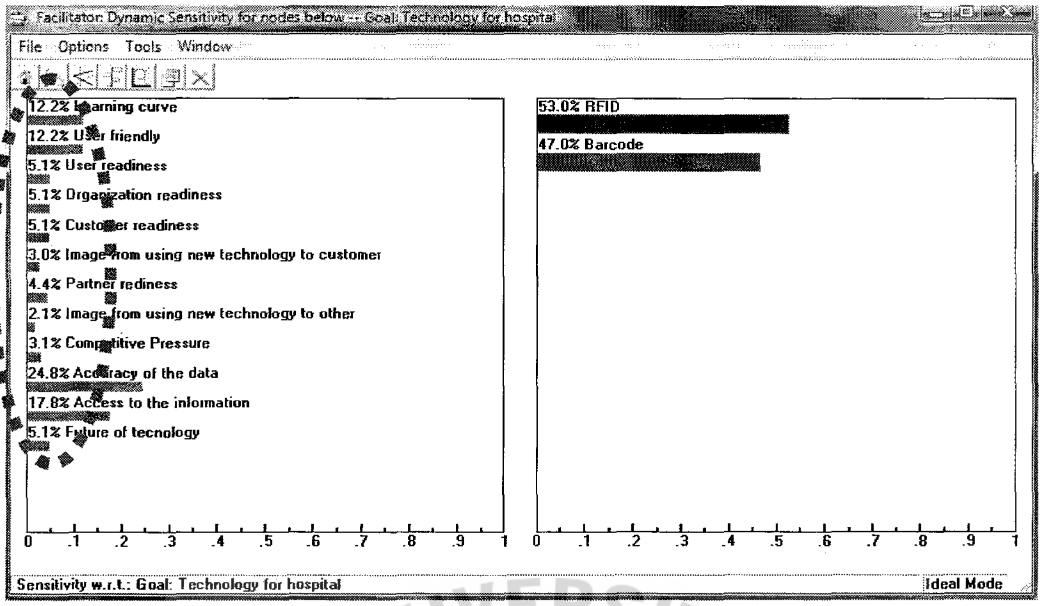


Figure 4-5 AHP: Dynamic Sensitivity of technology selection after removing the 14 criteria

It exhibited each factor affecting the decision making result, in the following percentages:-

1.	Learning curve	12.20%
2.	User friendly	12.20%
3.	User readiness	5.10%
4.	Organization readiness	5.10%
5.	Customer readiness	5.10%
6.	Image from using new technology to customer	3.00%
7.	Partner readiness	4.40%
8.	Image from using new technology to other	2.10%
9.	Competitive pressure	3.10%
10.	Accuracy of data	24.80%
11.	Access to information	17.80%
12.	Future of technology	5.10%
	Total	**100.00%**

However, the difference of the AHP value between Barcode and RFID is not much since the main criteria affecting the decision result have been removed.

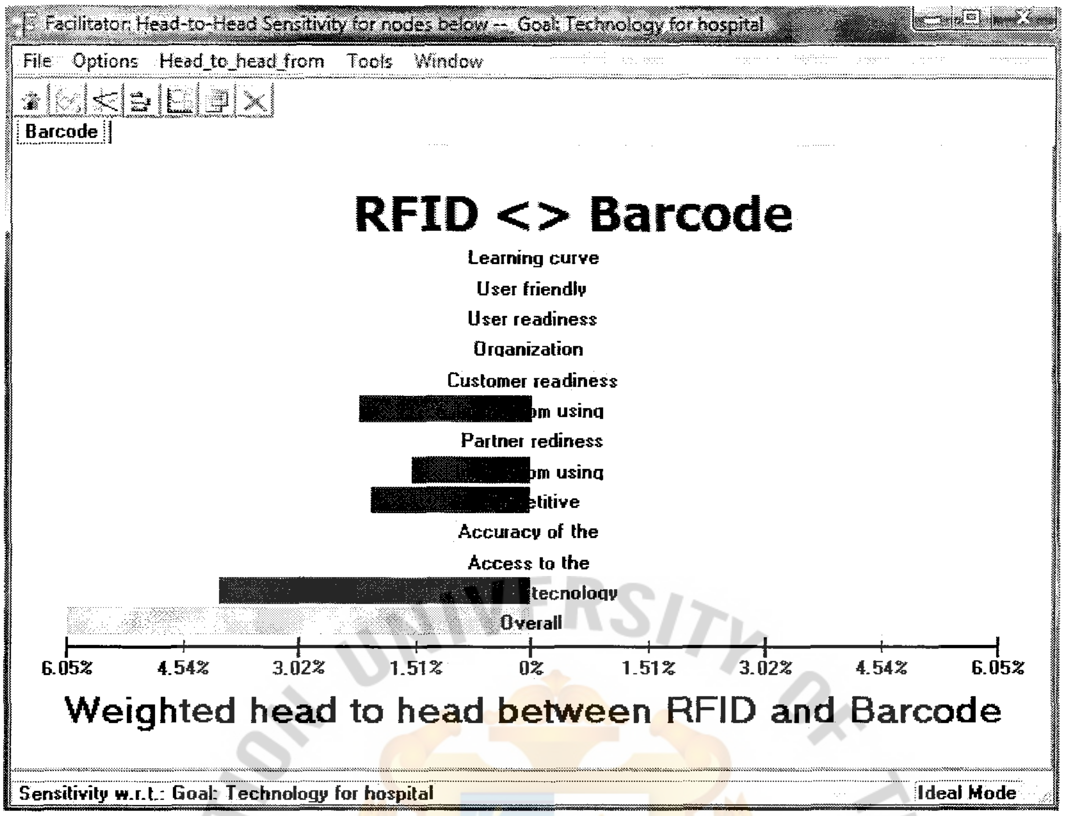
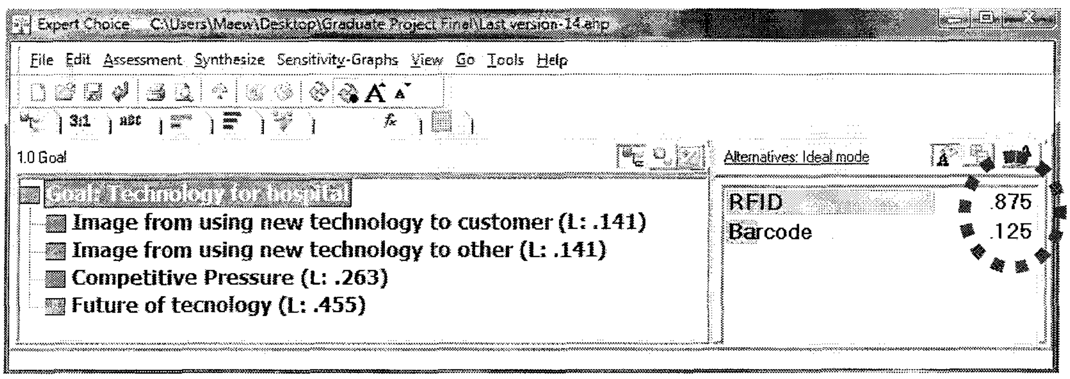


Figure 4-6 AHP: Weighted head to head between RFID and Bar code after removing the 14 criteria

In Figure 4-6, the difference of the AHP result between Barcode and RFID is 6.05% (from 0.53 - 0.47). It indicates that the gap between RFID and Barcode is not much. In this case, it will mean that the user finds it hard to make a decision when they must select the technology.

In the next step, if the study is focused only on the factors where RFID is stronger than Barcode, the result of the AHP absolutely changes to "RFID".



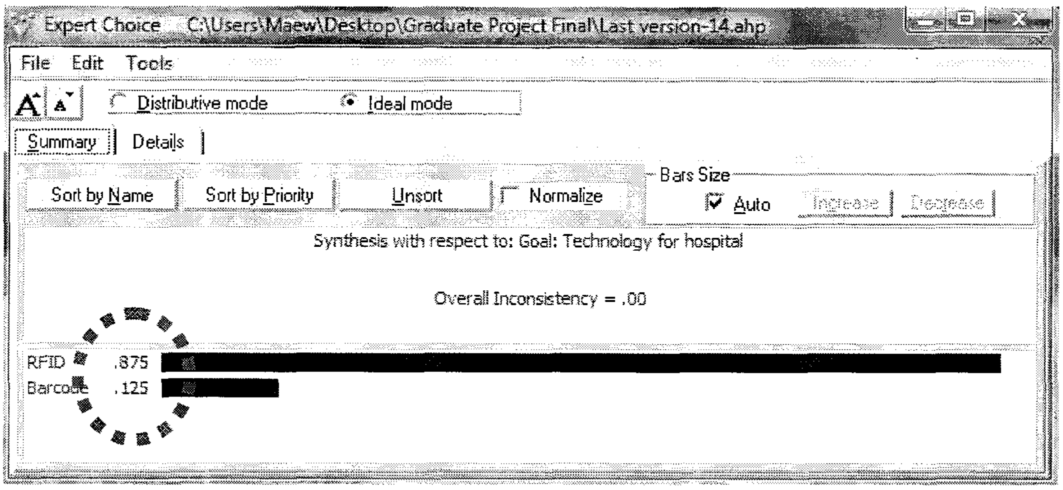


Figure 4-7 AHP: Summary of the result of technology selection when focusing only on the strong points of RFID

Figure 4-7 exhibits that when the study is considering only the 4 strong factor of RFID. The AHP result of RFID is totally different from Barcode with scores of 0.875 and 0.125 respectively.

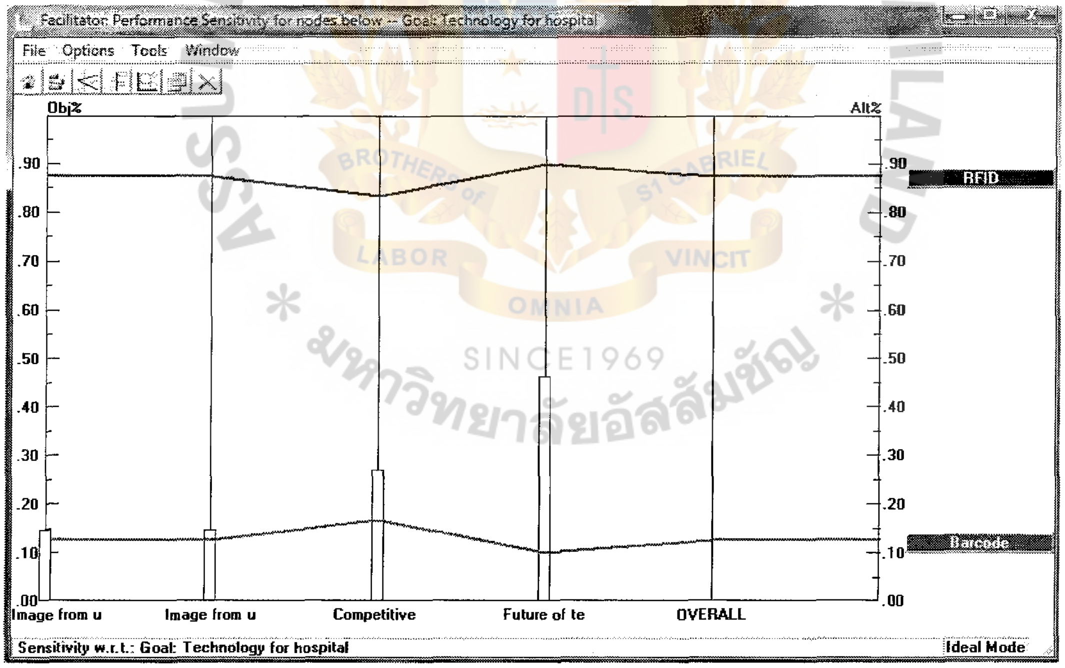


Figure 4-8 AHP: Performance sensitivity of technology selection when focusing only on strong points of RFID

Figure 4-8 illustrates the factors that make RFID better than Barcode by using line graph (Performance sensitivity model).

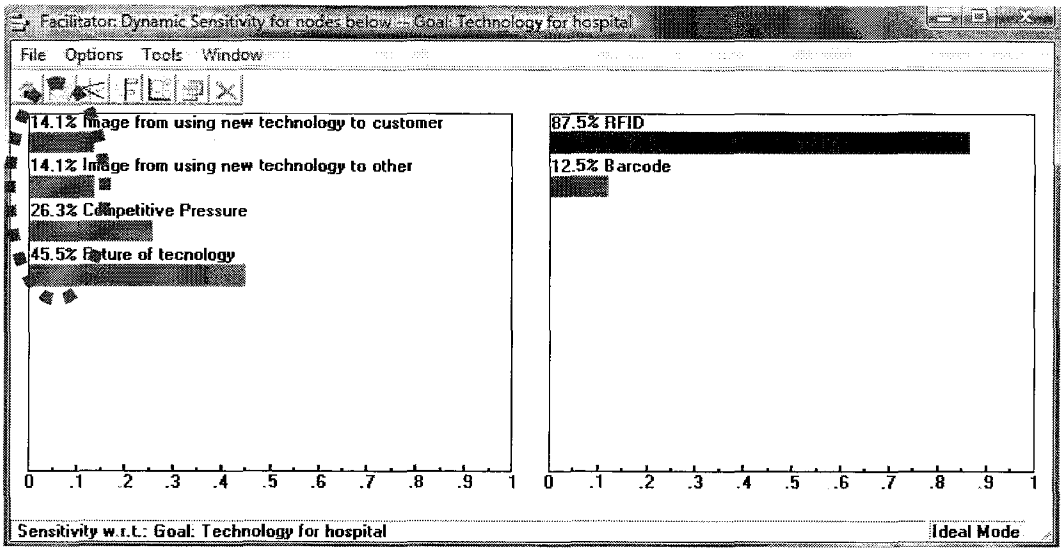


Figure 4-9 AHP: Dynamic Sensitivity of technology selection when focusing only on strong points of RFID

Figure 4-9 shows that each factor affecting the decision making result by the following percentages:-

1.	Image from using new technology to customer	14.10%
2.	Image from using new technology to others	14.10%
3.	Competitive Pressure	26.30%
4.	Future of technology	45.50%
	Total	**100.00%**

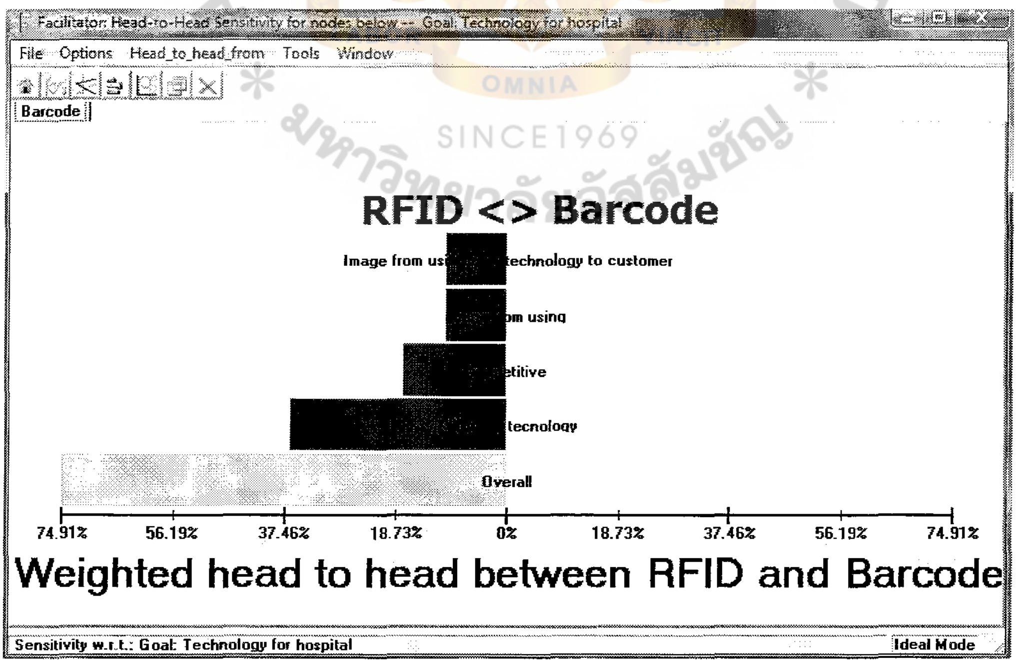


Figure 4-10 AHP: Weighted head to head between RFID and Bar code when focusing only on strong points of RFID

In Figure 4-10, the difference in AHP result between Barcode and RFID is 74.91 % (from 87.5% - 12.5%). It indicates that the gap between RFID and Barcode is very big. If the user considers only these 4 factors, then the result of the AHP will come out as "RFID"

The next step in this study is to prove that if RFID technology is developed and improved in the future, then RFID will be selected and recommended for use instead of Barcode, or not.

The first step is to adjust the weight of each factor. Table 4-1 exhibits the weighted score before and after adjustment.

Table 4-1 comparing weight score before / after adjustment

Criteria	Score of each alternative (Before)		Score of each alternative (After)	
	RFID	Barcode	RFID	Barcode
1.Limitation of System	0.167	0.833	0.500	0.500
2.Uncertainty of System	0.167	0.833	0.667	0.333
3. Learning curve	0.500	0.500	0.500	0.500
4. User friendly	0.500	0.500	0.500	0.500
5. User readiness	0.500	0.500	0.500	0.500
6. Organization readiness	0.500	0.500	0.500	0.500
7. Customer readiness	0.500	0.500	0.500	0.500
8. Image from using new technology	0.875	0.125	0.875	0.125
9. Partner readiness	0.500	0.500	0.500	0.500
10. Image from using new technology	0.875	0.125	0.875	0.125
11. Competitive Pressure	0.750	0.250	0.750	0.250
12. Compatibility of Software	0.250	0.750	0.500	0.500
13. Compatibility of Hardware	0.250	0.750	0.333	0.667
14. Accuracy of the data	0.500	0.500	0.750	0.250
15. Access to the information	0.500	0.500	0.500	0.500

16. Future of technology	0.900	0.100	0.900	0.100
17. Resource requirement	0.167	0.833	0.500	0.500
18. Easy to implement	0.167	0.833	0.333	0.667
19. Reliability	0.250	0.750	0.500	0.500
20. No. of vendor available	0.250	0.750	0.667	0.333
21. System Maintenance	0.250	0.750	0.667	0.333
22. No. of vendor available	0.250	0.750	0.667	0.333
23. Cost of Tag	0.250	0.750	0.333	0.667
24. Cost of Reader	0.250	0.750	0.500	0.500
25. Cost of Implementation	0.250	0.750	0.333	0.667
26. Cost of Application / Software	0.250	0.750	0.500	0.500

* The score in table 4-1 is adjusted and rated by an RFID professional.

The adjusted factors with the reason why they are adjusted are as follows:-

1. **Limitation of System**: In the future, if RFID is developed, the limitation of technology should be minimized. RFID will be able to be used in a wider scope than Barcode. However, there are still some limitations in both technologies. Then the score of RFID should be equal to Barcode.
2. **Uncertainty of System**: In the future, if RFID is developed, the uncertainty of technology should be minimized or eliminated. Then the score of RFID should be higher than Barcode.
3. **Compatibility of Software**: In the future, if RFID is developed. There will be no difference between RFID software and Barcode software. Then the scores should be the same.
4. **Compatibility of Hardware:** Like the Software Factor, Hardware of RFID will be developed. There will be no difference between RFID software and Barcode hardware because both RFID and Barcode are required to have reader, tag and server. Then the scores should be the same.
5. **Accuracy of the data:** In the future, if RFID technology is developed, the data can be accessed from an RFID system. Then, RFID data will be more accuracate than Barcode.

6. **Resource requirement:** Once the RFID is widely used, there will be no difference between implementation of RFID and Barcode. Both RFID and Barcode will require the same level of investment.
7. **Easy to implement:** Once the RFID is widely used, there will be no difference between implementation of RFID and Barcode. User will not feel any difference between implementation of RFID and Barcode because they will get use to both RFID and Barcode technology. However, Barcode has been used widely for a long time. Implementation of Barcode might be easier to implement. Anyway, RFID is higher technology. Then RFID will still be more complicated than Barcode technology.
8. **Reliability:** In the future, RFID technology will be developed until this technology is stable. Then Both RFID and Barcode are trustable technologies. So, there will be difference between RFID and Barcode.
9. **No. of vendors available (installation):** RFID expert believe that in the future, Barcode technology will be replaced by RFID technology. Barcode technology will be out of date technology. It will be obsolete from the market. Then Barcode vendors will turn into RFID vendor. So, the number of RFID vendors available in the market will be more and more.
10. **System Maintenance:** If RFID technology is widely used, system maintenance will not be a challenge anymore. There will be a lot of vendors available to service, in the Maintenance function.
11. **No. of vendors available (System Maintenance):** RFID experts believe that in the future, Barcode technology will be replaced by RFID technology. Barcode technology will be out of date technology. It will be obsolete from the market. Then Barcode vendors will turn themselves into RFID vendors. So, the number of RFID vendors available in the market will be more and more.
12. **Cost of Tag:** Although cost per unit of RFID tags will be cheaper in the future since the producer will produce more in order to serve the increasing demand in the market, Barcode tag is still cheaper because Barcode tag can be printed using a normal printer while the RFID cannot be printed out.

13. **Cost of Reader:** When the RFID is widely used in the future, the cost of the reader of both RFID and Barcode should not be different. The technology which is used in production should not be different.
14. **Cost of Implementation:** The effect from the cost of RFID tag will make the cost of RFID implementation higher than Barcode. However, the old technology which is widely used like Barcode should be cheaper but not by much.
15. **Cost of Application / Software:** Application and Software for RFID and Barcode will be easily found in the market. It depends on the user to select which technology to apply in their organization. Then, the cost of software should not be much different.

After adjustment of weighted scores in RFID and Barcode, the following comment is by an RFID Expert who currently implements RFID for Bumrungrad Hospital. The result of the AHP is exhibited in Figure 4-11 to Figure 4-14.

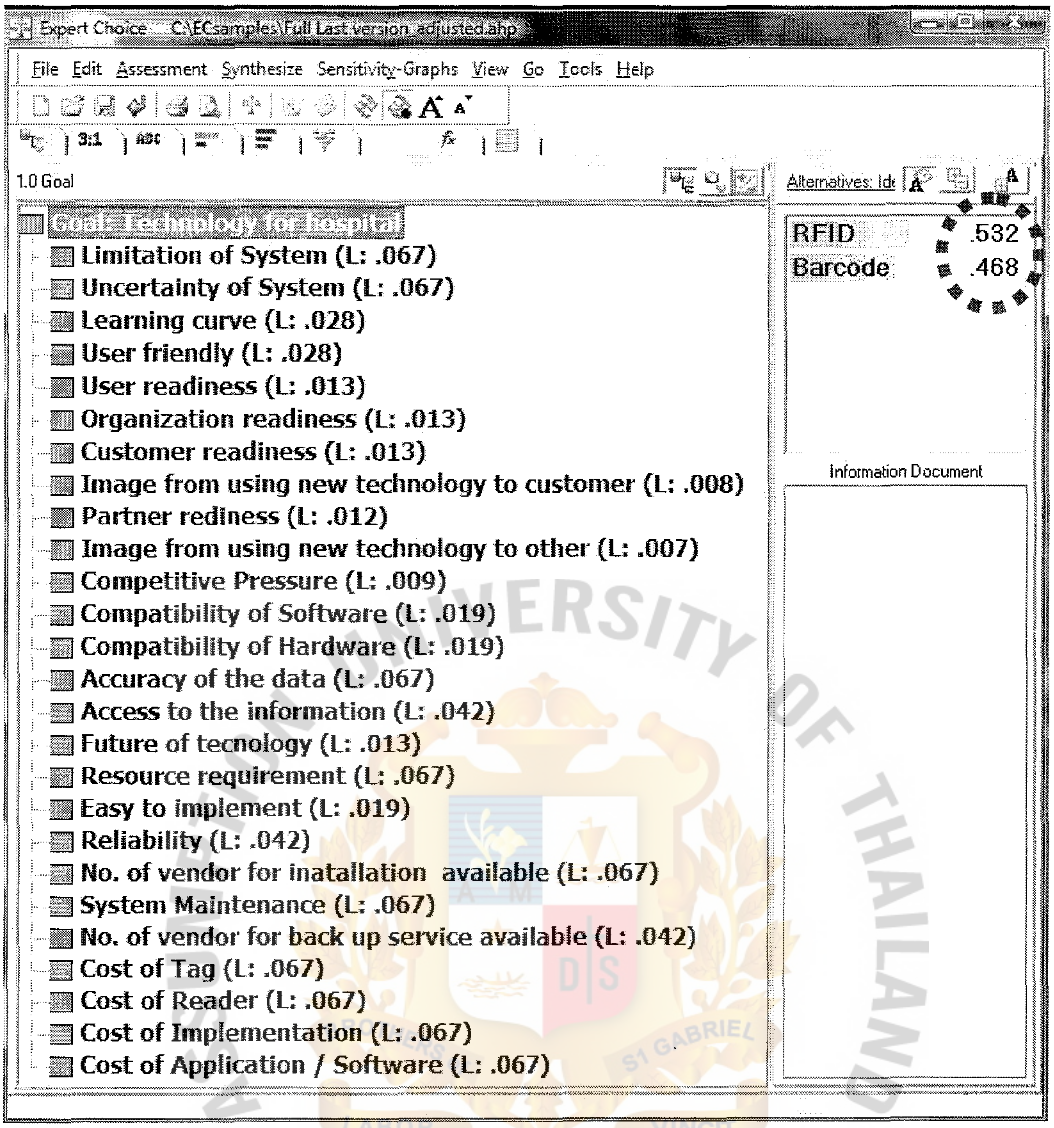


Figure 4-11 AHP: Summary the result of technology selection after changing the rating of 9 main criteria

Figure 4-11 and Figure 4-12, show that after changing the rating of 9 main criteria (15 factors), the AHP result changes from Barcode to RFID with scores of 0.532 and 0.468 respectively.

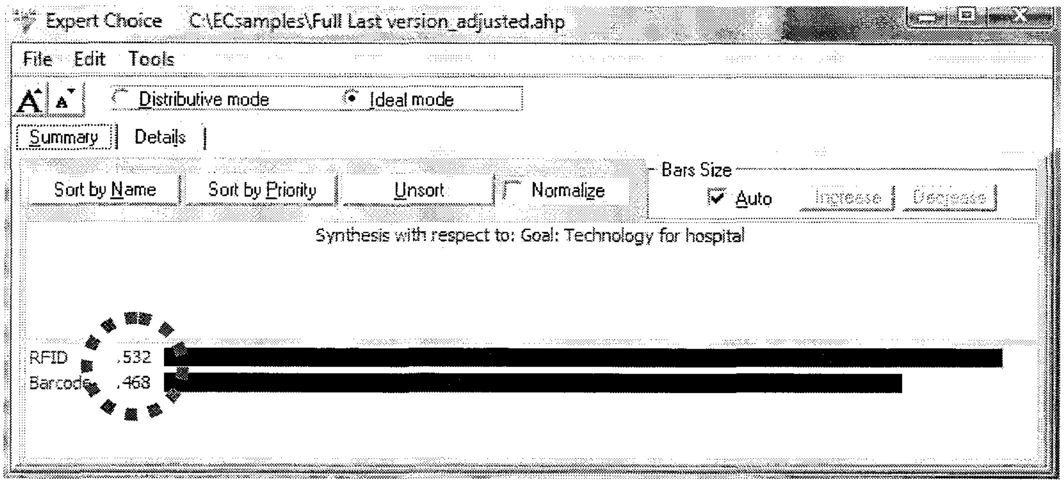


Figure 4-12 AHP: Summary the result of technology selection after change rating 9 main criteria II

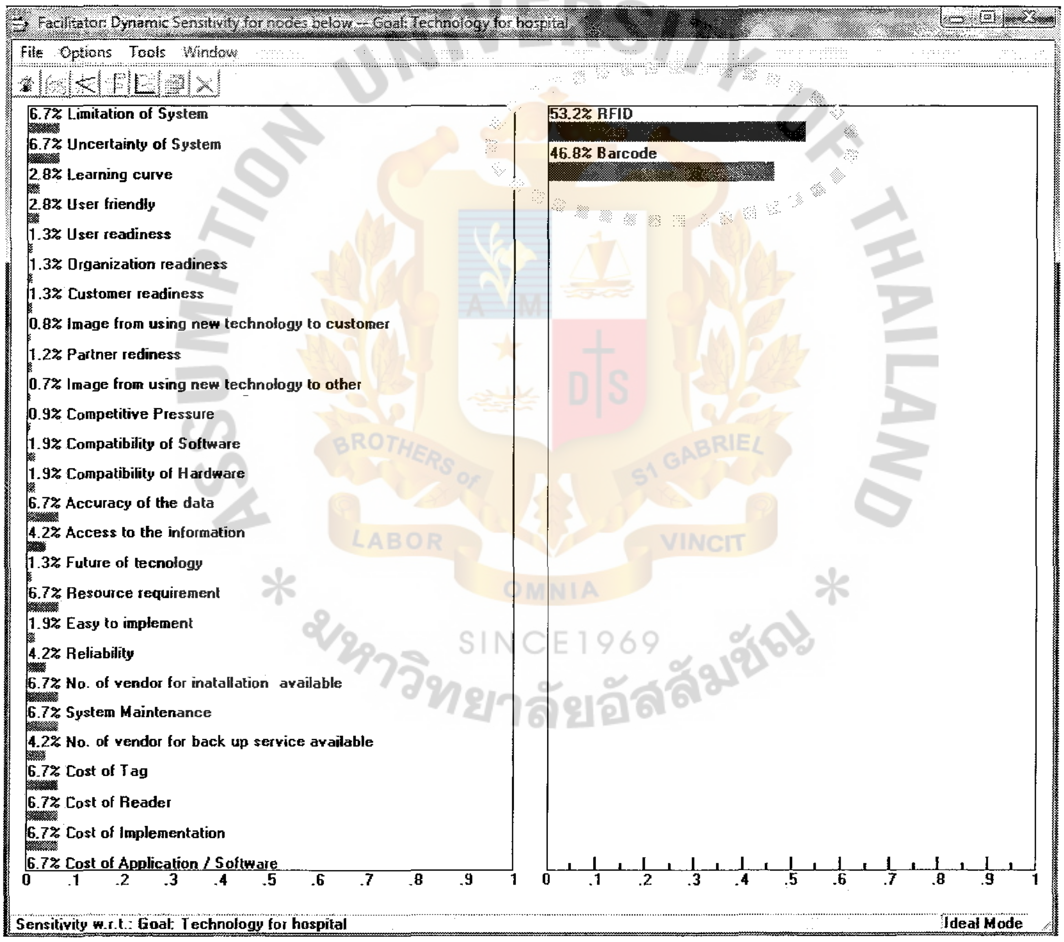


Figure 4-13 AHP: The result of technology selection after changing the rating of 9 main criteria (Dynamic Sensitivity)

From Figure 4-13, it exhibited the factors that RFID better than Barcode by using bar graph and also providing factors with percentage on the left hand side.

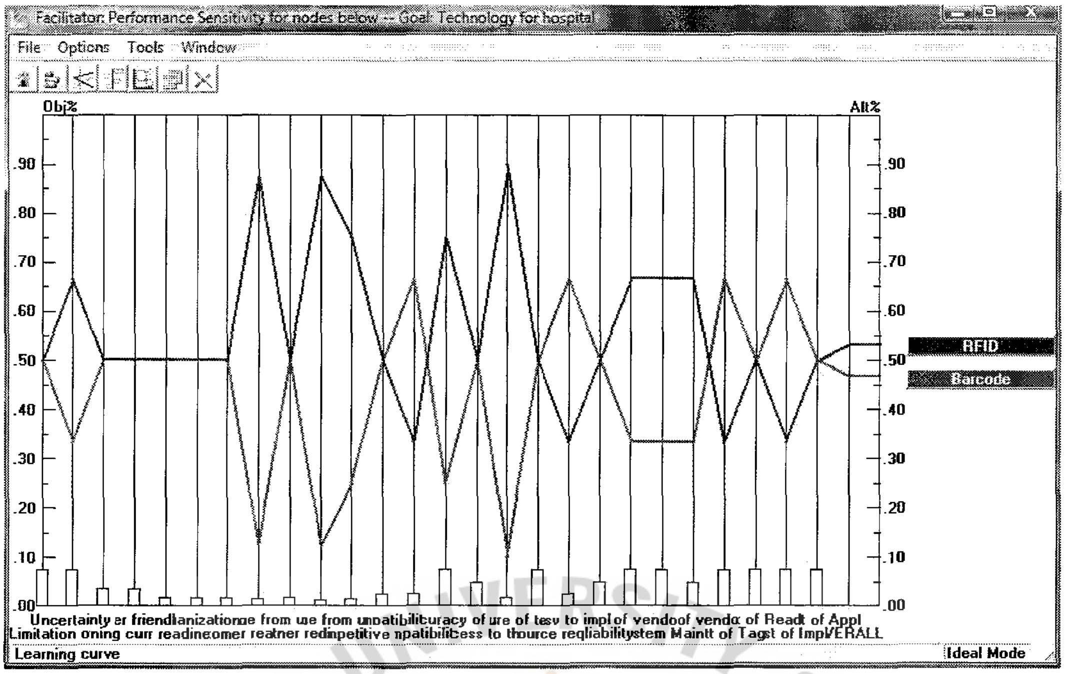


Figure 4-14 AHP: The result of technology selection after changing the rating 9 main criteria (Performance Sensitivity)

Figure 4-14 illustrates the factors in which RFID is better than Barcode by using line graph.

From the above factor adjustment, it might be concluded that if the following factors of RFID are developed, Barcode will be replaced by RFID and people will prefer to use RFID rather Barcode.

1) Technical Factors :Limitation and Uncertainty of System
2) Cost Factors : Installation, Software and Hardware
3) Back-up service : System maintenance and number of vendors available in the market

In the future, if RFID is developed and widely use in the industry like Barcode technology, then RFID technology will be recommended to be applied, replacing Barcode technology.

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The Bangkok Christian Hospital one hospital that is studying technology which could decrease the working lead time and also prevent medical errors by giving medical treatment to the wrong patient. There are two technologies that they are considering. Those technologies are RFID and Barcode.

After interviewing three IT managers in Grade A hospitals (Bumrungrad Hospital, Viphavadi Hospital and Bangkok Christian Hospital) and finding some articles about technology selection, the factors which should be considered are the following:-

1. Technical

- Limitation of System
- Uncertainty of System

2. Effect on Employees

- Learning curve
- User friendly
- User readiness

3. Effect on Organization

- Organization readiness

4. Effect on Customers

-Customer readiness

- Image from using new technology

5. Effect on Partners

- Partner readiness

6. Effect from others

- Image from using new technology
- Competitive Pressure

7. System and Technology

- Compatibility of Software
- Compatibility of Hardware
- Accuracy of the data
- Access to the information
- Future of technology

8. Installation

- Resource requirement
- Easy to implement
- Reliability
- No. of vendors available

9. Back-Up service

- System Maintenance
- No. of vendors available

10. Cost

- Tag
- Reader
- Implementation
- Application / Software

The result of AHP indicated that Barcode should be used in The Bangkok Christian Hospital.

Barcode is stronger than RFID on the following point:-

1. Limitation of the system
2. Uncertainty of the system
3. Compatibility of software
4. Compatibility of hardware

5. Resource requirement
6. Easy to implement
7. Reliability
8. No. of vendor available for installation
9. System maintenance
10. No. of vendor available in term of back up service
11. Cost of Tag
12. Cost of Reader
13. Cost of Implementation
14. Cost of Application

The above factors are considered as direct factor which mostly affect result of decisions on technology. The explanations are as following:-

1) **Cost** – Currently Tag, Reader, Implementation and Application / Software of Bar code technology are cheaper than RFID. Thus the hospital will spend less than if they invest in Barcode Technology.

2) **Limitation & Uncertainty of System** – since RFID technology is not yet well developed. This technology is not 100% utilized and still have some errors.

3) **Back-Up service** – The number of Suppliers and Supporting Companies in terms of equipment (Tag and Reader) and maintenance of RFID are rarely found when compared with Bar code technology.

In the AHP result, RFID is voted higher than Barcode in the factor " the customer perspective from using new technology", which is not considered as the main factor of identity identification technology selection. In the IT people's point of view, Image from using new technology is the main criterion to be considered because RFID is a new technology for the Health Care Industry in Thailand. IT departments in each hospital consider RFID technology as a new challenge to implement advance technology to improve their service.

The factors where RFID is better than Barcode are as follows:-

1. Image from using new technology to customer
2. Image from using new technology to other
3. Competitive Pressure
4. Future of technology

The factors which are weighted at the same rate for both RFID and Barcode are:-

1. User friendly
2. User readiness
3. Organization readiness
4. Customer readiness
5. Partner readiness
6. Accuracy of the data
7. Access to the information

4.1 Recommendation

As AHP result, Bar code is recommended for use. From the RFID expert's recommendation, if the RFID technology develops more stability, then the considered factors that should be adjusted as follows:-

1. Limitation of System
2. Uncertainty of System
3. Compatibility of Software
4. Compatibility of Hardware
5. Accuracy of the data
6. Resource requirement
7. Easy to implement
8. Reliability
9. No. of vendors available (installation)
10. System Maintenance
11. No. of vendors available (System Maintenance)
12. Cost of Tag
13. Cost of Reader

14. Cost of Implementation
15. Cost of Application / Software

After adjusting the score of RFID in these 15 factors, the result of AHP changes from barcode to RFID.

Within 1 - 2 years, barcode is the better technology to be used and implemented. In the longer term, the expert believes that RFID will replace barcode technology. So, the hospital should prepare their system to support expansion of RFID in the future.

4.2 Limitations of this Study

- The information in this project comes from interviews in hospitals in the Bangkok area, which are Bumrungrad Hospital, Viphavadi Hospital and Bangkok Christian Hospital. They are all considered as "Grade A" hospitals. However, with limited number of samples and specifications of IT departments' point of view, the direction may be misleading from the factual. In order to gain better information and widen the scope of study, the collecting of information should also include interviews with patients in those selected hospitals in order to gain information from the customer point of view. On the patient (considered as customer) point of view, there is no article which reports such research.
- This project has studied and compared only two technologies which are Barcode and RFID. In the market, there might be some other technology which is much more interesting than these two technologies such as Near Field Contact (NFC)

4.3 Future Research

In the interviews with 3 IT manager of 3 hospitals (Bumrungrad Hospital, Viphavadi Hospital and Bangkok Christian Hospital), all of them preferred RFID more than Barcode. The reasons that they provided are:-

1. RFID is the technology for the future but Barcode is an old technology and going to be replaced by other technologies

2. Up-to-dateness of Medical Technologies or Medical Equipment is one of the factors that patients consider when they select a hospital
3. Up-to-date technology enables the hospital to gain a "good image" from patients.

From the above information, further research should considered also the factor of "customer perception of using technology"

If there are changes which reflect on direct factors (cost, limitation & uncertainty of technology and back up service) in the future e.g. decreasing cost of RFID technology, stability of RFID technology and more RFID vendors available in the market; then the decision-making result may change from Barcode to RFID. So, in the future, this project topic should be re-studied again in order to confirm this assumption.

Another suggested recommendation is for future research comparing DEA (Data Environment Analysis).

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APPENDIX A: EXPERT CHOICE IN VENDER/SOURCE SELECTION

EXPERT CHOICE IN VENDER/SOURCE SELECTION

Expert Choice software is designed to enable decision-makers to develop consensus about what is really important in selecting the best product or service. When procuring complex goods and services, organizations often encounter gridlock in determining what is really needed. Some decision-makers may already favor a vendor or may have their own ideas of what constitutes best-value. Expert Choice consultants guide decision-makers to weight criteria using a unique process for developing priorities and building consensus.

Expert Choice can help manage the assessment of vendors by combining both quantitative and qualitative information into the selection of the best-value offering for the organization. When an organization is confronted with choosing the best vendor to deliver a good or service, the decision can often be very complex.

Powerful sensitivity graphs enable the purchaser to graphically display the relative strengths and weaknesses of vendors against the evaluation criteria. The analytical tools are extremely effective for rolling up vendor scores and comparing costs to truly measure best-value.

Expert Choice is often used by government agencies to dramatically reduce the amount of time it takes to select the best vendor, then justify the selection against protest using the advanced reporting capabilities of the software.

At the heart of Expert Choice's solutions is our powerful group decision support software application – Expert Choice 11. Based on the Analytic Hierarchy Process (AHP), Expert Choice provides you with the leading decision support application used by more than 15,000 users in over 60 countries to help you and your organization achieve:

- Better, faster, more justifiable decisions
- Organizational and strategic alignment
- A structured decision-making approach
- Consensus and improved communication
- An improved bottom line

APPLICATION

The Analytical Hierarchy Process (AHP) approach, as applied to the supplier selection problem, consists of five steps. We will show you the step and highlight the key sentences in example for the clarification the step.

<u>Step 1</u>: Specify the set of criteria for evaluating the supplier's proposals.
Key sentence is "Price, warranty and brand are importance factors."

<u>Step 2</u>: Obtain the pairwise comparisons of the relative importance of the criteria in achieving the goal, and compute the compute the priorities or weights of the criteria based on this information.
Key sentences are "He believes that the price is equally to moderately prefer over warranty, and price is extremely preferred to brand. Warranty is strongly to very strongly prefer over the brand."

<u>Step 3</u>: Obtain measures that describe the extent to which each supplier achieves the criteria.
Key sentences are "In price, he has determined that car1 is equal to moderately preferred to Car2. Car1 is very strongly preferred to Car3, and Car2 is moderately to strongly prefer to Car3."

Step 4: Using the information in step3, obtain the pairwise comparisons of the relative importance of the supplies with respect to the criteria and compute the corresponding priorities.

Step 5: Using the results of step 2 and step 4 compute the priorities of each supplier in achieving the goal of hierarchy.

Giving you the idea of application and calculation comparing in both from Microsoft Excel and Expert choice, Analytical Hierarchy Process (AHP) program, let's try selecting the new car.

Assume the buyer treat price, warranty and brand as importance factors. Buyer believes that the price is equally to moderately prefer over warranty, and price is extremely preferred to brand. Warranty is strongly to very strongly prefer over the brand.

Regarding to describe above, we have better translate to the matrix.

Table A - 1 AHP Example: Original matrix

Factor	Price	Warranty	Brand
Price	1	2	9
Warranty	1/2	1	6
Brand	1/9	1/6	1

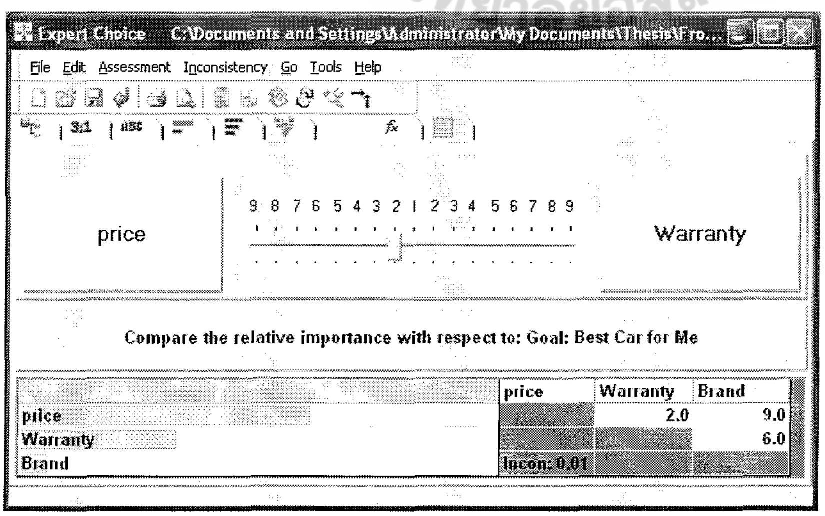

Figure A - 1 AHP Example: Original matrix Expert Choice Software

There are three different car models she is considering, Car1, Car2 or Car3. An important factor for him is the price. He has determined that car1 is equal to moderately preferred to Car2. Car1 is very strongly preferred to Car3, and Car2 is moderately to strongly prefer to Car3. Determine the priorities or factor evaluations for the three cars for price.

Table A - 2 AHP Example: Price matrix

Price	Car1	Car2	Car3
Car1	1	2	7
Car2	1/2	1	4
Car3	1/7	¼	1

Input the data into Expert Choice

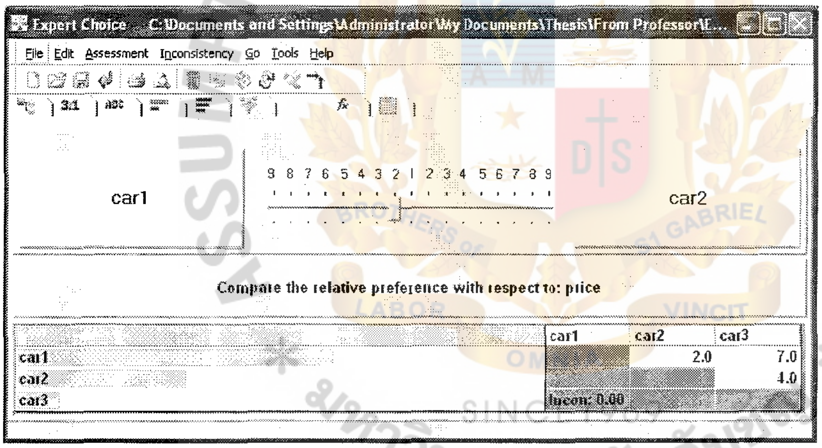

Figure A - 2 AHP Example: Price matrix in Expert Choice Software

Warranty, Car2 is moderately preferred to Car1. Car3 is very to extremely strongly preferred over Car1, Car3 is strongly preferred over Car2.

Here is the matrix for warranty:

Table A - 3 AHP Example: warranty Matrix

Warranty	Car1	Car2	Car3
Car1	1	1/3	1/8
Car2	3	1	1/5
Car3	8	5	1

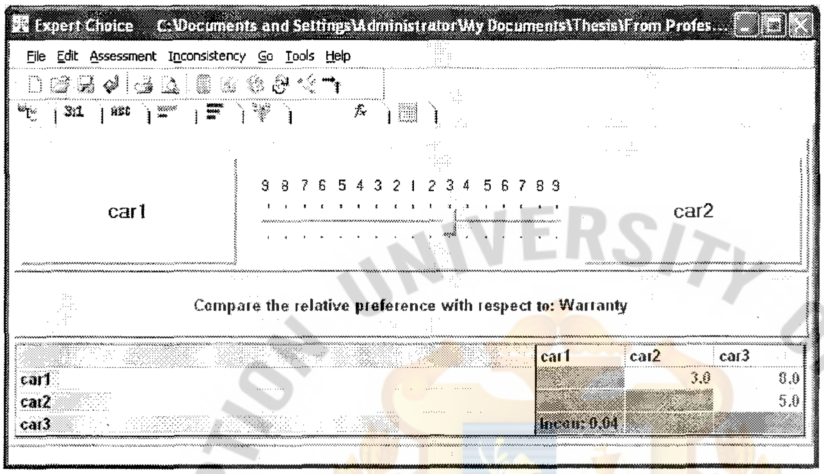

Figure A - 3 AHP Example: Warranty matrix in Expert Choice Software

Brand, Car2 is moderately preferred to Car1. Car1 is moderately preferred to Car3. Car2 is very to extremely strongly preferred over Car3.

Table A - 4 AHP Example: brand Matrix

Brand	Car1	Car2	Car3
Car1	1	1/3	3
Car2	3	1	8
Car3	1/3	1/8	1

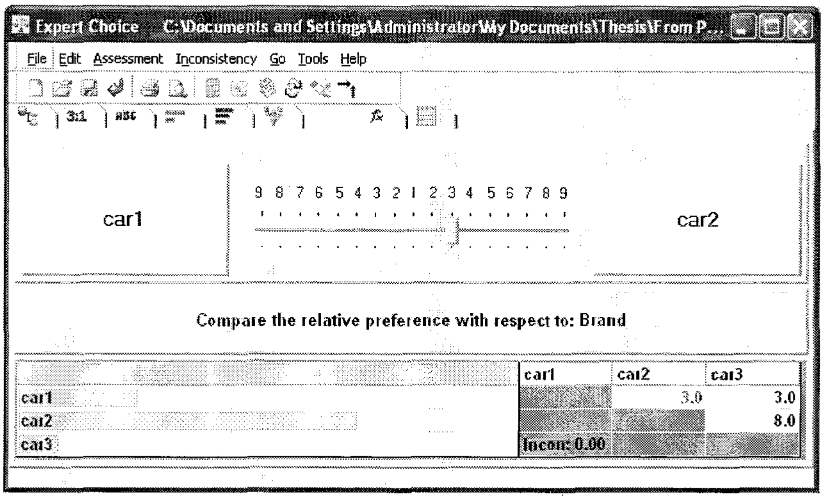

Figure A - 4 AHP Example: Brand matrix in Expert Choice Software

Bring in formation in matrix to calculation.

1 Sum of column

Table A - 5 AHP Example: Calculation on original matrix

Factor	Price	Warranty	Brand
Price	1	2	9
Warranty	1/2	1	6
Brand	1/9	1/6	1
Total	**1.611**	**3.167**	**16.000**

2 Divide each value by its column sum (so-called Normalized) and compute the row average

Table A - 6 AHP Example: Normalized original matrix

Normalized

Factor	Price	Warranty	Brand	**Weight**
Price	0.621	0.632	0.563	**0.605**
Warranty	0.310	0.316	0.375	**0.334**
Brand	0.069	0.053	0.063	**0.061**
Total	**1.000**	**1.000**	**1.000**	**1.000**

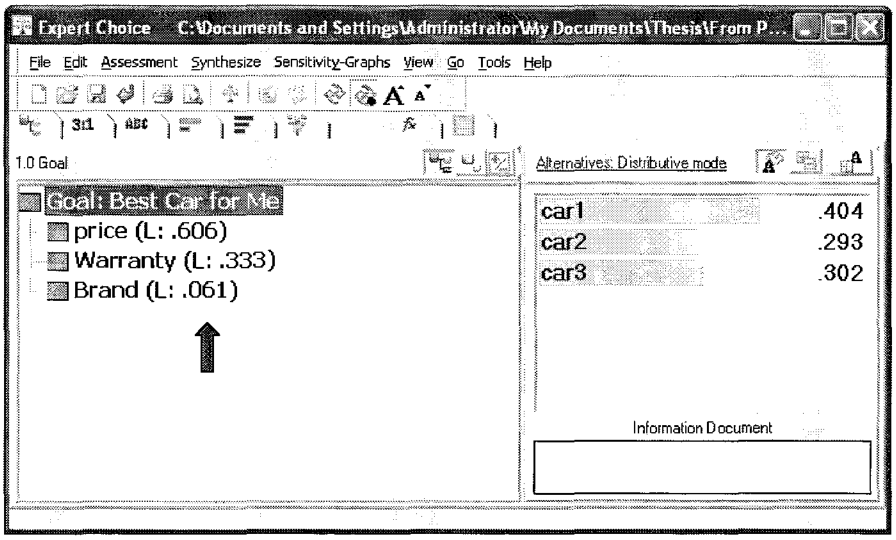

Figure A - 5 AHP Example: Result of original matrix in Expert Choice Software

Obtain the pair wise comparisons of the relative importance of the supplies with respect to the criteria, price, and warranty and brand accordingly.

Compute the corresponding priorities, Sum the column and normalized and average the row.

Price matrix

Table A - 7 AHP Example: Calculation and Normalized on price matrix

Price	Car1	Car2	Car3
Car1	1	2	7
Car2	1/2	1	4
Car3	1/7	1/4	1
Total	**1.643**	**3.250**	**12.000**

Normalized

Price	Car1	Car2	Car3	**Weight**
Car1	0.609	0.615	0.583	**0.602**
Car2	0.304	0.308	0.333	**0.315**
Car3	0.087	0.077	0.083	**0.082**
Total	**1.000**	**1.000**	**1.000**	**1.000**

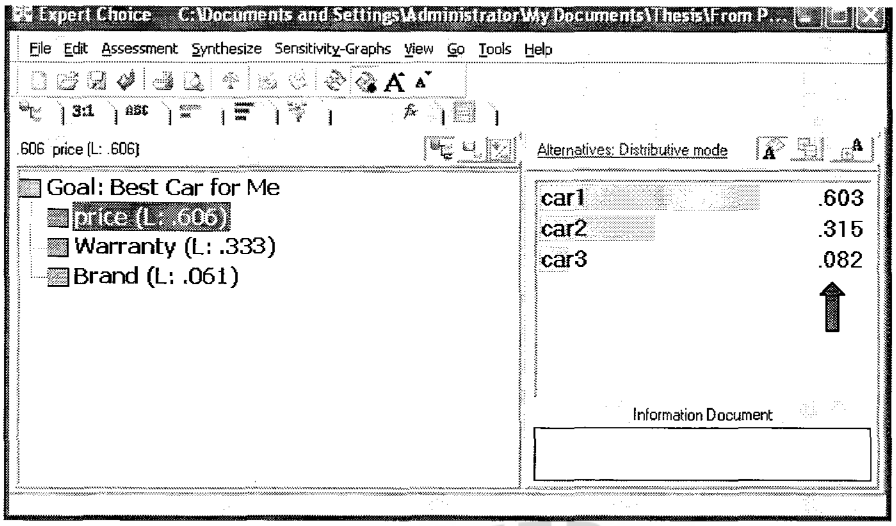

Figure A - 6 AHP Example: Result of price matrix in Expert Choice Software

Warranty matrix

Table A - 8 AHP Example: Calculation and Normalized on warranty matrix

Warranty	Car1	Car2	Car3
Car1	1	1/3	1/8
Car2	3	1	1/5
Car3	8	5	1
Total	**12.000**	**6.333**	**1.325**

Normalized

Warranty	Car1	Car2	Car3	**Weight**
Car1	0.083	0.053	0.094	**0.077**
Car2	0.250	0.158	0.151	**0.186**
Car3	0.667	0.789	0.755	**0.737**
Total	**1.000**	**1.000**	**1.000**	**1.000**

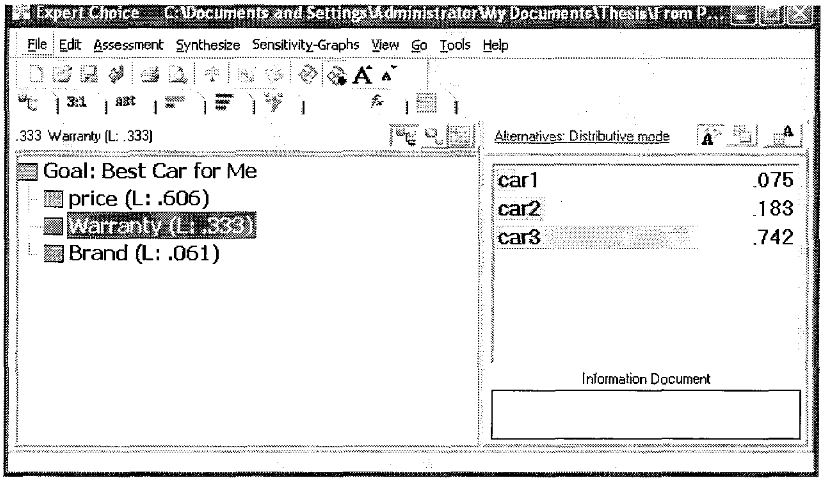

Figure A - 7 AHP Example: Result of warranty matrix in Expert Choice Software

Brand matrix

Table A - 9 AHP Example: Calculation and Normalized on brand matrix

Brand	Car1	Car2	Car3
Car1	1	1/3	3
Car2	3	1	8
Car3	1/3	1/8	1
Total	**4.333**	**1.458**	**12.000**

Normalized

Brand	Car1	Car2	Car3	**Weight**
Car1	0.231	0.229	0.250	**0.236**
Car2	0.692	0.686	0.667	**0.682**
Car3	0.077	0.086	0.083	**0.082**
Total	**1.000**	**1.000**	**1.000**	**1.000**

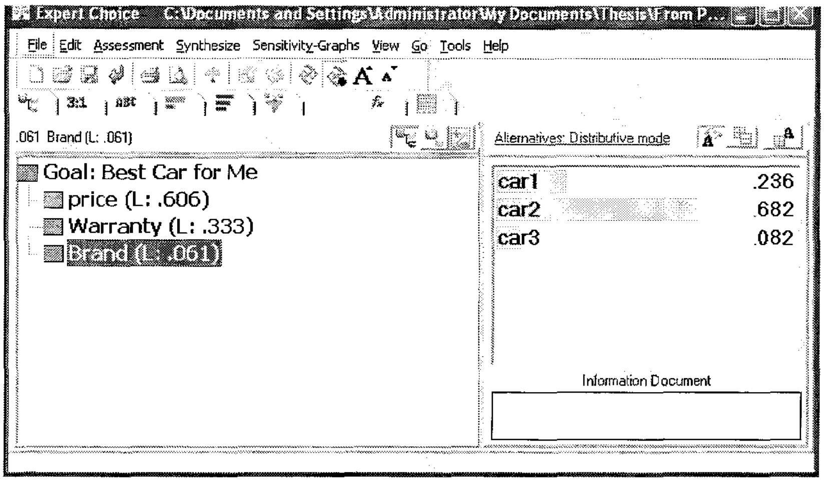

Figure A - 8 AHP Example: Result of brand matrix in Expert Choice Software

Summarized table by bring the weight of each criteria and Total value for Car1 is

Table A - 10 AHP Example: Summary of result

	Weight	Car1	Car2	Car3
Price	0.605	0.602	0.315	0.082
Warranty	0.334	0.077	0.186	0.737
Brand	0.061	0.236	0.682	0.082
Total		**0.405**	**0.295**	**0.301**

(0.605*0.602) + (0.334*0.077) + (0.061*0.236) = **0.405**

Repeat calculation for Car2 and Car3. The highest value will be judged as the best overall. For this case, we should choose Car1.

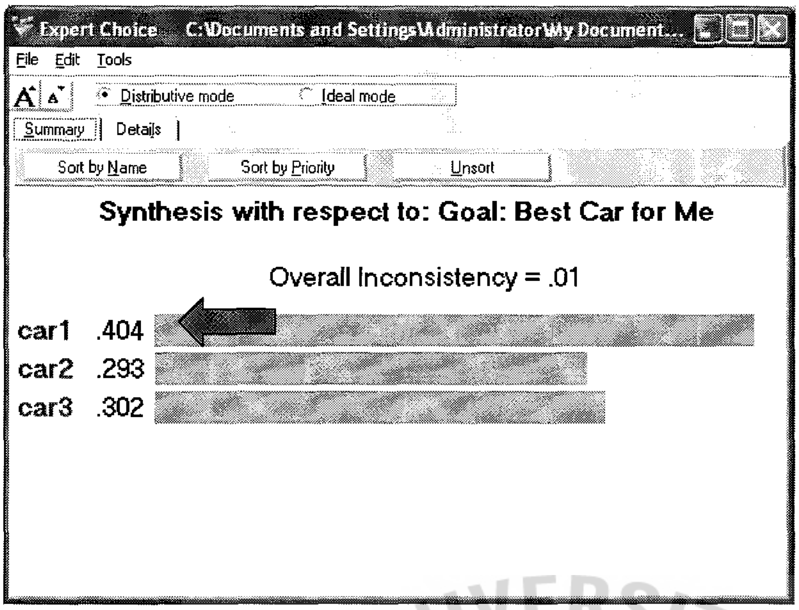

Figure A - 9 AHP Example: Result of selection in Expert Choice Software

Summary and compare the result

Table A - 11 AHP Example: the result from Excel spreadsheet

	Weight	Car1	Car2	Car3
Price	0.605	0.602	0.315	0.082
Warranty	0.334	0.077	0.186	0.737
Brand	0.061	0.236	0.682	0.082
Total		**0.405**	**0.295**	**0.301**

Table A - 12 AHP Example: the result from Excel spreadsheet

	Weight	Car1	Car2	Car3
Price	0.606	0.603	0.315	0.082
Warranty	0.334	0.075	0.183	0.742
Brand	0.061	0.236	0.682	0.082
Total		**0.404**	**0.293**	**0.302**

APPENDIX B: BACKGROUND OF THE BANGKOK CHRISTIAN HOSPITAL

The Bangkok Christian Hospital

Location

124 Silom Road, Bangrak District, Bangkok 10500

Telephone

0-2235-1000-7, 0-2233-6981-9

0-2634-0560, 0-2634-0953-64

Fax

0-2236-2911

Map

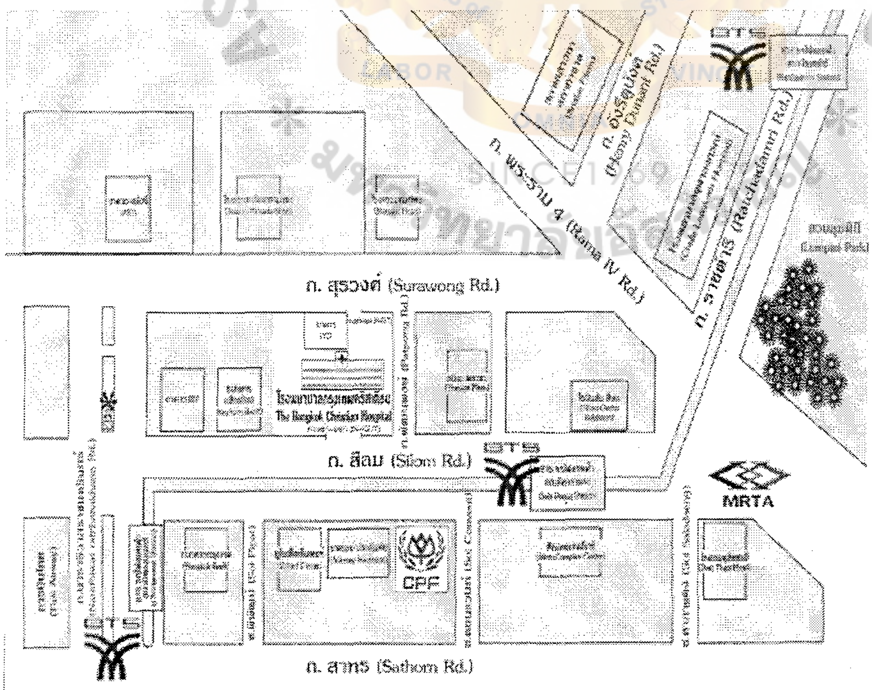

Figure B - 1 Map of The Bangkok Christian Hospital

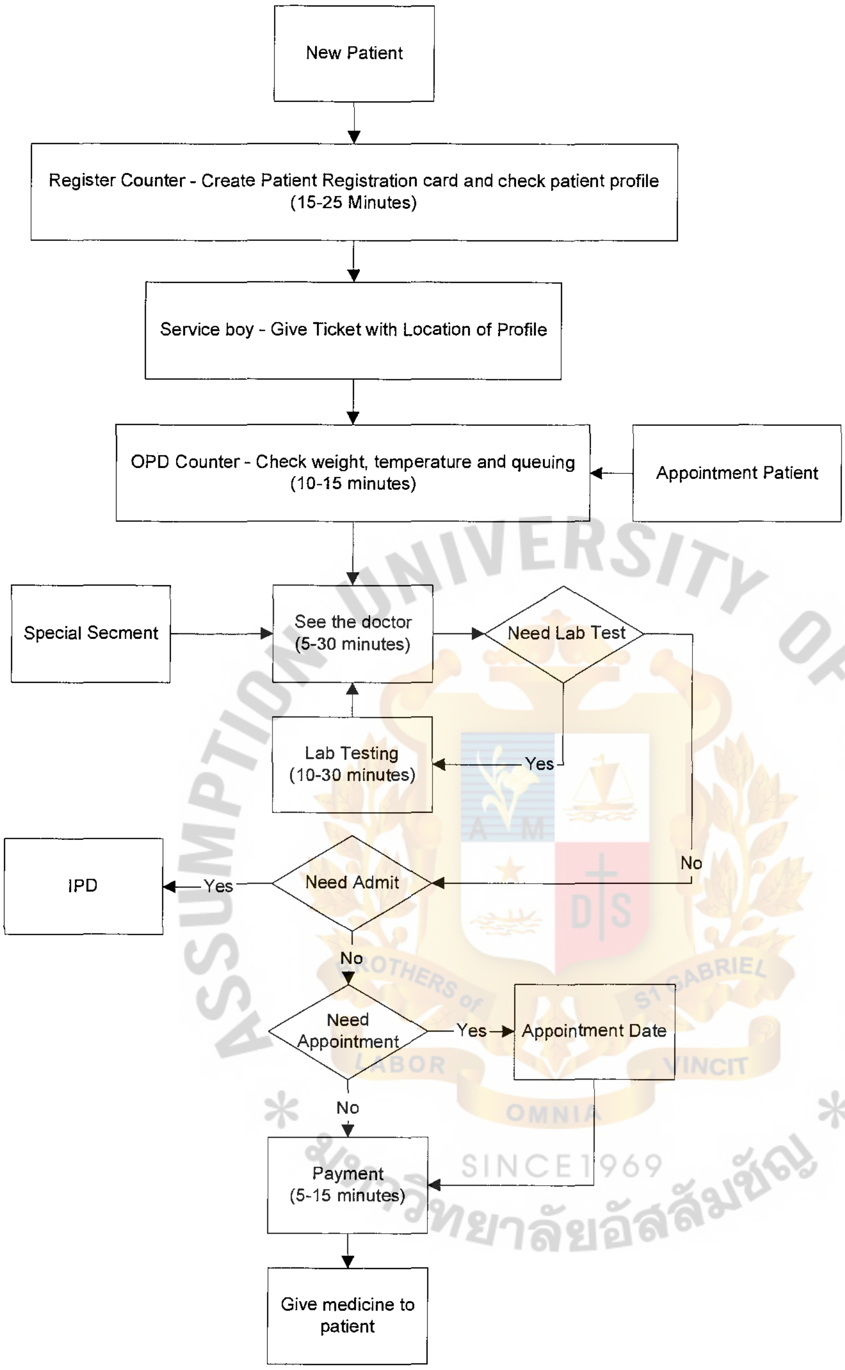

Figure B - 2 Current Work Flow

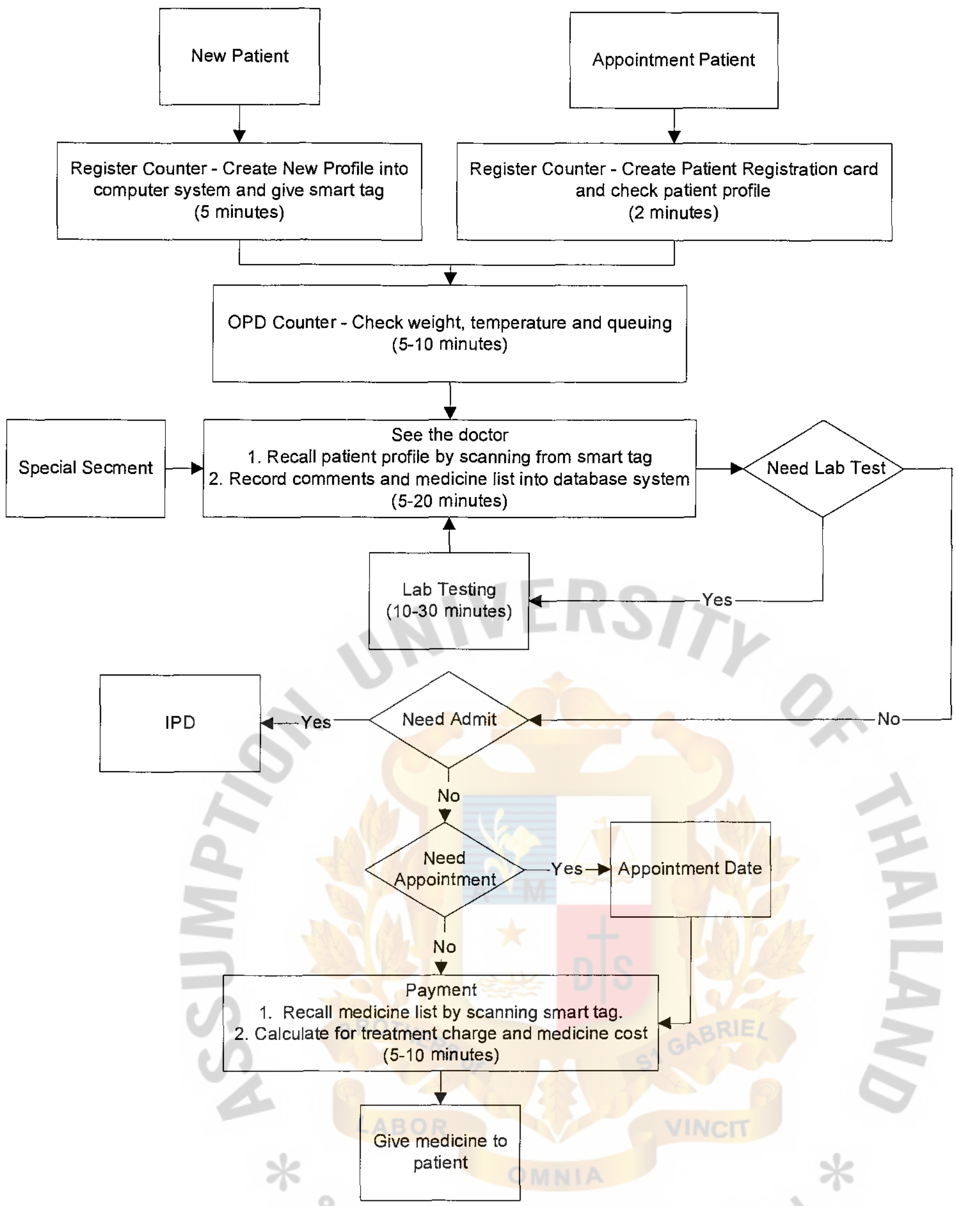

Figure B - 3 Expected New Work flow (after apply smart tag)

Improvement Areas

- The registration Part:
  - The Bangkok Christian spends around 15 – 25 minutes (KPI at 15 mins) to find Patient Profile in case that that patient is currently their customer.
  - They use 5 service boys and 3 registrars to proceed this function.
- OPD counter :
  - Gathering Patient information manually is time consuming, because the information first must be recorded at the point of activity, then later transcribed and entered into the computer system. The redundant manual data recording procedures provide two opportunities to incorrectly record the information. Current error rate are as following:-
    - 3.00% from wrong picking patient profile
    - 2.00% from miss delivery of Patient Profile to wrong place (windows)

Current Cost

- Salary for the service boy
- Salary for registrar
- Space cost (warehouse to keep the patient profile)
- Document and stationary cost
- Dissatisfaction from Customer
- Risk from human error (communication and wrong profile picking)

Table B - 1 Cost of Technology (Barcode)

Cost (Barcode):	Cost Per one unit	Unit		Total cost (Baht)
New Barcode equipment:				
Barcode Printer (Thermal Type)	20,000	3	Printer	60,000
Barcode Scanner	7,000	35	Scanner	245,000
Label 3.2cm x 2.5cm (5,000Label/Roll)	250	150	Roll	37,500
Barcode Ink	200	150	Unit	30,000
Software	15,000	1	Unit	15,000
Training costs:				
Computer Introduction	500	135	Person	67,500
Keyboard Skills	500	135	Person	67,500
Barcode Support System	1,500	135	Person	202,500
Other costs:				
Lost time: for assistance	500	260	Man day	130,000
Lost time: for doctor	2,500	280	Man day	700,000
Lost sales through disruption	200,000	1	Unit	200,000
Lost sales through inefficiency during first months: estimate:	100,000	1	Unit	100,000
Total cost				**1,855,000**

Table B - 2 Cost of Technology (RFID)

Cost (RFID):	**Cost Per one unit**	**Unit**		**Total cost (Baht)**
New RFID equipment:				
Reader/ Writer	105,000	3	Unit	315,000
RFID Antenna	35,000	35	Unit	1,225,000
RFID Chip	70	2,500	Unit	175,000
Software	49,000	1	Unit	49,000
Training costs:				
Computer Introduction	500	135	Person	67,500
Keyboard Skills	500	135	Person	67,500
Barcode Support System	1,500	135	Person	202,500
Other costs:				
Lost time: for assistance	500	260	Man day	130,000
Lost time: for doctor	2,500	280	Man day	700,000
Lost sales through disruption	200,000	1	Unit	200,000
Lost sales through inefficiency during first months: estimate:	100,000	1	Unit	100,000
Total cost				**3,231,500**

Table B - 3 Benefit from application of new technology

Benefits:	**Cost Per one unit**	**Unit**		**Total cost (Baht)**
Decrease number of staff in work flow	12,000	5	Person	720,000
Gain more space	1,000	50	Square meter	600,000
Eliminate all paper work and stationary cost	15,000	1	Set	180,000
Improved customer service and retention: estimate:	50,000	1	Unit	600,000
Improved accuracy of patient information: estimate:	20,250	1	Unit	243,000
More potential to manage patient profile: estimate:	50,000	1	Unit	600,000
Total Benefit				**2,943,000**

APPENDIX C: TECHNICAL AND DEFINITION TERMS

Table C - 1 Technical Term and Definition of terms

Technical Term	Definition
Barcode	Machine-readable representation of information (usually dark ink on a light background to create high and low reflectance
RFID	Radio Frequency identification Technology is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders.
AHP	Analytical Hierarchy Process is a structured technique for dealing with complex decisions. Based on mathematics and human psychology
IT	Information Technology
OPD	OutPatient Department
BCH	Bangkok Christian Hospital
VH	Vipavadhi Hospital
BH	Bumrungrad Hospital
SUM	Summary
Pairwise Comparison	Any process of comparing entities in pairs to judge which of each pair is preferred, or has a greater amount of some quantitative property.
Rating	A number, letter, or other mark that refers to the ability of something
Voting	A formalized choice on matters of administration
Performance Sensitivity	A predictive model subsequently melds system and application data in order to project a time-to-solution for each application and system pair.
Dynamic Sensitivity	The minimum leak rate which a leak detector is capable of sensing.
NFC	Near Field Contact is a new, short-range wireless connectivity technology that evolved from a combination of existing contactless identification
DEA	Data Environment Analysis is multidisciplinary approaches to environmental problem-solving. Acquisition and processing of environmental information focusing on atmospheric change and water resources. Analysis and interpretation of real- time and historical environmental data.