International Journal of Industrial Engineering & Production Research

September 2013, Volume 24, Number 3
pp. 151-167

http://IJIEPR.iust.ac.ir/

ISSN: 2008-4889

Multi-Criteria Risk-Benefit Analysis of Healthcare Management

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KEYWORDS

RFID Technology,
RFID-based system selection,
Healthcare applications,
Hierarchical fuzzy TOPSIS

ABSTRACT

The hierarchical TOPSIS model used in this article is able to grasp the ambiguity exists in the utilized information and the fuzziness appears in the human judgments and preferences. The use of the hierarchical fuzzy TOPSIS methodology offers a number of benefits: (1) being a systematic model and straight forward one for working on; and (2) capable of capturing human's appraisal of ambiguity when management would like to deal with complex multiple objective situations. The hierarchical fuzzy TOPSIS is in some way superior to the other Fuzzy multi criterion decision making techniques, such as fuzzy analytic hierarchy process (FAHP) and classical fuzzy TOPSIS methods. This is because while in the hierarchical structure no pair-wise comparisons among criteria, sub-criteria, and alternatives are necessary to be made, it is already being taken into consideration by the model. The objectives of this paper are two folds: (1) utilizing hierarchical fuzzy technique for order preference by similarity to ideal solution (TOPSIS) approach to evaluate the most suitable RFID-based systems decision, and (2) to highlight key risks and benefits of radio frequency identification technology in healthcare industry. Due to the fact that a better management of health care system is related to the full understanding of the technologies implemented and the system under consideration, sufficient background on the radio frequency identification technology is provided and the RFID systems most likely management would face with and select one are provided for decisions to be made on them.

1. Introduction

Many business enterprises and the health industry are applying the advantages of Radio Frequency Identification (RFID) to experimental projects to improve operational efficiency and to gain a competitive advantage (Bilge and Ozkarahan, 2004). The advantage of RFID tags is that they use a memory storage device to store a certain amount of data such as the product identification number, price, cost, manufacture date, location, and the inventory on hand. Due to this fact that this information can quickly be read by a wireless scanner, so RFID can process large volumes of multiple data sets at the same time and improve the efficiency of operations by using identification tags (Chao, et al., 2007).

Food and drug industries have enormous potential for utilizing radio frequency identification technology. This is largely because each chip is unique to the specific box of medication or food it is attached to. Therefore, tracking where each product is located

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Paper first received June, 09, 2011, and in accepted form July, 07, 2012.

becomes relatively simple. When a chip is attached to a box and manufacturer recalls a batch of products, then the RFID tags for the containers affected can be flagged electronically.

Eventually, food and/or drug retailers will not be able to sell recalled products because cash register and store's computer system will not allow it. Once this technology is coupled with the power of the Internet and there is a real-time product recalls, where retailers' own inventory control systems, tied into RFID databases, alert the store manager to pull specific type of drug off the shelves while leaving the rest (Kumar and Budin, 2006).

The introduction of RFID technologies has brought much debate and speculation about its potential impacts. This research shows that investments in RFID infrastructure will yield significant economic benefits for manufacturers and consumers alike. A study conducted by the University of Texas at Austin and sponsored by NXP shows the financial impacts of RFID in the US healthcare and retail stores. The key finding of this study can be summarized as listed below [30]:

- Companies in the retail and healthcare sectors have experienced, to date, a 900 percent rate of return (ROI) on their RFID investments
- Current adoption levels of RFID at the pallet and item levels in retail currently derive $12.05 billion in benefits from existing RFID applications
- Retail consumers see a $2.63 billion annual cost savings benefit
- Total benefits accruing to healthcare industry manufacturers, distributors, and hospitals is equal to $45.9 billion
- Improved patient care from RFID deployment is valued at $30.72 billion
- Benefits to the healthcare consumer, through enhanced patient care, is estimated at $165.12 billion.

In May 2002 Massachusetts General Hospital installed its first trial of the iRIS RFID system, which was developed by Mobile Aspects. The purpose iRIS was to manage inventory and access to medical supplies and surgical parts throughout the hospital. By the end of 2002, Massachusetts General Hospital had installed six iRIS units in its operating rooms. According to the RFID Journal, with the assistance of iRIS over $500,000 worth of equipment and supplies were tracked.

Additionally, iRIS has been integrated into the hospital's scheduling and billing system. As a result of the success of iRIS at the Massachusetts General Hospital, similar systems have been installed at the hospital of the University of Pennsylvania, the University of Pittsburgh Medical Center and the Carolinas Medical Center (Crayton, 2004).

In April 2004 Washington Hospital Center in Washington D.C. began a trial use of RFID tags focusing on RFID usage in hallways and in emergency rooms.

Washington Hospital is using active UWB or ultra-wide band tags, developed by Parco Wireless, to track medical devices in the hospital. Washington Hospital Center has the staff and patients wear credit card sized RFID tags to obtain and maintain patient and healthcare provider information (Crayton, 2004).

The potential benefits to RFID technology in the food industry are enormous.

Because each chip is unique to the specific box it is in, tracking the whereabouts of products becomes much simpler. If a manufacturer recalls a batch of products, the RFID tags for the containers affected can be flagged electronically.

Eventually, grocery retailers will not be able to sell recalled products because the register will not allow it (Hall et al., 2004). Looking further into the future we can see other sort of RFID capability as such as: homes—equipped with "smart appliances"—will also be linked to the network. Refrigerators will inform homeowners that the milk is expired; the microwave will alert the consumer that the product about to be warmed was recalled 6 hours earlier by the manufacturer. Even the pantry, if equipped, could print a grocery list based on current inventory (Hall et al., 2004).

RFID has been identified as one of the ten greatest contributory technologies of the 21st century. This technology has found a rapidly growing market, with the global sales expected to top $7 billion by year 2008 (Chao et al, 2007).

Companies lined up to use RFID and employing experts to improve the efficiency of their operations in order to gain competitive advantages over time. Manufacturers can use RFID solutions to reduce operating costs through decreasing the labor costs, claims and returns. This will help them to increase the operating income.

An RFID system is comprised of tags, a reader that can read data from the tag, antenna and the hardware and software. The main purpose for setting up an RFID system is to collect desirable data from a moving object or a fixed one. Although, there is piling news against the security of this technology and the privacy problem recent expert reports indicate that, during the past year, about one billion RFID tags are produced and implemented all around the world (Hall et al., 2004).

The rate of adoption of this technology by the pharmaceutical industry has been slower than expected by both component manufacturers and processing companies. This may be due to a number of reasons including: costs, IT complexity, component performance, read accuracy and installation performance (Adams, 2007). The selection of an RFID-based system is a multi-criteria decision making problem.

This is because of the availability of many qualitative criteria that should be considered in the decision making process. Since the judgments from decision makers are usually vague and linguistic rather than crisp, the judgments from experts should be expressed by using fuzzy sets which has explicitly handled vague and imprecise data (Kahraman et al., 2007). A hierarchical fuzzy TOPSIS is a new methodology, introduced by Kahraman et al. (2007) that takes the hierarchies in multi-criteria and/or multi-attribute problems into consideration. The classical fuzzy TOPSIS methods (Chen and Hwang, 1992) do not take hierarchy into the account. However, the developed hierarchical fuzzy TOPSIS method has the ability of considering the hierarchy among attributes and alternatives, and provides greater superiority to classical fuzzy TOPSIS methods (Kahraman et al., 2007). Using the concepts of fuzzy sets theory and linguistic values, author presents a systematic decision process based upon the TOPSIS method under fuzzy environment.

This author employs the hierarchical fuzzy TOPSIS approach for evaluating the RFID-based systems and then determines the most appropriate system among them. It is obvious enough that understanding the risks and benefits of RFID decisions can help managers in making decisions on which criteria should be considered in the decision process and how a decision model should be structured by using hierarchical fuzzy TOPSIS.

This work extends the application of fuzzy TOPSIS into the area of radio frequency identification (RFID) taking risk-benefits of that into consideration. The practicality of the proposed model is demonstrated using a case study. The rest of this paper is structured as follows: Section 2 introduces some RFID-enabled healthcare systems appeared in the literature recently. MCDM is the topic of section 3.

The topic of selection criteria for evaluation of RFID is given in section 4. The topic of RFID risks in healthcare is discussed in section 5 while RFID benefit is the topic of section 6. Fuzzy TOPSSIS method is discussed in section 7. The hierarchical fuzzy TOPSSIS is discussed in section 8. A case study on RFID is discussed in section 9. Author's conclusion is given in section 10.

2. RFID-Enabled Healthcare Systems

This section is devoted to the review of RFID-based healthcare management systems helping us to understand the role of RFID in healthcare management better and deeper. The cases to be used as our source of information are:

1. The healthcare supply chain (Kumar et al., 2008)
2. Emergency room management (Chen et al., 2008)
3. El Camino Hospital in Mountain View (Crayton, 2004)
4. Public views of mobile medical devices and services (Katz and Rice, 2008)
5. Children hospital (Crayton, 2004)
6. The social and organizational factors (Fisher, and Monahan, 2008)
7. Monitoring Alzheimer patients (Corchado et al., 2007)
8. Psychiatric Patient Localization (Huang, C-L, et al., 2008)

Table 1 lists the name of eight cases used in this study along with extra information helping to understand each case study individually and hence all together.

3. MCDM

A Multi Attribute Decision Making (MADM) model deals with the problem of choosing an option from a set of alternatives which are characterized in terms of their attributes.

It is a qualitative approach due to the existence of criteria subjectivity. The aim of the MADM is to obtain the optimum alternative that has the highest degree of satisfaction for all of the relevant attributes (Hwang and Yoon, 1981).

Modeling real world problems with crisp values under many conditions is inadequate because human judgment and preference are often ambiguous and cannot be estimated with exact numerical values (Chen, 2000; Chen, Lin, and Huang, 2006; Kuo, Tzeng and Huang, 2007).

There are ways to rank competitive alternatives but ranking competing alternatives in terms of their overall performance with respect to some criterions in fuzzy environment is made possible by the use of fuzzy TOPSIS methodology.

Bellman and Zadeh (1970) have introduced the concept of Fuzzy multi-criteria decision making (FMCDM) considering fuzzy constraints, fuzzy objectives and fuzzy decision.

The decision matrix employed in multi criterion decision making (MCDM) methods has four main parts that are comprised of: (1) alternatives; (2) attributes; (3) weight or relative importance of each attribute; and (4) scores of alternatives with respect to the attributes.

TOPSIS treats a multi attribute decision making problem with m alternatives as a geometric system with m points in the n-dimensional space (Kahraman et al., 2007) and it was developed by Hwang and Yoon (1981). The foundation of TOPSIS is grounded on the logic of defining the positive ideal solution and the negative ideal solution points. Positive ideal solution is the solution point that maximizes the benefit criteria and minimizes the cost criteria; whereas the negative ideal solution point maximizes the cost criteria and minimizes the benefit criteria.

Tab. 1. Identification of case type, uses of RFID, goals, applications, and the outcomes

Case	Case Type	RFID-based systemM	Goal	Outcomes	Practical Outcome
1	Healthcare supply chain (Kumar et al. 2008)	Yes	What is the most efficient and cost effective portions of the healthcare supply chain in which radio frequency identification devices (RFID) can be implemented	Costs can be drastically reduced and justified with the proper collaboration within the supply chain. Improving relationships, sharing the high capital costs, and democratically choosing technological standards will improve the likelihood of end users saving money and receiving better service.	Procurement, in-house and delivery productivity as a results of cost-effective improvement
2	Emergency room (Chen et al., 2008)	Yes	Examining key factors that contribute to the intention to continue using RFID to reduce healthcare costs, medical errors, and pressures of governmental mandates.	This study shows that emergency care givers who have a high perception of the usefulness room in front-end interoperability and of performance expectancy affirm a positive confirmation experience with the use of RFID technology. The relationship between perceived usefulness of back-end interoperability and confirmation experience is not significant.	The result of this study helps hospital management to build commitment to the RFID system and help equipment vendors to build loyalty to the technology. The growth of RFID adoption seems to have slowed in the hospital environment. Many have attributed the slower growth to a culture of technology resistance, expensive system costs, and disparate standards.
3	El Camino Hospital in Mountain View (Crayton, 2006)	Yes	Employing RFID to uniformly track medications, which are scanned and bar coded at the point of care.	As a result of establishing the system, the hospital claims to have one of the lowest error rates in the nation. Since establishing the system it has increased its rate of clinical interventions-the number of times a pharmacist has the opportunity to intervene in the drug-ordering process to prevent errors-by 250%, growing from 400 interventions per quarter to 1,200.	Reducing number of error by 25 %. Growing number of interventions from 400 to 1200 per quarter of year. Requiring large investment to add the RFID-based system to the hospital's management system. Reducing medication errors by 55%.
4	Healthcare (Katz and Rice, 2008)	Yes	What is the preliminary interest in cell phone and RFID-based healthcare services? Although many had believed that the attachment of RFID technology would be viewed by broad sectors of the public as undesirable or unacceptable it was found that	Public opposition to RFID technology does not appear to be widespread The survey revealed high levels of interest in emergency intervention services, but much less so in health information and monitoring services. Placement of RFID-based medical informatics devices on the arm by tape vs. as part of one's mobile phone does not seem to affect acceptability judgments except in a small percentage of the sample.	Evidence suggests that attachment of RFID devices to the body is not viewed as objectionable by much of the public.
5	Hospital and Social Dimensions (Fisher, and Monahan, 2008)	Yes	What are the social and organizational factors that contribute to the success or failure of RFID systems in hospitals?	RFID systems introduce a key ethical concern regarding privacy because of the surveillance potential of the technology. The extent to which surveillance becomes a reality is dependent upon the policies and practices developed in each hospital setting.	Hospitals implementing RFID systems tend to experience two types of constraint: (1) the mal-adaptation of the technological system to the hospital setting and (2) the organizational challenges for hospitals to utilize the system.
6	Children hospital) In Nashville, Tennessee	Yes	The RFID system is employed for real-time tracking and location identification of moveable and fixed assets, and detection, identification and tracking of assets as they are utilized throughout the hospital.	The pilot program was able to show that RFID systems can prevent the loss of equipment	An RFID-based system would be in place at both Children's Hospital and Vanderbilt University Hospital by the end of this year.
7	Alzheimer patients (Corchado, et al., 2007).	Yes	monitoring Alzheimer patients' health care in execution time in geriatric residences	The AGALZ system is designed to plan the nurses' working time dynamically, to maintain the standard working reports about the nurses' activities, and to guarantee that the patients assigned to the nurses are given the right care. The agent operates in wireless devices and is integrated with complementary agents into a multi-agent system capable of interacting with the environment.	Making the monitoring of Alzheimer patients' a possibility.
8	Psychiatric Patient Localization (Huang, C-L, et al., 2008))	Yes	Collaboration between Field Generators, Readers and Tags generates the required functions in using radio frequency identification (RFID) for psychiatric patient localization.	Due to the fact that certain phenomena can degrade the reliability of signal transmission and may decrease the feasibility of the localization system, a GCMD scheduling model is utilized for scheduling Field Generator transmissions in an RFID-based psychiatric patient localization system, thereby reducing interference caused by Field Generators located near one another.	Efficient localization of patients.

The optimal alternative is the one, which is closest to the positive ideal solution point and farthest to the negative ideal solution point. The ranking of alternatives in TOPSIS is based on ‘the relative similarity to the ideal solution point’, which avoids from the situation of having same similarity to both ideal and negative ideal solutions points (Hwang and Yoon, 1981).

Chen and Hwang (1992) and Negi et al. (1989), fuzzy numbers were applied to establish a prototype fuzzy TOPSIS. Many authors such as Chen (2000); Chen et al. (2006); Chen & Hwang (1992); Chen & Tzeng, (2004); Jahanshahloo et al. (2006); Liang (1999); Wang and Elhag (2006); Wang and Lee (2007); Wang, Luo, and Hua (2007); Yeh, Deng, and Chang (2000); and Yeh and Deng (2004) have contributed new materials on the development, extensions and applications of TOPSIS since its early development in 1981.

Its general extension for group decision making problems under fuzzy environment was published by Chen (2000). In 2007, Kahraman and his research team proposed a hierarchical fuzzy TOPSIS method that has ability to consider the hierarchy among the attributes and alternatives. This method provides greater superiority to classical fuzzy TOPSIS methods (Kahraman, et al. 2007).

Other researchers have employed TOPSIS and applied that to areas as such as company financial ratios comparison (Deng et al.2000), facility location selection (Chen and Tzeng, 2004), assessment of service quality in airline industry (Tsaur et al., 2002), materials selection (Jee and Kang, 2000), manufacturing plant location analysis (Yoon and Hwang, 1985), multiple resource selection (Yang and Chou, 2005), Robot selection (Parkan and Wu 1999), and water management (Srdjevic et al. 2004) to mention some. Chu and Lin (2003) have proposed a fuzzy TOPSIS approach for robot selection where the ratings of various alternatives under different subjective attributes and the importance weights of all attributes are assessed in linguistic terms represented by fuzzy numbers. They have presented an integrated fuzzy group decision-making method in order to deal with the fuzziness of preferences of the decision-makers.

Abo-Sinna (2005) extended TOPSIS approach to solve multi-objective dynamics programming (MODP) problems. He has showed that using the fuzzy max–min operator with nonlinear membership functions, the obtained solutions are always non-dominated solutions of the original MODP problems. Deng et al. (2000) formulate the inter-company comparison process as a multi criteria analysis model, and presented an effective approach by modifying TOPSIS for solving such problem. Chen (2000) extended the concept of TOPSIS to develop a methodology for solving multi-person multi-criteria decision-making problems in fuzzy environment.

4. Selection Criteria for Evaluation of RFID

Evaluating radio frequency identification decisions is not a well defined or structured problem in literature specially that RFID is a new technology and at the edge of its development and the glory to come. To the best of this author's knowledge and the evidence from the literature no such work has been done prior to this work in relation to this new technology so this research make a well contribution to the literature. To study this problem both positive (benefits) and negative (risks) aspects of RFID-based systems must be carefully considered in the decision process. Since benefits and risks of RFID decisions are intangible in nature different decision makers may assign the benefits and risks of RFID decisions and their importance differently.

Research to identify the list of key benefits and risks on RFID in the RFID-based systems (as such as SCM systems coupled with RFID) and other industrial areas is scarce. This is a step towards identifying such benefits and risks.

To find out what these benefits are, published articles on the RFID topics as well as the success factors of related technology are studies and then a list of appropriate benefits and risks of that in different forms, are determined. Yin (1994) pointed that a case study is an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially where the boundaries between the phenomenon and context are not clearly evidenced". Case studies are a valuable tool for examining a contemporary phenomenon, especially one that is not clearly understood, asking how and why questions, and capturing the context (Tzeng, et al., 2007). With this note in mind, this author considers using the case based approach as an appropriate tool for the analysis of the situation.

The hierarchical fuzzy TOPSIS methodology proposed by Kahraman (2007) is used to identify decision criteria for RFID evaluation problem. For this purpose, eight cases from the healthcare literature reporting the uses of RFID technology in their organizations are reviewed while two key aspects of risks and benefits being taken into consideration. In addition to those cases, related websites, scientific reported cases, and articles mainly related to RFID fields of agriculture and food industry (Wang, et al. 2006), health care supply chain management (Kumar et al, 2007), managing restaurant (Ngai, 2007), supply chain systems with mobile monitoring capability (Ngai, 2007, Wamba, 2007, Wamba, 2006), grocery stores (Kourouthanassis, 2003), monitoring patients with diet problem (Hall, 2004), pharmacy industry (Adams, 2007, Anonymous, 2005), hospital social impacts assessment (Fisher et al. 2008), pharmaceutical industry, and monitoring and tracking life animals (Wismans, 1999) are used and then six elements of risks and six elements of benefits of RFID are identified. These topics are discussed briefly below.

5. RFID Risks in Healthcare

To implement RFID, gaining management commitment is a big challenge. Here, management looks into the Return on Investment (ROI) to assess RFID investment before commits to its implementation. A challenge that companies face with is the high cost of implementation. To justify the adoption of RFID technology into business, cost-benefit analysis is a must. The key risks factors relate to the healthcare system are discussed below.

5.1. Overall Cost (OC)

The cost is one of the major factors influencing acceptance of RFID, although the production costs of RFID have reduced and Alien Technology has cut the tag price to less than $US0.20 (Collins, 2003, 2006). At present, the costs of RFID adoption comprise the major investment in hardware, application software, middleware, and tags, and the cost of integrating the RFID-based system with the legacy systems, of consultancy fees, and of employee training. Therefore, the cost of RFID tags may continue to present a major hurdle for RFID deployment.

Another cost of RFID adoption for many companies is the major investment in large scale IT infrastructure. Other costs for RFID adoption may be significant, including the purchase of initial hardware/software, integrating RF-enabled technology into distribution and warehousing activities and existing management systems, and additional maintenance costs for application upgrades, readers and software, and employee training (Smith, 2005).

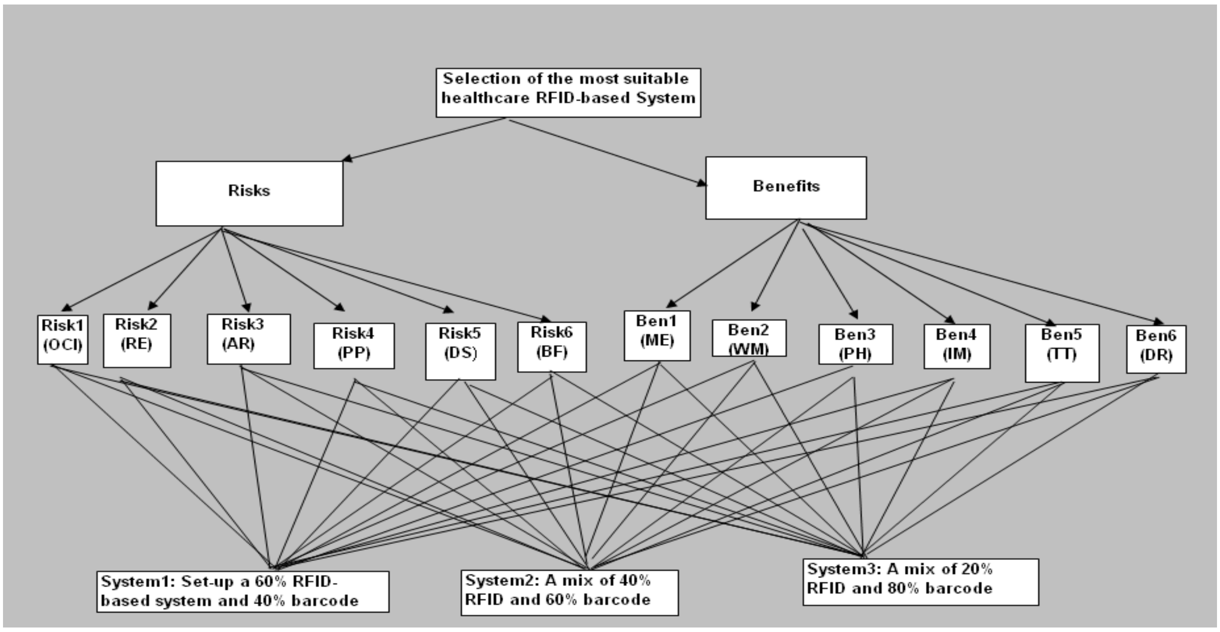

Fig. 1. The hierarchy for the selection of the most suitable healthcare management decision

5.2. RFID Expert (RE)

In a survey conducted by the Computing Technology Industry Association revealed that 80 percent of the responding companies said that there are not sufficient numbers of skilled RFID workers. About two-third of respondents pointed that training their employees to become proficient in RFID is the biggest challenges they faced in order to succeed in the RFID market (Morrison, 2005).

Hence, gaining management commitment in implementing RFID will be a big challenge considering this big hurdle. Unreliable performance has been an ongoing issue for RFID.

The proportion of defective tags and false reads, which in some pilot projects has been as high as 20–50%, is still not acceptable (Cooke, 2005; Proctor, 2005; Sullivan and Dunn, 2004; Wyld, 2006). As more tags and readers come into use, issues such as reader collision (the collision of signals from multiple readers), tag collision (the possibility of multiple tags confusing a reader), and interference from other wireless devices (e.g., cell phones) will likely need to be addressed (Twist, 2005). System issues, such as the complexity of system integration with existing applications and the vulnerability of RFID to computer viruses, also need to be addressed (Li and Visich, 2006).

5.3. The Access Rate (AR)

There are many factors that can influence the read/write efficiency of RFID. Some of those are: metal, mist, distance, and incorrect positioning of antennas. A point well deserved to be made is that when the distances among the tags are very close interference between them may be made or erroneous access may occurred.

5.4. The Patient Privacy (PP)

A big concern is the invasion of privacy due to the use of RFID that has been a major issue fueling the opposition from consumer protection organizations (Jones et al., 2004a). Privacy advocates are concerned about tracking customers (Ferguson, 2006; Boulard, 2005). There may be some patients that refuse to accept the new RFID-based system at first. Some patients might be unfamiliar or unwilling to use any new technology for not putting their own or family security and privacy at risk. Therefore it may become necessary to have someone at the health canter/hospital to have free lectures for them or give away brochures on the topic to clients discussing the issues.

5.5. Data Security (DS)

The biggest issue that must be taken into consideration when a new technology is addressed and employed is the level of the security that it may provide or needs in order to keep organizational data at the safe level. Hence, organization data security policies must be examined to ensure that security of customer data is not compromised at any price. Some of the available techniques that help to reach that are: data can be encrypted; password protected, or includes a "kill" feature to remove data permanently, so information stored is much more secure (Jones et al., 2004; and Boulard, 2005).

5.6. Barcode Factor (BF)

Bar codes are inexpensive, standardized, and, in some cases, are already achieving a satisfactory performance level (Twist, 2005). Although the popularity of bar codes is not believed to be a deterrent per se, their popularity has not helped spread larger-scale RFID deployment (Smith, 2005). Taking these key issues into consideration we will notice barcode factor is a big player in the spread of the RFID.

6. RFID Benefits in Healthcare

RFID-based systems include many benefits that surpass its disbenefits and risks. In the following sections some of these benefits are briefly discussed.

6.1. Medical Errors Prevention (ME)

Each hospital has an existing Hospital Information System (HIS) that stores information in a database containing patient, staff, and equipment information, etc. By incorporating RFID technology into a hospital managerial system error reduction can be achieved in the following areas: medication administration, medical diagnosis, and misplaced medical devices. The RFID applications for pharmacies include tracking counterfeit medicines, storing prescription information that is tagged with the Electronic Product Code (EPC), and automating medicine distribution.

6.2. Tracking Medical Waste and Medical Devices (WM)

Kureha Environmental Engineering Co. Ltd., a leading waste management company, will begin testing RFID tags to ensure that medical waste reaches its proper disposal point using medical tracking devices. A few of these device-tracking tools are DataLabel RFID tags, by Innovision Research & Technology, and Radianse ID tags (Radianse IPS).

6.3 Patient and Healthcare Provider Information (PH)

A priority for hospitals is to provide the most accurate Positive Patient Identification (PPI). RFID systems improve PPI by helping to ensure Patient Identification (PPI). RFID systems ensure PPI by helping to properly identify patients, which helps to reduce medical errors and saves hospitals money. A product that helps to ensure PPI is eShepard by Exavera, which uses patient and healthcare provider tracking using PDAs and Wi-Fi devices. There is also a RFID Wristband that obtains hospital admission information, retains patient information, and can track hospital staff or a patient’s whereabouts while on the hospital premises (Anonymous, 2005).

6.4. Information Management (IM)

Barcodes and magnetic strips can all be integrated into one RFID tag. With a suitable RFID tag that has memory for recording information and then supplying to the system, medications information, patients' info and experts' opinions can be stored on that. This system is capable of locating the location of medication, and patient in the hospital when it is necessary to be located. With the use of RFID-based system efficient operation of hospital, emergency room, patient centers, surgical and operations rooms begin. It brings the opportunity of not scanning barcodes one by one at all.

6.5. Traceability and Tracking Information (TT)

RFID automates the validation of sequence and components and speeds build times. If an issue is found, accurate tracking can help to reduce quality issues and errors. When RFID is integrated into the hospital information system, a patient can be tracked from the time they enter the hospital to the time they leave. This process starts when a patient is admitted and issued an RFID wristband. Once tagged, the patient can be monitored as they enter and exit different areas (Crayton, 2004). As care is provided to the patient, handheld readers and terminals with wireless capabilities may be used to input information about procedures performed. For example, during examination ER staff scans the patient wristband and all materials used in the care of the patient. This way, medicines and consumables would be associated with a patient and recorded automatically.

6.6. Data Accuracy and Reliability (DR)
The effective deployment of RFID has a potential to quickly provide accurate and reliable data that exceeds the bar coding or manual capabilities available today. This can have major impacts particularly in busy hospitals, emergency rooms, pharmacies, and care taking centers in university health care systems and public clinics in populated areas.

7. Fuzzy TOPSIS Algorithm

The following section is devoted to the steps of fuzzy TOPSIS developed by Chen and Hwang (1992). This algorithm is comprised of seven steps as are discussed below:

Step 1.
The very first step of TOPSIS algorithm is the determination of the decision matrix. This matrix has m rows and n columns, where m represents the number of alternatives to be ranked, Ai, (i=1,...,m), and n represents the number of criterions, based on that the ranking will be stated, C_j (j=1,…,n). In the model, it is assumed that there are K decision makers that subjectively assess the weighting vector of $W=(w_1,...,w_n)$ and the decision matrix X={ x_{ij} ,i =1,2,…,m; and j=1,2,…,n}.
While crisp data are inadequate for modeling the real life situations in MCDM, we apply linguistic variables to specifically describe the degrees of a criterion. A linguistic variable is a variable which apply words or sentences in a natural or artificial language to describe its degree of value, and we use this kind of expression to compare each criteria by linguistic variables in a fuzzy environment as ‘‘Very low”, ‘‘Low”, ‘‘Medium”, ‘‘High”, and ‘‘Very high” with respect to a fuzzy five level scale. We will use linguistic terms as described in table 2.

$$\mathbf{D} = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & \dots & X_j & \dots & X_n \end{array} \\ \begin{bmatrix} x_{11} & \dots & x_{1j} & \dots & x_{1n} \\ \vdots & & \vdots & & \vdots \\ x_{i1} & \dots & x_{ij} & \dots & x_{in} \\ \vdots & & \vdots & & \vdots \\ x_{m1} & \dots & x_{mj} & \dots & x_{mn} \end{bmatrix} \end{array}$$

The x_{ij} may have crisp values or fuzzy values. If x_{ij} and its corresponding weight w_j are fuzzy then we present them by a trapezoidal fuzzy number that can be represented as:

$$x_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij}) \quad (1)$$

and

$$w_{ij} = (r_{ij}, s_{ij}, t_{ij}, u_{ij}); \forall i = 1,..., m, \forall j = 1,..., n. \quad (2)$$

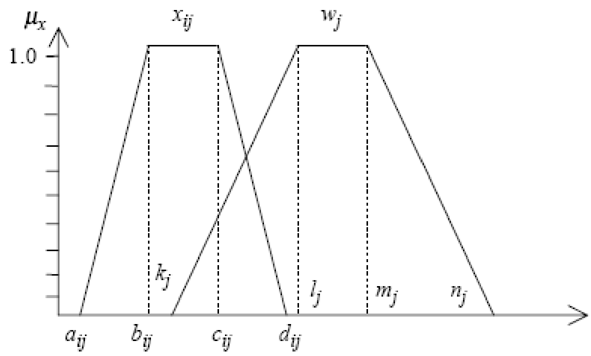

Fig. 2. Trapezoidal fuzzy numbers

Step 2. (Normalization of decision matrix)
Before we can make any use of data provided in step 1 we need to develop a normalized decision matrix. Doing so, we convert all incommensurable criterions into unique and common sense numbers. The decision matrix must first be normalized so that the elements will be unit-free. The structure of the normalized matrix for the k-th decision maker can be expressed as follows:

$$R^k = [r_{ij}^k]_{mxn} \quad k=1,2,...,K;\ i=1,2,...,m;\ j=1,...,n \quad (3)$$

Where r_{ij}^k is the normalized value of $f_{ij}^k = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$ which is calculated by the following formula:

$$r_{ij} = \left(\frac{x_{ij}}{x_j^*} \right) \quad (4)$$

Provided that $x_j^* = \max_i \{x_{ij}\}$ and j belong to the benefit criterions. On the other hand when j belong to the cost criterion the normalized value is calculated according to following formula:

$$r_{ij} = \left(\frac{x_j^-}{x_{ij}} \right) \quad (5)$$

And $x_j^- = \min_i \{x_{ij}\}$. After calculating r_{ij} using appropriate formulas we can rewrite the normalization fuzzy decision matrix as follow:

$$\mathbf{D}' = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & \dots & X_j & \dots & X_n \end{array} \\ \begin{bmatrix} r_{11} & \dots & r_{1j} & \dots & r_{1n} \\ \vdots & & \vdots & & \vdots \\ r_{i1} & \dots & r_{ij} & \dots & r_{in} \\ \vdots & & \vdots & & \vdots \\ r_{m1} & \dots & r_{mj} & \dots & r_{mn} \end{bmatrix} \end{array}$$

By taking values of $x_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij})$, $x^*_{ij} = (a^*_{ij}, b^*_{ij}, c^*_{ij}, d^*_{ij})$ and $x^-_{ij} = (a^-_{ij}, b^-_{ij}, c^-_{ij}, d^-_{ij})$ into consideration we can write following formula for the r_{ij}:

$$r_{ij} = \begin{cases} x_{ij}(\div)x_j^* = (\frac{a_{ij}}{d_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{b_j^*}, \frac{d_{ij}}{a_j^*}), \forall j \in B \\ x_j^-(\div)x_{ij} = (\frac{a_j^-}{d_{ij}}, \frac{b_j^-}{c_{ij}}, \frac{c_j^-}{b_{ij}}, \frac{d_j^-}{a_{ij}}), \forall j \in C \end{cases} \quad (6)$$

Step 3. (Weighted normalized decision matrix)
In this step, the weighted normalized decision matrix for the kth decision maker need to be constructed. Using the formula given below:

$$v_{ij} = r_{ij}(.)w_j \quad \forall \text{ i=1,2,…,m and } \forall \text{ j=1,2,…,n} \quad (7)$$

One thing that needs to be keep in mind is that when r_{ij} and w_{ij} are both crisp then v_{ij} is also crisp. On the other hand, when one or both of them are fuzzy then v_{ij} is also fuzzy. Now, we can write the above equation as follows:

$$v_{ij} = r_{ij}(.)w_j = (\frac{a_{ij}}{d_j^*}k_j, \frac{b_{ij}}{c_j^*}l_j, \frac{c_{ij}}{b_j^*}m_j, \frac{d_{ij}}{a_j^*}n_j), \forall j \in B \quad (8)$$

$$v_{ij} = r_{ij}(.)w_j = (\frac{a_j^-}{d_{ij}}k_j, \frac{b_j^-}{c_{ij}}l_j, \frac{c_j^-}{b_{ij}}m_j, \frac{d_j^-}{a_{ij}}n_j), \forall j \in C \quad (9)$$

The result is what is shown in below:

$$\mathbf{V} = \begin{array}{c} \\ A_1 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & \dots & X_2 & \dots & X_n \end{array} \\ \begin{bmatrix} v_{11} & \dots & v_{1j} & \dots & v_{1n} \\ \vdots & & \vdots & & \vdots \\ v_{i1} & \dots & v_{ij} & \dots & v_{in} \\ \vdots & & \vdots & & \vdots \\ v_{m1} & \dots & v_{mj} & \dots & v_{mn} \end{bmatrix} \end{array},$$

Step 4. (Distances from positive ideal and negative ideal points)
Two ideal solutions points known as positive ideal and negative ideal solution points are of highly concerned in the decision making process. The decision maker feels to stay away as far as possible from the negative ideal solution point and as close as possible to the positive ideal point. Although, these solution points are unreachable in reality they are of very concern and important to the decision maker. Therefore, the positive ideal solution shown by A* and negative ideal point shown by A^- is determined as follows:

$$A^* = (v_1^*, v_2^*, ..., v_n^*) \qquad A^- = (v_1^-, v_2^-, ..., v_n^-) \quad (10)$$

Where

$$v_j^* = \max_i\{v_{ij3}\} \qquad v_j^- = \min_i\{v_{ij1}\} \quad (11)$$

When data are crisp then calculation of v_j^* and v_j^- are simple and requires no extra work to do. But, when data is fuzzy the extra work is demanded. Chen and Hwang (1992) have employed the ranking method proposed by Lee and Li (1988) for comparison of fuzzy numbers. In this proposed ranking method v_j^* and v_j^- are the fuzzy numbers with the largest and smallest generalized mean, respectively. This generalized mean for fuzzy number v_{ij}, for all i and j, is computed as follows:

$$M(v_{ij}) = \frac{-a_{ij}^2 - b_{ij}^2 - c_{ij}^2 + d_{ij}^2 - a_{ij}b_{ij} + c_{ij}d_{ij}}{3(-a_{ij} - b_{ij} + c_{ij} + d_{ij})} \quad (12)$$

For each column j, we find v_{ij} whose greatest mean is v_j^* and lowest mean is v_j^-.

Step 5.
Now, determine the separation measures of S_i^* and S_i^- to be used for calculating the closeness coefficient of C_i later.

$$S_i^* = \sum_{j=1}^n D_{ij}^* \quad \text{i=1,2,…,m} \quad (13)$$

$$S_i^- = \sum_{j=1}^n D_{ij}^- \quad \text{i=1,2,…,m} \quad (14)$$

In the above formula, S_i^* is the separation of alternative i from the positive ideal solution and S_i^- is the separation of alternative i from the negative ideal solution. In calculating D_{ij}^{*} and D_{ij}^{-} two cases should be taken into consideration: (1) Crisp data and fuzzy data. When data is crisp the difference measures D_{ij}^{*} and D_{ij}^{-} are determined in according to following formula:

$$D_{ij}^{*} = \left| v_{ij} - v_{j}^{*} \right| \tag{15}$$

$$D_{ij}^{-} = \left| v_{ij} - v_{j}^{-} \right| \tag{16}$$

For fuzzy data, the differences between two fuzzy numbers $\mu_{v_{ij}}(x)$ and $\mu_{v_j^*}(x)$ based upon the Zadeh, 1965 work as was used by Chen and Hwang (1992) is

$$D_{ij}^{*} = 1 - \left\{ \sup_{x} \left[\mu_{v_{ij}}(x) \wedge \mu_{v_j^*}(x) \right] \right\} = 1 - L_{ij}, \quad \forall i, j, \tag{17}$$

Where L_{ij} is the highest degree of similarity of v_{ij} and v_{j}^{*}. The value of L_{ij} is as shown in the following figure.

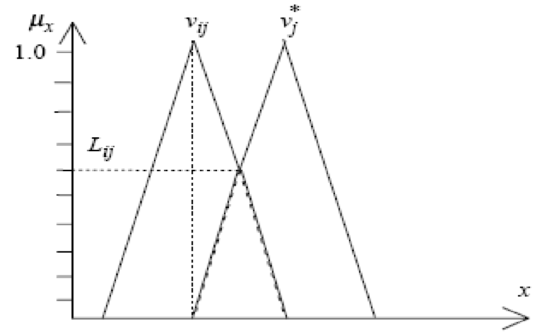

Fig. 3. The derivation of L_{ij}

In the same way we can define the differences between $\mu_{v_{ij}}(x)$ and $\mu_{v_j^-}(x)$ as defined below:

$$D_{ij}^{*} = 1 - \left\{ \sup_{x} \left[\mu_{v_{ij}}(x) \wedge \mu_{v_j^-}(x) \right] \right\} = 1 - L_{ij}, \quad \forall i, j. \tag{18}$$

Step 6. (Relative closeness to the ideal)
The relative closeness to the ideal solution for each alternative is computed in accordance with the following formula:

$$C_{i}^{-} = \frac{S_{i}^{-}}{S_{i}^{*} + S_{i}^{-}} \tag{19}$$

Step 7. (Rank the alternatives)
A set of alternatives can now be preference ranked according to the descending order of C_{i}^{-}, and the one with the maximum value of C_{i}^{-} is the best.

8. Fuzzy Hierarchical TOPSIS Method

In the section that follows the fuzzy hierarchical TOPSIS methodology developed by Kahraman et al. (2007) is reviewed and summarized for the RFID problem evaluation.

Assume that we have m alternatives, n main criterions, s sub-criterions, and K respondents that answer the questionnaires. In addition to that we assume that each main criterion has z_i sub-criteria, where the total number of sub-criterions will become $\sum_{i=1}^{n} z_i$ .The matrix of $\tilde{I}_{MC}$ is defined based upon the weights of the main criteria with respect to the goal as follows:

$$\tilde{\mathbf{I}}_{\mathrm{MC}} = \begin{array}{c} \mathrm{MC}_1 \\ \mathrm{MC}_2 \\ \vdots \\ \mathrm{MC}_p \\ \vdots \\ \mathrm{MC}_n \end{array} \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_p \\ \vdots \\ \tilde{w}_n \end{bmatrix},$$

The value of $w_{p}^{\sim}$ is the arithmetic mean of the weights obtained by the respondents' answers and it is computed as:

$$w_{p}^{\sim} = \frac{\sum_{i=1}^{K} w_{pi}^{\sim}}{K} \quad \text{for } p=1,2,\ldots,n \tag{20}$$

Table 1: A general representation of the decision matrix in hierarchical TOPSIS.

$$\tilde{\mathbf{I}}_{SC} = \begin{array}{c c} & \begin{array}{cccccc} \tilde{w}_1 & \tilde{w}_2 & \ldots & \tilde{w}_p & \ldots & \tilde{w}_n \\ \mathrm{MC}_1 & \mathrm{MC}_2 & \ldots & \mathrm{MC}_p & \ldots & \mathrm{MC}_n \end{array} \\ \begin{array}{c} \mathrm{SC}_{11} \\ \mathrm{SC}_{12} \\ \vdots \\ \mathrm{SC}_{1z_1} \\ \mathrm{SC}_{21} \\ \mathrm{SC}_{22} \\ \vdots \\ \mathrm{SC}_{2z_2} \\ \vdots \\ \mathrm{SC}_{pl} \\ \vdots \\ \mathrm{SC}_{n1} \\ \mathrm{SC}_{n2} \\ \vdots \\ \mathrm{SC}_{nz_n} \end{array} & \left[\begin{array}{cccccc} \tilde{w}_{11} & 0 & \ldots & 0 & \ldots & 0 \\ \tilde{w}_{12} & 0 & \ldots & 0 & \ldots & 0 \\ \vdots & \vdots & & \vdots & & \vdots \\ \tilde{w}_{1z_1} & 0 & \ldots & 0 & \ldots & 0 \\ 0 & \tilde{w}_{21} & \ldots & 0 & \ldots & 0 \\ 0 & \tilde{w}_{22} & \ldots & 0 & \ldots & 0 \\ \vdots & \vdots & & \vdots & & \vdots \\ 0 & \tilde{w}_{1z_2} & \ldots & 0 & \ldots & 0 \\ \vdots & \vdots & & \vdots & & \vdots \\ 0 & 0 & \ldots & \tilde{w}_{pl} & \ldots & 0 \\ \vdots & \vdots & & \vdots & & \vdots \\ 0 & 0 & \ldots & 0 & \ldots & \tilde{w}_{n_1} \\ 0 & 0 & \ldots & 0 & \ldots & \tilde{w}_{n_2} \\ \vdots & \vdots & & \vdots & & \vdots \\ 0 & 0 & \ldots & 0 & \ldots & \tilde{w}_{nz_n} \end{array} \right] \end{array},$$

In this formula, the value of $\tilde{W}_{pi}$ indicates the fuzzy score of pth main criteria with respect to goal determined by the ith respondent.

The second matrix $\tilde{I}_{SC}$ describes the weights of sub-criteria with respect to the main criteria and it is easily identified as follows:

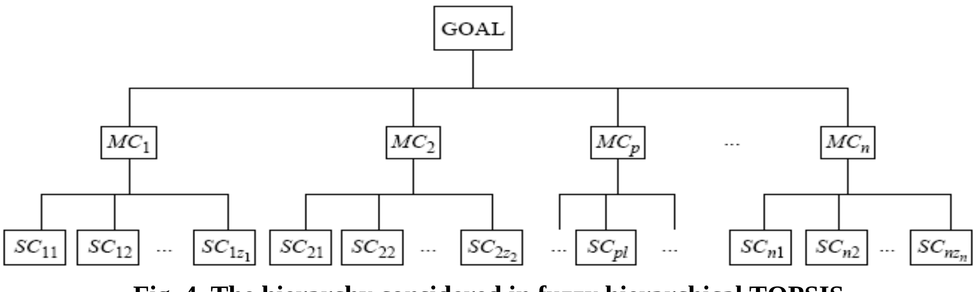

Fig. 4. The hierarchy considered in fuzzy hierarchical TOPSIS

In matrix $\tilde{I}_{SC}$, weight $w_{\tilde{pl}}$ is the arithmetic mean of the weights obtained by the respondents' answer and it is calculated as

$$w_{\tilde{pl}} = \frac{\sum_{i=1}^{K} w_{\tilde{pii}}}{K} \text{ for p=1,2,…,n} \qquad (21)$$

Where $w_{\tilde{pli}}$ represents the weight of the ith sub-criteria with respect to the pth main criteria determined by the ith respondent.

The third matrix $\tilde{I}_A$ is constructed from the scores of the alternatives with respect to the sub-criteria as follows:

$$\begin{array}{c} \tilde{w}_{11} \quad \tilde{w}_{12} \quad \dots \quad \tilde{w}_{1z_1} \quad \dots \quad \tilde{w}_{pl} \quad \dots \quad \tilde{w}_{nz_n} \\ SC_{11} \quad SC_{12} \quad \dots \quad SC_{1z_1} \quad \dots \quad SC_{pl} \quad \dots \quad SC_{nz_n} \end{array}$$

$$\tilde{I}_A = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_q \\ \vdots \\ A_m \end{array} \begin{bmatrix} \tilde{c}_{111} & \tilde{c}_{112} & \dots & \tilde{c}_{11z_1} & \dots & \tilde{c}_{1pl} & \dots & \tilde{c}_{1nz_n} \\ \tilde{c}_{211} & \tilde{c}_{212} & \dots & \tilde{c}_{21z_1} & \dots & \tilde{c}_{2pl} & \dots & \tilde{c}_{2nz_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ \tilde{c}_{q11} & \tilde{c}_{q12} & & \tilde{c}_{q1z_1} & & \tilde{c}_{qpl} & & \tilde{c}_{qnz_n} \\ \vdots & \vdots & & \dots & & \dots & & \dots \\ \tilde{c}_{m11} & \tilde{c}_{m12} & \dots & \tilde{c}_{m1z_1} & \dots & \tilde{c}_{mpl} & \dots & \tilde{c}_{mnz_n} \end{bmatrix},$$

In the above matrix

$$w_{pl}^{\sim} = \sum_{j=1}^{n} w_p^{\sim} w_{pj}^{\sim} \tag{22}$$

Since $w_{pj}^{\sim} = 0$ for $j \neq 0$ we can use equation (23) instead of equation (22):

$$W_{pl}^{\sim} = w_p^{\sim} w_{pl}^{\sim} \tag{23}$$

In matrix $\tilde{I}_A$, $c_{qpl}^{\sim}$ is the arithmetic mean of the scores obtained by the respondents' answers and it is computed as

$$w_{pl}^{\sim} = \frac{\sum_{i=1}^{K} c_{qpii}^{\sim}}{K} \quad \text{for p=1,2,…,n} \tag{24}$$

Where, $c_{qpli}^{\sim}$ indicates the fuzzy evaluation score of qth alternative with respect to lth sub-criteria under pth main criteria determined by the ith respondent. In order to determine the importance degree of each main criteria with respect to the goal and each sub-criterion with respect to the main criteria, the importance degrees for the triangular fuzzy numbers (TFNs) shown in Table 2 and the scores for alternatives given in Table 3 are used in our model (Kahraman et al., 2007). In the next step, we can rewrite the equations for the triangular fuzzy numbers which are used in this application. Since a TFN (a, b, c) can be represented in trapezoidal form as (a, b, b, c), it can be easily seen that equation 6 can be generally expressed as follows (Kahraman et al., 2007):

Tab. 2. The importance degrees

Very Low	(0,0,0.2)
Low	(0,0.2,0.4)
Medium	(0.3, 0.5, 0.7)
High	(0.6, 0.8, 1)
Very high	(0.8,1,1)

Tab. 3. The scores

Very Low	(0,0,20)
Low	(0,20,40)
Medium	(30, 50, 70)
High	(60, 80, 100)
Very high	(80,100,100)

$$r_{ij} = \begin{cases} x_{ij}(\div)x_j^* = \left(\frac{a_{ij}}{d_j^*}, \frac{b_{ij}}{b_j^*}, \frac{d_{ij}}{a_j^*}\right), & j \in B \\ x_j^-(\div)x_{ij} = \left(\frac{a_j^-}{d_{ij}}, \frac{b_j^-}{b_{ij}}, \frac{d_j^-}{a_{ij}}\right), & j \in C \end{cases} \tag{25}$$

Now, equation $M(v_{ij})$ for triangular fuzzy numbers can be shown as follow:

$$M(v_{ij}) = \frac{-a_{ij}^2 + d_{ij}^2 - a_{ij}b_{ij} + b_{ij}d_{ij}}{3(-a_{ij} + d_{ij})}. \tag{26}$$

D_{ij}^* and D_{ij}^- are defined as follows:

$$D_{ij}^* = \begin{cases} 1 - \frac{c_{ij} - a^*}{b^* + c_{ij} - a^* - b_{ij}}, & \text{for } b_{ij} < b^* \\ 1 - \frac{c^* - a_{ij}}{b_{ij} + c^* - a_{ij} - b^*}, & \text{for } b^* < b_{ij} \end{cases} \quad \forall i, j, \tag{27}$$

And

$$D_{ij}^* = \begin{cases} 1 - \frac{c^- - a_{ij}}{b_{ij} + c^- - a_{ij} - b^-}, & \text{for } b^- < b_{ij} \\ 1 - \frac{c_{ij} - a^-}{b^- + c_{ij} - a^- - b_{ij}}, & \text{for } b_{ij} < b^- \end{cases} \quad \forall i, j, \tag{28}$$

Where $v_j^* = (a^*, b^*, c^*)$ and $v_j^- = (a^-, b^-, c^-)$ are the fuzzy numbers with the greatest generalized mean and the lowest generalized mean, respectively.

9. Case Study

Although the cost of RFID technology implementation and maintaining is considered very high for many companies, the competitive environment dictates that for the success of the organization this new technology must be employed sometimes in the future. Therefore, the question is - what management wants to do? Start now or wait and implement it in the future. There are other alternatives open to the management. Instead of taking an initiative of developing a 100% RFID-based system a partial RFID-based system can be taken into consideration. This means investing on an RFID-based system for one or few departments in the organization and leaving the rest of departments as they are. However, to identify the most appropriate RFID-based system as a group of thinkers demand requires a methodology for identifying that. RFID-based system selection is affected by many different factors that each plays a significant role in its success in the long run. Although management is the key thinker in the technology selection and implementation there always are several experts from different parts of the organization that are involved in the selection of new technology and its enforcement. Considering that, a group of managements are those who make decisions on the employment of new technology and its implementation and then they push for its success as well. With the analysis performed from the literature it is concluded that the most appropriate types of alternatives that should be taken into consideration are those that relates RFID systems and barcode systems together. This is because of the power of the barcode and its popularity at the present time. Barcode is going to stay for a long time and will not disappear overnight. This is because the barcode system is less expensive to setup, manage, work with, and it is in use all around the world. Hence, this research is up to putting to vote the following RFID-based-mixed-systems as alternative to the team of decision makers:

1. System type 1: a system with 60 percent RFID power and 40% barcode capability
2. System type 2: a system with 40 percent RFID power and 60% barcode capability
3. System type 3: a system with 20 percent RFID power and 80% barcode capability

Sample calculation shown below is from the data collected on the RFID using a questionnaire with 26 questions. These questionnaires were all passed to 30 managers in healthcare industries. The results obtained are summarized and then converted to the type of data necessary as input to the model proposed here for the hierarchical fuzzy TOPSIS.

Table 4 shows the weights by goal elements (risks and benefits) while table 5 lists weights by risk elements (overall costs (OC), RFID experts (RE), the access rate (AR), the patient privacy (PP), data security (DS), and barcode factors (BF)) and benefits elements (medical errors prevention (ME), tracking medical waste and devices (TMW), patient and healthcare provider information (PH), information management (IM), traceability and tracking information (TT) and data accuracy and reliability (DR).

Tab. 4. weights by main objectives

	Goal
Risks	(0.56,0.76,0.91)
Benefits	(0.53,0.73,0.88)

Tab. 5. weights by main objectives

	Risks	Benefits
Risk1(Overall costs)	(0.49,0.68,0.82)	(0,0,0)
Risk2 (RFID experts)	(0.59, 0.79,0.92)	(0,0,0)
Risk3 (the access rate)	(0.49,0.68,0.82)	(0,0,0)
Risk4 (the patient privacy)	(0.62,0.82,0.94)	(0,0,0)
Risk5 (data security)	(0.34,0.54,0.71)	(0,0,0)
Risk6 (Barcode factors)	(0.46,0.64,0.78)	(0,0,0)
Ben1 (Medical errors prevention)	(0,0,0)	(0.55,0.75,0.87)
Ben2 (Tracking medical waste…)	(0,0,0)	(0.62,0.82,0.93)
Ben3 (Patient healthcare pro. Inf.)	(0,0,0)	(0.56,0.76,0.89)
Ben4 (Information management)	(0,0,0)	(0.47,0.66,0.80)
Ben5 (Traceability and tracking information)	(0,0,0)	(0.36,0.55,0.72)
Ben6 (Data accuracy and reliability)	(0,0,0)	(0.51,0.69,0.83)
Weights	(0.56,0.76,0.91)	(0.53,0.73,0.88)

The decision matrix (a matrix with X_{ij} elements) used in the model is a matrix of 3 (number of systems) by 12 (six risks elements and 6 benefits elements). The normalized decision matrix of (a matrix with R_{ij} elements) is shown in table 7 with the weighted normalized decision matrix (a matrix with V_{ij} elements) is given by table 8.

Tab. 6. Decision Matrix

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	(64,84,93)	(63,83,93)	(60,79,90)	(55,74,86)	(56,76,88)	(50,68,82)
System 2	(59,79,92)	(54,74,87)	(60,80,91)	(53,72,85)	(46,65,79)	(45,63,78)
System 3	(51,70,84)	(50,70,83)	(52,71,85)	(44,63,78)	(40,58,73)	(42,60,76)
	Ben1	**Ben2**	**Ben3**	**Ben4**	**Ben5**	**Ben6**
System1	(42,60,76)	(36,53,70)	(54,74,87)	(58,77,87)	(45,63,78)	(49,67,80)
System 2	(38,56,71)	(36,53,76)	(47,65,79)	(55,73,83)	(36,54,71)	(52,71,84)
System 3	(41,58,73)	(42,60,74)	(45,63,78)	(57,76,87)	(36,53,70)	(46,64,78)
X^-	(51,70,84)	(50,69,83)	(52,71,84)	(44,63,78)	(40,58,73)	(42,80,76)
X^*	(42,60,76)	(42,60,76)	(54,74,87)	(58,77,87)	(45,63,78)	(52,71,84)

Tab. 7. Normalization Table (rij)

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	(0.55,0.83,1.31)	(0.54,0.84,1.32)	(0.57,0.90,1.41)	(0.52,0.85,1.41)	(0.46,0.77,1.30)	(0.52,0.88,1.53)
System 2	(0.56,0.89,1.42)	(0.58,0.94,1.54)	(0.57,0.89,1.41)	(0.53,0.88,1.45)	(0.52,0.90,1.60)	(0.54,0.95,1.68)
System 3	(0.60,1,1,65)	(0.60,1,1.67)	(0.62,1,1.63)	(0.58,1,1.75)	(0.55,1,1.80)	(0.54,1,1.81)
	Ben1	**Ben2**	**Ben3**	**Ben4**	**Ben5**	**Ben6**
System1	(0.55,1,1.82)	(0.47,0.88,1.68)	(0.63,1,1.60)	(0.67,1,1.49)	(0.57,1,1.75)	(0.58,0.94,1.55)
System 2	(0.50,0.92,1.71)	(0.48,0.88,1.81)	(0.54,0.88,1.46)	(0.63,0.95,1.43)	(0.47,0.86,1.58)	(0.62,1,1.63)
System 3	(0.54,0.96,1.76)	(0.56,1,1.76)	(0.52,0.85,1.44)	(0.65,0.99,1.51)	(0.46,0.85,1.58)	(0.54,0.89,1.51)

Tab. 8. Weighted Normalization Table (vij)

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	(0.15,0.43,0.97)	(0.15,0.43,0.98)	(0.160.46,1.05)	(0.14,0.43,1.05)	(0.12,0.39,0.96)	(0.14,0.45,1.14)
System 2	(0.15,0.45,1.06)	(0.16,0.48,1.14)	(0.15,0.46,1.05)	(0.14,0.45,1.08)	(0.14,0.46,1.18)	(0.15,0.49,1.25)
System 3	(0.16,0.51,1.23)	(0.16,0.51,1.24)	(0.17,0.51,1.21)	(0.16,0.51,1.30)	(0.15,0.51,1.35)	(0.15,0.51,1.34)
	Ben1	**Ben2**	**Ben3**	**Ben4**	**Ben5**	**Ben6**
System1	(0.15,0.54,1.40)	(0.16,0.53,1.37)	(0.17,0.55,1.26)	(0.23,0.48,1.06)	(0.11,0.40,1.11)	(0.15,0.47,1.13)
System 2	(0.15,0.50,1.32)	(0.16,0.53,1.48)	(0.16,0.48,1.14)	(0.16,0.46,1.01)	(0.09,0.35,1.00)	(0.16,0.50,1.19)
System 3	(0.16,0.52,1.35)	(0.18,0.60,1.44)	(0.15,0.47,1.12)	(0.16,0.48,1.07)	(0.09,0.34,1.00)	(0.14,0.45,1.10)

Tab. 9. m(vij)

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.52	0.52	0.56	0.54	0.49	0.58
System 2	0.55	0.59	0.55	0.56	0.59	0.63
System 3	0.64	0.64	0.63	0.66	0.67	0.67
	Ben1	**Ben2**	**Ben3**	**Ben4**	**Ben5**	**Ben6**
System1	0.70	0.68	0.66	0.59	0.54	0.58
System 2	0.65	0.72	0.59	0.54	0.48	0.62
System 3	0.68	0.74	0.58	0.57	0.48	0.56

Tab. 10. Table of Distance D*ij

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.0000	0.0000	0.0043	0.0000	0.000	0.0000
System 2	0.0317	0.0569	0.0000	0.0153	0.0754	0.0346
System 3	0.0950	0.0933	0.0593	0.0803	0.1262	0.0595
	Ben1	**Ben2**	**Ben3**	**Ben4**	**Ben5**	**Ben6**
System1	0.0000	0.0600	0.0000	0.0000	0.0000	0.0300
System 2	0.0400	0.0500	0.0700	0.0300	0.0600	0.0000
System 3	0.0200	0.0000	0.0800	0.0000	0.0600	0.0500

Tab. 11. Table of Distance D-ij

	Risk1	Risk2	Risk3	Risk4	Risk5	Risk6
System1	0.0950	0.0933	0.0554	0.0803	0.1262	0.0595
System 2	0.0612	0.0341	0.0593	0.0646	0.0465	0.0240
System 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Ben1	Ben2	Ben3	Ben4	Ben5	Ben6
System1	0.0400	0.0000	0.0800	0.0300	0.0600	0.0200
System 2	0.0000	0.0000	0.0100	0.0000	0.0000	0.0500
System 3	0.0203	0.0600	0.0000	0.0200	0.0000	0.0000

Tab. 12. Final Ranking

	S_i^*	S_i^-	$S_i^* + S_i^-$	C_i	Rank
System1	0.0907	0.7432	0.8339	0.8913	1
System 2	0.4577	0.3619	0.8196	0.4416	2
System 3	0.7342	0.0974	0.8316	0.1171	3

The ranking determined by the hierarchical fuzzy TOPSIS are: (1) a system with 60 percent RFID power and 40% barcode capability, (2) a system with 40 percent RFID power and 60% barcode capability, and (3) a system with 20 percent RFID power and 80% barcode capability.

10. Conclusion

Hierarchical fuzzy TOPSIS is a good management tool for handling qualitative assessments about RFID evaluation problems. Relatively speaking, calculations are faster than the fuzzy AHP model here. The main drawback of this model is that the classical fuzzy TOPSIS is a highly complex methodology and requires more numerical calculations for assessing the ranking order of the alternatives than the hierarchical fuzzy TOPSIS methodology and hence it increases the effort, thus limiting its applicability to real world problems. This author employed the hierarchical fuzzy TOPSIS approach for evaluating the RFID-based systems and then determined the most appropriate system among them. It is obvious enough that understanding the risks and benefits of RFID decisions can help managers in making decisions on which criteria should be considered in the decision process and how a decision model should be structured by using hierarchical fuzzy TOPSIS.

This work extends the application of fuzzy TOPSIS into the area of radio frequency identification (RFID) taking risk-benefits of that into consideration. The practicality of the proposed model is demonstrated using a case study.

With regard to the data collected on the RFID using a questionnaire with 26 questions, it seems the best alternative under current circumstance is to employ a system with 60 percent RFID capability and 40% barcode power. In this article, researcher has explained the importance of selection criteria for evaluation of RFID-based system. It provided key elements on radio frequency identification, and fuzzy hierarchical TOPSIS methodology with the algorithm that can be followed to solve the problem. The hierarchical TOPSIS model used in this article is able to grasp the ambiguity exists in the utilized information and the fuzziness appears in the human judgments and preferences. The use of the hierarchical fuzzy TOPSIS methodology offers a number of benefits: (1) it is a systematic model and straight forward to work on; (2) capable to capture the human's appraisal of ambiguity when management should deal with a complex multiple objective situations.

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