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A Framework to Overcome Hesitancy of Decision-Makers in E-Government Web Site Evaluation

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Abstract Considering the undeniable role of websites in the success of interactions between citizens and governments, evaluating e-government web sites is a worthwhile topic. This research has developed a multi-attribute-decision-making technique rely on Step-Wise Weight Assessment Ratio Analysis and hesitant fuzzy weighted geometric Heronian mean decision-making methods, for evaluating e-government websites. Proposed framework overcome the limitations of previous investigations such as the possibility of aggregation of expert opinions using group decision-making and modeling the hesitancy of the experts (due to the incompleteness of their knowledge or their doubts in evaluating different aspects of the model) through hesitant fuzzy sets. The designed framework was used in Iran to evaluate e-government websites. In this regard, after a careful and systematic review of previous researches, a list of dimensions and evaluation criteria was presented in the form of a comprehensive model. Then, an expert-based process was proposed to localize the model according to the conditions of the case study. The results of the research show that the final rankings of the decision-making method used in the hesitant environment rarely changed for different operators. So as the experts have confirmed, the model used in this study has acceptable stability.

Keywords E-government · Website evaluation · Hesitant fuzzy set · Step-wise weight assessment ratio analysis · Hesitant fuzzy weighted geometric Heronian mean · Iran

1 Introduction

With the growing trend of globalization in many industries and increased innovation in the production of new products, there has been intense competition among organizations since the late twentieth century [1]. In the meantime, computers, Internet technology, and the Internet have created a suitable platform to reduce the running time of the processes [2] and also to increase the possibility of customizing products and service [3] and thus play a vital role in creating a competitive advantage for organizations. Accordingly, various economic sectors have linked to the Internet to preserve their core customers [4]. Like other sectors, the need to provide electronic services through the internet is felt in the public sector [5]. Entering the Internet in the public sector has led to the formation of the e-government concept. E-government's application in the management of processes has attracted the attention of various political groups. On the other hand, its use in obtaining online services has attracted the attention of popular groups to this phenomenon [6]. By definition, e-government refers to "the use of information and communications technologies by governments, in particular, the use of the Internet and related technologies in all sectors to facilitate the provision of services and information to their citizens, employees and business partners" [7]. Governments can acceptably reduce their decision-making time by adopting Internet technology [8]. These benefits have led governments to take measures to improve their services through the implementation of new technologies, especially

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government websites [9]. To improve the provision of public services, the creation of government websites reduces the time of provision of services and facilitates access of citizens to government information [8]. Despite these benefits, there are still some problems such as non-participation of citizens and their distrusting in this form of governmental services [10]. Evaluation of the quality of e-government websites, as one of the most critical steps in identifying the weaknesses and strengths of governments in providing services and planning for improvement, has attracted the attention of researchers and decision-makers in this field, so various countries such as Jordan, China, Indonesia, United Arab Emirates, Korea, and the United Kingdom have evaluated their e-government websites to improve this area. The study of the set of dimensions and indicators mentioned in previous studies shows that there is no general model to evaluate all aspects of e-government websites agreed upon by researchers. On the other hand, the use of multi-attribute decision-making methods has been approved due to features such as multiplicity of evaluation criteria and unevenness of their importance in ranking of websites, but in the previous studies, firstly there has not been much attention to uncertainty in the evaluation process, and secondly, two items have not been included in the final aggregation of the evaluation team members' views: the incompleteness of knowledge of each of the experts and their doubts in evaluating different aspects of the model. Therefore, this research has developed a multi-attribute-decision-making (MADM) technique rely on Step-Wise Weight Assessment Ratio Analysis (SWARA) and hesitant fuzzy weighted geometric Heronian mean (HFWGHM) decision-making methods, to overcome the limitations of previous investigations in e-government website evaluation field.

In Iran, to assess the maturity level of organizations in providing electronic services through the Web, Information Technology Organization of Iran (ITO) as trustee of e-government evaluates the websites of subsidiary governmental entities. For this purpose, in the first step, an attempt has been made to provide an appropriate framework for evaluating e-government websites, then this framework is implemented as a pilot project for six selected websites, and finally, the model is finalized by analyzing the evaluation results. To achieve the above goal, first, by carefully examining previous researches in this area, we have developed a list of dimensions and evaluation criteria in the form of a comprehensive model. Then, this list was given to members of the E-Government Evaluation Committee and the relevant working group as experts in this field. After modifying the list of criteria identified as the focal group, the original model was proposed in the form of a localized model and appropriate to the conditions in Iran. Since the dimensions and indicators identified are not equally important, the members of the evaluation team were asked to comment on the importance of each of the selected criteria. The SWARA method was used to calculate the weights of the criteria due to its benefits mentioned in the literature. Subsequently, the evaluation of each of the six selected websites was assigned to the members of the E-Government Website Assessment Working Group. Each expert, based on his level of knowledge and experience, provided the opportunity to evaluate the website based on each of the criteria using qualitative variables to present views. Subsequently, these numbers were aggregated in the form of hesitant fuzzy numbers. Finally, HFWGHM method was used to calculate the score of each website and eventually rank them.

The structure of the paper is as follows: in the second part of the paper, the research background is reviewed to identify the evaluation model and appropriate indicators. In the third part, the research steps, as well as the SWARA method, hesitant sets and the operators used, are described. In the fourth part of the study, the case study is presented, and then the findings obtained from using the framework designed for six pilot websites are shown. Finally, the analysis of research findings and results are done in the fifth part of the paper, and some suggestions for future researches are presented.

2 Literature Review

E-government involves the use of Internet tools and especially websites to provide the best possible services to citizens [11]. Due to the role of e-government websites in increasing satisfaction of citizens, the evaluation of these websites has been considered in recent years. Researches conducted to assess the features of e-government websites are considered as prerequisites in the assessment of the issues raised in e-government [12]. On the other hand, although there are a lot of researches in the field of web site evaluation [13, 14], these researches have general nature, and the evaluation model doesn't focus on a particular field. Therefore, researchers in various fields have tried to create appropriate and local evaluation models in their related areas in recent years. Among these are the researches on the evaluation of the tourism industry websites [15], the airline industry [16]. In the past few years, efforts have been made to provide a specific model for evaluating e-government web sites. According to the studies, researchers have generally accepted features such as usability, content, technical characteristics, citizen participation, etc. [17, 18], but it's not enough to focus on these indicators in the area of e-government websites. To this end, to extract the indicators for the evaluation of

e-government websites, the models used in the field of e-government service evaluation and e-government website evaluation indicators should be analyzed together.

As mentioned earlier, e-government enables users (including citizens, businesses, and public sectors) to access information and services through the use of Internet tools, especially websites [19, 20]. Services provided by governments in different countries have come in many forms. For example, in Singapore, integrated information and services are provided by government agencies to citizens. Also, online tax systems and bank account services are an example of government electronic services to its citizens in this country [21, 22]. In the United States, these services include the renewal of a driving license, parking information, online voting system, application for birth, death and marriage documents as well as licenses for hunting and fishing and access to online medical information from the health institution [21, 23]. According to the purpose of this research which is to provide a framework for evaluating e-government websites in accordance with the conditions of Iran, a review of the most important researches in this field has been done. According to literature, website evaluations can be reviewed from three main viewpoints: (1) users, (2) designers and observers, and (3) a combination of both [24]. Users point out in their assessment more about criteria such as design and content of a website which lead to the success of a website from their point of view [25]. In evaluating a website with the designer approach, criteria such as usability and accessibility often are considered [25]. Of course, we should not forget that it is not possible to assess accurately just by focusing on an independent view. Simultaneous focus on both aspects, in addition to covering the essential and important dimensions of websites, increases user satisfaction.

In the following, we have tried to provide the most important criteria in the field of evaluation of e-government websites that are considered by researchers. Hendradjaya and Praptini evaluated government websites in Indonesia and referred to 8 criteria for usability dimension in their research. These criteria include the degree of attractiveness in participation, the level of interactions, multilingual ability, accessibility, navigability, information understandability, function understandability and operational consistency [26]. Also, Abu-Shanab and Abu-Baker evaluated Jordanian e-government websites in Asia using statistical methods and quantified four criteria for usability dimension. These criteria include the existence of government-related information, the ability to feedback easily, the design tailored to the website, and the apparent attractiveness of the website [27].

Also, in past researches, websites have been evaluated as one of the tools providing electronic government services. For example, Papadomichelaki and Mentzas have also evaluated e-government services based on the SERVQUAL model according to six dimensions. These dimensions include ease of use, trust, interaction environment performance, confidence, content, and form of information [28]. Some studies in this area focus on the use of web site evaluation models. Barnes and Vidgen aimed at evaluating the online tax system using the WEBQUAL 4.0 model and examined the influential factors on website users in the UK. In this way, they first considered five dimensions for assessment, including usability, site design, information, reliability, and empathy. They set the questions asked in the WEBQUAL model in these five dimensions, and in the next step, put 29 comments in 3 dimensions of the WEBQUAL model including usability, information and the quality of services and interactions and used them as another source of data [29].

There are several criteria with different importance in website evaluation models. Also, each decision-maker has its weight and assessment score. So, researchers used MADM methods as a useful tool for measuring the website quality. In the following, a few examples of researches in the field of applying MADM methods for evaluating e-government websites are recognized. Burmaolu and Kazancoglu aimed at evaluating EU government websites and combining Fuzzy Analytical Hierarchy Process (AHP) and Fuzzy Vlsekriterijumska Optimizacija IKOmpromisno Resenje (VIKOR) methods to prioritize these websites. In their research, they referred to three main dimensions: e-democracy, e-services and website design, considering 15 criteria [30]. Markaki, Charila, and Askounis evaluated e-government websites using the Fuzzy AHP method. They recognized five dimensions with 16 sub-criteria in their review: usability, content, site quality, e-services, and e-democracy [31]. Dominic, Jati, and Kannabiran evaluated five Asian e-government websites using the AHP methodology, with six dimensions including response time, page loading time, size, number of items, validation system, and broken link [32]. Kangmin Yuan and Jiemin Yuan used the AHP method to evaluate the e-government website, considering five main dimensions and 19 criteria (technology evaluation, user evaluation, content evaluation, performance evaluation and design evaluation) [33].

The study of previous researches shows that the use of MADM methods can be very useful due to the nature of the problem of evaluating e-government web sites and in general, the evaluation of web sites. In examining the MADM methods used in this area, two important points should be considered:

1. There are some uncertainties arise in the process which is due to reasons such as the difficulty of obtaining accurate information on some criteria [1], the existence of some qualitative criteria, the difficulty in their

proper evaluation [1] and, finally, the need to use linguistic variables to express opinions, judgments and perceptions of experts on some criteria [2].

2. The specialty of evaluations in each of the different dimensions forces most of the evaluations to be made in the form of group decision-making. Due to the incompleteness of knowledge of each of the experts in different aspects of the model, it is necessary to use approaches to aggregate the views in order to take into account the lack of homogeneity of the knowledge of the experts in the various indicators. Although, fuzzy sets show somewhat uncertainty in some cases, due to the limitations of this set of numbers, in recent years decision-making methods based on Intuitionistic Fuzzy (IF), Interval-valued Intuitionistic Fuzzy (IVIF), and hesitant fuzzy have been developed. Among these, hesitant fuzzy numbers with a collective look to the opinions of different decision-makers have the potential to model the skepticism of the experts. Therefore, this set of numbers can be used in areas such as the evaluation of e-government web sites that due to the limited expertise and experience, each member of the working group cannot comment on all the indicators and there are doubts about some of the indicators.

On the other hand, the study of the set of dimensions and indicators mentioned in the researches shows that there is no general assessment model for e-government websites agreed upon by researchers [27] and many studies focus only on specific dimensions such as the accessibility of disabled people [34] or usability [35]. So, given the characteristics of the problem and the country in question, it seems to be reasonable to present a localized model suitable for evaluating e-government websites in Iran. To this end, in this paper, considering all the effective dimensions in the success of e-government websites, we have tried to provide a relatively comprehensive model approved by the decision-makers of this field and localized based on the situation of Iran.

3 Research Method

As mentioned, the purpose of this study is to provide an appropriate framework for evaluating e-government websites. Of course, in different stages of the research, it is tried to make this framework native according to the conditions of the country of Iran; therefore, the steps designed are finalized in the form of a pilot project for six selected websites. In this research, first, previous studies in the field of evaluating e-government websites were reviewed, and the initial list of criteria for assessing e-government websites was identified. The initial list of the criteria was then reviewed and modified by the members of the E-Government Evaluation Committee, and the final list of criteria was prepared. The members of this committee have been chosen in such ways that have the knowledge and capabilities necessary to evaluate the set of identified criteria. Therefore, in the process of selection, it is tried to have a team of people with a proper perspective both theoretically and practically in the fields of art, e-commerce, and e-government.

In the next step, due to non-uniformity of the nature of criteria and consequently, the unevenness of their importance level, we have calculated the weights of the criteria using the SWARA method. Considering the need for a better evaluation of e-government websites, the e-government website evaluation working group, composed of prominent individuals in each of the different dimensions of the model, was formed under the supervision of the E-Government Evaluation Committee. Given that each member of the working group is a specialist in a particular field, they can not comment on all the indicators and also are skeptical about some indicators. Hesitant sets have been used in this paper considering its use in these conditions. In this regard, after choosing six e-government websites in Iran, assessment of each website was carried out by the evaluation working group of e-government web sites in the form of linguistic variables, and finally, the opinions have been aggregated using hesitant fuzzy sets in the form of HFWGHM operator.

The proposed approach, on the one hand, develops and localizes the indicators for assessing e-government websites, and, on the other hand, uses a hesitant fuzzy set (as one of the most recent approaches to cope with uncertainty), to offer an executive framework which has proven its effectiveness in the process of evaluating pilot web sites as well as the possibility of modeling multidisciplinary evaluation problem.

The diagram presented in Fig. 1 shows the sequence of the research steps.

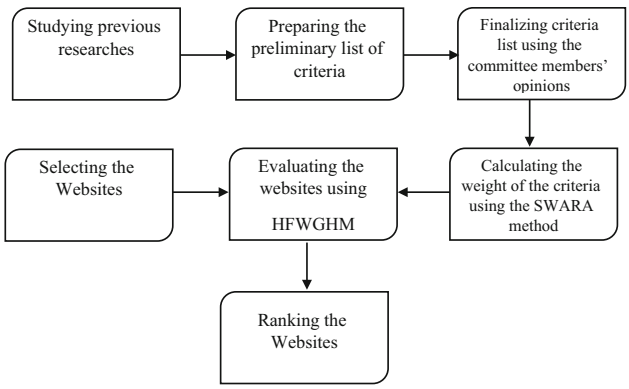

Fig. 1 The process of conducting research

3.1 SWARA Method

One method with less complexity than others is the SWARA method. This method is one of the newest weighting methods invented by Keršuliene et al. [36, 37]. In addition to user-friendliness, less complexity and reducing the time needed to apply [38, 39], one of important advantages of this method is the decision maker's ability to select, evaluate, and weight indicator. It also allows experts to apply their knowledge and experience in the relevant field [36]. In this regard, experts play a vital role in evaluating the indicators and their importance. The main steps for weighting based on the SWARA method are as follows [38, 39]:

Step 1: Sorting Indicators: At first, the indicators desired by decision-makers are selected and organized as final indicators based on the importance degree. Accordingly, the most important indicators are at higher levels and lower indicators are at lower ones.

Step 2: Determining the relative importance of each indicator (S_j): At this stage, the relative importance of each of the indicators should be determined in relation to the most important indicator, which is shown by S_j in the process of SWARA method.

Step 3: Calculating the coefficient K_j: The coefficient K_j, which is a function of the relative importance of each indicator, is calculated using the following Eq.:

$$K_j = S_j + 1. \tag{1}$$

Step 4: Calculating the initial weight of each indicator: The initial weights of the indicators can be calculated through Eq. 2. In this regard, it should be noted that the weight of the first indicator, which is the most important indicator, is considered to be 1.

$$q_j = \frac{q_{j-1}}{K_j}. \tag{2}$$

Step 5: Calculating the final normalized weight. In the final step of the SWARA method, the final weights of the indicators, which are normalized weights, are also calculated using Eq. 3.

$$w_j = \frac{q_j}{\sum q_j}. \tag{3}$$

3.2 HFWGHM Method

Multi-attribute decision-making is one of the research areas of interest in recent decades [40]. Various methods of decision-making have been widely used in various scientific fields. Nonetheless, real-world decisions are challenged for several reasons, such as the lack of quantitative information, information defects, inaccessible information, reliance on knowledge and personal preferences of experts, etc. [41]. Therefore, the researchers have proposed various developments, including fuzzy logic, intuitive fuzzy sets, type-2 fuzzy set, fuzzy multiset, and q-Rung Orthopair Fuzzy sets [42, 43]. Although these developments are able to cover a variety of aspects of the real world, they are still faced with challenges due to problems that are found in consensus among experts and decision-makers. In practical applications, due to lack of knowledge, time pressures, different levels of experience, etc., decision-makers do not usually agree on complex decisions on certain elements, so a certain membership degree can not be considered for elements, and practically decision-makers face a set of possible membership degrees [44]. To address such cases, recently, hesitant fuzzy set, proposed by Torra [45, 46], attracts a lot of researchers' interest [47, 48].

Table 1 Specifications of the selected websites

Code	Website title	Address of the website	Electronic services provided by the website
A1	Iran post company	http://post.ir	Postal mail tracking, postcards and all types of typical or express mail services
A2	Information portal Tehran bus company	http://bus.tehran.ir/	Travel timetables for buses comprehensive map of traffic, transportation, and lines
A3	Municipality of Region 20 of Tehran	http://region20.tehran.ir/	Information from various government departments in this region, keep track of legal cases, paying fees, and other electronic services
A4	Management Center of Country Roads	http://www.141.ir	All traffic information including traffic maps, surveillance cameras, vehicle technical assistance stations, fuel stations, gas station information on accidents, weather and other electronic services
A5	Islamic Republic of Iran railways	http://www.rai.ir/	Online purchase of tickets, participation and investment, and information about stations, travel agencies, trains and other electronic services
A6	Telecommunication Company of Iran	http://tct.ir/	High-speed Internet, landline, data and other services

Table 2 The final criteria for evaluating e-government websites

Row	Main dimensions (D)	Criteria (C)	Sub-criteria (S)	Description	References
1	Content (D1)	Newest information (C11)		Citizen can access to the newest information about government	[27]
		Up-to-date information (C12)		Website contains up-to-date information	[26, 27, 29, 30]
		Accurate information (C13)		Website information id = s accurate	[26, 27, 29, 31, 33]
		Validity (C14)		Provide information by authoritative sources or specialized experts in the field	[31, 33]
		Appropriate level of content details (C15)		Content presented in an appropriate level of details	[27, 29–31, 33]
2	Service and functionality (D2)	Availability (C21)		Find out what the website is about by entering the URL in the search engines	[27]
		Sense of community (C22)		This website conveys a sense of community	[26, 30]
		Assurance (C23)		This website is well known and has a good reputation	[27, 29]
		Electronic delivery of services (C24)		Using this website tasks are accomplished more quickly	[27, 33]
3	Usability and ease of use (D3)	Page design (C31)	New page speed-up (S311)	New page can be accessed within 10 s	[51]
			Appearance (S312)	The website has an attractive appearance	[27, 29–31]
			Colors (S313)	Do you think that the color of the website are visually appealing	[4]
			The possibility of predicting download time (S314)	Users can predict the response time in downloading large pages or multimedia files by indicating the size of the download next to the link	[51]
		Site design (C32)	Users can understand what to do in home pages (S321)	Users will be able to easily use the website with the help of the procedure specified on the website's home page	[51]
			FAQs (S322)	A good quality FAQ is provided to answer the user's questions	[4, 51]
			Search results (S323)	The search result page has sorted list of hits with the best hits at the top. The search result list eliminates duplicate occurrences of the same page	[51]
		Content design (C33)	Conciseness (S331)	The text is short and concise	[51]
			Page title (S332)	The page title has enough words to stand on its own and be meaningful when read in a menu or search listing	[51]
			Font size and paragragh alignment (S333)	The text is easy ti read in terms of size and paragraph alignment	[51]
			The existence of government-ralated information (S334)	Use and implementation of common features such as: information about government. The website contains easy and clear contact information	[27]
		Others (C34)	Ease of use (S341)	I find the site easy to use	[26, 27, 29]
			Navigation (S342)	I find the site easy to navigate	[4, 26, 27, 29–31, 35, 51]
			The ability to get around a site and find things (S343)	Finding easily the required information	[4, 26, 27]
			Broken links (S344)	Links in websites do not work properly	[25]
			Website is easy to read and understand (S345)	To what extent is the content on the website understandable?	[4, 27, 29]

Table 2 continued

Row	Main dimensions (D)	Criteria (C)	Sub-criteria (S)	Description	References
4	Privacy and security (D4)	Secure communication with government through the website (C41)		Assuring the users of secure communications with the government 's website	[27]
		It feels safe to complete transactions (C42)		The ability to create security for the users at the time of transactions	[29]
		User information security (C43)		It means keeping the information of the users secured	[27, 35]
5	Accessibility (D5)	High contrast between text and backgrounds (C51)		Users facilitation by the contrast of the text and background	[27, 51]
		Compatibility (C52)		The ability to run website in different search engines	[34]
		Changing the website's font to a larger (C53)		There is an option of larger fonts	[27]
		Use of color (C54)		Applying different colors in the website, taking into account users' vision problems	[34]
		Avoid using absolute fonts (C55)		The ability of websites to different letter shapes for users	[34]

In this paper, we use HFWGHM developed by [49] as an effective and flexible method to assist the decision-makers to make their decision.

Definition 1 Let X be a fixed set, then the hesitant fuzzy set on X is defined in terms of a function, when applied to the X set, returns a subset of numbers in $[0, 1]$. This set can be displayed as follows [50]:

$$E = \{\langle x, h(x)\rangle | x \in X\} \tag{4}$$

where $h(x)$ is a set of values in [0,1], which indicates the possible membership degree of each $x \in X$ in the set E. For ease, HFE (hesitant fuzzy element) is used to refer to $h(x)$.

Definition 2 If h, h_1 and h_2, are three HFEs then:

$$(1)\ h^{\lambda} = \bigcup_{\gamma \in h} \{\gamma^{\lambda}\} \tag{5}$$

$$(2)\ \lambda h = \bigcup_{\gamma \in h} \left\{1 - (1-\gamma)^{\lambda}\right\}; \tag{6}$$

$$(3)\ h_1 \oplus h_2 = \bigcup_{\gamma_1 \in h_1, \gamma_2 \in h_2} \{\gamma_1 + \gamma_2 - \gamma_1\gamma_2\} \tag{7}$$

$$(4)\ h_1 \otimes h_2 = \bigcup_{\gamma_1 \in h_1, \gamma_2 \in h_2} \{\gamma_1\gamma_2\}. \tag{8}$$

Definition 3 For hesitant fuzzy element h, $s(h) = \frac{1}{\#h}\sum_{\gamma \in h} \gamma$ is called the score function, where $\#h$ represents the number of elements of the set h. Also, if h, h_1, and h_2 are three HFEs, then the following rules and relationships govern this set:

$$(1)\ \text{If } s(h_1) > s(h_2) \text{ then}, h_1 > h_2; \tag{9}$$

If $s(h_1) = s(h_2)$then, $h_1 = h_2$.

Definition 4 Consider $h_i (i = 1, 2, \ldots, n)$ to be a set of HFEs and $\omega = (\omega_1, \omega_2, \ldots, \omega_n)^{\mathrm{T}}$ to be the weight vector of h_i, where ω_i represents the importance degree of h_i such that $\omega_i > 0$ and $\sum_{i=1}^{n} \omega_i = 1$. Then the weighted operators, HFWHM (Hesitant Fuzzy Weighted Geometric Heronian Mean), and HFWGHM, are defined as Eq. (10) and Eq. (11).

$$\mathrm{HFWHM}(h_1, h_2, \ldots, h_n) = \left(\frac{2}{n(n+1)} \sum_{i=1}^{n} \sum_{j=i}^{n} (w_i h_i)^p \otimes (w_j h_j)^q\right)^{\frac{1}{p+q}} \tag{10}$$

$$\mathrm{HFWGHM}(h_1, h_2, \ldots, h_n) = \frac{1}{p+q} \left(\bigotimes_{i=1, j=i}^{n} \left((ph_i)^{w_i} \oplus \left(qh_j\right)^{w_j} \right)^{\frac{2}{n(n+1)}} \right). \tag{11}$$

Theorem 1 *Consider* $h_i (i = 1, 2, \ldots, n)$ *to be a set of HFEs and* $\omega = (\omega_1, \omega_2, \ldots, \omega_n)^{\mathrm{T}}$ *to be the weight vector of* h_i*, where* ω_i *represents the importance degree of* h_i*, such that* $\omega_i > 0$ *and* $\sum_{i=1}^{n} \omega_i = 1$*. The aggregated value obtained from the HFWGHM or HFWHM operators will be in the form of Eq.* (12) *and* (13)*, respectively. The proof of this theorem is presented in* [49].

$$\mathrm{HFWHM}(h_1, h_2, \ldots, h_n) = \bigcup_{\xi_i \in h_i, \xi_j \in h_j} \left\{ \left(1 \prod_{i=1, j=i}^{n} \left(1 (1 - (1 - \xi_i)^{w_i})^p \left(1 - \left(1 - \xi_j\right)^{w_j}\right)^q \right)^{\frac{2}{n(n+1)}} \right)^{\frac{1}{p+q}} \right\}. \tag{12}$$

$$\mathrm{HFWGHM}(h_1, h_2, \ldots, h_n) = \bigcup_{\xi_i \in h_i, \xi_j \in h_j} \left\{ 1 - \left(1 - \prod_{i=1, j=i}^{n} \left(1 - (1 - \xi_i^{w_i})^p \left(1 - \xi_j^{w_j}\right)^q \right)^{\frac{2}{n(n+1)}} \right)^{\frac{1}{p+q}} \right\}. \tag{13}$$

4 Case Study

As mentioned, the present study was conducted in line with the issue defined by the ITO as an e-government trustee in Iran to assess the level of puberty of government agencies in providing electronic services through the web. As part of its tasks, the E-Government Evaluation Committee needed to provide a framework for evaluating the websites of government-owned subsidiaries. In this regard, four members of the E-Government Website Assessment Committee working group identified the criteria, determined their importance based on SWARA method, selected sample websites, calculated the score of each of the websites according to the final criteria and ultimately calculated the final score of each website using the HFWGHM method.

Of course, as mentioned earlier, with regard to the specialized areas of each working group member, each expert may be skeptical about website evaluation in different metrics, which has led to the use of hesitant fuzzy numbers in this paper.

Based on the research steps mentioned above, in first step, the committee members selected six websites among various e-government websites based on common criteria such as the popularity of the website (based on the number of visitors) and application diversity. The characteristics of the six selected websites are presented in Table 1. In the following, the methodology presented in this paper is used to evaluate these websites more precisely.

4.1 Identification and Extraction of Criteria

In the first step, the literature was reviewed in order to determine the main criteria and sub-criteria to evaluate the e-government websites. Previous researches have shown that different models have been developed by researchers to evaluate websites. Among these models, the Web-Qual model has become more prominent due to the special attention paid to the effective criteria in website evaluation. As outlined in the background review section, the initial model has undergone many changes over time, and gradually specialized and localized models have been proposed to evaluate specialized fields. In this paper, Abu-Shanab et al. [27] model has been considered because of its comprehensiveness compared to other evaluation models, which includes seven dimensions of services, ease of use, security and privacy, usability, accessibility, content and functionality. They investigated various versions of the Web-Qaul models and other models proposed in previous researches and tried to cover the research gap of this field by providing a comprehensive model. In order to identify the following indicators of these dimensions, complete review of the past literature has been done. In the following, the list of criteria was corrected and moderated by feedback from the members of the E-government

Table 3 Calculating the weight of each main dimension

Code	Criteria	Comparative importance of average value (*Sj*)	Coefficient (K_j)	Recalculated weight (q_j)	Weight (W_j)
D1	Content		1	1	0.2954
D3	Usability and ease of use	0.1	1.1	0.9091	0.2685
D4	Privacy and security	0.3	1.3	0.6993	0.2066
D2	Service and functionality	0.4	1.4	0.4995	0.1475
D5	Accessability	0.8	1.8	0.2775	0.082

Table 4 Calculating the weight of each e-government website evaluation criteria

Code	Criteria	Comparative importance of average value (S_j)	Coefficient (K_j)	Recalculated weight (q_j)	Weight (W_j)	Global weight
W_{D1} = 0.2954/(D1) criteria of content						
C11	Newest information		1	1	0.2843	0.08397
C12	Up-to-date information	0.1	1.1	0.9091	0.2584	0.07634
C13	Accurate information	0.4	1.4	0.6494	0.1846	0.05453
C14	Validity	0.1	1.1	0.5903	0.1678	0.04957
C15	Appropriate level of content details	0.6	1.6	0.3689	0.1049	0.03098
W_{D2} = 0.1475/(D2) criteria of service and functionality						
C21	Availability		1	1	0.3533	0.05213
C23	Assurance	0.2	1.2	0.8333	0.2944	0.04344
C24	Electronic delivery of services	0.3	1.3	0.641	0.2265	0.03342
C22	Sense of community	0.8	1.8	0.3561	0.1258	0.01856
W_{D3} = 0.2685/(D3) criteria of usability and ease of use						
C31	Page design		1	1	0.2785	0.07478
C33	Content design	0	1	1	0.2785	0.07478
C32	Site design	0.2	1.2	0.8333	0.2321	0.06232
C34	Others	0.1	1.1	0.7576	0.211	0.05665
W_{C31} = 0.07478/C31 sub-criteria of page design						
S311	New page speed-up		1	1	0.336	0.02512
S312	Appearance	0.1	1.1	0.9091	0.3054	0.02284
S313	Colors	0.3	1.3	0.6993	0.2349	0.01757
S314	The possibility of predicting download time	0.9	1.9	0.3681	0.1237	0.00925
W_{C2} = 0.06232/C32 sub-criteria of site design						
S321	Users can understand what to do in home pages		1	1	0.4248	0.02647
S322	FAQs	0.2	1.2	0.8333	0.354	0.02206
S323	Search results	0.6	1.6	0.5208	0.2212	0.01379
W_{C33} = 0.07478/C33 sub-criteria of content design						
S331	Conciseness		1	1	0.3392	0.02537
S334	The existence of government-related information	0.1	1.1	0.9091	0.3084	0.02306
S332	Page title	0.5	1.5	0.6061	0.2056	0.01537
S333	Font size and paragraph alignment	0.4	1.4	0.4329	0.1468	0.01098
W_{C4} = 0.05666/C34 sub-criteria of others						
S341	Ease of use		1	1	0.2819	0.01597
S342	Navigation	0.2	1.2	0.8333	0.2349	0.01331
S344	Broken links	0.2	1.2	0.6944	0.1958	0.01109
S343	The ability to get around site and find things	0.3	1.3	0.5342	0.1506	0.00853
S345	Website is easy to read and understand	0.1	1.1	0.4856	0.1369	0.00776
W_{D4} = 0.2066/(D4) criteria of privacy and security						
C41	Secure communication with government through the website		1	1	0.3438	0.07101
C43	User information security	0	1	1	0.3438	0.07101
C42	It feels safe to complete transactions	0.1	1.1	0.9091	0.3125	0.06455
W_{D5} = 0.082/(D5) criteria of accessability						
C51	High contrast between text and background		1	1	0.3103	0.02543
C53	Changing the website's font to a larger	0.4	1.4	0.7143	0.2216	0.01817

Table 4 continued

Code	Criteria	Comparative importance of average value (S_j)	Coefficient (K_j)	Recalculated weight (q_j)	Weight (W_j)	Global weight
C54	Use of colors	0.1	1.1	0.6494	0.2015	0.01651
C52	Compatibility	0.2	1.2	0.5411	0.1679	0.01376
C55	Avoid using absolute fonts	0.7	1.7	0.3183	0.0988	0.0081

Table 5 Linguistic variables

Linguistic variables	Sign	Value
Very Good	VG	1
Good	G	0.9
Fair	F	0.5
Medium Poor	MP	0.3
Poor	P	0.1

Assessment Committee and the relevant working group, and final criteria for assessing e-government websites were identified.

As shows in Table 2, the final model has five main dimensions (with 33 criteria) including content, services and functionality, usability and ease of use, security and accessibility.

4.2 Calculating the Weight of the Criteria

As seen in the previous section, there are several effective criteria for evaluating e-government websites. Due to different importances of these criteria in assessing a website, the SWARA method was used to determine the weight of each identified criterion. Regarding the necessity of aligning the views of all members of the working group on the importance of the criteria, the criteria were prioritized by aggregating the views of the members using the Borda method. In addition, the relative importance of each indicator (Sj) is calculated based on the average of the scores given by the members of the working group. In the following, the results of various steps of SWARA method are presented. In the first step, the members of the working group began to calculate the weight of each of the five main dimensions. Table 3 shows the weight calculation process. In this table, Sj is the relative importance of each indicator, which is calculated as the arithmetic average of scores of the members. In the following, the value of the coefficient K_j is calculated using Eq. 1. Then the initial weight of each indicator (q_j) is calculated based on Eq. 2, and finally the final normalized weight of each dimension $\left(w_j\right)$ is calculated using Eq. 3.

As the numbers in this table show, two dimensions of "content" and "usability and ease of use" are more important than other dimensions.

In the following, it was tried to calculate the importance of relevant criteria in each dimension. The computations of this section are carried out in the same way as calculations of dimension weights. The results are presented in Table 4. In this table, the Global Weight column is obtained by multiplying the weight of each criterion in the related dimension (local weight) by the weight of that dimension derived from column w_j in Table 3. In the calculation of the main dimensions and the sub-criteria of usability and ease of use (D3), this procedure has been conducted in two steps.

4.3 Evaluating Selected Websites and Prioritizing Them

After calculating the weight of each indicator, in order to prioritize the selected websites, the views of experts on the website ranking have been obtained based on each indicator using linguistic variables which are available in Table 5. The results are summarized in Table 6.

Now, the evaluations carried out by the experts can be converted to the hesitant fuzzy set. In other words, the initial decision matrix is changed to the hesitant fuzzy decision matrix. By converting the linguistic variables into equivalent values, the numerical form of the hesitant fuzzy decision matrix is formed as Table 7.

As can be seen in this matrix, in a hesitant fuzzy set, the difference in the opinions of the experts in the evaluations is well-modeled. For example, in the decision matrix, consider the value $h_{21} = \{0.9, 1\}$; this means that the experts have similar views on the assessment of Alternative 2 according to the "newest information" criterion. As another example, consider $h_{38} = \{1, 0.9, 0.1\}$. This means that two of the four members of the evaluation team have a similar view on the alternative 3 (region20.tehran.ir) according to the "website assurance" criterion, and two other members have presented a different view, which are not similar to each other. Therefore, HFE for evaluating the third alternative based on the "website assurance" criterion has three different members.

Table 6 Aggregated decision matrix (based on linguistic variables)

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
C11	Newest information	Positive	0.084	{G, F}	{G, VG}	{G, VG}	{G, VG, F}	{F, VG, G}	{VG, F, MP}
C12	Up-to-date information	Positive	0.0763	{VG, F, G}	{VG, P}	{VG}	{VG}	{VG, G}	{VG, MP}
C13	Accurate information	Positive	0.0545	{VG, G, P}	{VG, MP}	{VG, MP}	{VG, F}	{VG}	{VG, MP}
C14	Validity	Positive	0.0496	{VG, G}	{G, VG, MP}	{G, VG}	{VG, G}	{VG}	{VG, F}
C15	Appropriate level of content details	Positive	0.031	{VG, P}	{VG, F}	{VG, G}	{VG, G}	{VG, G}	{VG, MP}
C21	Availability	Positive	0.0521	{P}	{VG}	{VG}	{G, F, VG}	{VG, P}	{G, VG}
C22	Sense of community	Positive	0.0186	{MP, F}	{F, G, MP}	{MP, VG}	{MP, F, VG, G}	{MP, G}	{F, G, VG, P}
C23	Assurance	Positive	0.0434	{MP, VG, G}	{VG, G}	{VG, G, P}	{VG, G}	{G, VG, F}	{G, VG}
C24	Electronic delivery of services	Positive	0.0334	{VG, G, MP}	{F, G, VG}	{G, F}	{G, VG, F}	{G, VG, F}	{G, VG, P}
S311	New page speed-up	Positive	0.0251	{G, F, P}	{G, VG}	{G, VG, P}	{G, VG}	{VG, P}	{VG}
S312	Appearance	Positive	0.0228	{G, F, MP}	{G, F, VG, MP}	{F, MP, VG}	{G, VG, F}	{F, G}	{G, VG}
S313	Colors	Positive	0.0176	{VG, G, MP}	{VG, MP, P}	{MP, F, VG}	{F, VG, MP}	{F, MP}	{G, VG}
S314	The possibility of predicting download time	Positive	0.0092	{MP, P}	{MP, VG, F}	{MP, G, P, F}	{F, VG}	{MP, VG, F}	{MP, VG, F}
S321	Users can understand what to do in home pages	Positive	0.0265	{VG, G, MP}	{VG, G, F}	{VG, G, F}	{VG, F, P}	{G, VG, F}	{MP, VG, P}
S322	FAQs	Positive	0.0221	{VG, G, MP}	{VG, G, MP}	{VG, F, P, G}	{VG, G, MP}	{G, F}	{MP, G, VG, P}
S334	The existence of government-related information	Positive	0.0231	{F}	{VG, G}	{MP, G, P}	{VG}	{P, G, MP}	{G, F, VG}
S331	Conciseness	Positive	0.0254	{F, MP, P}	{G, VG, F}	{F, G}	{G, VG}	{MP, VG, G}	{G, VG, MP}
S332	Page title	Positive	0.0154	{VG, G, MP}	{VG, MP}	{VG, F}	{VG, G, F}	{G, VG, F}	{G, VG}
S333	Font size and paragraph alignment	Positive	0.011	{F, P}	{G, VG, MP}	{F, VG, MP}	{G, VG, MP}	{MP, VG}	{G, VG, F}
S323	Search results	Positive	0.0138	{F, G}	{VG, F, MP}	{G, VG}	{F, VG, MP}	{G, F, MP}	{F, VG, MP}
S341	Ease of use	Positive	0.016	{F, G}	{G, F}	{G, F}	{F, VG, P}	{F, G}	{F, MP, VG}
S342	Navigation	Positive	0.0133	{G, VG, F}	{G, F}	{F, G}	{G, F, VG, P}	{G, VG}	{MP, VG}
S343	The ability to get around site and find things	Positive	0.0085	{VG, G, F}	{VG, G, F}	{G, F}	{MP, F, VG, P}	{G, VG, MP}	{G, VG, MP}
S344	Broken links	Negative	0.0111	{P, MP}	{P, G}	{G, MP, VG}	{MP, G, VG}	{G, MP, P}	{MP, F, VG}
S345	Website is easy to read and understand	Positive	0.0078	{G, F}	{VG, G}	{G, VG, MP}	{G, VG, F}	{G, VG, F, MP}	{VG, G}
C41	Secure communication with government through the website	Positive	0.071	{F, MP}	{F, VG}	{VG, G, MP}	{F, VG}	{VG, F}	{G, VG}

Table 6 continued

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
C42	It feels safe to complete transactions	Positive	0.0646	{G}	{G, VG}	{VG, F, MP}	{VG, G}	{G, VG}	{G, VG}
C43	User information security	Positive	0.071	{G, F}	{VG, G}	{G, F, MP}	{VG, G}	{G}	{G, VG}
C51	High contrast between text and backgrounds	Positive	0.0254	{Mp, G, P}	{G, F, VG}	{G, F, MP}	{G, VG, MP}	{F, VG, MP}	{VG, F}
C52	Compatibility	Positive	0.0138	{F, G}	{G, VG}	{VG, G}	{VG, G}	{VG, G}	{VG, G}
C53	Changing the website's font to a larger	Positive	0.0182	{VG}	{P, G, VG}	{VG, G, P}	{VG, G}	{P, G, MP}	{VG, G}
C54	Use of color	Positive	0.0165	{F, MP}	{G, VG, F}	{G, F, VG}	{VG, P}	{F, G, MP}	{VG, G}
C55	Avoid using absolute fonts	Positive	0.0081	{P, F}	{Mp, F, P}	{MP, F, G}	{P, VG}	{P, G, F}	{P, VG, F}

Table 7 Aggregated decision matrix based on the equivalent values of the linguistic variables

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
C11	Newest information	Positive	0.084	{0.9, 0.5}	{0.9, 1}	{0.9, 1}	{0.9, 1, 0.5}	{0.5, 1, 0.9}	{1, 0.5, 0.3}
C12	Up-to-date information	Positive	0.0763	{1, 0.5, 0.9}	{1, 0.1}	1	1	{1, 0.9}	{1, 0.3}
C13	Accurate information	Positive	0.0545	{1, 0.9, 0.1}	{1, 0.3}	{1, 0.3}	{1, 0.5}	1	{1, 0.3}
C14	Validity	Positive	0.0496	{1, 0.9}	{0.9, 1, 0.3}	{0.9, 1}	{1, 0.9}	1	{1, 0.5}
C15	Appropriate level of content details	Positive	0.031	{1, 0.1}	{1, 0.5}	{1, 0.9}	{1, 0.9}	{1, 0.9}	{1, 0.3}
C21	Availability	Positive	0.0521	0.1	1	1	{0.9, 0.5, 1}	{1, 0.1}	{0.9, 1}
C22	Sense of community	Positive	0.0186	{0.3, 0.5}	{0.5, 0.9, 0.3}	{0.3, 1}	{0.3, 0.5, 1, 0.9}	{0.3, 0.9}	{0.5, 0.9, 1, 0.1}
C23	Assurance	Positive	0.0434	{0.3, 1, 0.9}	{1, 0.9}	{1, 0.9, 0.1}	{1, 0.9}	{0.9, 1, 0.5}	{0.9, 1}
C24	Electronic delivery of services	Positive	0.0334	{1, 0.9, 0.3}	{0.5, 0.9, 1}	{0.9, 0.5}	{0.9, 1, 0.5}	{0.9, 1, 0.5}	{0.9, 1, 0.1}
S311	New page speed-up	Positive	0.0251	{0.9, 0.5, 0.1}	{0.9, 1}	{0.9, 1, 0.1}	{0.9, 1}	{1, 0.1}	1
S312	Appearance	Positive	0.0228	{0.9, 0.5, 0.3}	{0.9, 0.5, 1, 0.3}	{0.5, 0.3, 1}	{0.9, 1, 0.5}	{0.5, 0.9}	{0.9, 1}
S313	Colors	Positive	0.0176	{1, 0.9, 0.3}	{1, 0.3, 0.1}	{0.3, 0.5, 1}	{0.5, 1, 0.3}	{0.5, 0.3}	{0.9, 1}
S314	The possibility of predicting download time	Positive	0.0092	{0.3, 0.1}	{0.3, 1, 0.5}	{0.3, 0.9, 0.1, 0.5}	{0.5, 1}	{0.3, 1, 0.5}	{0.3, 1, 0.5}

Table 7 continued

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
S321	Users can understand what to do in home pages	Positive	0.0265	{1, 0.9, 0.3}	{1, 0.9, 0.5}	{1, 0.9, 0.5}	{1, 0.5, 0.1}	{0.9, 1, 0.5}	{0.3, 1, 0.1}
S322	FAQs	Positive	0.0221	{1, 0.9, 0.3}	{1, 0.9, 0.3}	1, 0.5, 0.1, 0.9}	{1, 0.9, 0.3}	{0.9, 0.5}	{0.3, 0.9, 1, 0.1}
S334	The existence of government-related information	Positive	0.0231	0.5	{1, 0.9}	{0.3, 0.9, 0.1}	1	{0.1, 0.9, 0.3}	{0.9, 0.5, 1}
S331	Conciseness	Positive	0.0254	{0.5, 0.3, 0.1}	{0.9, 1, 0.5}	{0.5, 0.9}	{0.9, 1}	{0.3, 1, 0.9}	{0.9, 1, 0.3}
S332	Page title	Positive	0.0154	{1, 0.9, 0.3}	{1, 0.3}	{1, 0.5}	{1, 0.9, 0.5}	{0.9, 1, 0.5}	{0.9, 1}
S333	Font size and paragraph alignment	Positive	0.011	{0.5, 0.1}	{0.9, 1, 0.3}	{0.5, 1, 0.3}	{0.9, 1, 0.3}	{0.3, 1}	{0.9, 1, 0.5}
S323	Search results	Positive	0.0138	{0.5, 0.9}	{1, 0.5, 0.3}	{0.9, 1}	{0.5, 1, 0.3}	{0.9, 0.5, 0.3}	{0.5, 1, 0.3}
S341	Ease of use	Positive	0.016	{0.5, 0.9}	{0.9, 0.5}	{0.9, 0.5}	{0.5, 1, 0.1}	{0.5, 0.9}	{0.5, 0.3, 1}
S342	Navigation	Positive	0.0133	{0.9, 1, 0.5}	{0.9, 0.5}	{0.5, 0.9}	{0.9, 0.5, 1, 0.1}	{0.9, 1}	{0.3, 1}
S343	The ability to get around site and find things	Positive	0.0085	{1, 0.9, 0.5}	{1, 0.9, 0.5}	{0.9, 0.5}	{0.3, 0.5, 1, 0.1}	{0.9, 1, 0.3}	{0.9, 1, 0.3}
S344	Broken links	Negative	0.0111	{0.1, 0.3}	{0.1, 0.9}	{0.9, 0.3, 1}	{0.3, 0.9, 1}	{0.9, 0.3, 0.1}	{0.3, 0.5, 1}
S345	Website is easy to read and understand	Positive	0.0078	{0.9, 0.5}	{1, 0.9}	{0.9, 1, 0.3}	{0.9, 1, 0.5}	{0.9, 1, 0.5, 0.3}	{1, 0.9}
C41	Secure communication with government through the website	Positive	0.071	{0.5, 0.3}	{0.5, 1}	{1, 0.9, 0.3}	{0.5, 1}	{1, 0.5}	{0.9, 1}
C42	It feels safe to complete transactions	Positive	0.0646	0.9	{0.9, 1}	{1, 0.5, 0.3}	{1, 0.9}	{0.9, 1}	{0.9, 1}
C43	User information security	Positive	0.071	{0.9, 0.5}	{1, 0.9}	{0.9, 0.5, 0.3}	{1, 0.9}	0.9	{0.9, 1}
C51	High contrast between text and backgrounds	Positive	0.0254	{0.3, 0.9, 0.1}	{0.9, 0.5, 1}	{0.9, 0.5, 0.3}	{0.9, 1, 0.3}	{0.5, 1, 0.3}	{1, 0.5}
C52	Compatibility	Positive	0.0138	{0.5, 0.9}	{0.9, 1}	{1, 0.9}	{1, 0.9}	{1, 0.9}	{1, 0.9}
C53	Changing the website's font to a larger	Positive	0.0182	1	{0.1, 0.9, 1}	{1, 0.9, 0.1}	{1, 0.9}	{0.1, 0.9, 0.3}	{1, 0.9}
C54	Use of color	Positive	0.0165	{0.5, 0.3}	{0.9, 1, 0.5}	{0.9, 0.5, 1}	{1, 0.1}	{0.5, 0.9, 0.3}	{1, 0.9}
C55	Avoid using absolute fonts	Positive	0.0081	{0.1, 0.5}	{0.3, 0.5, 0.1}	{0.3, 0.5, 0.9}	{0.1, 1}	{0.1, 0.9, 0.5}	{0.1, 1, 0.5}

Table 8 Normalized aggregated decision matrix

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
C11	Newest information	Positive	0.084	{0.9, 0.5}	{0.9, 1}	{0.9, 1}	{0.9, 1, 0.5}	{0.5, 1, 0.9}	{1, 0.5, 0.3}
C12	Up-to-date information	Positive	0.0763	{1, 0.5, 0.9}	{1, 0.1}	1	1	{1, 0.9}	{1, 0.3}
C13	Accurate information	Positive	0.0545	{1, 0.9, 0.1}	{1, 0.3}	{1, 0.3}	{1, 0.5}	1	{1, 0.3}
C14	Validity	Positive	0.0496	{1, 0.9}	{0.9, 1, 0.3}	{0.9, 1}	{1, 0.9}	1	{1, 0.5}
C15	Appropriate level of content details	Positive	0.031	{1, 0.1}	{1, 0.5}	{1, 0.9}	{1, 0.9}	{1, 0.9}	{1, 0.3}
C21	Availability	Positive	0.0521	0.1	1	1	{0.9, 0.5, 1}	{1, 0.1}	{0.9, 1}
C22	Sense of community	Positive	0.0186	{0.3, 0.5}	{0.5, 0.9, 0.3}	{0.3, 1}	{0.3, 0.5, 1, 0.9}	{0.3, 0.9}	{0.5, 0.9, 1, 0.1}
C23	Assurance	Positive	0.0434	{0.3, 1, 0.9}	{1, 0.9}	{1, 0.9, 0.1}	{1, 0.9}	{0.9, 1, 0.5}	{0.9, 1}
C24	Electronic delivery of services	Positive	0.0334	{1, 0.9, 0.3}	{0.5, 0.9, 1}	{0.9, 0.5}	{0.9, 1, 0.5}	{0.9, 1, 0.5}	{0.9, 1, 0.1}
S311	New page speed-up	Positive	0.0251	{0.9, 0.5, 0.1}	{0.9, 1}	{0.9, 1, 0.1}	{0.9, 1}	{1, 0.1}	1
S312	Appearance	Positive	0.0228	{0.9, 0.5, 0.3}	{0.9, 0.5, 1, 0.3}	{0.5, 0.3, 1}	{0.9, 1, 0.5}	{0.5, 0.9}	{0.9, 1}
S313	Colors	Positive	0.0176	{1, 0.9, 0.3}	{1, 0.3, 0.1}	{0.3, 0.5, 1}	{0.5, 1, 0.3}	{0.5, 0.3}	{0.9, 1}
S314	The possibility of predicting download time	Positive	0.0092	{0.3, 0.1}	{0.3, 1, 0.5}	{0.3, 0.9, 0.1, 0.5}	{0.5, 1}	{0.3, 1, 0.5}	{0.3, 1, 0.5}
S321	Users can understand what to do in home pages	Positive	0.0265	{1, 0.9, 0.3}	{1, 0.9, 0.5}	{1, 0.9, 0.5}	{1, 0.5, 0.1}	{0.9, 1, 0.5}	{0.3, 1, 0.1}
S322	FAQs	Positive	0.0221	{1, 0.9, 0.3}	{1, 0.9, 0.3}	{1, 0.5, 0.1, 0.9}	{1, 0.9, 0.3}	{0.9, 0.5}	{0.3, 0.9, 1, 0.1}
S334	The existence of government-related information	Positive	0.0231	0.5	{1, 0.9}	{0.3, 0.9, 0.1}	1	{0.1, 0.9, 0.3}	{0.9, 0.5, 1}
S331	Conciseness	Positive	0.0254	{0.5, 0.3, 0.1}	{0.9, 1, 0.5}	{0.5, 0.9}	{0.9, 1}	{0.3, 1, 0.9}	{0.9, 1, 0.3}
S332	Page title	Positive	0.0154	{1, 0.9, 0.3}	{1, 0.3}	{1, 0.5}	{1, 0.9, 0.5}	{0.9, 1, 0.5}	{0.9, 1}
S333	Font size and paragraph alignment	Positive	0.011	{0.5, 0.1}	{0.9, 1, 0.3}	{0.5, 1, 0.3}	{0.9, 1, 0.3}	{0.3, 1}	{0.9, 1, 0.5}
S323	Search results	Positive	0.0138	{0.5, 0.9}	{1, 0.5, 0.3}	{0.9, 1}	{0.5, 1, 0.3}	{0.9, 0.5, 0.3}	{0.5, 1, 0.3}
S341	Ease of use	Positive	0.016	{0.5, 0.9}	{0.9, 0.5}	{0.9, 0.5}	{0.5, 1, 0.1}	{0.5, 0.9}	{0.5, 0.3, 1}
S342	Navigation	Positive	0.0133	{0.9, 1, 0.5}	{0.9, 0.5}	{0.5, 0.9}	{0.9, 0.5, 1, 0.1}	{0.9, 1}	{0.3, 1}
S343	The ability to get around site and find things	Positive	0.0085	{1, 0.9, 0.5}	{1, 0.9, 0.5}	{0.9, 0.5}	{0.3, 0.5, 1, 0.1}	{0.9, 1, 0.3}	{0.9, 1, 0.3}
S344	Broken links	Negative	0.0111	{0.9, 0.7}	{0.9, 0.1}	{0.1, 0.7, 0}	{0.7, 0.1, 0}	{0.1, 0.7, 0.9}	{0.7, 0.5, 0}
S345	Website is easy to read and understand	Positive	0.0078	{0.9, 0.5}	{1, 0.9}	{0.9, 1, 0.3}	{0.9, 1, 0.5}	{0.9, 1, 0.5, 0.3}	{1, 0.9}
C41	Secure communication with government through the website	Positive	0.071	{0.5, 0.3}	{0.5, 1}	{1, 0.9, 0.3}	{0.5, 1}	{1, 0.5}	{0.9, 1}
C42	It feels safe to complete transactions	Positive	0.0646	0.9	{0.9, 1}	{1, 0.5, 0.3}	{1, 0.9}	{0.9, 1}	{0.9, 1}
C43	User information security	Positive	0.071	{0.9, 0.5}	{1, 0.9}	{0.9, 0.5, 0.3}	{1, 0.9}	0.9	{0.9, 1}

Table 8 continued

Code	Criteria name	Type	Weight	A1	A2	A3	A4	A5	A6
C51	High contrast between text and backgrounds	Positive	0.0254	{0.3, 0.9, 0.1}	{0.9, 0.5, 1}	{0.9, 0.5, 0.3}	{0.9, 1, 0.3}	{0.5, 1, 0.3}	{1, 0.5}
C52	Compatibility	Positive	0.0138	{0.5, 0.9}	{0.9, 1}	{1, 0.9}	{1, 0.9}	{1, 0.9}	{1, 0.9}
C53	Changing the website's font to a larger	Positive	0.0182	1	{0.1, 0.9, 1}	{1, 0.9, 0.1}	{1, 0.9}	{0.1, 0.9, 0.3}	{1, 0.9}
C54	Use of color	Positive	0.0165	{0.5, 0.3}	{0.9, 1, 0.5}	{0.9, 0.5, 1}	{1, 0.1}	{0.5, 0.9, 0.3}	{1, 0.9}
C55	Avoid using absolute fonts	Positive	0.0081	{0.1, 0.5}	{0.3, 0.5, 0.1}	{0.3, 0.5, 0.9}	{0.1, 1}	{0.1, 0.9, 0.5}	{0.1, 1, 0.5}

In the next step, according to the steps discussed in solving hesitant fuzzy problems, the hesitant fuzzy decision matrix is normalized as Table 8 (Broken link criterion is negative).

Following the process, it is necessary to aggregate the performance values of each alternative using the HFWGHM operator, and the score corresponding to each alternative is calculated using Eqs. 12 and 13. After calculating these scores, using the equation outlined in Definition, the evaluation score of each alternative is calculated and their ranking is done. Also, in order to show the effect of the parameters p and q in this case, the evaluation scores of the alternatives are calculated based on different values of p and q and the ranking of alternatives for each of these scenarios is done. The results are shown in Table 9.

Two parameters p and q also change the aggregated values of HFEs using the HFWGHM operator, which can be seen separately for each of the alternatives in Fig. 2.

As shown in the Table 9, Alternative 4 (141.ir) is assigned the highest rank in all of the different values p and q. The reason for this is the difference in the weight of the criteria. In other words, because C11 and C12 have higher weights, and the aggregation of expert opinions on these criteria for Alternative 4 has higher degree compared to other alternatives, the fourth alternative has the highest rank by applying the multi-attribute decision-making method proposed in this study.

5 Comparision and Discussion

In order to analyze the stability of the method used, the results of the HFWGHM operator are compared with the results of the Hesitant Fuzzy Weighted Geometric Heronian Mean (HFWHM), hesitant fuzzy weighted Bonferroni mean (HFWBM) [52] and hesitant fuzzy weighted geometric Bonferroni mean (HFWGBM) [53] operators. In order to show the effect of the parameters p and q on the results of the operators, various values of p and q are used in the aggregation of HFE and the final ranking of the alternatives is presented for different values of p and q in the form of Table 10. As can be seen, the results of the decision-making method used in a hesitant environment for different operators are rarely changed. Therefore, the results of the applied model have acceptable stability, as is often reported in the literature [49].

For evaluating the performance of the HFWGHM operator and measure the similarity of the results obtained from this operator with the results of other operators, the Spearman rank correlation coefficient (Eq. 14) is used.

$$r_s = 1 - \frac{6\sum_i d_i^2}{n^3 - n} \tag{14}$$

Table 9 Calculating evaluation scores of selected websites and their ranks based on different values of p and q

EG websites	$p = 0, q = 1$		$p = q = 1$		$p = q = 5$		$p = 0, q = 10$		$p = 10, q = 0$	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Post.ir	0.979614	6	0.975325	6	0.940181	5	0.932952	5	0.931134	5
Tct.ir	0.987764	3	0.9808	5	0.907026	6	0.922804	6	0.913975	6
Region20.tehran.ir	0.984612	5	0.983881	3	0.950662	3	0.946289	3	0.948393	3
141.ir	0.993811	1	0.991298	1	0.97041	1	0.969617	1	0.964385	1
Rai.ir	0.992532	2	0.99031	2	0.967283	2	0.968494	2	0.963849	2
Bus.tehran.ir	0.98728	4	0.981083	4	0.943914	4	0.942691	4	0.934231	4

where d_i indicates the difference between the rank of ith alternative in the proposed method and the other methods and n denotes the number of available pair values. The values of the Spearman rank correlation coefficient for various values of p and q are given in Table 11.

As can be seen, in average, the HFWGHM operator is more correlated with HFWHM. Maybe this is because the other operators use the Bonferroni mean.

The literature points out that in the real decision-making problems, the decision-makers taking a gloomy view of the prospects can select the higher p and q while optimistic decision-makers can consider lower values for them [54]. The results in Table 11 shows that when $p = q = 1$, operators are more correlated. Hence, the method presented in this study is more flexible to evaluate the E-Government websites and make decisions compared to other improved MADM methods. The hesitant fuzzy MADM method based on HFWGHM operator uses the geometric mean operator for aggregation of the opinions of various experts and group decision-making. The final results of this analysis were also provided to the members of the e-Government Evaluation Committee of ITO organization and confirmed.

6 Conclusion

One of the tools that would create a competitive advantage for an organization is the Internet. By setting up websites on the Internet, organizations can offer their products and services. The importance of the existence of websites for the provision of electronic services is undeniable in government organizations because they have improved the achievement of e-government goals in countries. Hence, the importance of evaluating these categories of websites is obvious for governments. This has led to numerous studies aimed at evaluating e-government websites in different countries. The examination of the dimensions and indicators mentioned in previous studies shows that no general model exists to assess all dimensions of e-government websites agreed upon by researchers. This emphasizes the need for a relatively comprehensive model that is native and approved by decision-makers in this area (in Iran). Accordingly, in this research, we tried to present a list of dimensions and evaluation criteria in the form of a comprehensive model through a careful and systematic review of past researches in the field of evaluation of e-government websites. Then, this list was given to the members of the E-Government Evaluation Committee and the relevant working group, which were the experts in this area. Following the necessary reforms, the original model was changed to a localized model that was appropriate to the conditions of Iran.

On the other hand, because of the nature of the problem and the need to consider various criteria in evaluating these websites, the use of multi-attribute decision-making methods was confirmed in previous studies. In examining the MADM methods used in this area, two important points should be considered: first, uncertainties arise in the evaluation process due to several factors such as the difficulty of obtaining accurate information on some criteria, the existence of some qualitative criteria and their difficult evaluation and eventually the need to use linguistic variables to express opinions, judgments, and perceptions of experts about some of the criteria. Second, the specialty of evaluations in each dimension requires group assessment (usually in the form of committees and formal working groups). However, due to the incomplete knowledge of each of the experts in different aspects of the model, it is necessary to use approaches to aggregate the views taking into account the lack of homogeneity of the knowledge of the experts in the various indicators. The combination of SWARA and HFWGHM decision-making methods, on the one hand, allows for aggregation of opinions and group decision-making, and on the other hand, models the skepticism of the experts by using a hesitant fuzzy set. Hence, it can help decision-makers to overcome the problems. This issue will be more effective especially in cases where, due

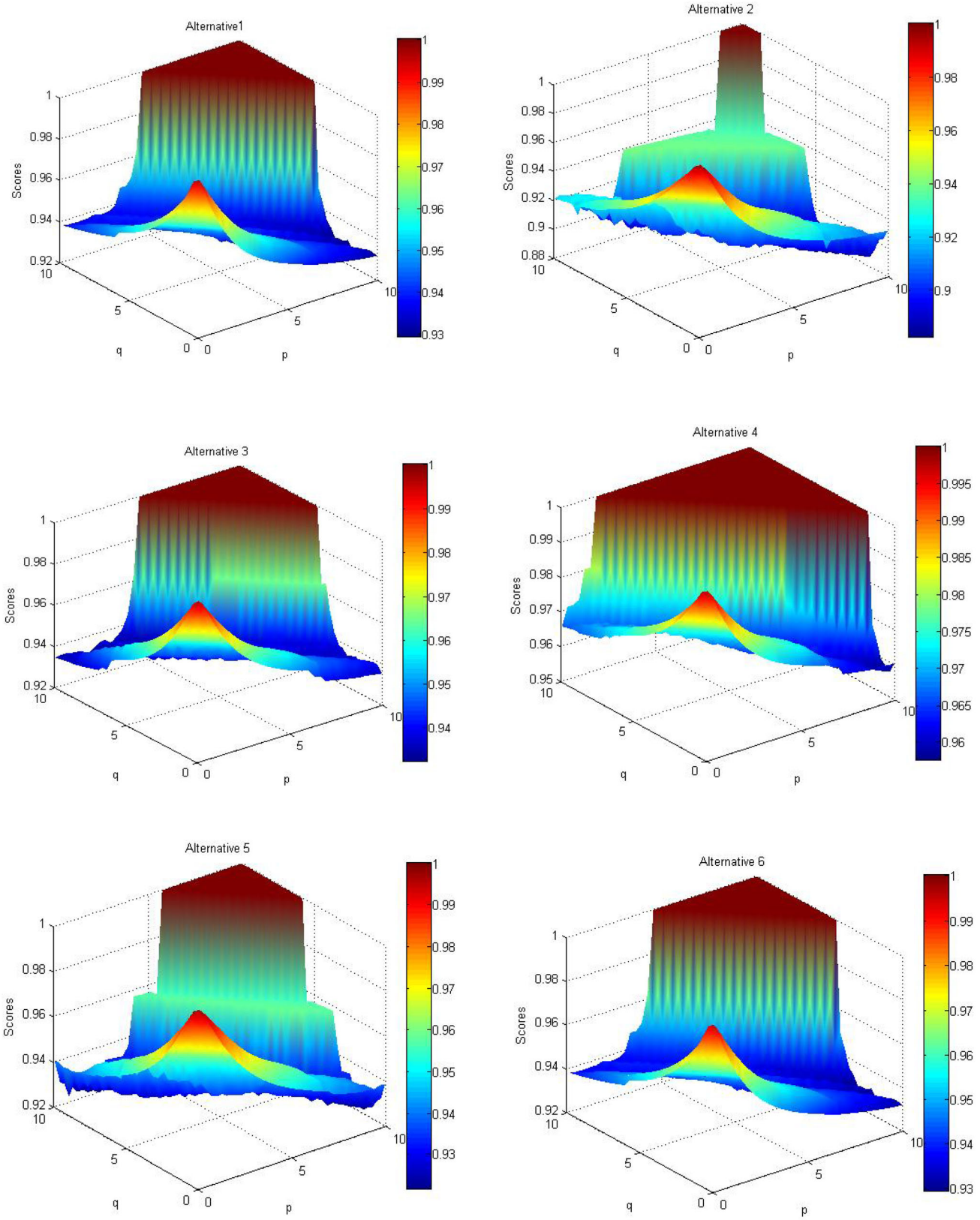

Fig. 2 Scores of each alternative (p ε (0,10]; q ε (0,10])

Table 10 Results of comparisons

EG Websites	$p = 0, q = 1$				$p = q = 1$				$p = q = 5$	
	HFWGHM	HFWHM	HFWBM	HFWGBM	HFWGHM	HFWHM	HFWBM	HFWGBM	HFWGHM	HFWHM
Post.ir	6	6	6	5	6	6	6	6	5	6
Tct.ir	3	3	3	6	5	3	3	4	6	3
region20.tehran.ir	5	5	2	1	3	4	1	1	3	1
141.ir	1	2	1	2	1	1	2	2	1	2
Rai.ir	2	1	5	3	2	2	4	3	2	4
Bus.tehran.ir	4	4	4	4	4	5	5	5	4	5

EG Websites	$p = q = 5$		$p = 0, q = 10$				$p = 10, q = 0$			
	HFWBM	HFWGBM	HFWGHM	HFWHM	HFWBM	HFWGBM	HFWGHM	HFWHM	HFWBM	HFWGBM
Post.ir	6	3	5	6	6	3	5	6	6	3
Tct.ir	3	4	6	4	3	5	6	3	3	5
region20.tehran.ir	1	1	3	1	1	1	3	1	1	1
141.ir	2	2	1	2	2	2	1	2	2	2
Rai.ir	4	2	2	3	4	2	2	4	4	2
Bus.tehran.ir	5	5	4	5	5	4	4	5	5	4

Table 11 Spearman rank correlation coefficient between HFWGHM operator and other operators

	HFWHM	HFWBM	HFWGBM	Average
$p = 0, q = 1$	0.942857	0.485714	0.2	0.542857
$p = q = 1$	0.828571	0.6	0.771429	0.733333
$p = q = 5$	0.428571	0.428571	0.6	0.485714
$p = 0, q = 10$	0.657143	0.428571	0.714286	0.6
$p = 10, q = 0$	0.428571	0.428571	0.714286	0.52381
Average	0.657143	0.474286	0.6	

to limited experience and expertise, each member of the working group may not comment on all the indicators, or there are doubts about some of the indicators.

On the other hand, due to the fact that the results of the decision-making method used in the hesitant environment have been rarely changed for different operators, the applied model has acceptable stability. Verification of the results of this analysis by the members of the E-Government Evaluation Committee also indicates that the framework is acceptable.

In this paper, it was tried to provide a fairly comprehensive model for evaluating e-government web sites. Next researches can validate the suggested model using statistical methods and structural equation modeling (SEM). Also, there is no specific weight for the experts in this study; however, considering the position and extent of the influence of experts in the decision-making committees, one can allocate weight for the opinion of each expert and make calculations in terms of this weight. Also, decision-making scholars can make more detailed studies on how to influence personality traits of decision-makers on the proper selection of model parameters p and q.

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