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A fuzzy superiority and inferiority ranking based approach for IT service management software selection

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Abstract

Purpose – Information technology service management (ITSM) has become a major IT department management system in organizations. Successful implementation of ITSM depends on select adequate ITSM software. Evaluation and selection of the ITSM solution or software packages is complicated and time-consuming decision-making problem. This paper aims to present an approach for dealing with such a problem.

Design/methodology/approach – This approach introduces functional, non-functional requirements and novel fuzzy out-ranking evaluation method for ITSM software selection. The presented approach breaks down ITSM software selection criteria into two broad categories, namely, functional (service strategy, service design, service transition, service operation, continual service improvement according to Information Technology Infrastructure Library V3) and non-functional requirements (quality, technical, vendor, implementation) including totally 46 selection criteria. A novel fuzzy superiority and inferiority ranking (FSIR) was developed and made applicable for ITSM software selection based on identified criteria.

Findings – The proposed approach is applied to IT services company to select and acquire ITSM software, and the provided numerical example illustrates the applicability of the approach for this choice. The approach can facilitate firms to achieve suitable ITSM software and have a precise acquisition decision; however, the limitation of dependency on experts' competence and proficiency in the both ITSM field and IT technical issues exists.

Research limitations/implications – The approach can facilitate firms to achieve suitable ITSM software and have a precise acquisition decision; however, the limitation of dependency on experts' competence and proficiency in the both ITSM field and IT technical issues exists.

Practical implications – Facilitating of ITSM implementation through its handy software selection is the major impact of current research.

Originality/value – A facile FSIR-based approach for software selection has been customized to contribute to the current literature in the ITSM field. Facilitating of ITSM implementation through its handy software selection is the major impact of current research.

Keywords Information technology service management (ITSM), Software selection, Superiority and inferiority ranking (FSIR)

Paper type Research paper

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1. Introduction

Information technology service management (ITSM) – as a concept to support this radical transformation – is a strategy by which information systems are offered under contract to customers and performance is managed as a service (Pollard and Cater-Steel, 2009). ITSM provides a framework to structure IT operations that enables organizations to deliver quality

IT services to meet business needs and adhere to service level agreements (Mesquida *et al.*, 2011). In addition, ITSM manages the IT function as a service. This stands in contrast to more technology-centered approaches to IT operations (Iden and Eikebrokk, 2013).

Information Technology Infrastructure Library (ITIL) is a collection of defined and published best practice processes for ITSM, developed in 1989 by the British government in their Central Computer Telecommunications Agency (CCTA, now the Office of Government Commerce). It serves as a roadmap for process improvement to help IT professionals build a foundation for ongoing service excellence while meeting budget and regulatory requirements (OGC, 2012). Iden and Eikebrokk (2013) have discussed that there are several reasons why ITSM and ITIL should attract researchers: First, there is evidence that ITSM and ITIL are highly popular among IT managers. For example, professionals from more than 150 countries have passed the various ITIL exams, which have been translated to more than 20 languages; that more than 270,000 exams were taken in 2010; that 24 ITIL software tools are endorsed to be ITIL compatible. Second, there is a growing research interest in IT function characterization. Extant literature is nevertheless fragmented and not properly integrated. Third, ITSM and ITIL open up an array of research perspectives, for example, service innovation, the capabilities of the IT function, business/IT alignment and IT governance.

There are factors that might have an influence on the ITSM implementation projects success and benefits acquisition such as top management support, personnel training, careful software selection, use of consultants, interdepartmental communication, organizational culture and customer-focused metrics (Ahmad *et al.*, 2013; Pollard and Cater-Steel, 2009). Processes are another key success factor of ITSM, and it must be taken into account that adequate techniques and tools must be applied (Stamelos *et al.*, 2000). Careful ITSM software selection is an important factor to an extent which would be hardly possible to achieve expected benefits without using a proper ITSM software (Pollard and Cater-Steel, 2009). According to Pollard and Cater-Steel (2009), the timing and selection of the ITSM software to support ITIL implementation can be problematic and even improper ITSM software have the potential to inhibit implementation of new processes in an organization.

The ITSM software industry is one of the fastest growing sectors in the computer software industry which now includes hundreds of ITSM software solutions in the market (Coyle *et al.*, 2010; Flycast-Partners, 2012). The number of ITSM software vendors and the range of their systems' functionality have further expanded in recent years. Hence, because of limitations in available resources, the range of functionality in ITSM software, and the diversity of alternatives, selecting an ITSM solution, that meets closely the specific needs of an organization is a time-consuming and complex task (Hubbert *et al.*, 2011) which calls for applicable methods or models for enhancing the selection process. However, having a review on ITSM literature, the author has found the lack of framework for evaluating and selecting ITSM software packages (Rouhani and Ravasan, 2014).

To sum up, following a holistic framework for assessing and selecting ITSM software from a variety of functional and non-functional perspectives can help IT managers to deal with this problem and diminish the need for future customizations. It is noticeable that each software selection framework needs its own criteria and its computation procedures. ITSM software is a novel issue, and there is no specific and certificate-based framework for ITSM software selection except the work of Rouhani and Ravasan (2014) whom customized The TOPSIS for ITSM selection. What is therefore needed is a holistic framework for assessing ITSM software from a variety of functional and non-functional perspectives which can be operated by exact values and human judgment. It should be clarified that recent studies such as Ghazanfari *et al.* (2014) and Rouhani *et al.* (2012) addressed the issue of evaluation for other software port community software (PCS) based on the criteria of intelligence which is far from the ITSM package requirements domain. And also, they utilized the conventional method of TOPSIS. Despite the recent works, "ITSM software selection model" that should include the criteria, process, suitable calculation method for human preferences and converter to best rank, is the gap in literature of information systems. This paper, as a potential contribution to ITSM literature, is intended to provide such a framework, and, hence, my goal is to develop a practical and holistic evaluation framework that is applicable to ITSM software selection efforts. In practice, the results of this paper would enable IT managers to achieve a comprehensive understanding of ITSM software selection criteria and help them to make a better system acquisition decision.

The paper is organized as follows: Section 2 presents literature reviews on the concept of ITSM, ITSM software market, software selection and finally ITSM solution selection criteria. Section 3 describes the FSIR method. Section 4 illustrates proposed approach. Section 5 provides a numerical example, and, finally, Section 6 offers the research findings and conclusion.

2. Literature review

This section encompasses a brief introduction of ITSM and related frameworks, a review of software selection methods and factors, and, finally, ITSM software selection criteria are provided with regard to the nearest relevant literatures.

2.1 Information technology service management

In the service marketing literature, services were traditionally distinguished from goods as having four unique characteristics, i.e. intangibility, heterogeneity, inseparability and perish ability (Jia and Reich, 2013). What is more, a service is a means of delivering value to customers by facilitating outcomes the customers want to achieve without the ownership of specific costs or risks. Also, service management is defined as a set of specialized organizational capabilities for providing value to customers in the form of services (van Bon *et al.*, 2007). ITSM is concerned with the delivery and support of IT services that are appropriate to the business requirements of an organization. ITSM provides specific processes, frameworks, methodologies and guidance to manage planning, implementation and assessment of IT service processes to optimize tactical and strategic IT operations-related activities (Mesquida *et al.*, 2011). However, being familiar with ITSM software, vendors' strengths, weaknesses and key systems' features would be useful for organizations wish to implement ITSM software. The information and material provided in this section can be considered as a starting point for gaining such awareness (Rouhani and Ravasan, 2014).

2.2 Information technology service management solution selection criteria

ITSM is a process-oriented framework which merges process management and industry best practices into a standard approach for optimizing IT services. ITSM provides specific processes, frameworks, methodologies and guidance to manage planning, implementation and assessment of IT service processes to optimize tactical and strategic IT operations-related activities (HP, 2003; itSMF, 2012). To cover these functionalities, ITSM solution or software should support wide range of functional and non-functional requirements to enable organization in ITSM deployment. Organization ought to utilize the standard criteria to assess and select ITSM software and solutions. Proper solution selection is critical for ITSM implementation. That is, the IT department role to make sure which they pick the right solution that fits its requirements to avoid ending up with an underutilized solution (Pollard and Cater-Steel, 2009). Pollard and Cater-Steel (2009) presents a case where proper solution selection allowed for easier configuration of the processes. In addition, solution selection is a critical issue because of its influence on perceived usefulness. Following, functional and non-functional criteria for ITSM solution selection are presented. Recently, Shrestha *et al.* (2015) have designed and evaluated a tool for IT process assessment. They considered ISO/IEC 15504, ISO/IEC 20000 and ITIL® as fundamentals for assessment criteria in their software-mediated process assessment approach which was surveyed online subsequently.

2.1.1 Functional criteria. To deploy the ITSM, organization needs sets of frameworks and best practices in the form of standard processes. Therefore, ITSM software (as process enabler) should have value added unique specifications based on those standard processes beside common automation specifications. The latest and most complete ITSM framework is ITIL V3 which is considered as unique functional criteria of this software type in my proposed approach. ITIL is defined here as a set of prescribed practices that an IT function may use to achieve ITSM (Iden and Eikebrokk, 2013).

To determine ITSM solution selection criteria, in this research, the processes of ITIL V3 (van Bon *et al.*, 2007) was considered as the base of functional requirements. It is because of the fact that ITIL V3 is believed to be one of the most popular service-oriented ITSM frameworks in the market (Axios-Systems, 2008; Hubbert, 2010; McNaughton *et al.*, 2010; Pollard and Cater-Steel, 2009).

2.1.2 Non- functional criteria. The non-functional requirements are features of the ITSM software that are not covered by its functional description but are related to the capability and resiliency of the software or solution. Some researchers and practitioners have developed categories for the non-functional requirements from different viewpoints. Jadhav and Sonar (2011) classified these criteria as quality, technical, vendor, output and opinion categories based on ISO/IEC9126. Similarly, Sen *et al.* (2009) divided these requirements into quality characteristics, technical factors and socio-economic factors (business and vendor). Previously, these different sets of non-functional criteria were proposed by Karlsson (1997); Erol and Ferrell (2003); Wei and Wang (2004); and Wei *et al.* (2005). In this research, I have considered Jadhav and Sonar (2011) and Sen *et al.* (2009) because their criteria are universal for all software types, and ISO has accepted their criteria for quality models of software engineering as ISO/IEC9126.

Based on above, functional and non-functional criteria for ITSM software or solutions are proposed as Table I. These criteria are adopted from Rouhani and Ravasan (2014).

The literature review shows that former studies consider only the traditional functional or non-functional criteria but do not offer a process that includes functional and non-functional requirements and a customized approach for ITSM software selection-based human judgments. In the current research, to fill that gap, various aspects of ITSM software evaluations, selection and implementation with novel idea of emphasis on ITSM requirements and applicable selection process are considered in proposed approach.

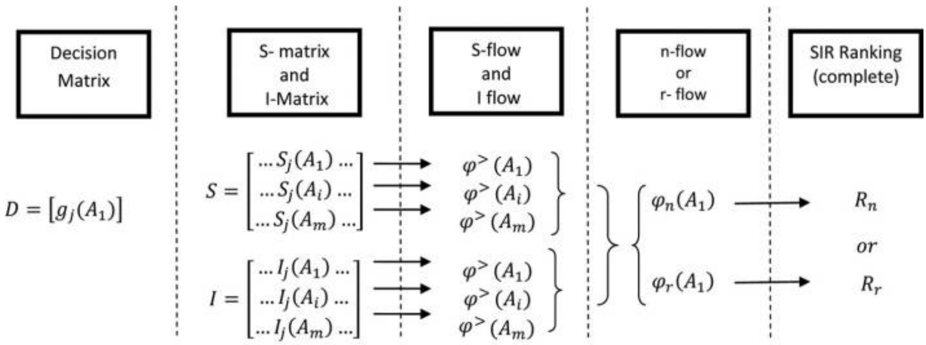
3. Fuzzy superiority and inferiority ranking

In current research, a novel fuzzy Multi Criteria Decision Making (MCDM) is presented and customized for ITSM software selection; therefore, here the theoretical background of this method is reviewed. The classical superiority and inferiority ranking (SIR) method was presented by Xu (2001) as a considerable development of outranking relations, which simultaneously uses the superiority and inferiority information, which can more comprehensively and can efficiently investigate the priority among alternatives. The classical SIR method which were introduced by Xu (2001) had five phases and was depicted in Figure 1.

Criteria label	Criteria name	Criteria label	Criteria name
C1	Service portfolio management	C24	Service reporting
C2	Demand management	C25	Service measurement
C3	Financial management	C26	Reliability
C4	Service catalog management	C27	Usability
C5	Service level management	C28	Maintainability
C6	Capacity management	C29	Efficiency
C7	Availability management	C30	Personalizability
C8	IT service continuity management	C31	Portability
C9	Information security management	C32	Communication protocol
C10	Supplier management	C33	Platforms
C11	Transition planning and support	C34	Database management system
C12	Change management	C35	Programming language
C13	Service asset and configuration management	C36	Documentations
C14	Release and deployment management	C37	Standard configurations
C15	Service validation and testing	C38	Security
C16	Service evaluation	C39	Vendor reputation
C17	Knowledge management	C40	Training and support
C18	Event management	C41	Length of experience
C19	Incident management	C42	Consulting service
C20	Problem management	C43	License price
C21	Access management	C44	Implementation cost
C22	Request fulfillment	C45	Implementation time
C23	Seven-step improvement process	C46	Training cost

Source: Rouhani and Ravasan (2014)

Table I. ITSM software selection criteria



Source: Xu (2001)

Figure 1. The process of SIR ranking

Then, one of the limitations of traditional technique for SIR is using crisp values in the evaluation process. Some criteria are difficult to measure by crisp values; so, during the evaluation, these criteria are often neglected (Dağdeviren and Yüksel, 2008). But, in many real cases, the human preference model is uncertain, and decision makers are unable to assign crisp values for their judgments (Chang *et al.*, 2007; Shyur and Shih, 2006). Decision makers face difficulty to handle uncertainties of real world in the traditional MCDM approach and prefer interval judgments than in pointing out their judgments in crisp values (Amiri, 2010). Thus, FSIR is a suitable method to solve ranking problems (Chai *et al.*, 2012).

Therefore, this study has developed the traditional MCDM method (SIR) under uncertain environments.

In this research, I use triangular fuzzy numbers (TFNs) for FSIR because of the ease of use for decision makers in doing calculations. Also, it has been displayed that modeling with TFNs is an effective way to formulate decision problems when the available information is subjective and inaccurate (Chang and Yeh, 2002; Chang *et al.*, 2007; Kahraman *et al.*, 2004). Some important basic definitions of fuzzy sets are given below (Amiri, 2010; Rouhani *et al.*, 2012):

(1) TFN $\tilde{a}$ can be defined by a triplet (l, m, u) as shown in Figure 2. The membership function $\mu_{\tilde{a}}(x)$ is defined as given below.

(2) If $\tilde{a}$ and $\tilde{b}$ are two TFNs, which are shown by the triplets (l_1, m_1, u_1) and (l_2, m_2, u_2), respectively, then the operational laws of these two TFNs are as follows:

$$\tilde{a}(+)\tilde{b} = (l_1, m_1, u_1)(+)(l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{1}$$

$$\tilde{a}(-)\tilde{b} = (l_1, m_1, u_1)(-)(l_2, m_2, u_2) = (l_1 - l_2, m_1 - m_2, u_1 - u_2) \tag{2}$$

$$\tilde{a}(\times)\tilde{b} = (l_1, m_1, u_1)(\times)(l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \tag{3}$$

$$\tilde{a}(/)\tilde{b} = (l_1, m_1, u_1)(/)(l_2, m_2, u_2) = (l_1/u_2, m_1/m_2, u_1/l_1) \tag{4}$$

$$\tilde{a} = (kl_1, km_1, ku_1) \tag{5}$$

(3) A linguistic variable, which is indicated by words such as very low, low, medium, high and very high, is used to describe a complex condition (Zadeh, 1976). These linguistic values can also be represented by fuzzy numbers (Amiri, 2010).

(4) The weighted, normalized, fuzzy-decision matrix is calculated using the formula below:

$$\begin{aligned} \tilde{v} &= \lfloor \tilde{v}_{ij} \rfloor_{n\times j}, \qquad i = 1, 2, \ldots, n, \qquad j = 1, 2, \ldots, m \\ \tilde{v}_{ij} &= \tilde{x}_{ij} \times W_i \end{aligned} \tag{6}$$

A set of the presentation rating of $A_j = (j = 1, 2, \ldots, m)$, concerning the criteria $C_i = (i = 1, 2, \ldots, n)$ is called $\tilde{x} = (\tilde{x}_{ij}, i = 1, 2, \ldots, n, \quad j = 1, 2, \ldots, m)$. A set of importance weights of each criterion is determined by $W_i = (i = 1, 2, \ldots, n)$.

In traditional SIR method, inputs and calculations are based on crisp values, although in current research, human input is used in ITSM evaluations and fuzzy input should be considered; consequently, I have extended Xu (2001) method for decision matrix input and criteria weighting. Based on the above fuzzy definition and classical SIR method proposed by Chai *et al.* (2012) and Xu (2001), the steps of proposed FSIR method applied in this paper can be summarized as below.

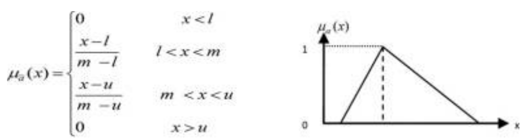


Figure 2. TFN $\tilde{a}$

Step 1: Selecting the linguistic value

Choose the linguistic values (x_{ij}, $i = 1, 2, \ldots, n, j = 1, 2, \ldots, m$) for alternatives concerning the criteria. The fuzzy linguistic rating (x_{ij}) keeps the ranges of normalized TFNs that belong to [0, 1]; hence, there is no need for normalization.

Step 2: Building a decision matrix

Assume $A_1, A_2, \ldots A_m$ be m alternatives and $g_1, g_2, \ldots g_n$ be n criteria and $g_1(A_i)$ be the criteria value of the ith alternative A_i with respect to the jth criterion g_j. With these criteria value, decision matrix with TFN was built:

$$D = \begin{bmatrix} g_1(l_1, m_1, u_1) & \cdots & g_j(l_1, m_1, u_1) & \cdots & g_n(l_1, m_1, u_1) \\ \cdots & & \cdots & & \\ g_1(l_i, m_i, u_i) & \cdots & g_j(l_i, m_i, u_i) & \cdots & g_n(l_i, m_i, u_i) \\ \cdots & & \cdots & & \cdots \\ g_1(l_m, m_m, u_m) & \cdots & g_j(l_m, m_m, u_m) & \cdots & g_n(l_m, m_m, u_m) \end{bmatrix}$$

Step 3: Computing the weighted, normalized, fuzzy-decision matrix

Assign fuzzy weight for each criteria by using equation (6).

Step 4: Computing $p_j(A_i, A_k)$

For each pair (A_i, A_k), $i, k = 1,\ldots, m$, $p_j(A_i, A_k) = f_j(g_j(A_i) - g_j(A_k)) = f(d)$ is called the preference intensity which represents the superiority of A_i over A_k and also the inferiority of A_k, over A_i, with respect to the *j*th criterion. For TFNs, $p_j(A_i, A_k)$ are calculated based on equation (2):

$$p_j(A_i, A_k) = f_j(g_j(l_i, m_i, u_i) - g_j(l_k, m_k, u_k)) = f(d)$$

$$p_j(A_i, A_k) = (l_i - l_k,\ m_i - m_u,\ u_i - u_k) = f(d) \tag{7}$$

Step 5: Converting fuzzy numbers to real values

There are several ways for defuzzification; in view of the fact, the difference of presented values for alternatives based on each criteria is the foundation of priority and reverse of this difference also consider in calculation. Therefore, defuzzification formula must also keep the sign of the differentiation of fuzzy numbers. Thus, in this paper, the regular defuzzification methods are not useable (radical operator or power operator omit the sign of difference). Therefore, the equation (8) is applied for defuzzification (Chen, 1999). So, because of importance of sign of numbers in SIR method, TFNs were converted to crisp values by applying this equation:

$$A_i = \frac{(l_i + 2m_i + u_i)}{4} \tag{8}$$

Step 6: Computing $f(d)$ with appropriate generalized criterion function

Where $f(d)$ is a non-decreasing function from R (the real number) to [0,1] such that $f(d) = 0$ for $d \leq 0$. Such a function is called a generalized criterion. In Xu (2001) several generalized criterion was introduced. In this paper, I select Gaussian criterion because it is the best nonlinear function:

$$f_{(d)}\begin{cases}1 - exp\left(-\dfrac{d^2}{2\sigma^2}\right) & if\, d > 0\\ 0 & if\, d \leq 0\end{cases} \tag{9}$$

Step 7: Calculating the SIR index

For alternative A_i, the superiority index $S_j\,(A_i)$ and the inferiority index $I_j\,(A_i)$ with respect to criterion j are defined by:

$$S_j(A_i) = \sum_{k=1}^{m} P_j(A_i, A_k) = \sum_{k=1}^{m} f_j(g_j(A_i) - g_j(A_k)) \tag{10}$$

$$I_j(A_i) = \sum_{k=1}^{m} P_j(A_k, A_i) = \sum_{k=1}^{m} f_j(g_j(A_k) - g_j(A_i)) \tag{11}$$

where P_j is the preference intensity and $j = 1 [\ldots], n, i, k = 1 [\ldots], m$. The superiority indexes and the inferiority indexes form two types of matrices, called S-matrix and I-matrix. The superiority matrix (S-matrix):

$$S = \begin{bmatrix} S_1(A_1) & \cdots & S_j(A_1) & \cdots & S_n(A_1)\\ \cdots & & \cdots & & \cdots\\ S_1(A_i) & \cdots & S_j(A_i) & \cdots & S_n(A_i)\\ \cdots & & \cdots & & \cdots\\ S_1(A_m) & \cdots & S_j(A_m) & \cdots & S_n(A_m)\end{bmatrix} or \quad S = (S_j(A_i))_{m\times n}$$

The inferiority matrix (I-matrix):

$$I = \begin{bmatrix} I_1(A_1) & \cdots & I_j(A_1) & \cdots & I_n(A_1)\\ \cdots & & \cdots & & \cdots\\ I_1(A_i) & \cdots & I_j(A_i) & \cdots & I_n(A_i)\\ \cdots & & \cdots & & \cdots\\ I_1(A_m) & \cdots & I_j(A_m) & \cdots & I_n(A_m)\end{bmatrix} or \quad I = (I_j(A_i))_{m\times n}$$

Step 8: Computing the SIR flow

If V be the aggregation function, then for each alternative A_i, the superiority flow and the inferiority flow defined as below:

$$\text{The superiority flow: } \varphi^{>}(A_i) = V[S_1(A_i), \ldots, S_n(A_i)] \tag{12}$$

$$\text{The inferiority flow: } \varphi^{<}(A_i) = V[I_1(A_i), \ldots, I_n(A_i)] \tag{13}$$

Obviously, the higher S-flow $\varphi^{>}(A_i)$ and the lower I-flow $\varphi^{<}(A_i)$, the better alternative A_i is.

Step 9: The SIR ranking

By applying the superiority flow, $\varphi^{>}(A_i)$ and the inferiority flow $\varphi^{<}(A_i)$, alternatives will be ranked. According to the constructions, the superiority flow $\varphi^{>}(A_i)$, measures how A_i is globally superior to all the others and the inferiority flow, $\varphi^{<}(A_i)$ measures how A_i is globally inferior to all the others. Therefore, the higher S-flow $\varphi^{>}(A_i)$ and the lower I-flow $\varphi^{<}(A_i)$, the better alternative $A_i$is.

According to the descending order of $\varphi^{>}(A_i)$, has obtained a complete ranking (called S-ranking) $R_{>} = \{P_{>}, I_{>}\}$ of the alternatives:

$$A_i P_{>} A_k \; iff \; \varphi^{>}(A_i) > \varphi^{>}(A_k) \text{ and } A_i I_{>} A_k \; iff \; \varphi^{>}(A_i) = \varphi^{>}(A_k)$$

Similarly, according to the ascending order of $\varphi^{<}(A_i)$, has obtained another complete ranking (called I-ranking) $R_{<} = \{P_{<}, I_{<}\}$ of the alternatives:

$$A_i P_{<} A_k \; iff \; \varphi^{<}(A_i) < \varphi^{<}(A_k) \text{ and } A_i I_{<} A_k \; iff \; \varphi^{<}(A_i) = \varphi^{<}(A_k)$$

In general, $R_{>}$ and $R_{<}$ are different complete rankings. The two complete ranking structures $R_{>} = \{P_{>}, I_{>}\}$ and $R_{<} = \{P_{<}, I_{<}\}$ are then combined into a partial ranking structure $R = \{P, I, R\} = R_{>} \bigcap R_{<}$ according to the following intersection principle. Given any two alternatives, A and A' has defined the preference relation P by:

$$APA' \, iff (AP_{>} A' \text{ and } AP_{<} A') \text{ or } (AP_{>} A' \text{ and } AI_{<} A') \text{ or } (AI_{>} A' \text{ and } AP_{<} A')$$

For complete ranking, some synthesizing flows can be used by decision maker. In this paper, I used net flow (n-flow) (like the net flow in PROMETHEE) and the relative flow (r-flow) (like the relative distance in TOPSIS):

$$\text{n} - \text{flow}: \varphi_n(A_i) = \varphi^{>}(A_i) - \varphi^{<}(A_i) \tag{14}$$

$$\text{r} - \text{flow}: \varphi_r(A_i) = \frac{\varphi^{>}(A_i)}{\varphi^{>}(A_i) + \varphi^{<}(A_i)} \tag{15}$$

Thus, $\varphi_n(A_i)$ or $(\varphi_r(A_i))$ can be used to gain complete ranking.

- Notice that $\varphi_n(A_i)$ can be any real number and $\varphi_r(A_i)$ is always between 0 and 1 (Xu, 2001).

4. The proposed fuzzy superiority and inferiority ranking approach

In many firms, the process of selecting ITSM software or service desk software is a main cause of stress and the final decision often comes after months of deliberation. Typically, this is because of the wide variations in available features across products and the lack of a clear understanding of which features will best suit the company's needs. However, this process can be made easier by utilizing proposed approach. In this research, FSIR has been used to evaluate and select ITSM software with respect to the criteria presented in Tables II and Appendixes. There are three stages to the evaluation and selection of the ITSM software based on evaluation criteria:

1. determining ITSM software to be evaluated as alternatives, and recognizing the criteria to be used in the assessment process;
2. structuring the fuzzy decision-matrix and assigning criteria weights; and
3. computing the superiority and inferiority of alternatives with FSIR and finally, ranking the evaluation report.

A schematic diagram of these stages is illustrated in Figure 3. In following sections, this approach is applied to solve a numerical example.

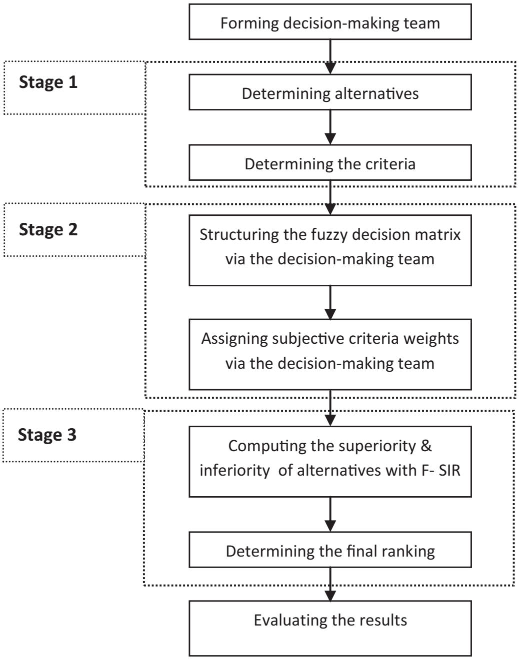


Figure 3.
The proposed ITSM software selection approach based on FSIR method

5. Numerical example

The proposed approach has been applied in local Iranian company in the field of IT services. The company is one of the largest providers of internet services and local/global network connections in the Iranian private sector. Providing diverse solutions for internet access, international telephone calls and data center services such as web hosting, domain registration, dedicated servers and many more are among the most important activities and services provided by the company. The company services more than 1.5 million customers mainly subscribing for ADSL service all over the country which has been growing throughout the past few years. The company employs more than 700 managers and work force to provide all customers with good quality services. To sustain the company's competitiveness in the market and improve efficiency while decreasing service support cost, executive managers of the company decided to select and acquire ITSM software. According to the research steps described above, the proposed FSIR approach was explained along with applications and ITSM software for the company was selected using the approach.

5.1 Forming decision-making team

Expert teams should be formed to evaluate the functional and non-functional aspects for alternatives of ITSM software. The teams consisted of service-related managers in the company (five people for the five service departments) from all departments for evaluation of functional criteria. And, one team included technical managers of company (three people) have responsibility for evaluation of non-functional criteria. Concurrently, external consultants of the company (two people) with telecom experiences and IT service skills helped to evaluate the functional and non-functional requirements for considered solutions of vendors. The FSIR technique was introduced to them (ten people), and they were trained for filling the spreadsheets of evaluation by verbal and simple propositions.

5.2 Identification of alternatives and criteria

If there are more ITSM software alternatives in the list than expected, a pre-selection process should be used to reduce the number of alternatives to an acceptable level (five or four) so that the selection process will not be too lengthy. Therefore, sequential elimination methods are only used to separate the strong candidates among others and the elimination standards were eliminating companies with regard to sanction limitations (USA) against Iran and lack of experience in Telecom sector. As a result, five ITSM software were considered for evaluation identified in the paper as ITSM I, ITSM II, ITSM III, ITSM IV and ITSM V.

All of the explored selection criteria from the literature review were assessed, and 46 criteria were selected, as shown in Table II. These were named C1, C2 […] C46. The reason for election all of them was the objective of case company to achieve ISO 20000 and accordance of these criteria with ISO necessary qualifications.

5.3 Structuring the fuzzy decision-matrix and assigning weights to the criteria

Linguistic values were used for the evaluation of the alternatives and weights of the criteria. The membership functions of these linguistic values and the TFNs related to these variables are shown in Figure 4. In applications, it is often convenient to work with TFNs because of their simplicity and they are useful in promoting representation and information processing in a fuzzy environment. Therefore, in the current research, TFN is chosen.

Based on the linguistic variables (Figure 4), alternatives and the criteria were assessed by the decision-making team, which also assigned appropriate weights to each criterion by asking experts in the field of ITSM and help desk software and solutions. A fuzzy decision-averages matrix for enterprise systems was created, based on the judgment of experts, as shown in Appendix 1.

5.4 Evaluating alternatives and determining the final rank

After the fuzzy decision-matrix has been established, the next step is to compute the fuzzy, weighted decision-matrix. This matrix is calculated with equation (6). Equation (7) is applied to compute $p_j(A_i, A_k)$ and $p_j(A_k, A_i)$. Then by using equation (8), TFNs were converted to real values. In next step, $f_{(d)}$ were calculated by equation (9), and, by equations (10) and (11), superiority and inferiority matrices were built. The superiority and inferiority matrices for this step have depicted in Appendices 2 and 3.

Linguistic variables	Fuzzy numbers	Membership Functions
Very low (VL)	(0.0,0.0,0.2)	
Low (L)	(0.0,0.2,0.4)	
Medium (M)	(0.2,0.4,0.6)	
High (H)	(0.4,0.6,0.8)	
Very high (VH)	(0.6,0.8,1.0)	
Excellent (E)	(0.8,1.0,1.0)	

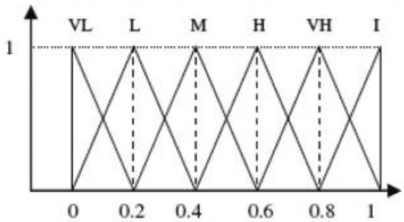


Figure 4. Linguistic values and fuzzy numbers

Then by applying equations (12) and (13), the superiority flow and inferiority flow were calculated. Subsequently, n-flow and r-flow were computed by equations (14) and (15). Table II shows the results of two last steps.

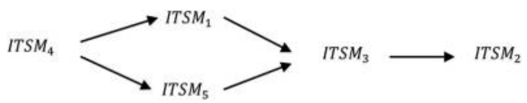
By using S-flows and I-flows, two complete ranking are generated:

$$R_{>}: ITSM_4 \rightarrow ITSM_1 \rightarrow ITSM_5 \rightarrow ITSM_3 \rightarrow ITSM_2$$

$$R_{<}: ITSM_4 \rightarrow ITSM_5 \rightarrow ITSM_3 \rightarrow ITSM_1 \rightarrow ITSM_2$$

The result of partial ranking is:

$$R = R_{>} \cap R_{<}:$$



The n-flows and r-flows obtain the two complete rankings that can be seen below:

$$R_n: ITSM_4 \rightarrow ITSM_5 \rightarrow ITSM_3 \rightarrow ITSM_1 \rightarrow ITSM_2$$

$$R_r: ITSM_4 \rightarrow ITSM_5 \rightarrow ITSM_3 \rightarrow ITSM_1 \rightarrow ITSM_2$$

A comparison of S-flows ($\varphi^{>}(ITSM_1)$, $\varphi^{>}(ITMS_2)$, $\varphi^{>}(ITMS_3)$, …, $\varphi^{>}(ITSM_5)$) and I-flows ($\varphi^{<}(ITSM_1)$, $\varphi^{<}(ITMS_2)$, …, $\varphi^{<}(ITSM_5)$) that reflects the capabilities of ITSM software and solutions, its strengths and weaknesses is shown in Figure 5. As shown in Figure 5. ITSM4 has highest S-flow and lowest I-flow, so it is the best alternative.

Based on the r-flows, complete rankings of the evaluated ITSM software are shown in Figure 6 (ITSM IV > ITSM V > ITSM III > ITSM I > ITSM II). Based on these results,

S-flows	I-Flows	n-flows	r-flows
$\varphi^{>}(ITSM_1) = 1.773$	$\varphi^{<}(ITSM_1) = 2.907$	$\varphi_n(ITSM_1) = -1.134$	$\varphi_r(ITSM_1) = 0.379$
$\varphi^{>}(ITSM_2) = 0.774$	$\varphi^{<}(ITSM_2) = 2.993$	$\varphi_n(ITSM_2) = -2.219$	$\varphi_r(ITSM_2) = 0.206$
$\varphi^{>}(ITSM_3) = 1.429$	$\varphi^{<}(ITSM_3) = 2.041$	$\varphi_n(ITSM_3) = -0.611$	$\varphi_r(ITSM_3) = 0.412$
$\varphi^{>}(ITSM_4) = 4.847$	$\varphi^{<}(ITSM_4) = 0.598$	$\varphi_n(ITSM_4) = 4.249$	$\varphi_r(ITSM_4) = 0.890$
$\varphi^{>}(ITSM_5) = 1.634$	$\varphi^{<}(ITSM_5) = 1.886$	$\varphi_n(ITSM_5) = -0.252$	$\varphi_r(ITSM_5) = 0.464$

Table II. Final computation results

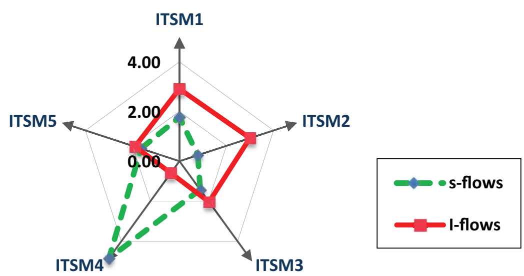


Figure 5. Evaluation of S-flows and I-flows for ITSM software

the ITSM IV was selected to implement in the studied case company and proposed approach guarantees the maximum coverage of functional and non-functional requirements with respect to selection criteria.

Now, the case company is utilizing ITSM IV as its ITSM solution and help desk for five months. The costumer survey shows the growths of 24 per cent in satisfaction and reduction of service time for 35 per cent in average. Also, service managers are assured with the selected solution. These issues can be considered as results of this selection.

6. Conclusion

This research tried to elaborate on the importance of ITSM software selection to achieve successful ITSM implementation. It was shown that selecting the proper ITSM software and adopting organizations are a difficult task with parameters that can be expressed in linguistic values. Such values are somewhat vague in essence and are subject to expert judgments which involve uncertainties. Therefore, the FSIR technique was used to deal with this problem appropriately. In addition, the fuzzy approach is an applicable technique in providing decision makers with estimated values under uncertainty in the preference judgments. So, the FSIR technique has been applied in proposed ITSM software selection approach. Using this approach, the different ITSM software can be evaluated, and the best solution is selected for any organization plans to acquire an ITSM software. The proposed ITIL-based framework breaks down ITSM software selection criteria into two broad categories, namely, functional and non-functional requirements, including totally 46 selection criteria. The proposed approach was then applied to a local Iranian company in the field of IT services to select and acquire ITSM software. Five ITSM software were considered for evaluation using the approach and the most merit one is proposed for the company. To compare the results of ranking and selection of this approach by the results of Rouhani and Ravasan (2014), who utilized FTOPSIS, it can be understood that the ranking order is similar, but, because of the emphasis of SIR on best and worst option, the distance of normalized scores between first rank ITSM (4) last rank (2) is magnified in fuzzy superiority and inferiority ranking which helps to decide on selection decisively.

The main novel points and merits of the paper are as follows. First, this paper, as one of the first attempts in ITSM literature, demonstrated the significance of ITSM software selection in successful ITSM implementation projects. Second, an ITSM selection approach has been proposed using both functional and non-functional criteria. Third, FSIR-based approach for software selection has been proposed to contribute to the current literature in the ITSM field. This approach can handle the inherent uncertainty and imprecision of human decision-making. Fourth, this paper presents an application of the proposed approach to a real selection case. To discuss about practical implication of

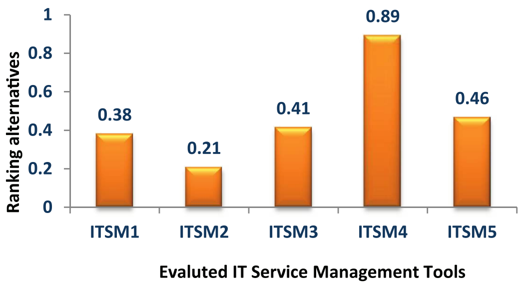


Figure 6. Ranking the evaluated ITSM software

this research, the author suggests that the proposed approach and results is able to facilitate practitioners and buyer firms to assess ITSM software more accurately and have a better software acquisition decisions. Besides, this research will be useful for ITSM software vendors and industry to tailor their products up on the criteria that are standard and near to evaluation model of selection.

The proposed approach is a practical and usable solution for real case problems. But, it suffers from some limitations. The main limitation of the approach is that the usability of the model and the validity of the achieved results were heavily dependent on experts' competence and proficiency in the both ITSM field and IT technical issues. Another limitation of the study is that the approach presented here does not consider all the possible factors and criteria might be associated with ITSM software selection. The approach presented here was based on the ITIL framework in evaluating functional criteria which might limit the applicability of the approach in evaluation ITSM software which are constructed based on some other ITSM frameworks.

Although the provided numerical example helps to understand the applicability of the approach for ITSM software selection, I believe that room still remains for future validation and improvement. So, further research in other contexts and industries is necessary to fine tune the proposed approach and assess its validity in others cases. Applying other MCDM methods in a fuzzy environment to ITSM software selection and comparing the results of these methods is also recommended for future research. Moreover, mathematical models or meta-heuristics can be combined with the existing method.

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Appendix 1

ITSM solutions	C1	C2	C3	C4	C5	C6	C7	C8
ITSM I	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)
ITSM II	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)
ITSM III	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)
ITSM IV	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.8, 1.0, 1.0)
ITSM V	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0,0.0, 0.2)	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)
Weight	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)	(0.0, 0.2, 0.4)
ITSM solutions	C9	C10	C11	C12	C13	C14	C15	C16
ITSM I	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)
ITSM II	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)	(0.8, 1.0, 1.0)	(0.4, 0.6, 0.8)	(0.0,0.0, 0.2)	(0.0, 0.0, 0.2)	(0.0, 0.2, 0.4)
ITSM III	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)
ITSM IV	(0.0, 0.0, 0.2)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)
ITSM V	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.8, 1.0, 1.0)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)
Weight	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)
ITSM solutions	C17	C18	C19	C20	C21	C22	C23	C24
ITSM I	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.0, 0.0, 0.2)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.4, 0.6, 0.8)
ITSM II	(0.0, 0.2, 0.4)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)
ITSM III	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)
ITSM IV	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.0, 0.0, 0.2)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.8, 1.0, 1.0)
ITSM V	(0.0, 0.0, 0.2)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.0, 0.2)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)
Weight	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.0, 0.2, 0.4)	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)
ITSM solutions	C25	C26	C27	C28	C29	C30	C31	C32
ITSM I	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.0, 0.0, 0.2)	(0.4, 0.6, 0.8)
ITSM II	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)
ITSM III	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.0, 0.2)
ITSM IV	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)
ITSM V	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)
Weight	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)
ITSM solutions	C33	C34	C35	C36	C37	C38	C39	C40
ITSM I	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)
ITSM II	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.0, 0.0, 0.2)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)
ITSM III	(0.0, 0.2, 0.4)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.8, 1.0, 1.0)	(0.0, 0.2, 0.4)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)
ITSM IV	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.8, 1.0, 1.0)
ITSM V	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)
Weight	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.8, 1.0, 1.0)	(0.4, 0.6, 0.8)	(0.8, 1.0, 1.0)	(0.0, 0.0, 0.2)	(0.8, 1.0, 1.0)
ITSM solutions	C41	C42	C43	C44	C45	C46		
ITSM I	(0.4, 0.6, 0.8)	(0.2, 0.4, 0.6)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.0, 0.0, 0.2)	(0.0, 0.2, 0.4)		
ITSM II	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)	(0.0, 0.2, 0.4)	(0.2, 0.4, 0.6)	(0.4, 0.6, 0.8)		
ITSM III	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)	(0.4, 0.6, 0.8)		
ITSM IV	(0.2, 0.4, 0.6)	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)	(0.4, 0.6, 0.8)	(0.8, 1.0, 1.0)	(0.4, 0.6, 0.8)		
ITSM V	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)	(0.2, 0.4, 0.6)		
Weight	(0.2, 0.4, 0.6)	(0.6, 0.8, 1.0)	(0.8, 1.0, 1.0)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)	(0.6, 0.8, 1.0)		

Table AI. Fuzzy decision-matrix for ITSM software

Appendix 2

ITSM solutions	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
ITSM I	0.000	0.000	0.002	0.005	0.159	0.130	0.013	0.000	0.225	0.003	0.004	0.018
ITSM II	0.007	0.013	0.000	0.000	0.000	0.000	0.048	0.002	0.063	0.000	0.000	0.018
ITSM III	0.043	0.063	0.000	0.005	0.054	0.022	0.000	0.000	0.024	0.003	0.001	0.000
ITSM IV	0.127	0.184	0.002	0.045	0.159	0.676	0.048	0.006	0.000	0.003	0.004	0.006
ITSM V	0.007	0.063	0.000	0.005	0.008	0.000	0.013	0.000	0.063	0.022	0.012	0.000

ITSM solutions	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
ITSM I	0.000	0.151	0.108	0.008	0.031	0.000	0.025	0.000	0.008	0.000	0.000	0.075
ITSM II	0.002	0.000	0.000	0.008	0.005	0.038	0.084	0.017	0.000	0.002	0.074	0.013
ITSM III	0.000	0.005	0.017	0.067	0.031	0.000	0.000	0.108	0.054	0.007	0.074	0.000
ITSM IV	0.002	0.005	0.017	0.099	0.099	0.038	0.025	0.000	0.172	0.018	0.236	0.372
ITSM V	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.054	0.000	0.011	0.013

ITSM solutions	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	C35	C36
ITSM I	0.054	0.006	0.006	0.000	0.000	0.000	0.000	0.159	0.064	0.006	0.019	0.387
ITSM II	0.000	0.006	0.000	0.010	0.002	0.011	0.002	0.008	0.000	0.000	0.000	0.000
ITSM III	0.013	0.000	0.006	0.000	0.014	0.001	0.018	0.000	0.000	0.000	0.003	0.000
ITSM IV	0.013	0.019	0.006	0.000	0.045	0.011	0.002	0.054	0.014	0.029	0.019	0.157
ITSM V	0.013	0.000	0.000	0.074	0.014	0.004	0.018	0.341	0.161	0.073	0.003	0.036

ITSM solutions	C37	C38	C39	C40	C41	C42	C43	C44	C45	C46
ITSM I	0.007	0.074	0.000	0.000	0.010	0.000	0.000	0.013	0.000	0.000
ITSM II	0.000	0.000	0.000	0.149	0.000	0.000	0.088	0.000	0.041	0.063
ITSM III	0.242	0.011	0.000	0.149	0.010	0.038	0.088	0.075	0.122	0.063
ITSM IV	0.007	0.448	0.001	0.542	0.000	0.301	0.255	0.075	0.441	0.063
ITSM V	0.007	0.448	0.000	0.056	0.000	0.000	0.018	0.013	0.041	0.013

Table AII. Superiority matrix

Appendix 3

ITSM solutions	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
ITSM I	0.105	0.221	0.000	0.007	0.000	0.070	0.012	0.003	0.000	0.003	0.001	0.000
ITSM II	0.036	0.075	0.002	0.039	0.242	0.296	0.000	0.000	0.020	0.022	0.014	0.000
ITSM III	0.007	0.013	0.002	0.007	0.025	0.168	0.097	0.003	0.064	0.003	0.005	0.020
ITSM IV	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.272	0.003	0.001	0.002
ITSM V	0.036	0.013	0.002	0.007	0.113	0.296	0.012	0.003	0.020	0.000	0.000	0.020
ITSM solutions	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
ITSM I	0.007	0.000	0.000	0.025	0.007	0.025	0.006	0.058	0.075	0.011	0.255	0.036
ITSM II	0.002	0.052	0.058	0.025	0.043	0.000	0.000	0.013	0.187	0.004	0.018	0.101
ITSM III	0.007	0.028	0.013	0.000	0.007	0.025	0.061	0.000	0.013	0.001	0.018	0.235
ITSM IV	0.002	0.028	0.013	0.000	0.000	0.000	0.006	0.058	0.000	0.000	0.000	0.000
ITSM V	0.000	0.052	0.058	0.099	0.109	0.025	0.061	0.013	0.013	0.011	0.105	0.101
ITSM solutions	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	C35	C36
ITSM I	0.000	0.001	0.000	0.025	0.051	0.018	0.027	0.013	0.007	0.016	0.000	0.000
ITSM II	0.074	0.001	0.010	0.008	0.019	0.000	0.006	0.171	0.098	0.044	0.032	0.237
ITSM III	0.006	0.015	0.000	0.025	0.003	0.007	0.000	0.316	0.098	0.044	0.006	0.237
ITSM IV	0.006	0.000	0.000	0.025	0.000	0.000	0.006	0.063	0.036	0.003	0.000	0.018
ITSM V	0.006	0.015	0.010	0.000	0.003	0.002	0.000	0.000	0.000	0.000	0.006	0.088
ITSM solutions	C37	C38	C39	C40	C41	C42	C43	C44	C45	C46		
ITSM I	0.050	0.139	0.001	0.627	0.000	0.101	0.307	0.025	0.407	0.162		
ITSM II	0.114	0.524	0.000	0.053	0.006	0.101	0.018	0.125	0.101	0.000		
ITSM III	0.000	0.318	0.000	0.053	0.000	0.036	0.018	0.000	0.036	0.000		
ITSM IV	0.050	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000		
ITSM V	0.050	0.000	0.000	0.162	0.006	0.101	0.105	0.025	0.101	0.038		

Table AIII. Inferiority matrix

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