Review Article

Applying Fuzzy Analytic Hierarchy Process (FAHP) in Healthcare System

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Manuscript received: 19th Oct 2014, Reviewed: 10th Nov 2014, Author Corrected: 20th Nov 2014, Accepted for Publication: 24th Nov 2014

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Abstract

Background and Purpose: Managers are applying multi-criteria decision-making methods like analytic hierarchy process (AHP) during the recent two decades mostly due to their positive properties. Moreover, integration of Fuzzy logic and multi-criteria decision-making methods increases capabilities of these methods. This study evaluates the FAHP method in healthcare system. **Method:** In this study, a systematic search done by means of Fuzzy Analytic Hierarchy Process, FAHP keywords separately and along with the words medical decision making, healthcare, health and their Persian equivalent inside PubMed, GOOGLE SCHOLAR, PROQUEST, SCOPUS, CINAL, SID and Iran doc databases without time periods and just regarding input and output criteria. **Findings:** finally 15 articles studied among 127 extracted articles in which the most application of this method is in evaluation of quality service and positioning while the least application is in other fields of healthcare system. **Conclusion:** Although applying FAHP methods in healthcare system increased but it is still low in contrast to other fields which can be due to unfamiliarity of authorities and students of the system.

Keywords: Analytic Hierarchy Process (AHP), Fuzzy, Healthcare System

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Introduction

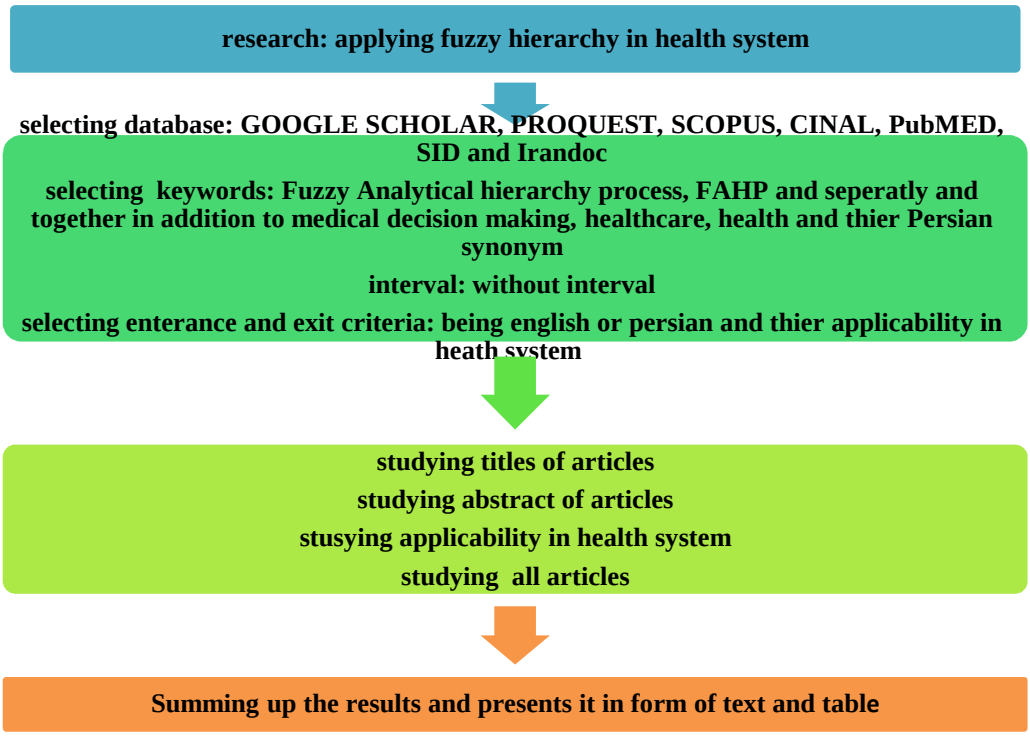
Service department grew significantly during the recent century in which 70% of workforces are in this department. Healthcare department in this case is very special and the smallest mistake may be irrecoverable [1]. Daily increasing of healthcare system expenditures over the world is one of the main concerns of managers and decision-makers of the system. Continuous development of expensive and modern technologies in this field, increase in societies expectations from healthcare systems and growth of chronic diseases among people are of major reasons of such growth in expenditures [2]. Of course, significant part of these expenditures are not need-based and can be spent more efficiently [3]. Number of decision-making indices in healthcare system, diversity of qualitative and quantitative criteria and regarding them synchronically, importance of effects and results of a decision and any other similar factors increases the complexity of decisions [4]. During the recent two decades, mathematical methods especially multi-criteria decision-making methods applied by managers most frequently [5]. AHP is one of the multi-criteria decision-making methods applied mostly where indices are opposite of each other qualitatively and quantitatively [6]. This method invented by Thomas L. Saati originally from Iraq in 1970 [7]. AHP can be used when decision-making faced with several opponent and criteria choices. The criteria can be qualitative or quantitative. This decision-making method based on pairwise comparisons. The decision-maker starts making decision by providing hierarchy tree [8]. Decision hierarchy tree illustrates the compared factors and evaluated opponent choices in a decision. Then, some pairwise comparisons was conducted. These comparisons illustrate weight of each factor in line with evaluated opponent choices in a decision. Finally, the AHP logic integrates the matrixes resulted from pairwise comparisons in a way optimal decision achieved [9]. Although the experts make use of their intellectual abilities for comparisons in AHP but it should be noticed that traditional AHP is not capable of reflecting human thinking style perfectly [10]. In other words,

using Fuzzy sets is more compatible with oral and even ambiguous explanations of human. Therefore, it is better to use Fuzzy set for long-term prediction and decision-making in real world [11]. Fuzzy logic presented by Lotfizadeh, professor of Berkley University of California in 1965. It is a multi-value logic conceptually [12]. Classic logic shows anything based on a pairwise system (true/false, 0/1, black/white) but Fuzzy logic shows trueness of anything by a number between 0 and 1. For instance, if black is 0 and white is 1, then gray is a number near 0 [13]. Nowadays Fuzzy logic is very applicable especially in management field. This logic is very applicable for evaluating qualitative problems and patterns and answering many problems in humanities majors especially management [14]. The first FAHP method created by Larhon and Pedrick in 1983 but not accepted due to complicated calculations. In 1996, another method presented by a Chinese researcher Yung Chang with many applications [15]. Application of these methods also becomes common in healthcare system [16]. There is a review on previous studies about application of FAHP in healthcare system in the present article.

Research Method

The present study is a systematic review to find previous researches about application of FAHP technique in healthcare system in PubMed, CINAL, SCOPUS, PROQUEST, GOOGLE SCHOLAR, SID and Irandoc databases without time conditions by searching FAHP, Fuzzy analytic hierarchy process keywords separately and along with words health, healthcare, medical decision making and their Persian equivalent under the supervision of professors. Persian or English articles, applicability of FAHP in healthcare system, and published in creditable journals are conditions of selecting articles for this study. Presented articles are not studied in seminars and conferences. The searching result was 89 articles just found in PubMed and GOOGLE SCHOLAR databases regarding in/out criteria of articles in this study. First, title of all articles studied and 39 of them removed due to irrelevancy. In second phase, 6 of them removed due to repetition, 17 articles removed because FAHP technique not mentioned in their abstract and 14 of them removed after final study and due to irrelevancy to the healthcare system. After all, 13 articles remained and 2 articles added through searching in references that content of finally 15 articles studied.

Flowchart of studying articles and selecting them



Findings

All of 15 articles, used FAHP technique in healthcare, applied in evaluation and ranking field although in quality service field (5 cases) and in evaluation of appropriate location (3 cases to establish hospital and 1 case for land filling) applied more than other fields. In evaluation of other fields such as evaluation of factors effective on diseases (2 cases) and 4 other cases related

to evaluation in other fields. No article found before 2008 and most of them (5 and 4 articles) related to 2011 and 2013 respectively and 3 articles related to 2012 and the least number of articles related to 2008, 2010 and 2014 which was just one. Most of the articles related to Iran and there were not more than two articles in a magazine (Table 1).

Table 1: Studies related with Fuzzy Analytic Hierarchy Process (FAHP) in Healthcare System

No.	Name of Article	Authors	Magazine	Summary	Year
1	Strategic analysis of health care service quality using fuzzy AHP methodology	Gulcin Buyukozkan Gizem Cifci Sezin Guleryuz	Expert System With Application [18]	Evaluating service quality using FAHP	2011
2	The study of construct key success factors for the Taiwanese hospitals of location selection by using the fuzzy AHP and sensitivity analysis	Lin, Chin-Tsai, Cheng-Ru Wu, and Huang-Chu Chen	International journal of information and management sciences [22]	Determining appropriate location for hospital using FAHP	2008
3	Municipal landfill site selection for Isfahan City by use of fuzzy logic and analytic hierarchy process	Afzali, A., J. M. V. Samani, and M. Rashid	Journal of Environmental Health Science & Engineering[25]	Determining appropriate location for landfilling using FAHP	2011
4	Hospital ranking using fuzzy analytical hierarchy process-balance score card	Mousakhani, Morteza, Hamed Rahmani, and Naser Hamidi	Asian Journal of Management Research[17]	Ranking hospitals using FAHP	2010
5	Application of fuzzy-AHP extent analysis to determine the relative importance of risk factors in operative mortality after Coronary Artery Bypass surgery	Nouei, Mahyar Taghizadeh, et al	International Journal on Computer Science & Engineering[27]	Ranking factors effective o death after CABS using FAHP	2013
6	A fuzzy MCDM approach for health-care waste management	Dursun, Mehtap, E. Ertugrul Karsak, and Melis Almula Karadayi	World Academy of Science, Engineering and Technology[29]	Selecting the best method for managing wastes using FAHP	2011
7	Potential hospital location selection using fuzzy AHP :An empirical study in rural India	Chatterjee, Debmallya, and Bani Mukherjee	International journal of innovative technology and research[23]	Selecting the best location for hospital using FAHP	2013
8	Comparing user acceptance factors between research software and medical software using AHP and FUZZY AHP	Mohamadali, Noor Azizah KS	UKCI[31]	Comparing factors of user acceptance between two medical and research software using FAHP	2011
9	Applying Fuzzy Analytic Hierarchy Process (FAHP) to Evaluate Factors Locating Emergency Logistics Platforms	Zejli, Karima, Abdellah Azmani, and Sanae KHALI ISSA	International Journal of ComputerApplications[30]	Evaluating factors of determining location of emergency supplies platforms using FAHP	2012

10	Hospital Site Selection Using Two-Stage Fuzzy Multi-Criteria Decision Making Process	Soltani, Ali, and Ibrahim Zargari Marandi	Journal of Urban and Environmental Engineering[24]	Selecting location for hospital using FAHP	2011
11	Evaluation of service quality by using fuzzy MCDM: A case study in Iranian health-care centers	Afkham, Leili, Farshid Abdi, and A. Komijan	Management Science Letters[19]	Evaluating service quality using FAHP and ServQual questionnaire	2012
12	Performance evaluation of the hospital services-a fuzzy analytic hierarchy process model	Sinimole, K. R	International Journal of Productivity and Quality Management[20]	Evaluating service quality in hospitals using indices of ServQual questionnaire	2012
13	Fuzzy AHP Ranking of Occupational Safety System Quality Indicators	Savić, Suzana, Miomir Stanković, and Goran Janaćković	Information theory and complex systems[28]	Evaluating and ranking indices of occupational safety in road making using FAHP	2013
14	"Identification and prioritizing the effective factors on addiction by use of Fuzzy analytical hierarchy process	Najafi, Moslem Lari, and Maryam Nasiri	Life Science Journal[26]	Identifying factors effective on addiction and their ranking using FAHP	2013
15	Performance evaluation of the hospital services-a fuzzy analytic hierarchy process model in hospitals of Zahedan	Baradaran Kazemzadeh, R., M. Sepehri, and F. Firouzi Jahantigh	Hospital[21]	Evaluating service quality of hospitals using FAHP and indices of ServQual questionnaire	2014

Service Quality

There were 5 articles in this field during 2010 to 2014 in which 3 of them related to Iran and the other related to Turkey and India. By means of this technique in the first article, Morteza Musakhani, Hamed Rahmani and Naser Hamidi used balanced scorecards to evaluate the performance of a hospital [17]. G Büyüközkan et al ranked and evaluated 4 hospitals in Turkey by this method in which sympathy, professionalism, reliability and responsibility from experts' viewpoint and treatment accuracy, responsibility and hospital appearance from patients' viewpoint had more importance respectively [18]. Leili Afkham et al also ranked 4 hospitals in Shiraz by means of ServQual questionnaire including tangible cases, reliability, responsibility, guarantee and sympathy criteria filled by patients [19]. In India, also K. R. Sinimole in 2012 evaluated service quality of 4 hospitals in Kerala State through FAHP technique by means of ServQual questionnaire criteria filled by patients and weighed by experts [20]. In addition, Kazemzadeh et al in 2014 evaluated service quality in hospitals of Zahedan city through this method by means of ServQual questionnaire criteria in which sympathy got reaped the highest importance from the patients' viewpoint [21].

Selecting location

In the first study done in 2008 using FAHP technique by Chin-Tsai Lin and Cheng-Ru Wu in Taiwan, they got 6 criteria and 18 sub-criteria for selecting a location to build a hospital through a questionnaire arranged by 17 hospital managers. They also determined the evaluation criteria and created a hierarchical structure regarding factor conditions including investment of hospital in production time i.e. work and land capital, demand conditions and effective factors such as medical market demand like population, density and age distribution of population. They determined assessment criteria, developed a hierarchical structure, compared decision making components by means of pairwise comparison and considered obtained scores. Pairwise comparison matrix developed and vector eigenvalue of each pairwise comparison matrix selected. Compatibility of each matrix tested and for selecting the best location, the relative weight of each level component evaluated and integrated [22]. In a similar study conducted by Debmallya

Chatterjree and Bani Mukerjee in India (by FAHP), 12 experienced physicians in the field of hospital management and health care contributed for selecting the best location and a questionnaire distributed among them. The main factors for selecting the best location were cost, population coordinates, location and sub-factors such as land cost, topography and ownership, executive cost and maintenance, population density, education, economic conditions, proximity to the public transportation, appropriate space for the future constructions, availability of available infrastructures and proximity to the market. It was determined that sub-factors such as land cost, population density, proximity to the public transportation and market and economic conditions played an important role in evaluating the location of a hospital in India [23]. In a similar study conducted by Ali Soltani and Ebrahim Zargari Marand in region 5 of Shiraz, Iran (2010), 4 criteria considered which were: distance to main streets and healthcare, population density and size of the land. In the above-mentioned study, two stage decision-making used for determining the appropriate location. At first three lands and finally one land selected [24]. Afzali, Samani and Rashid (2010) conducted a study for selecting the appropriate location for waste landfill in Isfahan. They conducted this study by means of hierarchical analytic technique. In this case a region 40 km far from Isfahan selected as the under study area. The criteria divided into two categories: limitations and factors. Limitations effect on decision-making and some of research locations deleted. Boolean method used for limitations. By means of this method, the studied area divided into appropriate and inappropriate categories. Factors show the appropriateness of a location. In fact, factor is a criterion, which increases or decreases the usage of something. Sin this study, factors mentioned by bite scale (from 0 to 225). Zero and 225 indicated the most inappropriate and appropriate location for waste landfill, respectively. Fuzzy membership functions measured the weight of all factors. Limitation factors included fault, sensitive habitat and airport. Three criteria considered for selecting the location: physical criteria (slope, soil permeability, surface water, groundwater and fault), environmental factors (sensitive habitats) and socioeconomic criteria (land use, road network, residential areas and airport). Factors compared by pairwise comparison in each level. About 16% of the studied area deleted because of the existence of Kolah Ghazi Park in the south, airport in the north and fault in the northeast. Existence of residential areas in the west limited 55% of the above-mentioned area. Moreover, existence of gardens and farmlands was a problem. Role of the slope factor was not important. In this case, regions less than 135 ha ignored. Since, regarding population density and amount of the waste production, an area more than 135 ha is required. Therefore, five regions of considered regions selected [25].

Identifying factors effective on diseases

Addiction is a physiological disorder. Several factors are effective in this case and finally resulted in drug abuse and addiction. In order to discuss about this subject, previous researches investigated and one group of factors effective on addiction evaluated. FAHP used in this study. The factors studied by this method are psychological characteristics (traditional values, urgent need, lack of self-control, lack of self-confidence, lack of social skills); mental disorders (depression, personality disorder, OCD); positive attitude and opinions about drugs (sense of identity, chronic pain relief, mental relaxation, drug abuse without addiction); sense of experience (experiencing drug once and curiosity); and emotional shortages (depression, anxiety, aggression and jealousy). About 100 respondents participated in this study and results collected by Expert Choice software. Pairwise comparison used in this case. Obtained results show that psychological factors effective on addiction ranked as follows: personal characteristics, mental disorders, sense of experience, emotional shortage and positive attitude toward drugs. The present study is a new work and we could not compare our results with other results unfortunately [26]. Mahyar Taghi Zadeh Nobi, Ali Vahediyan Kamyad, Somayyeh Ghezelbash and Mahmood Reza Sar Zaiim (2013) conducted a study by FAHP for relative importance of risk factors in death (after coronary artery bypass surgery). In this study, which conducted by searching Medline and Science Direct articles, 11 articles screened. Collected data of these articles are number of studied population, related characteristics, start and end of data collection, publication year, outcome, procedure type, scale of C index, multi variant relationship among predictive factors and outcome in terms of random ratios. Death risk factors after CABG such as age, gender were weal LVEF of alternative methods. Ages above 80 years old, LVEF, ages between 75 to 80, emergency state, ages between 70 to 75, creatine increase and repeated surgery had highest weights among variables and considered as the main variables. The other variables such as ages less than 70 years old, medium LVEF, female gender, severe MI, NYHA, using inter aortic balloon and emergency surgery were some of risk factors related to death after CABG which obtained by FAHP method [27].

Other areas of healthcare

Suzana Savic et al (2013) conducted a study by means of FAHP for ranking the quality of occupational safety system. Occupational safety system composed of different components such as employees, purpose of the work

(material, energy and information), production tools (machinery, equipment and tools), workplace (a place in which tools and social work conditions formed). This study conducted in Serbia. The 48 indices formed and divided into technical (11), human (15), organizational (16) and environmental (6) categories. In the present study, FAHP used for defining purpose, identifying criteria, sub-criteria and alternative ways, developing hierarchical structures, pairwise comparisons and determining priority vectors. Here, our problem illustrated in four levels: 1. Work and duty (ranking key indices); 2- Related criteria (risk, cost and social responsibility); 3- Technical, human and organizational sub-criteria and external factors and 4- Key indices. It is concluded that based on the available risk, safety at work evaluated and then technical and environmental factors assessed. Regarding social responsibility, organizational and external factors are important and then human and technical factors considered. Defining key indices of occupational safety system and their ranking through appropriate methods, improved the quality of the system [28]. Mehtap Dursun, Ertugrul Karsak and Melis Almula Karadayi (2011) conducted a study by means of FAHP technique and studied different methods of managing wastes for health care in Istanbul. Studied methods are burning wastes, sterilizing by steam or autoclave, microwave and landfill. It is shown that the best methods are sterilizing by steam, microwave, burning wastes and landfilling, respectively [29]. Moreover, in other studies FAHP method used for comparing factors of user acceptance between two medical and research software and factors of determining location of emergency supplies platforms [30, 31].

Discussion/Conclusion

Decision-making is the main essence of management and decision-making is the most difficult duty of each manager [32]. Today, managing affairs of organizations is not dependent on personal judgment of individuals. It should be based on scientific methods, detailed information and decision-making techniques [33]. Because of its special nature, decision making in health system is more important than other sectors. Since, using appropriate and accurate decision making methods can decrease potential costs of wrong decisions [34]. Using multi-criteria decision making methods can help managers in making appropriate decisions [35]. In addition to powerful theoretic base, multi-criteria decision making provides the possibility of formulating and reviewing the problem and considering different options with quantity and quality criteria (sometimes conflicting) and their integration and considering opinions of different individuals [36]. One of the most powerful methods of multi-criteria decision-making is hierarchical analytic method [37]. In the above-mentioned method, formulating the problem hierarchically, considering different criteria and determining the amount of decisions compatibility and incompatibility is possible [38]. However, since there is uncertainty in the real world, explaining most factors with classic mathematic logic is not possible. In fact, in most cases, whole or part of a problem is in unreliable and fuzzy conditions and using classic logic is not helpful. Therefore, in order to solve such problems, considering uncertainty is important and in the other words, we should make them fuzzy [39]. Using fuzzy hierarchical analytic techniques instead of classic hierarchical techniques removes uncertainty [40]. Classic hierarchical analytic method used in health system and all areas such as policymaking, health and therapy [41]. However, fuzzy hierarchical method used in the other systems too [42-45]. In the recent years, applying this method increased in the health system. However, in comparison to the other sectors, using this method and similar methods is limited. This method can be used in all fields in which managers should select among two or more options and rank them (such as selecting suppliers, university, college, professor or superior physician and also in the related areas to the therapy such as causes of diseases and their therapy or developing health and therapy facilities. It seems one of the most important obstacles for research is unfamiliarity of health authorities with these methods. In this case, adding related lessons to the disciplines such as management of health and therapeutic services suggested.

Funding: Nil, **Conflict of interes**t: None
Permission from IRB: Yes

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How to cite this article?

Ameryoun A, Zaboli R, Haghoost AA, Mirzae T, TofighiS, Shamsi MA Applying Fuzzy Analytic Hierarchy Process (FAHP) in Healthcare System. *Int J Med Res Rev* 2014;2(6):610- 617.