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OPERATING SYSTEM SELECTION USING FUZZY AHP AND TOPSIS METHODS

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Abstract- The aim of study is developing a fuzzy decision model to select appropriate operating system for computer systems of the firms by taking subjective judgments of decision makers into consideration. Proposed approach is based on Fuzzy Analytic Hierarchy Process (FAHP) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methods. FAHP method is used in determining the weights of the criteria by decision makers and then rankings of the operating systems are determined by TOPSIS method. Empirical study has also been demonstrated.
Keywords- Multi-criteria decision making, FAHP, TOPSIS, Operating system selection

1. INTRODUCTION

Today, the technology is developing at an incredible speed. With the acceleration of the development in the field of technology, it becomes necessary to take decisions more frequently for the update of the technology. Therefore, firms and organizations should consider the changes and update the information technologies so that they can create more efficient working environment and labor force and so doing, they can keep up with the technological advancements. One of these technology-related changes occurs in relation to the indispensable part of the computer; that is operating systems. Operating system is system software responsible for the direct control and management of the hardware, basic system operations and operating the programs of application. It provides the links to the memory, input/output devices and file system. If more than one program are operating simultaneously, the operating system is responsible for reserving enough sources for each of them in the system and preventing overlapping among these programs. Traditional engineering economy models overlook the benefits intrinsic to the operating systems and hence, comprehensive multi-criteria decision making techniques (TOPSIS, ELECTRE, Analytic Hierarchy Process (AHP), PROMETHEE etc.) are needed for the solutions of the problems [27].

Multi-criteria decision making refers to find the best opinion from all of the feasible alternatives in the presence of multiple, usually conflicting, decision criteria [11]. AHP technique investigated in the present study is a multi-criteria decision-making technique developed by Saaty [23]. Although traditional AHP technique may display expert knowledge, it can not reflect human thinking [14]. Therefore, FAHP technique was developed [28, 2, 4]. TOPSIS method was firstly proposed by Hwang and Yoon [10]. According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution [19, 1]. FAHP and TOPSIS methods can be used together for complex decision problems [6, 8, 9, 22, 25]. Tolga et. al. [27] dealt with the problems of selecting operating system by using Fuzzy Replacement Analysis and AHP. In the present study, on the other hand, for the selection of operating systems, FAHP and TOPSIS method is examined by using technical attributes of operating systems.

2. FEATURES OF OPERATING SYSTEMS

An operating system acts as an intermediary between the user of a computer and the computer hardware. The purpose of an operating system is to provide an environment in which a user can execute programs in a convenient and efficient manner [24]. Operating systems can be found on almost anything made with integrated circuits, such as personal computers, internet servers, cell-phones, music players, routers, switches, wireless access points, network storage, game consoles, etc.

There are many features to be taken into consideration while selecting operating system. According to Tanenbaum and Woodhull [26], Silberschatz et all [24] and McKusick and Neville-Neil [20], main attributes are categorized as follows: Memory Management, Process Management, Storage Management, Protection and Security, Software Features, Distributed Structure and Requirements.

Memory Management (C_1): To improve both the utilization of the CPU and the speed of its response to users, the computer must keep several processes in memory: *Main Memory* (C_{11}) and *Virtual Memory* (C_{12}). Programs, together with the data they access are in main memory during executions. Virtual Memory allows the execution of processes that are not completely in memory.

Process Management (C_2): A Process is an instance of a computer program that is being sequentially executed by a computer system that has the ability to run several computer programs concurrently [17]. Although traditionally a process contained only a single thread of control as it ran, most modern operating systems now support processes that have multiple threads. The operating system is responsible for the following activities in connection with process and thread management: *Process Handling* (C_{21}), *Multithreading* (C_{22}), CPU *Scheduling* (C_{23}), *Process Synchronization* (C_{24}) and *Deadlocks* (C_{25}).

Storage Management (C_3): Since main memory is usually too small to accommodate all the data and programs permanently, the computer system must provide secondary storage to back up main memory. Modern computer systems use disks as the primary on-line storage medium for information. The file system provides the mechanism for on-line storage of and access to both data and programs residing on the disks. Attributes of Storage Management: *File System Interface* (C_{31}), *I/O Systems* (C_{32}), *Mass-Storage Structure* (C_{33}), and *File System Implementation* (C_{34}).

Protection and Security (C_4): Protection is internal problem. Security, in contrast, must consider both the computer system and the environment. *Protection* (C_{41}): The Processes in an operating system must be protected from one another's activities. Protection refers to a mechanism for controlling the access of programs, processes, or users to the resources defined by a computer system. Protection increases the reliability of operating system. *Security* (C_{42}): Computer resources must be guarded against unauthorized access, malicious destruction or alteration, and accidental introduction of inconsistency.

Software Features (C_5): An operating system must provide application software in large quantities and good quality to satisfy user requests. Software features are

Programming Interface (C_{51}), *Graphical User Interface* (C_{52}), *Availability and Support* (C_{53}), *Applications and Tools* (C_{54}). Programming Interface provides several ways for developers to access to system resources such as kernel objects, I/O devices and etc. Graphical User Interface takes advantage of the computer's graphics capabilities to make interacting user and operating system easier. To satisfy user requests, applications and tools must be always available and supported by developers.

Distributed Structure (C_6): A distributed system is a collection of processors that do not share memory or a clock. Instead, each processor has its own local memory, and the processors communicate with one another through communication lines such as local area or wide are networks. *Distributed System Structures* (C_{61}): The communication network design must include routing and connection strategies, and it must solve the problems of contention and security. *Distributed File Systems* (C_{62}): A distributed file system is a distributed implementation of the classical time-sharing model of a file system, where multiple users share files and storage resources. *Distributed Coordination* (C_{63}) : In a distributed system with no common memory and no common clock, it is sometimes impossible to determine the exact order in which two events occur. Timestamps and mutual exclusion can be used to provide a consistent event ordering.

Requirements (C_7): Before using the operating system, computer system must ensure B*asic Requirements* (C_{71}) such as fast processor, minimum RAM, available space on the hard disk and etc. Cost is another important requirement of an operating system and *Cheapness* (C_{72}) is a remarkable feature.

3. FUZZY SETS AND FUZZY NUMBERS

Zadeh [31] introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data [15]. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for common-sense reasoning in decision making in the absence of complete and precise information [8]. The classical set theory is built on the fundamental concept of set of which is either a member or not a member. A sharp, crisp and unambiguous distinction exists between a member and non-member for any well-defined set of entities in this theory and there is a very precise and clear boundary to indicate if an entity belongs to the set. But many real-world applications cannot be described and handled by classical set theory [5]. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or non-membership at all, whereas fuzzy sets allow partial membership.

Fuzzy numbers are the special classes of fuzzy quantities. A fuzzy number is a fuzzy quantity M that represents a generalization of a real number r. Intuitively, M(x) should be a measure of how well M(x) “approximates” r [21]. A fuzzy number M is a convex normalized fuzzy set. A fuzzy number is characterized by a given interval of real numbers, each with a grade of membership between 0 and 1. It is possible to use different fuzzy numbers according to the situation. Generally in practice triangular and trapezoidal fuzzy numbers are used [16]. In applications it is often convenient to work with triangular fuzzy numbers (TFNs) because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment [8]. A triangular fuzzy number, M is shown in Figure 1 [7]:

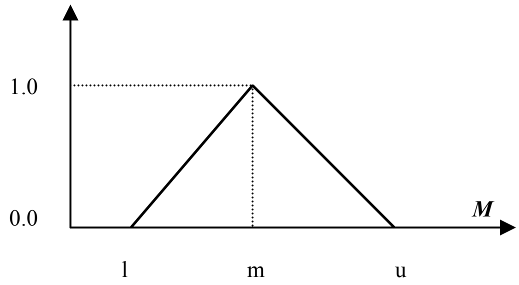

Figure 1. A Triangular fuzzy number, $\tilde{M}$

TFNs are defined by three real numbers, expressed as (*l, m, u*). The parameters *l, m,* and *u,* respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Their membership functions are described as;

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u \end{cases} \tag{1}$$

There are various operations on triangular fuzzy numbers. But here, three important operations used in this study are illustrated. If we define, two positive triangular fuzzy numbers (l_1, m_1, u_1) and (l_2, m_2, u_2) then:

$$(l_1,m_1,u_1)+(l_2,m_2,u_2)=(l_1+l_2,m_1+m_2,u_1+u_2) \tag{2}$$

$$(l_1,m_1,u_1)\cdot(l_2,m_2,u_2)=(l_1\cdot l_2,m_1\cdot m_2,u_1\cdot u_2) \tag{3}$$

$$(l_1,m_1,u_1)^{-1}\approx(1/u_1,1/m_1,1/l_1) \tag{4}$$

Other algebraic operations with fuzzy numbers can be found in [32, 12, 13].

4. FUZZY AHP

There are many FAHP methods in literature [28, 2, 4]. Let $X = \{x_1, x_2, x_3, ..., x_n\}$ be an object set, and $G = \{g_1, g_2, g_3, ..., g_n\}$ be a goal set. According to the method of Chang [3, 4] extent analysis, each object is taken and extent analysis for each goal, g_i, is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M^1_{gi}, M^2_{gi}, ...M^m_{gi}, \qquad i = 1,2,....,n,$$

where M^j_{gi} $(j = 1, 2, ...,m)$ all are TFNs. The steps of Chang's extent analysis can be given as in the following [4]:

Step 1: The value of fuzzy synthetic extent with respect to the *i* th object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{5}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{6}$$

and to obtain $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, perform the fuzzy addition operation of M^{j}_{gi} $(j = 1, 2,...,m)$ values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{7}$$

and then compute the inverse of the vector above, such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) .$$

(8)

Step 2: As $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = \sup_{y \geq x} \left[min\left(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(y) \right) \right] \tag{9}$$

and can be equivalently expressed as follows:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_2}(d) \tag{10}$$

$$= \begin{cases} 1, \text{ if } \; m_2 \geq m_1 \\ 0, \text{ if } \; l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, \text{ otherwise} \end{cases} \tag{11}$$

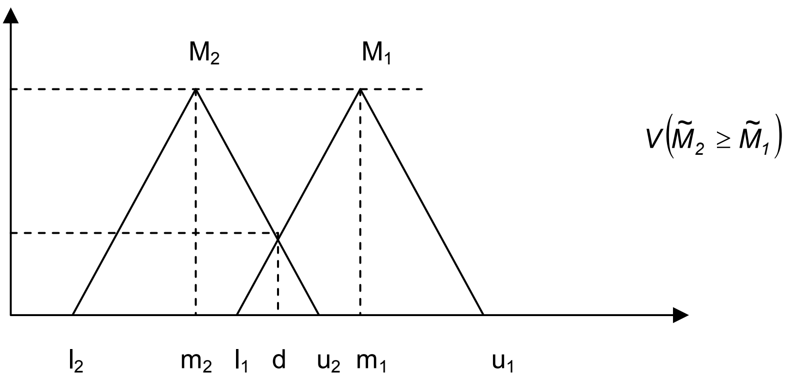

Figure 2. The intersection between M_1 and M_2

Figure 2 illustrates Eq. (11) where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}. To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$

Step 3: The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy M_i (i=1, 2, k) numbers can be defined by

$$\begin{aligned} V(M \geq M_1, M_2, \ldots\ldots M_k) &= V[(M \geq M_1) \ \ and \ \ (M \geq M_2) \ \ and \ldots and \ \ (M \geq M_k)] \\ &= \min \ \ V(M \geq M_i), \ \ i = 1,2,3,\ldots\ldots,k \end{aligned} \tag{12}$$

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2,\ldots\ldots,n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots\ldots, d'(A_n))^T \tag{13}$$

where $A_i = (i = 1,2,\ldots n)$ are *n* elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots\ldots, d(A_n))^T \tag{14}$$

where W is a non-fuzzy number.

5. TOPSIS METHOD

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is one of the useful Multi Attribute Decision Making techniques that is very simple and easy to implement, so that it is used when the user prefers a simpler weighting approach. On the other hand, the AHP approach provides a decision hierarchy and requires pairwise comparison among criteria. The user needs a more detailed knowledge about the criteria in the decision hierarchy to make informed decisions in using the AHP [18]. TOPSIS method was firstly proposed by Hwang and Yoon [10]. According to this technique, the best alternative would be the one that is nearest to the positive ideal solution and farthest from the negative ideal solution [1]. The positive ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria [29, 30]. In other words, the positive ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution consists of all worst values attainable of criteria [8]. In this study, TOPSIS method is used for determining the final ranking of the operating systems. The method is calculated as follows:

Step 1. Decision matrix is normalized via Eq. (15):

$$r_{ij} = \frac{w_{ij}}{\sqrt{\sum_{j=1}^{J} w_{ij}^2}} \qquad j = 1,2,3,...,J \quad i = 1,2,3,...,n \tag{15}$$

Step 2. Weighted normalized decision matrix is formed:

$$v_{ij} = w_{ij} * r_{ij} \ , j = 1,2,3,...,J \ ,i = 1,2,3,...,n \tag{16}$$

Step 3. Positive ideal solution (PIS) and negative ideal solution (NIS) are determined:

$$A^* = \{v_1^*, v_2^*, ..., v_n^*,\} \text{ Maximum values} \tag{17}$$

$$A^- = \{v_1^-, v_2^-, ..., v_n^-,\} \text{ Minimum values} \tag{18}$$

Step 4. The distance of each alternative from PIS and NIS are calculated:

$$d_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \ , j = 1,2,...,J \tag{19}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \ , \ i = 1,2,...,J \tag{20}$$

Step 5. The closeness coefficient of each alternative is calculated:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \ , \ i = 1,2,...,J \tag{21}$$

Step 6. By comparing CC_i values, the ranking of alternatives are determined.

6. EMPIRICAL STUDY

A numerical example is illustrated and trial data is used for selecting best operating system according to decision maker or expert preference. Assume that three operating systems: A, B, C are evaluated under a fuzzy environment. For selecting operating system, main criteria C_1-C_7 and their sub-criteria which are used in application, are explained in section two. Figure 3 shows the all main criteria and sub-criteria in hierarchic view. To create pairwise comparison matrix, linguistic scale is used which is given in Table 1.

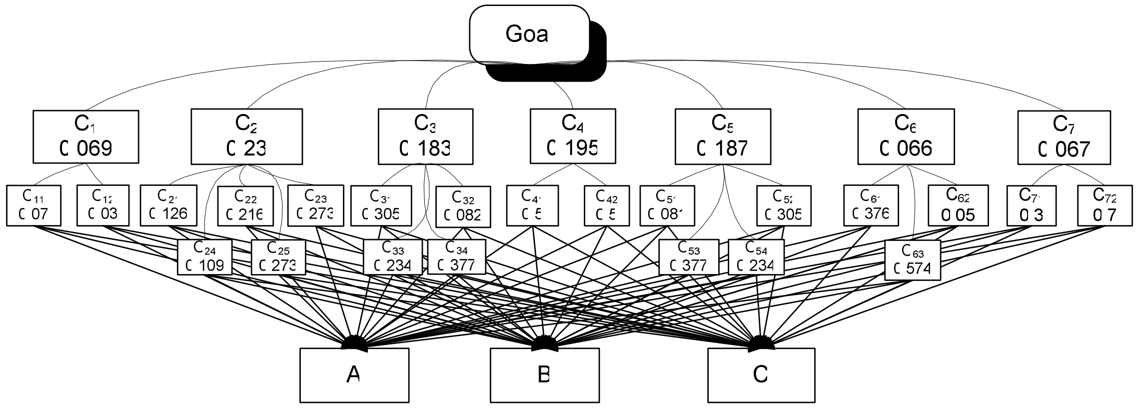

Figure 3. Hierarchy of Operating System Selection Problem

Table 1. The Linguistic Scale and Corresponding Triangular Fuzzy Numbers

Linguistic scale	Explanation	TFN	Inverse TFN
Equal Importance	Two activities contribute equally to the objective	(1,1,1)	(1,1,1)
Moderate Importance	Experience and judgment slightly favor one activity over another	(1,3,5)	(1/5,1/3,1)
Strong Importance	Experience and judgment strongly favor one activity over another	(3,5,7)	(1/7,1/5,1/3)
Very Strong Importance	An activity is favored very strongly over another, its dominance	(5,7,9)	(1/9,1/7,1/5)
Demonstrated Importance	The evidence favoring one activity over another is highest possible order of affirmation	(7,9,11)	(1/11,1/9,1/7)

According to decision maker's preferences for main criteria, pairwise comparison values are transformed into TFN's as in Table 2.

Table 2. Fuzzy pairwise comparison matrix

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)
C_2	(1,3,5)	(1,1,1)	(1,3,5)	(1,3,5)	(1,1,1)	(1,5,7)	(1,3,5)
C_3	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,3,5)	(1,3,5)
C_4	(1,3,5)	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1,3,5)
C_5	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1,3,5)
C_6	(1,1,1)	(1/7,1/5,1)	(1/5,1/3,1)	(1/7,1/5,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)
C_7	(1,1,1)	(1/5,1/3,1	(1/5,1/3,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)

After forming fuzzy pair-wise comparison matrix, weights of all criteria and sub-criteria are determined by the help of FAHP. According to the FAHP method, firstly synthesis values must be calculated. From Table 1, synthesis values respect to main goal are calculated like in Eq. (5):

$S_{C1} = (4.60, 5, 7) \otimes (1/109, 1/71.40, 1/41.69) = (0.042, 0.070, 0.168)$
$S_{C2} = (9, 19, 29) \otimes (1/109, 1/71.40, 1/41.69) = (0.082, 0.267, 0.695)$
$S_{C3} = (6.20, 12.33, 19) \otimes (1/109, 1/71.40, 1/41.69) = (0.057, 0.172, 0.455)$
$S_{C4} = (7.40, 13.67, 21) \otimes (1/109, 1/71.40, 1/41.69) = (0.068, 0.191, 0.503)$
$S_{C5} = (7, 13, 19) \otimes (1/109, 1/71.40, 1/41.69) = (0.064, 0.182, 0.456)$
$S_{C6} = (3.69, 4.07, 7) \otimes (1/109, 1/71.40, 1/41.69) = (0.033, 0.057, 0.168)$
$S_{C7} = (3.80, 4.33, 7) \otimes (1/109, 1/71.40, 1/41.69) = (0.035, 0.060, 0.168)$

These fuzzy values are compared by using Eq. (11) and these values are obtained:

$V(S_{C1} \geq S_{C2}) = 0.30$, $V(S_{C1} \geq S_{C3}) = 0.52$, $V(S_{C1} \geq S_{C4}) = 0.45$, $V(S_{C1} \geq S_{C5}) = 0.48$,
$V(S_{C1} \geq S_{C6}) = 1$, $V(S_{C1} \geq S_{C7}) = 1$, $V(S_{C2} \geq S_{C1}) = 1$, $V(S_{C2} \geq S_{C3}) = 1$,
$V(S_{C2} \geq S_{C4}) = 1$, $V(S_{C2} \geq S_{C5}) = 1$, $V(S_{C2} \geq S_{C6}) = 1$, $V(S_{C2} \geq S_{C7}) = 1$,
$V(S_{C3} \geq S_{C1}) = 1$, $V(S_{C3} \geq S_{C2}) = 0.79$, $V(S_{C3} \geq S_{C4}) = 0.95$, $V(S_{C3} \geq S_{C5}) = 0.98$,
$V(S_{C3} \geq S_{C6}) = 1$, $V(S_{C3} \geq S_{C7}) = 1$, $V(S_{C4} \geq S_{C1}) = 1$, $V(S_{C4} \geq S_{C2}) = 0.84$,
$V(S_{C4} \geq S_{C3}) = 1$, $V(S_{C4} \geq S_{C5}) = 1$, $V(S_{C4} \geq S_{C6}) = 1$, $V(S_{C4} \geq S_{C7}) = 1$,
$V(S_{C5} \geq S_{C1}) = 1$, $V(S_{C5} \geq S_{C2}) = 0.81$, $V(S_{C5} \geq S_{C3}) = 1$, $V(S_{C5} \geq S_{C4}) = 0.98$,
$V(S_{C5} \geq S_{C6}) = 1$, $V(S_{C5} \geq S_{C7}) = 1$, $V(S_{C6} \geq S_{C1}) = 0.90$, $V(S_{C6} \geq S_{C2}) = 0.28$,
$V(S_{C6} \geq S_{C3}) = 0.49$, $V(S_{C6} \geq S_{C4}) = 0.42$, $V(S_{C6} \geq S_{C5}) = 0.45$, $V(S_{C6} \geq S_{C7}) = 0.97$,
$V(S_{C7} \geq S_{C1}) = 0.93$, $V(S_{C7} \geq S_{C2}) = 0.29$, $V(S_{C7} \geq S_{C3}) = 0.50$, $V(S_{C7} \geq S_{C4}) = 0.43$,
$V(S_{C7} \geq S_{C5}) = 0.46$, $V(S_{C7} \geq S_{C6}) = 1$

Then priority weights are calculated by using Eq. (12):

$d'(C_1) = \min (0.30, 0.52, 0.45, 0.48, 1, 1) = 0.30$
$d'(C_2) = \min (1, 1, 1, 1, 1, 1) = 1$
$d'(C_3) = \min (1, 0.79, 0.95, 0.98, 1, 1) = 0.79$
$d'(C_4) = \min (1, 0.84, 1, 1, 1, 1) = 0.84$
$d'(C_5) = \min (1, 0.81, 1, 0.98, 1, 1) = 0.81$
$d'(C_6) = \min (0.90, 0.28, 0.49, 0.42, 0.45, 0.97) = 0.28$
$d'(C_7) = \min (0.93, 0.29, 0.50, 0.43, 0.46, 0.97) = 0.29$

Priority weights form $W' = (0.303, 1, 0.80, 0.85, 0.82, 0.290, 0.293)$ vector. After the normalization of these values priority weights respect to main goal are calculated as (0.069, 0.230, 0.183, 0.195, 0.187, 0.066, 0.067). Then, weights of sub-criteria and priority values of operating systems for each sub-criteria are calculated similarly. Weights of sub-criteria are shown in Fig. 3. Priority values of operating systems for each sub-criteria are given in Table 3.
Normalization of these values is made via Eq. (15). Then, weighted normalized matrix is formed by multiplying each value with their weights. All weighted values that form

each sub-criterion are aggregated. Then, these aggregated values and the weights of each main criterion are multiplied to form Table 4.

Table 3. Sub-Criteria Priority values of Operating Systems

Sub-Criteria	A	B	C
c_{11}	0.182	0.409	0.409
c_{12}	0.210	0.578	0.210
c_{21}	0.234	0.196	0.571
c_{22}	0.581	0.211	0.211
c_{23}	0.571	0.234	0.196
c_{24}	0.581	0.211	0.211
c_{25}	0.444	0.191	0.363
c_{31}	0.182	0.409	0.409
c_{32}	0.581	0.211	0.211
c_{33}	0.182	0.409	0.409
c_{34}	0.571	0.196	0.234
c_{41}	0.051	0.575	0.376
c_{42}	0.182	0.409	0.409
c_{51}	0.574	0.376	0.051
c_{52}	0.363	0.191	0.444
c_{53}	0.051	0.376	0.574
c_{54}	0.409	0.409	0.182
c_{61}	0.338	0.549	0.112
c_{62}	0.051	0.574	0.376
c_{63}	0.196	0.571	0.234
c_{71}	0.376	0.574	0.051
c_{72}	0.376	0.574	0.051

Table 4. Total weighted values of main criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A	0.004	0.031	0.018	0.006	0.014	0.004	0.007
B	0.009	0.013	0.015	0.026	0.016	0.010	0.010
C	0.006	0.018	0.016	0.021	0.020	0.003	0.001

Positive and negative ideal solutions are determined by taking the maximum and minimum values for each criterion:

$A^* = \{0.009, 0.031, 0.018, 0.026, 0.020, 0.010, 0.010\}$

$A^- = \{0.004, 0.013, 0.015, 0.006, 0.014, 0.003, 0.001\}$

Then the distance of each firm from PIS and NIS with respect to each criterion are calculated with the help of Eqs. (19) and (20). Then closeness coefficient of each operating system is calculated by using Eq. (21) and the ranking of the operating systems are determined according to these values in Table 5. Considering the Table 5, preferred operating system is B for decision maker's preference. Different rankings can be obtained by using different decision maker's preference values.

Table 5. Ranking of the operating systems according to CC_i values

Rank	Operating System	CC_i
1	B	0.624
2	C	0.470
3	A	0.415

7. CONCLUSION

With the selection of appropriate operating system, organizations may have some positive results in a world of competition and globalization such as decreased the costs, time-efficiency and increased quality and increased work performance. In this paper, FAHP and TOPSIS are integrated for selection of best operating system. FAHP is used for determining the weights of the criteria and priority values of operating systems for sub-criteria. Then TOPSIS method is used for determining the ranking of the operating systems. FAHP is a useful approach for evaluating complex multiple criteria alternatives involving subjective and uncertain judgment. TOPSIS is one of the well-known outranking methods for multiple-criteria decision-making and can be easily used for ranking alternatives. The integration of FAHP and TOPSIS approaches enables experts and users to efficiently select a more suitable operating system for specific purpose and requirements. In future studies other multi-criteria methods can be used to select operating systems.

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