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Fuzzy decision making model for selection of real time location systems

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ABSTRACT

Real Time Location Systems (RTLS) have gained importance in contemporary world since they allow real time positioning of assets, people and workflows. They can be used in different sectors to increase work efficiency and quality in areas of application. The selection of the appropriate RTLS technology becomes a major decision problem since it has a multi-criteria structure which includes both qualitative and quantitative factors. In this study, a decision making model is developed for selection of the appropriate RTLS technology for companies operating in different sectors. Three main criteria are determined by existing literature and with the help of the experts, namely economic, technical and implementation factors. The Fuzzy Analytic Hierarchy Process (FAHP) method is proposed to select the appropriate RTLS technology. Also sensitivity analysis is performed according to the incremental rates of main criteria. The model is applied to a hospital in Turkey considering three types of RTLS systems which are given as IR–RF hybrid, UHF RFID and Active RFID. Since the scores of the hybrid system for economic, implementation and technical factors are higher comparing the other technologies, it is selected as the best alternative.

1. Introduction

Real Time Location System (RTLS) is a wireless system that allows real time positioning and tracking of assets, people and workflows. By using the RTLS technology, speed, ambient temperature, humidity and other information predefined on object or human can be obtained and the changes can be monitored. According to the definition of Malik [1], RTLS is a system that we can reach the information regarding the location and other properties anytime we want from a person or an object. On the other hand, in the definition Cyplik and Patecki [2] made in their study, RTLS is locating a defined object in a specified three-dimensional field.

Real-time positioning systems are complete technological systems that consist of several equipments. They generally practice the applications by communicating between the devices via radio waves and these can be changed according to the technology used. Systems and devices constituting the system are tags, positioning sensors and engine, interface software and application. Tags can be placed on the object or person that requires tracking. The information regarding the target object or person is gathered by communicating with the tag on the target. This data of object or person can be about the location, speed, temperature, being in a specified area or other information defined.

The main objective of RTLS is to increase work efficiency and quality in areas of application. By using the RTLS, organization efficiency is increased as security is provided, service quality is increased, human factor is minimized in quality control operations, customer satisfaction is increased and return on investment is accelerated. Commonly used RTLS technologies can be listed as Ultra-Wide Band, RFID, Wi-Fi, Zigbee, Bluetooth and Infrared. Moreover, RTLS technologies have become more important in the contemporary world and can be used in many different sectors such as logistics, manufacturing and healthcare.

Health sector is a field where RTLS are being used since 10 years for positioning the assets, patients and staff [1,3]. Due to various technologies, applications are different from each other. By developing technology, hospitals are using more intelligent systems and reach high monitoring capacity. In a hospital, with reliable and accurate positioning, automation level increases and efficiency increase is obtained in a short time period. Due to realtime positioning, the investments of expensive equipments made by hospitals can be decreased. Positioning of the personnel, monitoring patient movements, decreasing of waiting periods, tracking the equipment positions are among the aims of RTLS usage purposes.

Although the RTLS technologies are used for determining the locations of materials such as pallet, container, etc. in open areas at first place, locating in room bases and use of it in closed areas

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has become widespread after the advance in tag technology. With determining the location in room bases, the use of RTLS technologies in hospitals increased [2].

The places of use and the functions of the RTLS can be listed as below:

- Pre- and post-surgery: locating in room bases.
- Emergency: locating doctors and specified equipment in a quick and updated.
- Locating the workers.
- Specifying the location at room bases: Provide workers to work efficiently.
- Acquiring the necessary equipment more quickly.
- Tracking people, assets and equipment.
- Tracking patient movements.

When comparing the operating features of the RTLS technologies; precision, speed and security are the main topics that should be analyzed. The system should provide these three factors at an optimum level. In addition, RTLS technologies should be selected carefully by taking the environment to work in into account and adapted to the organization.

RTLS technology selection is a multiple criteria decision-making problem. The aim of the paper is to analyze the important both quantitative and qualitative decision criteria for selection of RTLS technologies and develop a decision making model. Three main criteria are determined with the help of the experts, namely economic, technical and implementation factors. The Fuzzy Analytic Hierarchy Process (FAHP) method is proposed to select the appropriate RTLS technology and the proposed model is applied to a hospital in Istanbul. Since, in some cases AHP method often have not enough capability to evaluate the alternatives when decision maker express preferences using without numerical values. For this, in some cases, Fuzzy Analytic Hierarchy Process (FAHP) is required to identify vagueness of human thoughts instead of crisp numbers efficiently [4].

The rest of this paper is organized as follows. Section 2 presents a literature review. Section 3 provides criteria and sub-criteria definition for multi-criteria RTLS selection problem. In Section 4, the methodology for the problem is presented. The application of the model is given in Section 5. In Section 6, results are discussed. Section 7 presents the sensitivity analysis. Finally, Section 8 concludes the paper.

2. Literature review

There are many studies available related with technology selection and various methodologies are utilized to select the appropriate technology. Some of the relevant studies are given below.

Davoudpour [5] established a mathematical model to select the technology portfolio by maximizing the organization value and support of the organization's strategy at an R&D center. İç [6] dealed computer integrated manufacturing technology selection problem. Both TOPSIS and design of experiment methods are used to determine the attributes. Jiang [7] presented pair-wise comparison approach of Analytic Hierarchy Process to select the best remanufacturing technology and an example is illustrated.

Technology selection problem also can be analyzed with FAHP method. The most important benefit of fuzzy AHP is that, it can be dealed with both quantitative and qualitative data and suitable tool to analyze. In addition FAHP is an important method for multi-criteria decision making under uncertainty.

Ma [8] designed a technology selection process by using FAHP and Delphi method. Then the model is applied to select the technology alternatives for Taiwan's future photovoltaic industry. Duran [9] proposed a fuzzy AHP method for selection of computerized maintenance management systems. An example is given to illustrate the proposed methodology. Finally, a software prototype for implementing this method was provided. Cebeci [10] developed a FAHP approach to select a suitable ERP (enterprise resource planning system) for textile industry. Tolga et al. [11] designed a decision support system for Operating System (OS) selection for decision makers. There are two factors of technology selection problem which are economic and non-economic. The economic part of the decision problem has been developed by Fuzzy Replacement Analysis. FAHP is used to evaluate non-economic factors and financial figures. Naghadehi et al. [12] developed fuzzy model to selection the optimum mining method by determined major criteria and taking subjective assessment from decision makers. Kahraman and Kaya [13] proposed a fuzzy AHP-based methodology for the selection of best energy policy in Turkey. Hsu et al. [14] designed a new approach toward the technology selection. Firstly, they proposed Fuzzy Delphi Method to analyze the factors of the lubricant regenerative technologies by interviewing experts. Then, Fuzzy Analytic Hierarchy Process is applied to find the importance degree of each criterion as the measurable indices of the lubricant regenerative technologies. Lee et al. [15] established a strategic hydrogen energy technology selection system by considering economical, commercial potential, inner capacity, and technical impacts. Then a Fuzzy Analytic Hierarchy Process (FAHP) is suggested. Cebeci [16] proposed an analytical tool to select the best quality consultant providing the most customer satisfaction by using FAHP. Nieto-Morote [17] also used FAHP for an example on evaluation of several combined cooling, heat, and power production systems. Martin et al. [18] proposed an information delivery model by using multi criteria decision making technique to find the best alternative in MCDM problem. Then fuzzy MCDM technique was applied which resolves inconsistency and uncertainty issues involved in decision making of information delivery for bank users.

Kaya et al. [19] designed two-phased multi-criteria methodology to select the best investment alternative for public transportation with respect to the predetermined criteria. In the first phase, a selection among transportation types is made, and secondly, selection among transportation modes of the selected transportation type is made. A case study for Istanbul is given in the application section. Kaya and Kahraman [20], developed Analytic Hierarchy Process (AHP) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), are used for intelligent building assessment. Kahraman et al. [21] proposed Fuzzy Analytic Hierarchy Process (AHP) is used for the selection among four possible health research investment alternatives. Bilisik et al. [22] create a hybrid fuzzy approach for the evaluation of SERVQUAL of public transportation system. With this aim, four alternative companies are evaluated.

When considering the relevant literature about RTLS, it is observed that there are few studies about indoor localization, and implementation of RTLS in healthcare systems. Yang et al. [23] designed a hybrid RFID sensor for a resource information management system in humanitarian logistics centers. By using the system, it is provided monitoring all of their resources including equipment, people and environment. Deak et al. [24] compared the localization systems based on different factors, these are the wireless technology used, positioning algorithm, accuracy and precision, complexity, scalability and costs.

Meiller et al. [25] proposed an adaptive knowledge-based system framework for health care and illustrate with RFID-generated information. Fisher et al. [26] evaluate 23 different hospitals and examine types of RTLS and analyze their degree of functionality, the organizational effects of implementing RTLS.