Journal of System Management (JSM)
Online ISSN: 2538-1571
Print ISSN: 2322-2301
6(3), Fall 2020, pp. 31-76
Research Paper

Evaluation of Failure Causes in Employing Hospital Information Systems

Hossein Sayyadi Tooranloo [1] **Sepideh Saghafi** [2]
Arezoo Sadat Ayatollah [3]

Abstract T Today, the information systems play a critical role in business for each organization. Like other organizations, hospitals use information systems for data collection, data storage, data processing and the like to have long-term and short-term achievements. Despite the very benefits of implementing HIS and its costly implementation, the HIS project sometimes fails. The importance of the HIS failure and preventive practices in this regard have led researchers investigate the causes of failure for information systems in hospitals. In this paper, an FMEA-based model is presented in an intuitionistic fuzzy environment to evaluate the HIS failure factors. For this purpose, Data required to implement the proposed model were collected in 5 hospital, in Kerman (Iran). Based on research studies and survey of hospital academic experts, a total number of 27 failure modes were determined for the implementation HIS. The results of the proposed approach indicated that 8 factors are of paramount importance in terms of HIS failure causes: Individuals' lack of skill/knowledge, lack of integration between system and organizational activities, unrealistic planning, lack of IT management or weak project team (information system), improper software development, lack of managerial skills, misdiagnosis of roles and responsibilities, inconsistency between corporate culture and change requirements (compatibility).

Keywords *Hospital Information Systems (HIS); Failure Mode and Effects Analysis (FMEA); Intuitionistic Fuzzy*

Received: 22/07/2020 Accepted: 12/11/2020

[1] Department of Management, Meybod University, Meybod, Iran, Corresponding Author
Email: h.sayyadi@meybod.ac.ir
[2] Department of Public Adminstration, University of Tehran Kish International campus, Tehran, Iran
[3] Department of Information Technology Management, University of Science & Art,Yazd, Iran

Introduction

For many years, information systems (ISs) have played a significant role in organizations so that each organization enjoys an IS in its business and plays a role as a business center (Safa'a, 2012; Carvalho et al, 2017; Mozaffar et al, 2018; Salahuddin et al, 2019). Like other organizations, health care institutions produce massive amounts of data that need to be collected, transmitted, recorded, retrieved and summarized. In this regard, the ISs are developed and implemented at various sizes for hospitals (Mcgonigle & Mastrian, 2014; Carvalho et al, 2017; Khajouei et al, 2018). The ultimate goal of these systems is to increase the efficiency and effectiveness of business practices, integrate business domains and protect them (Safa'a, 2012; Carvalho et al, 2017; Gartner et al, 2017; Mozaffar et al, 2018). Hence, the HIS is an integrated and widespread system that, as a part of the health information system, meets the information needs of organizations, planning, patient care and documentation (Amin et al, 2011). The HIS consists of a variety of available software applications including the patient's medical records system, pharmacy management, accounting, radiology, nursing and lab systems and uses certain standards for data exchange at the network level (Samy et al, 2009; Robertson & Saveraid, 2008). The use of the IS in hospitals can help the medical profession to increase the health care quality. This quality enhances automatically and continuously (Mohanty et al, 1999) and provides new management for healthcare centers (Kimiafar et al, 2007). Actually, with the increase in the amount of patient data routinely collected each day from clinical practices, large electronic health databases have been formed. The many benefits from accessing this huge and useful amount of data in the field of medical research are now being realized (Samra er al, 2019). Thus, HIS play an important role in improving the delivery of health care services(Gartner et al, 2017). The HIS affects the reduction of medical errors, efficiency gains, timely decisions, and improvements in the quality of health services (Sulaiman & Wickramasinghe, 2014; Ahmadi et al, 2015), timely provision of information and provision of accurate information for managerial needs and improved operational effectiveness (Chen & Hsiao, 2012). In addition, professionals have access to a large amount of patient-related information (Ammenwerth et al, 2004). since the hospital is an information-centered organization (Borzekowski, 2009; chen & Hsiao, 2012) and faces compressed data and considerable information needs (chen & Hsiao, 2012). The notion of healthcare without information technology seems to be nonsense (Ammenwerth et al, 2007). More importantly, the use of ISs in all hospitals leads to cost reductions within 3 to 5 years after the implementation of HIS (Borzekowski, 2009). Ford et al. (2010) stated that the cost of applied health IT programs in 2009 was estimated around half of the total hospital budget. Evidently, ISs in hospitals are pervasive; however, some studies have shown that many of these projects have failed in spite of the heavy costs of the HIS implementation (Safa'a, 2012; Mozaffar et al, 2018). Many sociotechnical and organizational factors including informational complexity of care processes, organizational structures and practices of healthcare organizations, and the safety criticalness of the sector are among the many reasons than inhibit smooth and timely implementation of HIS (Mozaffar et al, 2018; Sligo et al, 2017). The failure of the IS projects implies a waste of resources as a major obstacle to the organizational investment (Nauman et al, 2005) and that organizations cannot obtain benefits from these systems. Thus, determining the causes of the HIS failure is of necessity and evaluating the factors affecting the HIS failure can provide the appropriate grounds for successful implementation of these systems. One of the oft-used methods is to adopt intuitionistic fuzzy FMEA approach. The technique aims to detect and prioritize potential failure modes by assessing an index called Risk Priority

Number (RPN). The index is constructed as the product of three concepts, namely the probability of failure occurrence (O), severity of failure (S), and failure detection (D) (Segismundo et al., 2008; Mangeli et al., 2019; Mirghafoori et al, 2020; Qin et al., 2020). Probability of occurrence refers to the likelihood of occurrence of a cause/mechanism. Severity indicates the potential impact of failure on parts, sub-systems, or customers. And, detection refers to the capability of detecting potential causes/mechanisms before the occurrence of a failure (Ireson et al., 1995; Segismundo et al, 2008; Mangeli et al., 2019). These three factors are estimated by experts on a scale of 1 to 10(Qin et al., 2020). RPN is a measure of failure risk. Therefore, it can be used to rank failures and prioritize required actions. In the course of calculating RPN, probability indices for severity and occurrence are used directly, whereas detection index is used inversely. Hence, a higher value for RPN index indicates a more critical failure for which corrective actions should be given higher priority. FMEA can provide some measures to reduce the likelihood of faults/ failures and help users to determine the key design features and processes that require special control (McDermott et al., 1996; Keskin and Özkan, 2009). By using fuzzy concepts, assessors can use linguistic terms in the form of verbal expressions to evaluate the risk factors for each item of failure, and then relate these expressions to appropriate membership functions to provide a better and more accurate analysis for the scores of failure modes (Chen & Li, 2011; Deschrijver et al, 2004; Park et al, 2011; Wu & Zhang, 2011). In 1986, Atanassov extended the theory of fuzzy sets and introduced the concept of intuitionistic fuzzy sets. Since then, theory of intuitionistic fuzzy sets has become increasingly popular (Zhao & Wei, 2013) to deal with uncertainty (Park et al, 2013). In the current study, the FMEA technique was used in an intuitionistic fuzzy environment to evaluate the HIS failure causes.

Theoretical Framework

Nowadays, hospitals are to focus on plans that are supportive in achieving long-term and short-term success and improve their performance(Thakare & Khire, 2014; Engin and Gürses, 2019; Gartner et al, 2017; Carvalho et al, 2017; Salahuddin et al, 2019; Salahuddin et al, 2019). Hence, some hospitals, which are called the Hospital Information System (HIS), employ an IS that uses information management, data collection, data storage, data processing and data exchange in accordance with the user's operating requirements(Ratnaningtyas & Surendro, 2013; Engin and Gürses, 2019; Gartner et al, 2017; Carvalho et al, 2017; Salahuddin et al, 2019; Salahuddin et al, 2019). The hospital ISs are of importance to preserve patient's comprehensive medical information and different types of relevant data and information as well as to maintain all patient medical services such as diagnosis, treatment and research, follow-up reports and critical medical decisions(Khalifa & Alswailem, 2015; Shortliffe & Barnett, 2014; Engin and Gürses, 2019). These hospital systems result in the patient care improvement through increasing user knowledge and reducing uncertainty and consequently provide the grounds for wise decisions to be made based on integrated information (Handayani et al, 2016; Engin and Gürses, 2019; Gartner et al, 2017; Samra et al, 2019) and The stored information would ultimately be presented for processing, making better decisions and facilitating the access for those who would like to use the systems (Thakare & Khire, 2014; Reichertz, 2006; Engin and Gürses, 2019; Samra et al, 2019; Salahuddin et al, 2019). According to Vegoda (1987), there are two keys to this definition: (1) HIS is an integrated system; and (2) providing the required information in a usable format makes the HIS accurate, immediate and certain for decision making, indicating the provision of services in a more effective way(Ratnaningtyas & Surendro, 2013). As a result, it can be claimed that the

HIS refers to a computerized system of containing day-to-day medical services, facilitating the management of clinical and administrative data and processing health insurance and treatment services (Liu et al, 2006). The HIS, therefore, is defined as the sociotechnical hospital subsystem, which involves all relevant information processing systems (Handayani et al, 2016; Breton et al, 2014) serving other objectives (conflicting objectives such as optimal use of resources and performance improvements) (Reichertz, 2006). According to Chen and Hsiao (2012), the HIS is an integrated information system and plays a key role in supporting hospital affairs through employing an appropriate IT. The HIS could be effective in improving the operating efficiency of the healthcare organization, reducing risk and controlling costs. It also supports the healthcare organization through an infrastructure providing high-quality, medium-sized and immediate services for a long term with regard to the financial aspects that lead to sustainable development of the company (Joshi & Nash, 2005; Engin and Gürses, 2019; Samra et al, 2019). The HIS, thus, offers a comprehensive set of solutions for hospitals and other healthcare providers who need competitive operations in today's healthcare environment (Özogul et al, 2009; Engin and Gürses, 2019; Samra et al, 2019). Meanwhile, a systematic hospital information system also presents faster and more efficient hospital services as well as the better control of the offered services (Ismail et al, 2015). Furthermore, it reduces administrative tasks and enhances productivity at all levels. Indeed, the HIS would control costs through avoiding errors, reducing cycle temporal duration, maximizing the supply chain of the hospital and exploiting the employees(Nilashi et al, 2016; Thakare & Khire, 2014; Lee et al., 2012; Triantaphyllou et al., 1998). Kensing et al. (2007) and Ismail et al. (2010) suggested that the HIS implementation is beneficial and of numerous advantages (Nilashi et al, 2016). Despite the very benefits of implementing HIS and its costly implementation, the HIS project, however, sometimes fails (Nauman et al, 2005). As recent studies have shown, the HIS fails at a rate around 50%-80% (Safa’a, 2012). Studies conducted by the medical institute and other centers revealed that the use of technology throughout the health care industry was at a level lower than favorable (Meli, 2008). Research has also conceded that an employee's attitude towards employing modern IT in his organization is considered as a major factor affecting the successful selection of that technology(Lapczinski, 2004). The hospital personnel are the ones who decide whether or not to use the patient's electronic recording systems. Unfortunately, they have not responded well to these systems. Even in some hospitals taking more benefits from the HIS, details of daily observations as well as the physicians and nurses' notes are not included in the computer systems (Hamidfar, 2008). Consequently, one of the major challenges in the exploration of the ISs is to delve into the factors affecting the acceptance or non- acceptance of computer systems by the staff (Davis et al, 1989). Beuscart-Zephir et al. in their study showed that the role of human factors in the implementation and application of the HIS can increase these systems' potentials (Beuscart-Zephir et al, 2001). Littlejohns et al. enumerated the failure causes for the HIS to be inadequate training, user resistance, negative attitudes and management variations (Littlejohns et al, 2003). The lack of institutional support is also regarded as a major impediment to the successful use of these systems. Management support ensures sufficient budget and resources available for the successful implementation of the project. In addition, organizational variation imposed by the new system heavily depends on the management support (Laudon & Laudon, 2001). Organization supervisors can encourage users to use these systems through rewards, system deployment and appropriate interaction. The colleagues, on the other hand, affect this process by supplying information or negative attitudes towards the use of the system, believing that the system requires a fundamental change in their working process(Chatzoglou et al, 2010). Thus, the importance of the HIS failure and preventive methods in this regard has made the researchers examine the failure factors of the IS. As summarized in Table 1, the researchers have used various methods to evaluate the IS failure factors.

Table 1

IS Failure Factors

Factors	Researchers
Lack of design by similar systems, inapplicability for users, multiple users or developers, variation across users, developers or maintainers, lack of support system, inability to specify the goals or characteristics of users, inability to predict and influence the infrastructures, problems in technical issues, cost-Efficiency	Seventies, 1978
Technical complexity, degree of novelty or program structure, technological changes and project size	Zmud, 1980
Size of costs, time, potentials of manpower or parties involved, organization information system with the target technology, how to organize the project well	McFarlan, 1981
Existence and stability of applied conditions, users' capability to determine requirements, analysts' capability to extract requirements and evaluate their integrity and completeness	Davis, 1982
Failure of resources (conflicts between individuals, time and project domain), Failure of requirements (weak specifications of requirements)	Block, 1983
Lack of personnel, unrealistic programs and budgets, improper software development, improper user interface development, unnecessary project features, lack of equipped external components, lack of performed external tasks, lack of computer capabilities and real-time performance	Boehm’s, 1991
Task complexity, extent of variation, failure of resources, significance of potential damages	Barki et al, 1993
Inadequate requirements, lack of user participation, resource shortage, unrealistic expectations, executive failure, lack of planning, change of requirements, lack of need, lack of IT management, technology illiteracy	CHAOS report, 1994

Factors	Researchers
Failure to direct the profession with the technology in the project plan, lack of focus on human relationships for technology, poor management, poor counseling, lack of design provided by the hospital board of directors, lack of a technical solution to a problem, poor suitability of project management and project team, poor selection of decisions	Flowers, 1996
Complexity, lack of structure, instability of project objectives, technology novelty, users, information management system, high levels of management and project size	Ewusi, 1997
Target change, conflict among different sectors	Keil et al, 1998
Poor project planning, poor business case, lack of involvement for senior and support manager	CMA Management, 1998
Planning and scheduling, performance (system features), contractors (contracting), requirements management, use of resources, performance management and personnel management	Lyytinen et al, 1998
Project size, technological change, novelty of application area, personnel change	Jiang & Klein, 1999
Project complexity, continuous development of information technology and business environment, technical specifications and unspecified business requirements	Murray, 2000
Non-commitment of senior management to the project, non-commitment of the user, misinterpretation of conditions, personnel's lack of knowledge and skills, instability of situation, objectives change, introducing new technologies, failure in managing the users' final expectations, inadequate/inappropriate human resources, conflict among users	Schmidt et al, 2001
Inexperienced or untrained managers, failure to set and manage expectations, poor leadership at all levels, lack of adequate knowledge, poor plans and processes, poor estimation of efforts, cultural and ethical conflicts, conflicts between project team and organizations' services, misuse or abuse methods, insufficient communication (to track and report)	Winters, 2002
inexperienced project management, poor project planning, poor requirements management (lack of sufficient requirements, changing needs), dependence on project management tools, poor leadership, inappropriate tests, amateur technology, lack of user involvement, poor business plan, poor communication, non-monitoring of the existing business	Yardley, 2002

Factors	Researchers
Scope and extent of project management, set of specified project objectives, executive support, leadership stability, scope of project management, project plan and organization, interaction with stakeholders, user engagement, risk management, progress of timely feedback, compatibility with unexpected events	Yardley, 2004
Non-commitment of senior manager to the project, uncertainty of objectives, program shortcomings, irresponsibility, lack of planning or inadequate planning, lack of skilled personnel, lack of change management, lack of user involvement, poor risk management	Smith et al, 2006
Senior manager disapproval, poor project manager, lack of documented requirements, lack of change control	Kappelman et al, 2006
Technological factors (ease of perceived use, perceived usefulness, adaptability, impact, pleasure); personal factors (age, gender, personality, training, skills, self-efficacy, previous experience) and organizational factors (training, communication, coordination, organizational commitment, user participation, size)	Yucel et al, 2012
Individual (lack of change management, Lack of managerial skills, Lack of project management methods, wrongly-defined roles and responsibilities, Lack of understanding of requirements, poor control, poor risk management, wrong choice of development strategy, lack of skills in project leadership, lack of programs or inappropriate program); Task (wrong estimates, lack of development of effective process, effort to develop new method during project, lack of required skills and knowledge in individual projects, poor team relationship, inappropriate staff, excessive use of external counselors, introducing new technology, stability of technical architecture, multiple projects); client (non-commitment of senior manager, failure to achieve the user commitment, conflict among sectors and groups, failure to receive project approval from all groups, failure in managing end user expectations, failure of users to collaborate, failure to identify all stakeholders, growth of users' higher expectations, managing multiple relations with stakeholders, lack of user experience, lack of understanding / specified goals, number of organizational units involved, lack of constant requirements, novelty of the subject for users and developers, development financing, maintenance budget) and environment (instability in business, lack of the adaptation between company culture and change requirements, unsustainable environment, senior management change, human resource change, changing objectives, lack of control over counselors, unfamiliar foreign affiliation)	Safa’a, 2012

Fuzzy FMEA provides a tool that works best with vague concepts and in the lack of sufficient information (Dosoinescu, 2004; Balaraju et al., 2019). Using fuzzy theory is essential when dealing with some degrees of uncertainty in relationships among various criteria or when relations cannot be expressed in the form of definite numbers. Fuzzy FMEA has been applied by several earlier studies to assess risk (Chanamool & Naenna, 2016; Jiang et al., 2017). For example, Chang et al(2001) used grey theory for FMEA. Their study first used fuzzy expressions such as very low, low, medium, high and very high to evaluate O, S and D, and then applied grey relational analysis to determine the risk ratings of potential causes. By performing the grey relational analysis, fuzzy expressions were converted to definitive values, and the lowest levels of O, S and D were defined as the standard series. Data regarding these three factors for each potential cause was seen as comparative series and grey relational coefficients and degree of grey relation were compared against the standard series under the rules of grey theory. The highest degree of grey relation indicated minimal effect of potential cause (Chang et al., 1999). Braglia et al. also proposed a multi-criteria decision making approach called fuzzy TOPSIS for FMECA. As a well-known multi-criteria decision-making method, TOPSIS is based on the idea that the best decision should have minimum distance from the positive ideal and maximum distance from the negative ideal. The fuzzy TOPSIS approach provides the possibility of evaluating risk factors (O, S and D) and their relative importance using triangular fuzzy numbers (Braglia, 2003). Bawls and Peláez (1995) proposed a fuzzy logic-based approach to prioritize failures in a FMEA system (Bowles & Peláez, 1995). This approach used verbal expressions to describe O, S, D and the risks of failure. In this approach, the relationships between risk and O, S, D were described using fuzzy if-then rules obtained from experts' opinion. Garcia et al. (2005) proposed a fuzzy data envelopment analysis approach combined with fuzzy sets to determine the rating of failure modes. Chen and Ko calculated fuzzy RPN by using fuzzy ordered weighted geometric averaging (FOWGA) operator (Chen and ko, 2007). Similarly, Wang et al. proposed a new definition for fuzzy RPN by using fuzzy weighted geometric mean (FWGM). Fuzzy RPN can also be calculated using alpha-cut sets, linear programming model and defuzzification through center of gravity method, to obtain the final ranking of failure modes (Wang et al., 2009). Kutlu & Ekmekcioglu (2012) proposed a hybrid approach based on TOPSIS and AHP in a fuzzy setup to analyze failure modes. Their study used the fuzzy AHP method to determine the weight of risk factors. After assigning the weights and generating the failure items decision matrix for risk factors, fuzzy TOPSIS was performed to prioritize the failure modes. The study by Liu et al. (2012) developed a model based on fuzzy VIKOR techniques to assess and prioritize risk factors. It used linguistic terms and corresponding fuzzy numbers to determine the weight of risk factors based on expert opinions. Then, the fuzzy ordered weighted decision matrix for factors of failure modes was calculated and the VIKOR technique was used to prioritize failure modes. In another attempt, Kumru and YildizKumru (2013) investigated the applications of fuzzy FMEA to improve procurement processes of a hospital. They concluded that fuzzy FMEA technique could properly solve problems associated with traditional FMEA and could be useful for exploring potential failure modes and their effects. Finally, the study by Rafie and Samimi (2015) proposed a hybrid approach comprising fuzzy rules and neural network to evaluate the RPN in FMEA. It used fuzzy rules to determine severity (S) and detection (D), while occurrence (O) was determined using neural network. Intuitionistic fuzzy set (IFS) is one of the generalizations from the fuzzy sets theory (Zadeh, 1965; He et al., 2020; Krawczak and Szkatuła, 2020). Out of several higher-order fuzzy sets, IFS has been found to be more capable of dealing with vagueness. First introduced by Atanassov (Atanassov, 1983; Zhang et al., 2020; Qin et al., 2020; Ngan et al., 2020; Kumar, 2020; Krawczak and Szkatuła, 2020; He et al., 2020; Alcantud et al., 2020), IFS can be viewed as an alternative approach to conventional fuzzy set in dealing with cases with insufficient information. Fuzzy sets only consider the degree of acceptance, whereas IFS is characterized by both a membership function and a non-membership function so that the sum of both values is less than one (Atanassov, 1986). Intuitionistic fuzzy sets have been used across different fields of science, including the studies by Atanassov (1986, 1989, 1999, 2000), Atanassov and Gargov (1989), Szmidt and Kacprzyk (2000), Buhaescu (1989), Ban (2006), Deschrijver and Kerre (2002) and Stoyanova (1993).

Definition 1: Assume reference set. In this case, set A which is a subset of X is an Atanassov's intuitionistic fuzzy set defined as below:

$$A=\{\prec x,u_A(x),v_A(x)\succ \forall x\in X\} \quad (1)$$

In the above definition, $u_A(x),v_A(x)$ are degree of membership and non-membership respectively, which are defined as $u_A(x):x\rightarrow[0,1],v_A(x):x\rightarrow[0,1]$ and satisfy $0\le u_{ij}(x)+v_{ij}(x)\le 1$. In addition, for each $x\in X$, intuitionistic index π_x is defined as $\pi_x=1-u_x-v_x$ (Atanassov, 1986).

Definition 2: Based on Atanassov, $(u_{ij}(x),v_{ij}(x),\pi_{ij}(x))$ is an intuitionistic fuzzy number that satisfies the following conditions:

$$\mu_{ij}(x)\in[0,1],v_{ij}(x)\in[0,1],\pi_{ij}(x)\in[0,1],0\le\mu_{ij}(x)+v_{ij}(x)\le 1,\pi_{ij}(x)=1- \quad (2)$$

Although intuitionistic fuzzy number is similar (in appearance) to triangular fuzzy number (a,b,c), it is quite different. Triangular fuzzy number is a convex normal fuzzy set with a membership function in which $(a\prec b\prec c)$

, whereas an intuitionistic fuzzy number is a point in three-dimensional space constructed by axes $u_{ij}(x), v_{ij}(x), \pi_{ij}(x)$ (Szmidt & Kacprzyk, 2001). Atanassov and Gargov (1989) and Gau and Buehrer (1993) have described intuitionistic fuzzy number $(0.50, 0.20, 0.30)$ as a scenario where votes in favor of adoption are 0.5, votes against it are 0.2 and abstained votes are 0.30. In this context, the following relationship holds true:

$$\mu_{ij}^{\beta}(x) + v_{ij}^{\beta}(x) \leq 1 \text{ , } 0 \leq \mu_{ij}^{\alpha}(x) \leq \mu_{ij}^{\beta}(x) \leq 1 \text{ , } 0 \leq v_{ij}^{\alpha}(x) \leq v_{ij}^{\beta}(x) \leq 1 \qquad (3)$$

These numbers are better suited to deal with uncertainty and provide a more logical mathematical framework to deal with inexact facts and incomplete information (Zhang et al, 2010). Some of the operators and relationships between these numbers are provided as the following. For simplicity's sake, these numbers are expressed as $[u_{ij}(x), v_{ij}(x), \pi_{ij}(x)]$ where $u_{ij}(x)$ ، $v_{ij}(x)$ and $\pi_{ij}(x)$ are numbers in the range of [0, 1].

Definition 3: Assume intuitionistic fuzzy numbers $A = \{\langle x, \mu_A(x), v_A(x) | x \in X \rangle\}$, $A_1 = \{\langle x, \mu_{A1}(x), v_{A1}(x) | x \in X \rangle\}$, $A_2 = \{\langle x, \mu_{A2}(x), v_{A2}(x) | x \in X \rangle\}$, and the real number n. According to De et al. (2000) and Atanassov (1986) the following relationships are defined:

$$\overline{A} = \{\langle x, v_A(x), \mu_A(x) | x \in X \rangle\} \qquad (4)$$

$$A_1 \cap A_2 = \{\langle x, \min\{\mu_{A_1}(x), \mu_{A_2}(x)\}, \max\{v_{A_1}(x), v_{A_2}(x)\} | x \in X \rangle\} \qquad (5)$$

$$A_1 \cup A_2 = \{\langle x, \max\{\mu_{A_1}(x), \mu_{A_2}(x)\}, \min\{v_{A_1}(x), v_{A_2}(x)\} | x \in X \rangle\} \qquad (6)$$

$$A_1 + A_2 = \{\langle x, \mu_{A_1}(x) + \mu_{A_2}(x) - \mu_{A_1}(x) \cdot \mu_{A_2}(x), v_{A_1}(x) \cdot v_{A_2}(x) \,|\, x \in X \rangle\} \qquad (7)$$

$$A_1 \cdot A_2 = \{\langle x, \mu_{A_1}(x) \cdot \mu_{A_2}(x), v_{A_1}(x) + v_{A_2}(x) - v_{A_1}(x) \cdot v_{A_2}(x) \,|\, x \in X \rangle\} \qquad (8)$$

$$nA = \left\{\left\langle x, 1-(1-\mu_A(x))^n, (v_A(x))^n \middle| x \in X \right\rangle\right\} \tag{9}$$

$$A^n = \left\{\left\langle x, (\mu_A(x))^n, 1-(1-v_A(x))^n \middle| x \in X \right\rangle\right\} \tag{10}$$

Where n is a Positive integer.

Evaluation of Failure Causes in Employing Hospital Information Systems Based on FMEA Approach in an Intuitionistic Fuzzy Environment

There has been much discussion about the easy and accurate determination of risk factors for failure occurrence (O), severity (S) and detectability (D). Since verbal evaluation has an approximate nature, it can be said that the theory of intuitionistic fuzzy sets is suitable to deal with the uncertainty of such estimates and to achieve more accurate results. Accordingly, in the present section we have dealt with proposing a group decision-making model using entropy and TOPSIS techniques to evaluate failure items based on FMEA model in the intuitionistic fuzzy space. Suppose that there is m failure items $FM_i(1,\cdots,m)$ that is assessed by an FMEA based on h members $TM_k(1,\cdots,h)$ according to linguistic variables intuitionistic fuzzy contained in Table 2.

Table 2

Intuitionistic Fuzzy Linguistic Variables

Detectability		**Failure severity probability**		**Failure occurrence probability**	
Intuitionistic fuzzy number	Linguistic term	Intuitionistic fuzzy number	Linguistic term	Intuitionistic fuzzy number	**Linguistic term**
(1,0)	Absolutely Impossible	(1,0)	Risky Without Warning	(0.9,0.1)	Very High

Detectability		Failure severity probability		Failure occurrence probability	
(0.9,0.1)	Highly Unlikely	(0.9,0.1)	Risky With Warning	(0.75,0.2)	High
(0.8,0.1)	Unlikely	(0.8,0.1)	Very High	(0.5,0.45)	Medium
(0.7,0.2)	Very Low	(0.7,0.2)	High	(0.35,0.6)	Low
(0.6,0.3)	Low	(0.6,0.3)	Medium	(0.1,0.9)	Very Low
(0.5,0.4)	Medium	(0.5,0.4)	Low		
(0.4,0.5)	Relatively High	(0.4,0.5)	Very Low		
(0.25,0.6)	High	(0.25,0.6)	Insignificant		
(0.1,0.75)	Very High	(0.1,0.75)	Very Insignificant		
(0.1,0.9)	Absolutely Possible	(0.1,0.9)	None		

Consider $\tilde{x}_{ij} = ([u_{ijk}(x), v_{ijk}(x)])$ as the intuitionistic fuzzy of *i*th failure degree in *j*th risk factor $(j = O, S, D)$ that is assessed by the *k*th member of FMEA (TM_k) team and consider $q_k (k = 1,2,...,h)$ as the relative importance of each of FMEA team members when conditions $\sum_{k=1}^{h} q_k = 1$ and $0 \le q_k \le 1 (k = 1,2,...,h)$ are met.

In this case, we will have *k* matrix as follows:

$$D_k = \begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1j} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{i1} & \cdots & \tilde{x}ij \end{bmatrix} \tag{11}$$

Based on the above assumptions, *m* failure items may be ranked using the following steps.

Step 1: Determining the weight of Experts and the risk factors using entropy method

The concept of entropy is derived from thermo dynamics .C.E. Shannon has recently applied it to information theory. The basic principle is that entropy can be used as a measure of the useful information that the data provides. The entropy weight Method has been widely used in the decision-making process. In this paper, the entropy coefficient method that developed by Li et al(2015), is applied to determine the weights of experts and risk factors in group decision making using IIFS.

Entropy Weight Method for Determination of Expert Weights

Definition 4 (the entropy of expert). Let E_k be the entropy of expert k:

$$E_k = -\frac{1}{Ln\, n}\sum_{i=1}^{m}\left(\frac{S_{ik}}{\sum_{i=1}^{m} S_{ik}} \times Ln\left|\frac{S_{ik}}{\sum_{i=1}^{m} S_{ik}}\right|\right) \tag{12}$$

Where S_{ik} can be calculated by formula (13), and its form is as follows:

$$S_{ik} = \frac{1}{2}\left[(u_{iok} - v_{iok}) + (u_{isk} - v_{isk}) + (u_{idk} - v_{idk})\right] \tag{13}$$

Formula (13) is based on the score function, which is proposed by Xu(2007). It is used to calculate the overall evaluating values of expert k to the failure mode i.

Definition 5 (the expert weights). Using the properties of entropy, we find that if the degree of disorder in a system is high, the entropy value will correspondingly be larger. In group decision making, if experts have similar opinions about different failure modes,the entropy value will be larger. That is, the greater the entropy value of expert E_k is, the smaller the differences the results will show. Let q_k be the entropy weight of expert k; its form will be as follows:

$$q_k = \frac{1 - E_k}{h - \sum_{k=1}^{h} E_k} \tag{14}$$

Where $\sum_{k=1}^{h} q_k = 1,\ 0 \le q_k \le 1$

Entropy Weight Method for Determination of Attribute Weights

After a series of calculations ,we will derive the aggregation of the experts matrix as $\vec{R}(m \times n)$; the element of $\vec{R}(m \times n)$ is $\left([u_{ij}(x), v_{ij}(x)]\right)$, which means that experts evaluate every failure mode j of every risk factor i. That is to say, when all of the experts' evaluations of all of the failure modes are put together, they equal one expert's evaluation of all of the failure modes. So, we consider this matrix an overall evaluation matrix:

$$r_{ij} = \left(\left[1 - \prod_{k=1}^{h}\left(1 - u_{ijk}(x)\right)^{q_k}, \prod_{k=1}^{h} v_{ijk}(x)^{q_k}\right]\right) \tag{15}$$

$$j = O, S, D$$

where $q_k \ge 0,\ i \in 0,1,2,\ldots,h,\ \sum_{k=1}^{h} q_k = 1$

After determining the experts integration matrix, we will deal with assessing failure items based on entropy method.

Definition 6 (the entropy of attributes). Let e_j be the entropy of attribute j:

$$e_j = -\frac{1}{Ln\,n}\sum_{i=1}^{m}\left(\frac{h_{ij}}{\sum_{j=1}^{n} h_{ij}} \times Ln\left|\frac{h_{ij}}{\sum_{j=1}^{n} h_{ij}}\right|\right) \qquad j = O,S,D \tag{16}$$

where h_{ij} can be calculated by formula (17), and its form is as follows(Qi et al., 2011):

$$h_{ij} = \left(1 - d\left(\left[u_{ij}(x), v_{ij}(x)\right], [0.5, 0.5]\right)\right) \tag{17}$$

Formula (17) has to satisfy the following conditions:

(1) the relative importance of evaluation attributes and failure modes is independent;

$$(2)\, d\left(\tilde{r}_{ij}, [0.5,0.5]\right) = 1/2\left(\left(u_{ij}(x) - 0.5\right)^2 + \left(v_{ij}(x) - 0.5\right)^2\right)^{1/2} \tag{18}$$

Formula (17) is based on the Euclidean distance of IIFS. The interval valued intuitionistic fuzzy sets $[0.5,0.5]$ has no hesitancy degree, but its entropy attains the maximum value. That is to say, the positive and negative evidence of this number are accounted equally, and it is impossible to use fuzzy information to describe or make a reasonable judgment.

Definition 7 (the attribute weight). According to the theory of entropy, when the entropy of attribute j is greater than the value of other attributes, the value of attribute j between every failure mode and the optimal strategy will have a smaller difference .In order to facilitate a comprehensive evaluation, the weight of attribute j can be determined by e_j. Let W_j be the weight of attribute j; it is formedas follows:

$$W_j = \frac{1 - e_j}{m - \sum_{j=1}^{m} e_j} \tag{19}$$

Where $0 \le w_j \le 1$, $\sum_{j=1}^{m} w_j = 1$

Step 2: Assessing formation of weighted matrix failure items in risk factors

Consider $\vec{R}(m \times n)$ as experts' integration matrix that is obtained according to equation (15). If W_j is the weight of O, S and D risk factors determined on the basis of equation (19), then matrix $N(m \times n)$ where $\tilde{n}_{ij} = ([u_{ij}(x), v_{ij}(x)])$, weighted matrix of assessment failure in risk factors determined based on equation (21).

$$\tilde{n}_{ij} = \left(\left[(1 - u_{ij}(x))^{w_j}, v_{ij}(x)^{w_j},\right]\right),\ i = 1,\dots,m \quad j = O, S, D \tag{20}$$

Step 3: Determining positive and negative ideal values:

Among the three risk factors O, S and D, two factors O and S are of positive type measures. This means that as the amount of this factor gets high for the item failure, it makes the items more sensitive. However, the D-factor is of the negative criteria or cost. In other words, as the probability of detection (D) of an item is higher, sensitivity towards it reduces. Low probability of detection will make the aforementioned items to be of higher rank in ranking failure items (assuming constant values of other factors). With this description, the ideal values for positive and negative risk factors include:

$$A^{+} = \left(\left[u_j(x)^{+}, v_j^{\beta}(x)^{+}\right]\right) = \left\langle \underset{i}{Max}\,\tilde{n}_{iO}, \underset{i}{Max}\,\tilde{n}_{iS}, \underset{i}{Min}\,\tilde{n}_{iD} \right\rangle,\ i = 1,..,m \tag{21}$$

$$A^{-} = \left(\left[u_j(x)^{-}, v_j(x)^{-}\right]\right) = \left\langle \underset{i}{Min}\,\tilde{n}_{iO}, \underset{i}{Min}\,\tilde{n}_{iS}, \underset{i}{Max}\,\tilde{n}_{iD} \right\rangle,\ i = 1,..,m \tag{22}$$

Step 4: Calculating the distance of every item from positive and negative ideal option:

To calculate the distance between two intervals valued intuitionistic fuzzy sets different methods are provided (Li et al., 2015). In this study, the method described by Hemming (Li et al., 2015) has been used to calculate the distance of each of failure items from the positive and negative ideal. This distance is determined by the following equation.

$$d_i^+ = \frac{1}{4}\sum_{j=1}^{m}\left[\left|u_{ij}(x) - u_j(x)^+\right| + \left|v_{ij}(x) - v_j(x)^+\right|\right],\ i = 1,..,n \tag{23}$$

$$d_i^- = \frac{1}{4}\sum_{j=1}^{m}\left[\left|u_{ij}(x) - u_j(x)^-\right| + \left|v_{ij}(x) - v_j(x)^-\right|\right],\ i = 1,..,n \tag{24}$$

Step 5: Calculating closeness coefficient index:

Closeness coefficient index (C_i) for each failure item is obtained based on the following equation.

$$C_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{25}$$

After determining the above index value for each failure item, failure items are ranked in a descending order. Failure item that has more C_i, possessed a higher rank.

Analysis

In this section, the proposed model is used to evaluate the failure modes related to the implementation of HIS. Data required to implement the proposed model were collected in 5 hospital, in Kerman (Iran). Based on research studies and survey of hospital academic experts, a total number of 27 failure modes were determined for the implementation HIS. These modes are shown in Table 3.

Table 3

Assessing Failure Items of HIS with Intuitionistic Fuzzy Sets

	Factors	Reference
A_1	Changing objectives	Seventies, 1978; Chaos, 1994; Keil et al, 1998; Schmidt et al, 2001; Smith et al, 2006; Safa'a, 2012
A_2	Lack of managerial skills	Winters, 2002; Yardley, 2002; Yardley, 2004; Safa'a, 2012
A_3	Senior Management Change	Safa'a, 2012
A_4	Non-commitment of senior management	Chaos, 1994; CMA, 1998; Schmidt et al, 2001; Smith et al, 2006; Kappelman et al, 2006; Safa'a, 2012
A_5	Wrongly-defined roles and responsibilities	Safa'a, 2012;
A_6	Inappropriate planning	Flowers, 1996; CMA, 1998; Smith et al, 2006; Safa'a, 2012
A_7	Lack of IT management or poor project team (IS)	Chaos, 1994; Keil et al, 1998; Flowers, 1996; Winters, 2002; Yardley, 2002; Smith et al, 2006; Kappelman et al, 2006
A_8	Lack of project maintenance budget	McFarlan, 1981; Safa'a, 2012
A_9	Lack of coordination (conflict among sectors and groups, failure to receive project approval from all sectors)	Block, 1983; Keil et al, 1998; Schmidt et al, 2001; Safa'a, 2012
A_{10}	Excessive use of external counselors	Safa'a, 2012
A_{11}	Lack of control over external counselors	Safa'a, 2012
A_{12}	Failure to specify user attributes	Seventies, 1978
A_{13}	Excessive number of organizational units involved	Block, 1983; Safa'a, 2012
A_{14}	Unrealistic programs	Boehm's, 1991; Winters, 2002; Yardley, 2002
A_{15}	Lack of skill / knowledge	McFarlan, 1981; Boehm's, 1991; Chaos, 1994; Schmidt et al, 2001; Schmidt et al, 2001; Smith

	Factors	Reference
		et al, 2006; Safa'a, 2012; Yucel et al, 2012; Khalifa & Alswailem, 2015
A16	Lack of employees participation	Seventies, 1978; Chaos, 1994; Schmidt et al, 2001; Yardley, 2004; Smith et al, 2006; Yucel et al, 2012; Safa'a, 2012
A17	Negative beliefs about computer systems	Khalifa & Alswailem, 2015
A18	Non-commitment (accountability) of users	Schmidt et al, 2001; Smith et al, 2006; Yucel et al, 2012; Safa'a, 2012
A19	Inappropriate personnel training	Yucel et al, 2012
A20	project novelty and unfamiliarity	Zumd, 1980; Jiang & Klein, 1999; Safa'a, 2012
A21	Lack of ease of use	Yucel et al, 2012
A22	Multiple users	Seventies, 1978
A23	excessive complexity of project plan flaws	Seventies, 1978; Williams, 1999; Murray, 2000; Smith et al, 2006
A24	Lack of integration between system and organizational activities	McFarlan, 1981; Barki et al, 1993
A25	Improper software development	Boehm's, 1991
A26	Inconsistency between company culture and change requirements (compatibility)	Barki et al, 1993; Yucel et al, 2012; Safa'a, 2012
A27	Technology based on human relations	Flowers, 1996

After determining the modes of failure related to the HIS, the research questionnaire was designed and distributed among the experts. The results of the evaluation of failures modes related to the HIS provided based on the opinions of 5 experts are shown in Table 4-6. These results are based on converting linguistic terms listed in Table 1 to their corresponding intuitionistic fuzzy numbers.

Table 4

Occurrence Assessment of HIS Failure Modes Using Intuitionistic Fuzzy Numbers

O	D1	D2	D3	D4	D5
A1	[0.9,0.1]	[0.75,0.1]	[0.35,0.6]	[0.75,0.1]	[0.5,0.45]
A2	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]
A3	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]
A4	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A5	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]
A6	[0.75,0.1]	[0.9,0.1]	[0.5,0.45]	[0.35,0.6]	[0.75,0.1]
A7	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A8	[0.75,0.1]	[0.9,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]
A9	[0.5,0.45]	[0.75,0.1]	[0.9,0.1]	[0.75,0.1]	[0.75,0.1]
A10	[0.5,0.45]	[0.5,0.45]	[0.35,0.6]	[0.35,0.6]	[0.75,0.1]
A11	[0.35,0.6]	[0.1,0.9]	[0.5,0.45]	[0.35,0.6]	[0.5,0.45]
A12	[0.9,0.1]	[0.75,0.1]	[0.75,0.1]	[0.9,0.1]	[0.75,0.1]
A13	[0.1,0.9]	[0.5,0.45]	[0.5,0.45]	[0.35,0.6]	[0.5,0.45]
A14	[0.9,0.1]	[0.75,0.1]	[0.75,0.1]	[0.75,0.1]	[0.9,0.1]
A15	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A16	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A17	[0.75,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]	[0.9,0.1]
A18	[0.75,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A19	[0.75,0.1]	[0.5,0.45]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]
A20	[0.5,0.45]	[0.5,0.45]	[0.35,0.6]	[0.75,0.1]	[0.1,0.9]
A21	[0.5,0.45]	[0.5,0.45]	[0.75,0.1]	[0.75,0.1]	[0.9,0.1]
A22	[0.1,0.9]	[0.9,0.1]	[0.5,0.45]	[0.75,0.1]	[0.1,0.9]
A23	[0.75,0.1]	[0.5,0.45]	[0.75,0.1]	[0.5,0.45]	[0.75,0.1]
A24	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]	[0.75,0.1]	[0.75,0.1]
A25	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]	[0.9,0.1]
A26	[0.9,0.1]	[0.9,0.1]	[0.75,0.1]	[0.9,0.1]	[0.9,0.1]
A27	[0.5,0.45]	[0.1,0.9]	[0.1,0.9]	[0.35,0.6]	[0.5,0.45]

Table 5

Severity Assessment of HIS Failure Modes Using Intuitionistic Fuzzy Numbers

S	D1	D2	D3	D4	D5
A1	[0.8,0.1]	[0.5,0.4]	[0.9,0.1]	[0.7,0.2]	[1,0]
A2	[1,0]	[0.7,0.2]	[1,0]	[0.8,0.1]	[1,0]
A3	[1,0]	[0.7,0.2]	[0.8,0.1]	[0.8,0.1]	[1,0]
A4	[0.8,0.1]	[0.7,0.2]	[0.8,0.1]	[1,0]	[1,0]
A5	[0.7,0.2]	[0.6,0.3]	[1,0]	[1,0]	[0.8,0.1]
A6	[0.9,0.1]	[0.8,0.1]	[0.8,0.1]	[0.7,0.2]	[0.8,0.1]
A7	[0.9,0.1]	[0.9,0.1]	[0.8,0.1]	[1,0]	[0.9,0.1]
A8	[0.9,0.1]	[0.9,0.1]	[0.8,0.1]	[0.7,0.2]	[0.7,0.2]
A9	[0.8,0.1]	[0.5,0.4]	[0.7,0.2]	[0.8,0.1]	[0.6,0.3]
A10	[0.1,0.9]	[0.6,0.3]	[0.7,0.2]	[0.25,0.6]	[0.4,0.5]
A11	[0.25,0.6]	[0.6,0.3]	[0.5,0.4]	[0.1,0.75]	[0.4,0.5]
A12	[0.8,0.1]	[0.9,0.01]	[0.7,0.2]	[0.9,0.1]	[0.8,0.1]
A13	[0.25,0.6]	[0.1,0.9]	[0.4,0.5]	[0.6,0.3]	[0.5,0.4]
A14	[0.8,0.1]	[0.8,0.1]	[1,0]	[1,0]	[0.8,0.1]
A15	[1,0]	[1,0]	[0.8,0.1]	[0.9,0.1]	[0.8,0.1]
A16	[0.9,0.1]	[0.8,0.1]	[0.9,0.1]	[0.9,0.1]	[0.8,0.1]
A17	[0.8,0.1]	[0.8,0.1]	[0.7,0.2]	[0.6,0.3]	[0.7,0.2]
A18	[0.9,0.1]	[0.8,0.1]	[0.9,0.1]	[0.7,0.2]	[0.9,0.1]
A19	[0.7,0.2]	[0.8,0.1]	[0.8,0.1]	[0.8,0.1]	[0.8,0.1]
A20	[0.1,0.75]	[0.6,0.3]	[0.5,0.4]	[0.7,0.2]	[0.25,0.6]
A21	[0.6,0.3]	[0.7,0.2]	[0.5,0.4]	[0.6,0.3]	[0.5,0.4]
A22	[0.1,0.9]	[0.4,0.5]	[0.1,0.75]	[0.1,0.9]	[0.25,0.6]
A23	[1,0]	[1,0]	[0.8,0.1]	[1,0]	[0.7,0.2]
A24	[1,0]	[0.8,0.1]	[1,0]	[0.9,0.1]	[1,0]
A25	[1,0]	[0.8,0.1]	[0.8,0.1]	[0.8,0.1]	[1,0]
A26	[1,0]	[1,0]	[0.8,0.1]	[0.8,0.1]	[1,0]
A27	[0.4,0.5]	[0.6,0.3]	[0.1,0.75]	[0.4,0.5]	[0.25,0.6]

Table 6

Detectability Assessment of HIS Failure Modes Using Intuitionistic Fuzzy Numbers

D	D_1	D_2	D_3	D_4	D_5
A1	[0.4,0.5]	[0.5,0.4]	[0.6,0.3]	[0.4,0.5]	[0.5,0.4]
A2	[0.25,0.6]	[0.4,0.5]	[0.25,0.6]	[0.1,0.75]	[0.5,0.4]
A3	[0.7,0.2]	[0.6,0.3]	[0.5,0.4]	[0.7,0.2]	[0.5,0.4]
A4	[1,0]	[0.9,0.1]	[0.9,0.1]	[0.7,0.2]	[0.8,0.1]
A5	[0.1,0.75]	[0.4,0.5]	[0.1,0.75]	[0.5,0.4]	[0.4,0.5]
A6	[0.1,0.9]	[0.1,0.75]	[0.1,0.75]	[0.25,0.6]	[0.1,0.75]
A7	[0.6,0.3]	[0.25,0.6]	[0.1,0.75]	[0.25,0.6]	[0.1,0.75]
A8	[0.7,0.2]	[0.8,0.1]	[0.9,0.1]	[0.8,0.1]	[0.9,0.1]
A9	[0.4,0.5]	[0.5,0.4]	[0.6,0.3]	[0.5,0.4]	[0.5,0.4]
A10	[0.4,0.5]	[0.6,0.3]	[0.7,0.2]	[0.6,0.3]	[0.5,0.4]
A11	[0.7,0.2]	[0.6,0.3]	[0.7,0.2]	[0.5,0.4]	[0.5,0.4]
A12	[0.1,0.75]	[0.25,0.6]	[0.5,0.4]	[0.4,0.5]	[0.6,0.3]
A13	[0.6,0.3]	[0.7,0.2]	[0.7,0.2]	[0.8,0.1]	[0.9,0.1]
A14	[0.1,0.9]	[0.25,0.6]	[0.1,0.9]	[0.1,0.75]	[0.1,0.75]
A15	[0.1,0.9]	[0.1,0.9]	[0.1,0.9]	[0.1,0.75]	[0.25,0.6]
A16	[0.4,0.5]	[0.25,0.6]	[0.4,0.5]	[0.4,0.5]	[0.1,0.75]
A17	[0.25,0.6]	[0.1,0.75]	[0.4,0.5]	[0.5,0.4]	[0.1,0.75]
A18	[0.1,0.75]	[0.25,0.6]	[0.5,0.4]	[0.7,0.2]	[0.8,0.1]
A19	[0.1,0.9]	[0.1,0.9]	[0.1,0.9]	[0.1,0.75]	[0.1,0.9]
A20	[0.9,0.1]	[0.8,0.1]	[0.9,0.1]	[0.6,0.3]	[0.7,0.2]
A21	[0.4,0.5]	[0.5,0.4]	[0.25,0.6]	[0.5,0.4]	[0.7,0.2]
A22	[0.4,0.5]	[0.5,0.4]	[0.5,0.4]	[0.6,0.3]	[0.6,0.3]
A23	[0.8,0.1]	[0.9,0.1]	[0.4,0.5]	[0.6,0.3]	[0.6,0.3]
A24	[0.1,0.75]	[0.1,0.75]	[0.1,0.9]	[0.1,0.75]	[0.1,0.9]
A25	[0.4,0.5]	[0.25,0.6]	[0.5,0.4]	[0.25,0.6]	[0.25,0.6]
A26	[0.25,0.6]	[0.4,0.5]	[0.5,0.4]	[0.4,0.5]	[0.25,0.6]
A27	[0.5,0.4]	[0.6,0.3]	[0.4,0.5]	[0.5,0.4]	[0.6,0.3]

Step 1: Determining the weight of experts, using entropy method based on the equation (12) to (14). First, the values of E_k for each of the experts was determined as follows.

$$E_k = \left| \begin{array}{ccccc} K_1 & K_2 & K_3 & K_4 & K_5 \\ 0.971 & 0.947 & 0.98 & 0.968 & 0.966 \end{array} \right|$$

Finally, the weight of each of the experts was determined as follows.

$$q_k = \left| \begin{array}{ccccc} K_1 & K_2 & K_3 & K_4 & K_5 \\ 0.174 & 0.314 & 0.121 & 0.191 & 0.199 \end{array} \right|$$

Step 2: Calculating the experts' viewpoint integration matrix: Based on the weights obtained for each of the experts and equation (15), experts' viewpoint integration matrix($\vec{R}(m \times n)$) was determined as follows.

Table 7

Experts' Viewpoint Integration ($\vec{R}(m \times n)$)

Items	O	S	D
A1	[0.725,0.168]	[1,0]	[0.347,0.54]
A2	[0.881,0.1]	[0.808,0.114]	[0.131,0.742]
A3	[0.881,0.1]	[1,0]	[0.287,0.571]
A4	[0.9,0.1]	[0.833,0.131]	[0.828,0.113]
A5	[0.881,0.1]	[0.678,0.209]	[0.498,0.402]
A6	[0.755,0.169]	[0.456,0.437]	[0.567,0.331]
A7	[0.9,0.1]	[0.419,0.463]	[0.599,0.298]
A8	[0.86,0.1]	[0.852,0.053]	[0.377,0.499]
A9	[0.748,0.13]	[0.368,0.538]	[0.766,0.164]
A10	[0.527,0.365]	[1,0]	[0.15,0.738]
A11	[0.338,0.621]	[1,0]	[0.132,0.802]
A12	[0.821,0.1]	[0.857,0.1]	[0.302,0.574]
A13	[0.418,0.536]	[0.74,0.154]	[0.258,0.609]
A14	[0.822,0.1]	[0.847,0.114]	[0.525,0.337]
A15	[0.9,0.1]	[0.785,0.113]	[0.1,0.869]
A16	[0.9,0.1]	[0.492,0.387]	[0.798,0.142]
A17	[0.869,0.1]	[0.607,0.29]	[0.51,0.38]
A18	[0.883,0.1]	[0.236,0.675]	[0.527,0.372]

Items	O	S	D
A19	[0.768,0.16]	[1,0]	[0.759,0.187]
A20	[0.492,0.401]	[1,0]	[0.1,0.795]
A21	[0.708,0.208]	[1,0]	[0.313,0.553]
A22	[0.671,0.273]	[1,0]	[0.362,0.521]
A23	[0.645,0.214]	[0.42,0.464]	[0.544,0.355]
A24	[0.809,0.1]	[1,0]	[0.347,0.54]
A25	[0.9,0.1]	[0.808,0.114]	[0.131,0.742]
A26	[0.888,0.1]	[1,0]	[0.287,0.571]
A27	[0.321,0.643]	[0.833,0.131]	[0.828,0.113]

Step 3: Determining the weight of risk factors: Based on the matrix of table (7) and equations (16) to (19) the weight of each risk factor was determined as follows.

$$e_j = \begin{vmatrix} O & S & D \\ 2.991 & 2.970 & 3.000 \end{vmatrix}$$

$$W_j = \begin{vmatrix} O & S & D \\ 0.334 & 0.330 & 0.335 \end{vmatrix}$$

The above results suggest that O factor has more weight than other two factors, but the weighs of three factors is nearly the same.

Step 4: Formation of weighted matrix of failure items in risk factors: By multiplying weight vector of risk factors in matrix $\vec{R}(m \times n)$ according to equation (20), the matrix of weighted evaluation of failure items of HIS $N(m \times n)$ is obtained as follows.

Table 8

Weighted Matrix of Evaluation of Failure Items: $N(m \times n)$

Items	O	S	D
A1	[0.35,0.551]	[1,0]	[0.133,0.813]
A2	[0.509,0.463]	[0.421,0.488]	[0.046,0.905]
A3	[0.509,0.463]	[1,0]	[0.107,0.829]
A4	[0.537,0.463]	[0.446,0.511]	[0.446,0.481]
A5	[0.509,0.463]	[0.313,0.596]	[0.206,0.736]
A6	[0.375,0.552]	[0.182,0.761]	[0.245,0.69]
A7	[0.537,0.463]	[0.164,0.775]	[0.264,0.666]
A8	[0.482,0.463]	[0.468,0.378]	[0.147,0.792]
A9	[0.369,0.506]	[0.141,0.815]	[0.385,0.545]
A10	[0.221,0.714]	[1,0]	[0.053,0.903]
A11	[0.129,0.853]	[1,0]	[0.046,0.928]
A12	[0.437,0.463]	[0.474,0.467]	[0.114,0.83]
A13	[0.165,0.812]	[0.359,0.539]	[0.095,0.847]
A14	[0.439,0.463]	[0.462,0.488]	[0.221,0.694]
A15	[0.537,0.463]	[0.399,0.486]	[0.035,0.954]
A16	[0.537,0.463]	[0.201,0.731]	[0.415,0.519]
A17	[0.493,0.463]	[0.266,0.664]	[0.213,0.723]
A18	[0.511,0.463]	[0.085,0.878]	[0.222,0.717]
A19	[0.387,0.543]	[1,0]	[0.38,0.57]
A20	[0.202,0.737]	[1,0]	[0.035,0.926]
A21	[0.337,0.592]	[1,0]	[0.118,0.82]
A22	[0.31,0.648]	[1,0]	[0.14,0.804]
A23	[0.293,0.597]	[0.165,0.776]	[0.232,0.706]
A24	[0.425,0.463]	[1,0]	[0.133,0.813]
A25	[0.537,0.463]	[0.421,0.488]	[0.046,0.905]
A26	[0.519,0.463]	[1,0]	[0.107,0.829]
A27	[0.121,0.863]	[0.446,0.511]	[0.446,0.481]

Step 5: Determining the ideal positive and negative values: According to the results of table (8) and equations (21) and (22), the ideal positive values and negative ideal were determined as follows.

$$\begin{array}{r|ccc|} & O & S & D \\ A^{+} = & [0.537,0.463] & [1,0] & [0.035,0.954] \\ A^{-} = & [0.121,0.863] & [0.085,0.878] & [1,0] \end{array}$$

Step 6: Calculating the distance of each option and determining the positive and negative ideal proximity factor: According to relations (23) to (25), the distance of each failure item from ideal positive and negative distance and closeness index value are as given in Table 9.

Table 9

Results of Distance of each Option from the Ideal Positive and Negative and Closeness Coefficient

	Factors	d_i^+	d_i^-	C_i	Rank
A1	Changing objectives	0.161	0.971	0.858	10
A2	Lack of managerial skills	0.064	1.067	0.943	6
A3	Senior Management Change	0.141	0.991	0.875	9
A4	Non- commitment of senior management	0.480	0.652	0.576	19
A5	Wrongly-defined roles and responsibilities	0.067	1.065	0.941	7
A6	Inappropriate planning	0.345	0.787	0.695	15
A7	Lack of IT management or poor project team (IS)	0.049	1.082	0.956	4
A8	Lack of project maintenance budget	0.501	0.631	0.557	20
A9	Lack of coordination (conflict among sectors and groups, failure to receive project approval from all sectors)	0.471	0.661	0.584	18
A10	Excessive use of external counselors	0.655	0.477	0.422	22
A11	Lack of control over external counselors	0.731	0.400	0.354	25

	Factors	d_i^+	d_i^-	C_i	Rank
A12	Failure to specify user attributes	0.321	0.811	0.716	13
A13	Excessive number of organizational units involved	0.789	0.343	0.303	27
A14	Unrealistic programs	0.042	1.090	0.963	3
A15	Lack of skill / knowledge	0.009	1.122	0.992	1
A16	Lack of employees participation	0.299	0.833	0.736	12
A17	Negative beliefs about computer systems	0.348	0.784	0.693	16
A18	Non-commitment (accountability) of users	0.375	0.757	0.669	17
A19	Inappropriate personnel training	0.329	0.803	0.709	14
A20	project novelty and unfamiliarity	0.738	0.393	0.348	26
A21	Lack of ease of use	0.534	0.598	0.528	21
A22	Multiple users	0.657	0.475	0.419	23
A23	excessive complexity of project plan flaws	0.277	0.855	0.755	11
A24	Lack of integration between system and organizational activities	0.035	1.097	0.969	2
A25	Improper software development	0.054	1.077	0.952	5
A26	Inconsistency between company culture and change requirements (compatibility)	0.068	1.063	0.94	8
A27	Technology based on human relations	0.718	0.414	0.366	24

Discussion

In the present study, the proposed model was assessed to evaluate and prioritize the failure causes of FMEA-based HIS in an intuitionistic fuzzy environment in the case of Kerman hospitals, Iran. In this regard, first, decision-makers weight and risk factors were calculated based on linguistic terms and intuitionistic fuzzy numbers of Table 2. Aggregate decision matrix was then calculated based on the obtained weights and principles of intuitionistic fuzzy numbers. Finally, the intuitionistic fuzzy TOPSIS technique (Boran et al., 2009) was used to prioritize the failure modes for the failure causes of HIS.

The findings indicated that the following factors have the greatest impact on the HIS failure.

- Lack of skills/knowledge
- Lack of integration between system and organizational activities
- Unrealistic planning
- Lack of IT management or poor project team (IS)
- Improper software development
- Lack of managerial skills
- Wrongly-defined roles and responsibilities
- Inconsistency between company culture and change requirements (compatibility)

According to the findings, lack of skill/knowledge is the first factor contributing to the HIS failure. Personnel have a great contribution to the success of the programs. Obviously, the higher the employees' level of awareness is and the more positive attitude they have, the greater impact they will have on the success of a program. Hence, the HIS users should have an appropriate understanding of how the HIS operates; otherwise, system failures would be probable. If the users who run the HIS system have no knowledge about this system, achieving the desired goals will be difficult (Mbananga et al, 2002). The next factor affecting the HIS failure is the lack of integration between system and organizational activities. The HIS is effective and efficient when the system interacts with the hospital activities and is well-connected. Each of the software and ISs-based business processes are developed at a specific time; therefore, the non-failure of such processes is defined based on the interaction of the HIS with the activities. The third HIS failure factor is the unrealistic planning for these systems. Sometimes, the IS projects fail because their scope is broad and no value has been created for them over the years. In other words, expanding the scope is the result of a weak attempt to define demands explicitly. The problem arises when the difference between needs and demands is ignored. Defining needs and demands in each project is often a phase where simple mistakes are unavoidable. Projects are used for various objectives like technical, financial and commercial ones so the demands are at different levels of the projects. The systematic assessment of the HIS supports the activities to continuously improve the performance, avoid medical errors and reduce stressful responses and their related costs by matching software with the needs of the staff and network users(Hamborg et al., 2004). The fourth factor affecting the HIS failure is the lack of IT management or poor IS project team. The project manager's perception and belief in the developed system would definitely enhance the IS project managerial and organizational support. When there is no such commitment and belief among the IT managers regarding the implementation and success of ISs, the consequence certainly is the system failure. In some cases, it is not clear who is in charge of performing a task; therefore, each group wriggles out of his duties. Each group usually attributes success to their own performance and failures to poor performance of other groups. The role of managers is of effect when accepting the change and adopting technology by executive staff. Further, the supervisors act as facilitators through delegating responsibility to individuals and as supporters in sharing knowledge through communication with their subordinates(Hamidfar, 2008). If the HIS project bears the IT management support and responsibilities, then it's likely that this process will be viewed positively by both end-users and the technical staff of the ISs and their employees. The poor management reduces the efficiency and enhances the IS project costs and it is confirmed more than any other factor. The fifth HIS failure factor was the improper software development. The IS projects spend much more time and cost than the initial predicted values in almost each organization; however, the completed systems do not function properly in spite of all these costs and time. Prior to implementing an IS, the managers must define their information needs. Managers should also consider defining data and eliminating ambiguities and mistakes. Some of these problems are imposed by the technology employed in the ISs; however, a majority of them are associated with the management and organization. Next significant factor is the lack of managerial skills. The manager's talent and ability plays the most significant role in project success since today's concerns are not technical but management issues. The inexperienced managers lack communication, leadership and management skills. Unfortunately, the technical competence is the only criterion for selecting a project manager in many organizations and they certainly appoint such highly skilled programmers or analysts to job positions regardless of the project management conditions. The seventh factor influencing the HIS failure was the wrongly-defined roles and responsibilities. Failure of systems in the first place is not due to technical defects but rather due to failure to concern those who are involved or affected by the system. Individuals involved and affected by any system have some expectations from the system, which should be of concern. If the system is exposed to a large amount of user interaction, it is successful and if the user does not use it or fail to use it properly, it fails and is unsuccessful. The source of the conflict refers back to the failure to define the role of each party involved in the design and implementation of the system. To avoid the conflicts, the best solution is to inform the analyst and designer of the roles and tasks. In other words, the analyst and designer should be familiar with the activities. The conflicts are mainly due to the lack of knowledge of each other. The last major factor in the HIS failure is inconsistency between company culture and change requirements (compatibility). An IS is considered to be a failure if its design does not conform to the structure, culture or intended objectives. IS managers and designers should regard whether or not the HIS is compatible with the hospital culture. IS should not only contradict the hospital structure and function but also facilitate it.

Conclusions

HIS is a set of processes to improve the efficiency and effectiveness of a healthcare organization (hospital) so that the hospital would perform its functions well and achieve the desired goals (Lærum et al, 2004). In fact, the HIS is designed to integrate information in clinical and administrative management fields by computers. These systems should have the potentials to store, accurately and timely retrieve information, integrate data and provide effective data and exchange data with other applications in the hospital environment (Gupta, 2007). Surveys, however, show that over 50% of these projects fail (Safa'a, 2012). Failure of the hospital IS projects implies the waste of resources, i.e. a major obstacle to organizational investment (Nauman et al, 2005). Since a large number of ISs are problematic, their designers, builders and users should know why and how the systems succeed or fail. If the IS cannot achieve its goals, the expected benefits would not be achieved. In this case, the system cannot resolve the organizational problems, especially those of a time-consuming project that requires significant financial investment to ensure its success (Lee et al, 2008). In this regard, prioritizing the HIS failure causes is of paramount importance. Among the various methods for risk assessment, FMEA is one of the most effective approaches, which is capable of detecting and assessing risks (SAE, 2002). History of multi-criteria decision-making methods denotes that such methods have been used either separately or with other methods for the assessment of risks in different cases. Fuzzy sets are vague sets with imprecise boundaries, which were first introduced by Lotfi A. Zadeh in an article in 1965, which aimed to create a simpler model for complex systems. Following the development of fuzzy logic, intuitionistic fuzzy logic and fuzzy sets were introduced by Atanassov in 1983, as an extension to fuzzy logic (Atanassov, 1986). A part from a degree of membership, intuitionistic fuzzy sets also have a degree of non-membership. This leads to a decision matrix with a more accurate and reliable assessment and subsequently a more efficient and effective decision-making capability. Theory of intuitionistic fuzzy set does not rule out the theory of fuzzy set and does not diminish its capabilities. Instead, it provides a more effective and efficient tool for dealing with uncertainty by using the extended form of fuzzy sets. On this basis, the current paper used the theory of intuitionistic fuzzy sets for the analysis of failure mode and effects. This study aimed to assessment of HIS failure modes using intuitionistic fuzzy FMEA in Kerman province; therefore, this study is geographically limited to Kerman province. In terms of analysis techniques, entropy and Topsis are the only techniques used; thus, this research can be conducted in other communities, using other decision making techniques.

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