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House of Quality-Based Analysis of New Service Development Using Context Free Grammar Evaluation-Enhanced Fuzzy Hybrid Modelling

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ABSTRACT The purpose of this study is to analyze new service development competencies based on house of quality (HoQ) in the healthcare industry by using a hybrid interval-valued intuitionistic decision-making approach with fuzzy linguistic information modelled by hesitant fuzzy linguistic term sets (HFLTSs) and linguistic 2-tuples. The novelty of the manuscript is to identify a list of criteria, dimensions, and alternatives for HoQ-based new service development used for the investment decisions in healthcare industry. Thus, a hybrid model with HFLTSs has been proposed, considering 2-tuple linguistic information, Interval-Valued Intuitionistic Fuzzy Sets (IVIFSs) and a defuzzification process with an attitudinal expected score function. Hence, a DEMATEL extension dealing with HFLTSs, linguistic 2-tuple and IVIFS has been developed and used to weigh the criteria and dimensions of customer needs. Similarly, a TOPSIS extension dealing with the same type of information is introduced and applied in order to rank the technical requirements, the so-called ''new service development competencies in healthcare industry''. Thus, this study contributes to the literature of health economics and management by proposing an original methodology. It is identified that financial expectations play the most significant role for demanders of healthcare services. Hence, competitive pricing strategies should be generated to obtain consumer loyalty in the healthcare industry. Moreover, technological infrastructure is found as the best ranked technical requirement of new service development competencies.

INDEX TERMS Hesitant fuzzy linguistic term sets, linguistic 2-tuples, interval-valued intuitionistic fuzzy sets, DEMATEL, new service development, healthcare industry.

I. INTRODUCTION

Quality improvement is the most prominent issue in the service industry. Globalization has led to new service development activities because of competitive market activities. Technological developments have increased the flow of knowledge globally and has helped obtain the market conditions and specifications easily and comparatively [1]. Therefore, the quality management and development of innovative strategies form part of the new trends of global trade and market environment [2]. With this is mind, companies are trying to enhance customer satisfaction by developing strategies to improve quality management.

All parties of market providers, including producers, suppliers, and dealers should strictly comply with the expectations of customers to survive in the global competitive market. Accordingly, HoQ was introduced in the 1970s and applied successfully by Japanese producers to develop the quality functions [3]. This technique illustrates the needs of a target market, and of including wholesale and/or retail customers systematically by matching them to a set of technical facilities. Thus, it is possible to figure out the importance degrees of customer expectations in terms of technical requirements [4]. Similarly, this technique could be also applied in the healthcare industry to try to understand customer and patient needs more accurately, in the context of the technical requirements of healthcare services [5], [6].

The exact factors of customer/patient needs should be defined by understanding the market trends and expectations.

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To do so, one of the most important phenomena is defining customer expectations in financial terms [7]. Customers generally expect service prices to be fair. Potential customers and patients should be able to afford the pricing policies of healthcare services [8], [9]. Furthermore, if competitive pricing policies are used as strategic tools for the health industry, they could help companies become market leaders [10], [11]. Additionally, some patients also search for payment options, such as instalment sales and delays with flexible payments. Therefore, the producers and sales-including service providers in the healthcare industry should attempt to satisfy these types of customer expectations in financial services to fulfil the market gaps [12], [13].

Additionally, customers not only call for the functionality of the services rendered, but they also expect financial facilities. In the health industry, patients and demanders of health services want the health industry to be convenient for all kinds of market needs and expectations. Accordingly, patients frequently request ease of access to the healthcare services [14]. For this purpose, alternative distribution channels such as telehealth and e-health could be diversified to provide multi-channel services of the healthcare industry [15]. Moreover, improving the reliability of healthcare services could lead to greater patient loyalty in the long term [16]. Thus, it is possible to achieve customer retention by increasing cross-selling possibilities in the healthcare industry. Similarly, customer support is also expected by the demander of healthcare services to be able to reach to continuous healthcare services [17].

Another important issue arising from customer expectations in the healthcare industry is making sufficient physical facilities available to provide customer satisfaction in medical services. Competitive health services force health companies to be more generous than conventional healthcare suppliers. For instance, hospitals and medical companies could operate their activities with flexible working hours. Thus, service demanders of the healthcare industry could get medical assistance in a wide range of working times [18]. Location is another physical condition that is the important for the patients [19]. Generally, the customers expect to obtain services in a central place, and this could be made possible by increasing the branches of hospitals and the number of medical services effectively [20]. Finally, hygiene is one of the most important factors in the physical conditions demanded/expected by patients and other demanders of healthcare services. This factor is standardized by regulations, but the hygiene level of medical services could be increased according to the services customers expect to receive from the medical companies [21].

However, suppliers of healthcare services should operate their activities with technical requirements that are suited to customer needs in the health industry. Within this framework, medical companies and other suppliers in the healthcare industry should focus on the competitive technical requirements by considering the innovation and new service development competencies to improve their service quality. Organizational capacity should be managed more effectively by the best providers of healthcare services [22].

Technological background has also been considered for the incremental improvement of service quality. Healthcare companies and hospitals regularly invest in technological devices and equipment entitled non-current assets. Hence, medical companies can operate their activities more effectively with high-technological devices, meeting patient expectations [23]. By providing this functionality, medical services can offer more flexibility according to the needs of the healthcare industry [24]. Operational convenience is another technical requirement of the healthcare industry. Thus, technical standards are obtained globally with operational appropriateness and therefore the operational mistakes of the healthcare industry are reduced [25]. Furthermore, cost management in the healthcare industry is one of the most efficient technical factors that can help provide competitive healthcare services to the patients. As such, pricing policies could be redesigned with efficient service management [26].

The use of multi-criteria decision-making (MCDM) models for the HoQ technique is quite limited in the literature, and generally, conventional decision-making models have been applied to analyze the quality improvement of the service industry [27], [28]. New service development and innovation are novel issues for the application of HoQ. HoQ, however can also consider several sources of information for complex decision-making issues, such as context-free grammar evaluations and the continuous presentation of linguistic evaluations for both customer and technical factors. Accordingly, HFLTSs, 2-tuple linguistic information, and IVIFSs could provide more comprehensive and coherent results in the complex decision-making problems of quality studies. Additionally, the decision makers' attitudinal character can be used to check the consistency of the defuzzified values. So, the attitudinal expected score function could be applied to provide comprehensive results and the sensitivity analysis. Moreover, DEMATEL reveals the mutual relationships and influences between criteria. TOPSIS is a unique method used to rank alternatives by ordering preferences according to the distance from the ideal solution. Hence, this paper aims at providing a novel perspective by combining a hybrid decision making approach with the proposed criteria and dimensions of patient needs and the technical requirements of new services in healthcare industry. Accordingly, hesitant fuzzy linguistic based with 2-tuple and IVIF DEMATEL and TOPSIS models are defined and used in the house of quality-based evaluation of new service development competencies in healthcare investments.

To achieve the main goal of this proposal, several novelties are introduced throughout this paper as follows:

- Construct a theoretical background of new service development by using an HoQ approach in the health industry.
- Propose a hybrid decision making model with the extensions of DEMATEL and TOPSIS based on HFLTSs, 2-tuple linguistic information, and IVIFSs.

- Integrate the attitudinal expected score function to compute the results of the local and global criteria and dimension weights and facilitate a sensitivity analysis.

Thus, this study contributes to the literature of health economics and management by proposing a hybrid decision making approach that includes DEMATEL and TOPSIS based on 2-tuple linguistic information and IVIFSs and adapts HoQ to the new service development competencies in healthcare investments. By using this novel model, it is aimed to solve complex decision-making problems more effectively. Therefore, with the help of this combination, more appropriate innovative investment strategies can be presented for the healthcare industry. Additionally, owing to considering IVIF sets, vagueness information can be handled more effectively. This situation has a positive influence on reaching more accurate findings. On the other side, by comparing with other MCDM techniques, DEMATEL has some superiorities, such as creating the impact relation map. Moreover, the main reason of considering TOPSIS is using the distances to both negative and positive optimal solutions.

Section 2 indicates the literature evaluation of HoQ for production and service industries as well as healthcare services in detail. The following section explains the methodology with the extended methods of DEMATEL and TOPSIS. Section 4 gives information on its application in the healthcare industry. In the last sections, the paper is discussed and concluded for future research.

II. LITERATURE REVIEW

HoQ is one of the well-known techniques in the research areas of quality improvement. It has been frequently studied in several areas of the production industry, such as technological development [29], [30], organizational factors [31], design [32], [33], environmental issues, and efficiency [34]. However, in the literature, limited studies using the HoQ are available in the field of service industries. Essential HoQ topics studied in the service industry are detailed below.

The most studied HoQ topic in the service industry is logistic and transportation service. Bottani and Rizzi [35] highlight the strategic importance of quality improvement for logistic industry and construct a fuzzy-based houses of quality approach to analyze the efficiency of logistics process. Outcomes are generalized for customer satisfaction in logistic industry. Vazifehdan and Darestani [27] present a comprehensive model for ranking the outsourced green logistics based on HoQ factors using fuzzy ANP and DEMATEL. It is understood that green political decision-making is the most influential item, while quality should be redesigned to achieve sustainable business operations with high customer satisfaction. Ho *et al.* [28] imply the strategic logistic outsourcing by using HoQ. Fuzzy AHP-based HoQ is used to evaluate the optimal third-party logistic service providers together with the needs of stakeholders in Hong Kong. The proposed method is employed along with the outsourcing and third-party logistics services to obtain the optimal business strategies. Wang [36] assesses the service quality of the Chinese cargo sector, using the HoQ to figure out the competitive factors of the airline industry. The findings show/suggest that the quality of the technology used could increase both industry performance and customer expectations. Pandey [37] explores the strategic design factors of low-cost airlines using quality function deployment by integrating an HoQ analysis with fuzzy sets. The results show that the strategic factors could be generated by considering customer-oriented factors.

Another important research area of HoQ-based service analysis is the supply chain and management. Büyüközkan and Berkol [38] integrate analytic network processes and goal programming with HoQ to design a sustainable supply chain management. For this purpose, several economic, social, and environmental requirements are defined in order to provide service networks to suppliers, manufacturers, and customers. The results are discussed to determine the most effective design requirements of the sustainable supply chain management. Na *et al.* [39] measure the amount/level of power supply service quality that meets both customer satisfaction and service requirements with HoQ. The proposed model is recommended for the managerial decision-making process of service items. Santos *et al.* [40] propose a HoQ-based multi-criteria evaluation model for the environmental service providers of waste generator companies, including recycling, recovery, transportation, and disposal facilities. It is concluded that these applications could be applied in a broader sense to potential relationships shared between the environmental factors.

Additionally, internet services and innovation management are also studied with HoQ. Zuo *et al.* [41] investigate the commercial e-services quality requirements for businesses using the Kano model. The requirements and specifications of quality are measured with the HoQ technique. It is concluded that the HoQ-based measurement could improve the quality of e-commerce services and provide effective implications for company policies. Min and Kim [42] define a QFD planning model for the design requirements of internet services with HoQ dimensions. It is proposed that high-speed internet service is required to improve customer loyalty in project selection. Lin *et al.* [43] propose an HoQ model with fuzzy linguistic preferences, including external and internal service management factors, to address the service innovation processes and tourist satisfaction. The experimental results demonstrate that effective directions are required for service innovations and in order to gain competitive advantage in the hotel industry.

Some studies in the field of modularization and retailing serve as a guide for improving service quality. Geum *et al.* [44] use a modified HoQ approach to compare the manufacturing and modularization of services. The relationship between module drivers and decomposed service factors are employed with the strategic modularability matrix in the HoQ structure. The results show that the service-specific module drivers modularize services and analyze the interrelations among the factors. Trappey *et al.* [45] employ a computerized HoQ approach for retail services to design competitive strategies in the market environment. It is recommended that managerial objectives be rethought by implementing, as an object-oriented quality system prototype, customer-driven strategic plans. Park *et al.* [46] have promoted the Korean food industry to international customers using the HoQ technique. Food services are introduced with the requirements of food services, and the expectations of international customers and the relative importance of the selected factors are defined to develop the most effective food service strategies.

However, HoQ is seldom studied in health economics and management. Bas [5] investigates HoQ with an integrated model using capital budgeting for occupational health and safety as a system thinking approach. In this study, interrelationships between several factors, including tasks and hazards, hazards and events, events and preventive measures are measured using? the quality function deployment stages. Some policies are generated for the continuous development of occupational health and safety in the construction industry. On the other hand, Wey and Chiu [47] assess the effects of pedestrian environment to analyze non-motorized transportation modes that lead to emission reduction and improve public health. Analysis results show that transit-oriented planning could positively affect traffic speed and pedestrian accessibility in the context of the development of public health. Additionally, Kuo *et al.* [6] study outpatient services to establish an age-friendly healthcare system in Taiwan. For this purpose, HoQ is used to measure the outpatient services with Kano's model and an analytic network process technique. The results show that the analysis with HoQ could increase the quality of medical care together with cost efficiency. Zadry *et al.* [48] identify the design requirements for the ergonomic issues when quality function deployment and emergency medical services are applied to integrate customer needs into the engineering requirements. The findings are illustrated to focus on the design priorities of the provided services.

As seen in the literature review, customer satisfaction plays an essential role in the healthcare industry. However, it is also understood that hospitals should make necessary technological developments to meet customer expectations. Hence, this paper will provide several novel contributions to the health economics and management literature. Firstly, based on the HoQ approach, both customer expectations and technical requirements are used. This will help us to understand which factors the hospitals should be developed with respect to the technical aspects to meet customer expectations. Moreover, while providing a novel hybrid decision making model based on 2-tuple linguistic information and IVIFSs, as well as HoQ-based evaluation of new service development in health investments, the methodology seems to become very different to those presented in similar studies in the literature.

III. BACKGROUND

In complex decision-making problems, conventional methods have been modified and extended to obtain more accurate and coherent results. Earlier studies of complex problems were introduced by Zadeh in the 1960s by using fuzzy sets [49], and studies have since used several extensions of fuzzy sets to provide comprehensive outcomes [50]. Currently, some decision-making problems are still waiting to learn from the integrated decision-making models. These problems could be referred to as consensus difficulties in linguistic evaluations made by the decision makers [51] and the need for intermediate values as well as computing with words in/to create/construct linguistic information [52].

To solve this type of complex problem, hesitant fuzzy linguistic term sets could be used to create better knowledge and preference modelling by using context-free grammar. This would facilitate the elicitation of complex linguistic evaluations and make it more like a human being's cognitive process, including mental and reasoning processes, which would enable the development of linguistic decision making with computing with words [53]. Accordingly, the 2-tuple linguistic model was introduced at the beginning of 2000s by Herrera and Martinez [52] and it has successfully contributed to the methodological soundness in the research areas of computing with words and linguistic decision and modelling.

However, intuitionistic fuzzy sets are a well-known extension of fuzzy sets that have, to date, once again become a hot topic in the decision-making area [54], [55]. They have several advantages, for example, they provide the extreme limits for the belongingness and non-belongingness elements and construct the vague sets more accurately [56]. Atanassov [57] introduced the intuitionistic sets in the 1980s as a generalized form of fuzzy sets and developed IVIFSs [58], [59]. The earlier extensions of intuitionistic fuzzy sets were studied by Gau and Buehrer [60] and Bustince and Burillo [61] to provide close similarities to the intuitionistic sets and MCDM methods.

In this study, 2-tuple linguistic information and HFLTs are integrated into the extension of IVIFSs. The essentials of 2-tuple linguistic information, HFLTs and IVIFSs are illustrated respectively as follows:

A. LINGUISTIC 2-TUPLE MODEL

The 2-tuple fuzzy linguistic representation model is a symbolic based method [62] and takes the concept of Symbolic Translation as the basis of its representation.

Definition 1 [52]: The Symbolic Translation of a linguistic term $s_i \in S = \{s_0, \ldots, s_g$ *is a numerical value assessed in* [-0.5, 0.5) *that supports the "difference of information" between an amount of information* $\beta \in [0, g]$ *and the closest value in* {0,..., g} *that indicates the index of the closest linguistic term in* $S(s_i)$*, where* [0, g] *is the interval of granularity of S.*

From this concept, a new linguistic representation model is developed that represents linguistic information by means of 2-tuples (si, αi), si ∈S and αi ∈ [−0.5, 0.5]. It defines the two different functions of linguistic 2-tuples and numerical values as:

Definition 2 [52]: Let $S = \{s_0, \ldots, s_g$ *be a linguistic term set and* $\beta \in [0, g]$ *a value supporting the result of a symbolic aggregation operation. Then the 2-tuple that expresses the equivalent information to* β *is obtained with the following function:*

$$\begin{aligned} &\Delta : [0, g] \rightarrow S \times (-0.5, .0.5) \\ &\boldsymbol{\Delta(\beta) = (s_i, \alpha)},\ \ with \\ &\begin{cases} s_i & i = round(\beta) \\ \alpha = \beta - i & \alpha \in\ [-0.5, 0, 5) \end{cases} \end{aligned} \tag{1}$$

where round(·) is the usual round operation, s_i has the closest index label to "β" and "α" is the value of the symbolic translation.

Proposition 1 [52]: Let $S = \{s_0, \ldots, s_g$ *be a linguistic term set and* (s_i, α_i) *be a linguistic 2-tuple. There is always a*Δ^{-1} *function, such that, from a 2-tuple it returns its equivalent numerical value* $\beta \in [0, g]$ *in the interval of granularity of S.*

Proof: If it is trivial, we consider the following function: $\Delta^{-1} : S \times [-0, 5, 0.5) \rightarrow [0, g]$, $\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta$.

This model has a computational technique based on the 2-tuples and multiple operators as can be seen in [53]. The results with 2-tuple linguistic information are presented as (S_i, α) and $\alpha_i \in [-.5, .5)$. They are illustrated as seen in Figure 1 [52], [63], [64].

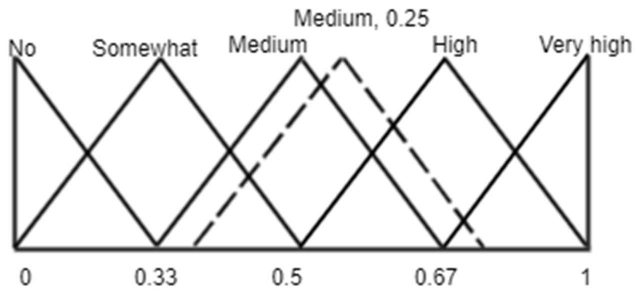

FIGURE 1. 2-tuple linguistic information and sets.

B. HESITANT FUZZY LINGUISTIC TERM SETS

In [65], the concept of HFLTS was introduced.

Definition 3 [65]: Let $S = \{s_0, \cdots, s_\tau\}$ be a linguistic term set. An HFLTS (H_S) is defined as follows

$$H_S = \left\{s_i, s_{i+1}, \cdots, s_j\right\}, \quad s_k \in S, k \in \{i, \cdots, j\} \tag{2}$$

The use of context-free grammars $G_H = (V_N, V_T, I, P)$ was introduced to generate comparative linguistic expressions. An illustrative context free grammar used to build such expressions was provided in [38] as,

$$\begin{aligned} &V_N = \left\{ \begin{matrix} \langle primary\ term\rangle, (composite\ term), \\ \langle unary\ term\rangle, \langle binary\ term\rangle, (conjunction) \end{matrix} \right\}, \\ &V_T = \left\{ \begin{matrix} lower\ than, greater\ than, at\ least, \\ at\ most, between, and, S_0, S_1, \ldots, S_t \end{matrix} \right\}, \\ &I \in V_N, \\ &P = \{I\ ::= \langle primaryterm\rangle \mid \langle compositeterm\rangle, \\ &\langle composite\ term\rangle\ ::= \langle composite\ term\rangle \\ &\langle primary\ term\rangle \\ &\quad \mid \langle binary\ relation\rangle\ \langle primary\ term\rangle \\ &\quad \mid \langle conjunction\rangle\ \langle primary\ term\rangle\ , \\ &\langle primary\ term\rangle\ ::= S_0 \mid S_1 \mid \ldots \mid S_t, \\ &\langle unary\ relation\rangle\ ::= lower\ than \mid greater\ than \\ &\mid atleast\ \mid atmost, \\ &\langle binary\ relation\rangle\ ::= between, \\ &\langle conjunction\rangle\ ::= and\}. \end{aligned}$$

Such expressions can be transformed into HFLTS by means of the transformation function given below.

Definition 4 [65]: Let $S = \{s_0, \cdots, s_\tau\}$ be a linguistic term set, the transformation function E_{G_H} converts the comparative linguistic expressions $ll \in S_{ll}$ generated by the context-free grammar G_H into HFLTSs, H_S.

$$E_{G_H} : S_{ll} \rightarrow H_s \tag{3}$$

S_{ll} is a domain. The comparative linguistic expressions ll are obtained in a similar way to the fuzzy linguistic variables, using fuzzy membership functions (trapezoidal ones) to compute their fuzzy envelops [66], [67]:

$$F\left(H_s\right) = T\left(a, b, c, d\right) \tag{4}$$

C. IVIFSs

IVIFSs are a generation of fuzzy set and define the membership and non-membership degrees of elements with extreme values. Therefore, it is possible to obtain more precise results with complex decision-making problems [68]. Intuitionistic fuzzy set I on U is illustrated as in Equation (5) [69].

$$I = \{\langle\vartheta, \mu_I(\vartheta), n_I(\vartheta)\rangle\ / \vartheta\ \in U\} \tag{5}$$

where the $\mu_I\left(\vartheta\right) : U\ \rightarrow\ [0, 1]$ and $n_I\left(\vartheta\right) : U\ \rightarrow\ [0, 1]$ are the membership and non-membership degrees, defined as $0 \leq \mu_I\left(\vartheta\right) + n_I\left(\vartheta\right) \leq 1$.

$\mu_I(\vartheta)$ and $n_I(\vartheta)$ are intervals which are also the degrees of belongingness and non-belongingness of ϑ, respectively.

$\vartheta \epsilon U$ is for each interval, and $\mu_{IU}(\vartheta)$ is the upper value and $\mu_{IL}(\vartheta)$ is the lower value of $\mu_I\left(\vartheta\right)$ whereas $n_{IU}(\vartheta)$ is the upper value and $n_{IL}(\vartheta)$ is the lower value of $n_I(\vartheta)$ that are given as $\mu_{IL}(\vartheta)$,$\mu_{IU}\left(\vartheta\right)$, $n_{IL}(\vartheta)$,$n_{IU}(\vartheta)$. Intuitionistic fuzzy set I on U is presented with Equation (6).

$$I = \{\vartheta, [\mu_{IL}\left(\vartheta\right), \mu_{IU}\left(\vartheta\right)], [n_{IL}\left(\vartheta\right), n_{IU}(\vartheta)]\ / \vartheta \epsilon U\} \tag{6}$$

where

$$\begin{aligned} 0 \leq \mu_{IU}\left(\vartheta\right) + n_{IU}\left(\vartheta\right) \leq 1 \\ \mu_{IL}\left(\vartheta\right) \geq 0, \quad n_{IL}\left(\vartheta\right) \geq 0 \end{aligned} \tag{7}$$

Unknown degree of an intuitionistic fuzzy interval of $\vartheta \epsilon U$ in I is defined as follows

$$\tau_I\left(\vartheta\right) = 1 - \mu_I\left(\vartheta\right) - n_I\left(\vartheta\right) \tag{8}$$

The elements from the IVIF set (I) are given as

$$I = \left([a, b], [c, d]\right) \tag{9}$$

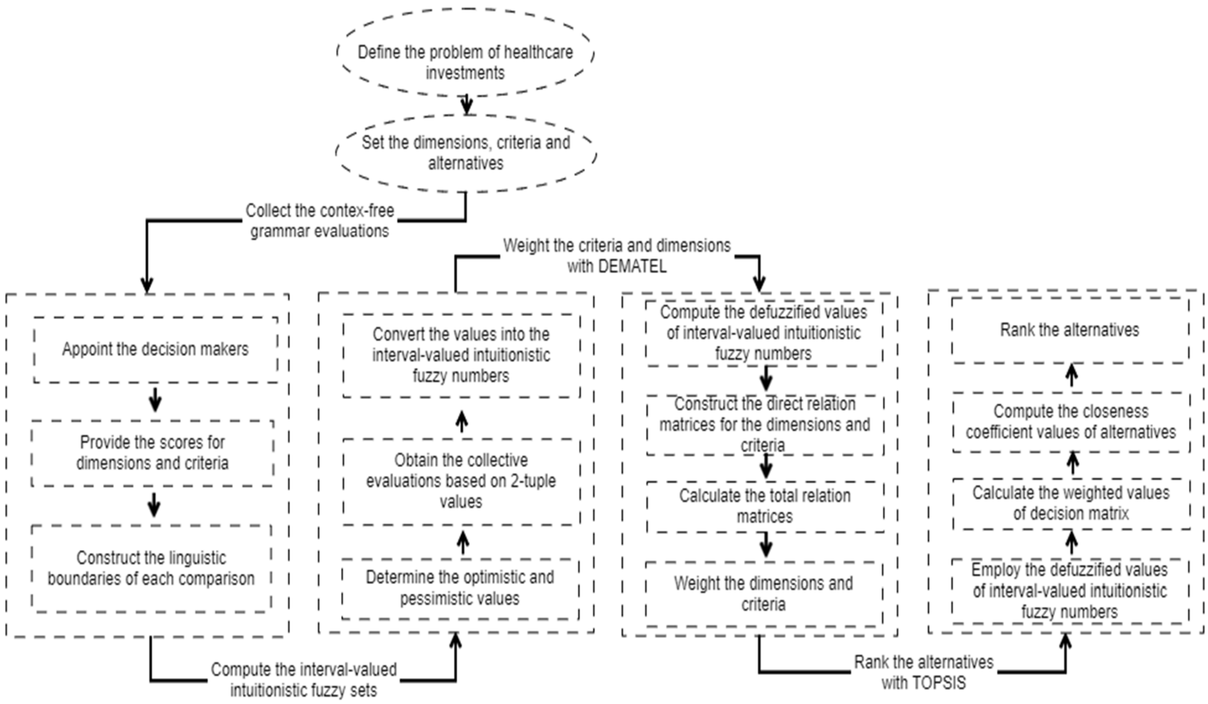

FIGURE 2. Flowchart of proposed model.

where a, b, c, d are $\mu_{IL}(\vartheta), \mu_{IU}(\vartheta), n_{IL}(\vartheta), n_{IU}(\vartheta)$ respectively.

IV. ANALYSIS FOR HEALTHCARE INVESTMENTS WITH FUZZY LINGUISTIC INFORMATION AND IVIFSs

In this section, a novel hybrid multi-criteria decision-making model is proposed to analyze the new service development process in the healthcare industry and investments by using HFLTSs, 2-tuple fuzzy linguistic information and IVIFSs properly. To this end, the house of quality-based decision matrix is defined by meeting the customer expectations and technical requirements of healthcare investments. The analysis flowchart and the details of novel extensions for the hybrid model are illustrated accordingly in the following subsections.

A. HYBRID MODEL BASED ON IVIFSs

This study aims to evaluate new service development process for healthcare investments. Therefore, we aim to understand which factors in technical aspects should be of more importance to hospitals to meet customer expectations. HoQ approach is considered as it considers both technical requirements and customer satisfaction. Moreover, in this study, a hybrid multi-criteria decision-making model with HFLTSs, 2-tuple linguistic information and IVIFSs is proposed to determine the weights of the criteria and the dimensions of customer requirements, and to rank the alternatives of technical requirements for the new service development competencies of healthcare investments. Accordingly, this hybrid method contributes to the literature of multi-criteria decision-making by using the extensions of DEMATEL and TOPSIS methods, and including the HFLTs, 2-tuple linguistic information and IVIFSs. Thus, this paper aims to provide more comprehensive and accurate results using the modified technique on the house of quality-based new service development competencies in healthcare investments. The proposed flowchart is illustrated in Figure 2.

The steps of the proposed hybrid decision making model are summarized as follows

Step 1: Define the MCDM problem of healthcare investments based on house of quality.

Step 2: Identify customer needs and technical requirements for new service development in the healthcare industry with HoQ.

Step 3: Appoint those decision makers that are academicians and experts in the field of the healthcare industry.

Step 4: Collect evaluations from the experts.

Step 5: Set the boundaries of linguistic evaluations for the collective evaluations with 2-tuple information.

Step 6: Generate the IVIFSs by considering the optimistic and pessimistic values of customer expectation factors for the healthcare industry.

Step 7: Compute the defuzzified values with accuracy functions for criteria, dimensions, and alternatives for the HoQ-based evaluation of healthcare investments.

Step 8: Construct direct relation matrices.

Step 9: Compute total relation matrices.

Step 10: Apply the attitudinal expected score function to compute the local and global weights of criteria and the decision matrix.

Step 11: Define the decision matrix for the technical requirement alternatives.

Step 12: Compute the weighted decision matrix by using the global weights of customer expectations.

Step 13: Calculate the values of D+, D− and the closeness coefficient for the alternatives of technical requirement in healthcare investments.

Step 14: Measure the HoQ-based new service development competencies for healthcare investments.

A more detailed description of the extensions of the DEMATEL and TOPSIS methods proposed in the previous model are provided in the following subsections.

B. A NOVEL EXTENSION OF DEMATEL DEALING WITH HFTLSS, IVIF SETS AND LINGUISTIC 2-TUPLES

DEMATEL is the abbreviation of Decision-Making Trial and Evaluation Laboratory and was introduced by the Geneva Research Centre in the 1970s to analyzing the impact and relationship degrees of criteria in a comprehensive manner [70]. This method is one of the most popular decision-making techniques as it measures the mutual relationship directions and weights among the criteria [71]. In the literature, there are several fuzzy extensions of DEMATEL found in the managerial [72]–[75] and economic issues [76]–[79], where the triangular and trapezoidal fuzzy sets are used to measure the weights of those factors found in a complex decision-making environment.

However, use of IVIFSs is extremely limited in the current literature concerning DEMATEL [80]. IVIF sets with 2-tuple linguistic information contribute to the DEMATEL literature as the expert's choices can be evaluated more accurately by using linguistic fuzzy information and computing with words simultaneously at the boundaries of optimistic and pessimistic evaluations. The computation procedures of DEMATEL based on IVIFSs and 2-tuple linguistic information are summarized in the following steps:

Step 1: Collect the decision makers' preferences that were elicited by complex expressions based on HFLTSs assessed in $S = \{S_0, S_1, \ldots, S_t\}$. These HFTLSs are transformed into fuzzy membership functions by computing their envelopes F(Hs) (see eq. (4)).

Step 2: Construct the interval-valued intuitionistic fuzzy sets: The optimistic and pessimistic values are calculated. After that, optimistic and pessimistic values are defined as the degrees of belongingness $\mu_I(\vartheta)$ and non-belongingness $n_I(\vartheta)$ of ϑ respectively. The extreme values of optimistic and pessimistic evaluations are given in the form of $\mu_{IL}(\vartheta)$,$\mu_{IU}(\vartheta)$, $n_{IL}(\vartheta)$,$n_{IU}(\vartheta)$. Obtained values are presented in the interval-valued intuitionistic fuzzy sets I as

$$\tilde{Z}_{ij} = \left(\left(a_{ij}, b_{ij}\right), \left(c_{ij}, d_{ij}\right)\right) \tag{10}$$

where, $\tilde{Z}_{ij}$ is the value of direct relation matrix based on IVIFSs. $a_{ij}, b_{ij}, c_{ij}, d_{ij}$ are the relation degrees of criteria and dimensions in the IVIFSs. In this context, a_{ij} and b_{ij} give the extreme values of the belongingness degree. The terms c_{ij} and d_{ij} are the lower and upper values of non-belongingness for the criteria and dimensions.

A defuzzification process is applied by computing the score function of IVIFSs. There are several methods that can be employed to obtain the defuzzified values of the relation and decision matrices. However, the additional parameters could add to the score function to be able to provide more comprehensive results. For instance, the specifications of the experts can be also considered in the defuzzification process. Accordingly, attitudinal expected score function gives comprehensive information with the decision makers' attitudinal character to check the consistency of the evaluations and apply the sensitivity analysis [81]. This score function is computed by Equation (11) and is used as a defuzzification process:

$$A(i) = \frac{(1-\lambda) \times (a_{ij} - c_{ij}) + \lambda \times \left(b_{ij} - d_{ij}\right) + 1}{2} \tag{11}$$

where $A(i)$ is the attitudinal expected score degree of IVIFSs and $A(i) \in [0, 1]$. λ is the parameter that defines the decision makers' attitudinal character.

The direct relation matrix is illustrated with Formula (12).

$$A_k = \begin{bmatrix} 0 & \cdots & a_{1nk} \\ \vdots & \ddots & \vdots \\ a_{n1k} & \cdots & 0 \end{bmatrix} \tag{12}$$

Step 3: Calculate the normalized values of the direct relation matrix: the normalized matrix is defined by the Equation (13)

$$B = \left[b_{ij}\right]_{nxn} = \frac{A}{max \sum_{j=1}^{n} a_{ij}} \tag{13}$$

where b_{ij} is between 0 and 1.

Step 4: Compute the total relation matrix: the total relation matrix C is defined as

$$C = \left[c_{ij}\right]_{nxn} = B(I-B)^{-1} \tag{14}$$

where C presents the total relation matrix whereas I defines the identity matrix.

Step 5: Calculate the sums of all vector rows and columns: the values of D and E are provided by summing all vector rows and columns of the total matrix, respectively. The values of D+E define the prominence degrees while the values of D-E give the impact-relation directions with the Equations (15) and (16).

$$D = \left[d_{ij}\right]_{nx1} = \left[\sum_{j=1}^{n} c_{ij_{ij}}\right]_{nx1} \tag{15}$$

$$E = \left[e_{ij}\right]_{1xn} = \left[\sum_{j=1}^{n} c_{ij_{ij}}\right]_{1xn} \tag{16}$$

			Technical Requirements								
			Organizational capacity	Technological infrastructure		Functionality		Operational convenience			Cost manage ment
			C1 C2..C(n-1)								Cn
Customer Expectations	Price fairness	C1	C1,C1	C1,C2	...	...	...	...	...	...	C1,Cn
		C2	...	...	...	...	...	.. .	...	...	...
	Competitive charges	.	.	.	.	.	.	.	.	.	.
		.	.	.	.	.	.	.	.	.	.
	Payment facilities	.	.	.	.	.	.	.	.	.	.
	Ease of access	.	.	.	.	.	.	.	.	.	.
			.	.	.	.	.	.	.	.	.
	Reliability	.	.	.	.	.	.	.	.	.	.
	Customer support	.	.	.	.	.	.	.	.	.	.
	Working hours	.	.	.	.	.	.	.	.	.	.
	Hygiene	.	C(n-1),C1	...	...	...	...	.. .	...	...	C(n-1),Cn
	Location	C(n-1) Cn	Cn,C1	....	...	...	...	.. .	...	...	Cn,Cn

FIGURE 3. House of Quality-based decision matrix.

C. A NOVEL EXTENSION OF TOPSIS DEALING WITH HFLTSS, IVIF SETS AND LINGUISTIC 2-TUPLES

The technique for order performance by similarity to ideal solution (TOPSIS) is one of the most well-known MCDM methods used to rank alternatives in terms of negative and positive ideal solutions. This method was generated by Yoon and Hwang in the 1980s and the applicability of this method has since been improved by computing the distances from the ideal solution, the shortest distance to the positive solution and the longest distance to the negative solution [82], [83]. In the TOPSIS literature, there are immense studies in the different areas of economics and management, such as supplier selection [84], [85], firm evaluation [86], location selection [87], economy development [88]. Several extensions of TOPSIS are also introduced to provide more comprehensive results in the literature. In this study, by utilizing the advantages of computing with words and intervals of fuzzy linguistic term sets, we aim to propose an extension of TOPSIS based on 2-tuple linguistic information and IVIFSs. The procedures of extended TOPSIS are given in the following steps:

Step 1: Collect the HFLTS based evaluations of decision makers whose extreme values are defined into the interval-valued intuitionistic fuzzy sets to construct the IVIF decision matrix. Similarly, the first two procedures of the extended DEMATEL are applied to compute the overall values of the decision matrix.

Step 2: Construct the decision matrix: the results of accuracy function are used to obtain the defuzzified values of the 2-tuple IVIF decision matrix with Formulas (17) and (18).

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C1 & C2 & C3 & & \ldots & Cn \end{array} \\ \begin{bmatrix} h_{11} & h_{12} & h_{13} & & \cdots & h_{1n} \\ h_{21} & h_{22} & h_{23} & & \cdots & h_{2n} \\ h_{31} & h_{32} & h_{33} & & \cdots & h_{3n} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ h_{m1} & h_{m2} & h_{m3} & & \cdots & h_{mn} \end{bmatrix} \end{array} \tag{17}$$

$$h_{ij} = \frac{1}{k}\left[\sum_{e=1}^{n} h_{ij}^{e}\right] \tag{18}$$

where $A_1, A_2, \ldots, A_m$ defines the alternatives as $C_1, C_2, \ldots,$ and C_n gives information on the criteria. However, the term h_{ij} is the evaluation of the results of alternatives on criteria, obtained using accuracy function. $i = 1, 2, 3, \ldots, m$. and k indicates the expert numbers. Averaged values of the decision makers are employed to define the decision matrix.

Step 3: Weight the decision matrix: the decision matrix is weighted using the Equations (19) and (20).

$$A^{+} = \max(v_1, v_2, v_3, \ldots v_n) \tag{19}$$

$$A^{-} = \min(v_1, v_2, v_3, \ldots v_n) \tag{20}$$

where (A^{+}) represents the positive values and (A^{-}) the negative values for the ideal solutions. Also, v_{ij} illustrates the weighting results of the decision matrix.

Step 4: Calculate the values of the closeness coefficient: the values of D+ and D− are computed to measure the values of the closeness coefficient (CC_i) with the formulas (21)-(23).

$$D_i^{+} = \sqrt{\sum_{i=1}^{m}(v_i - A_i^{+})^2} \tag{21}$$

$$D_i^- = \sqrt{\sum_{i=1}^{m} (v_i - A_i^-)^2} \tag{22}$$

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{23}$$

For the list of the performance of alternatives, the values of CC_i are ranked in descending order.

V. ANALYSIS

This study aims at identifying the more significant criteria to help increase customer satisfaction. Additionally, this paper also attempts to understand which factors companies should develop in respect to technological requirements to be able to achieve this objective. A hybrid decision making approach based on 2-tuple linguistic information and IVIFSs has been proposed to analyze the HoQ-based new service development competencies in the healthcare industry. To this end, the healthcare industry MCDM problem was defined and the factors of HoQ were adapted to the new service development competencies in the healthcare industry. After that, the context-free linguistic evaluations were collected from the decision makers, who are academicians and experts in the field of healthcare services. By obtaining values for the criteria, dimensions, and alternatives, the extended DEMATEL and TOPSIS methods are applied consecutively to the house of quality-based evaluations of new service development competencies in healthcare industry. The analysis results are given in the following stages.

A. STAGE 1. DEFINE THE MCDM PROBLEM

MCDM problem is defined with customer expectations and technical requirements of new service developments in the healthcare industry. Figure 3 presents the healthcare industry decision matrix with the HoQ factors.

The criteria and dimensions of customer expectations and the technical requirements of new service development competencies for the healthcare industry are determined using the supported literature. Tables 1 and 2 show 3 dimensions and 9 criteria of customer expectations as well as 5 technical requirements for the HoQ-based evaluation in the healthcare industry.

Table 1 represents the 3 dimensions of customer expectations entitled financial (dimension 1), functionality (dimension 2), and physical conditions (dimension 3), which are defined for the house of quality-based evaluation of the healthcare industry. Price fairness (criterion 1), competitive charges (criterion 2), and payment facilities (criterion 3) are employed for the sub-dimensions of financial dimension. The dimension of functionality is also divided into 3 criteria: ease of access (criterion 4), reliability (criterion 5), and customer support (criterion 6), while the criteria of physical conditions are defined as working hours (criterion 7), hygiene (criterion 8), and location (criterion 9). However, Table 2 shows the technical requirements of new service development competencies for healthcare investments.

TABLE 1. Customer expectations for healthcare industry.

Dimensions	Criteria	References
Financial (Dimension 1)	Price fairness (criterion 1)	[7], [8]
	Competitive charges (criterion 2)	[10], [11]
	Payment facilities (criterion 3)	[12], [13]
Functionality (Dimension 2)	Ease of access (criterion 4)	[14],[19]
	Reliability (criterion 5)	[16], [17]
	Customer support (criterion 6)	[16], [17]
Physical conditions (Dimension 3)	Working hours (criterion 7)	[18], [89]
	Hygiene (criterion 8)	[21], [22]
	Location (criterion 9)	[19], [20]

TABLE 2. Technical requirements of new service development competencies.

Technical Requirements	References
Organizational capacity (alternative 1)	[22], [25]
Technological infrastructure (alternative 2)	[13], [24]
Functionality (alternative 3)	[24], [25]
Operational convenience (alternative 4)	[23], [25]
Cost management (alternative 5)	[26], [90]

TABLE 3. Linguistic scales.

CT	AT	Evaluation Numbers
No influence (n)	Worst (w)	1
somewhat influence (s)	Poor (p)	2
medium influence (m)	Fair (f)	3
high influence (h)	Good (g)	4
very high influence (vh)	Best (b)	5

In Table 2, the technical requirements of HoQ are determined as organizational capacity (alternative 1), technological infrastructure (alternative 2), functionality (alternative 3), operational convenience (alternative 4), and cost management (alternative 5) to measure the new service development competencies of healthcare investments.

B. STAGE 2: WEIGHT THE CRITERIA AND DIMENSIONS OF CUSTOMER EXPECTATIONS FOR THE HEALTHCARE INDUSTRY

The extension of the DEMATEL method based on the HFLTSs, 2-tuple linguistic information and IVIFSs is applied to determine the weights of the dimensions and criteria of customer expectations for the healthcare industry. To this end, three experts who are academicians and top managers in the healthcare industry are selected. They have at least ten years of experience and research in the areas of healthcare management and economics. Hence, they have sufficient

TABLE 4. Evaluations for dimensions.

	DI1			DI2			DI3		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
DI1				ls "m"	bw "m"-"h"	bw "m"-"h"	ls "m"	bw "s"-"h"	ls "m"
DI2	ms "h"	ls "s"	ls "m"				gr "s"	bw "m"-"h"	ms "m"
DI3	ms "m"	ls "m"	bw "m"-"vh"	gr "m"	ms "m"	ms "m"			
DI: dimension; DEC: decision makers; ls: at least; ms: at most; bw: between; gr: greater than									

TABLE 5. Evaluations of criteria of DI1.

	CT1			CT2			CT3		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
CT 1				ms "m"	ls "m"	bw "s"-"h"	ls "m"	bw "s"-"vh"	bw "s"-"vh"
CT 2	ls "m"	ls "m"	bw "h"-"vh"				ls "h"	ls "m"	ms "h"
CT 3	gr "m"	ms "h"	bw "m"-"vh"	gr "m"	ms "m"	sm "m"			
CT: criterion; DEC: decision makers; ls: at least; ms: at most; bw: between; gr: greater than									

TABLE 6. Evaluations of criteria of DI2.

	CT4			CT5			CT6		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
CT 4				ms "m"	ms "m"	bw "m"-"h"	bw "m"-"vh"	bw "s"-"vh"	bw "h"-"vh"
CT 5	lw "h"	bw "m"-"vh"	ls "h"				ls"m"	ls "h"	ms "m"
CT 6	gr "h"	bw "m"-"h"	ls "m"	gr "h"	bw "h"-"vh"	ms "h"			
CT: criterion; DEC: decision makers; ls: at least; ms: at most; bw: between; gr: greater than; lw: lower than									

TABLE 7. Evaluations of criteria of DI3.

	CT7			CT8			CT9		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
CT 7				ms "m"	bw "h"-"h"	lw "h"	bw "s"-"h"	bw "m"-"vh"	bw "m"-"vh"
CT 8	ms "h"	ls "m"	bw "m"-"h"				ms "h"	ls "m"	ls "m"
CT 9	ms "h"	ls "h"	ls "m"	bw "m"-"vh"	ms "h"	gr "m"			
CT: criterion; DEC: decision makers; ls: at least; ms: at most; bw: between; gr: greater than; lw: lower than									

experience to evaluate new service development process in the healthcare industry. Linguistic choices are then provided by decision makers to construct the relation matrices and define the degrees of influence among the criteria and dimensions. Table 3 shows the linguistic scales.

Five-point linguistic scales are defined as no influence (n), somewhat influence (s), medium influence (m), high influence (h), and very high influence (vh) for the criteria and dimensions. Similarly, worst (w), poor (p), fair (f), good (g), best (b) are given as a set of linguistic scales for the alternatives. Tables 4-7 present the evaluations.

In the following step, intuitionistic fuzzy sets based on 2-tuple linguistic information are constructed with the Equations (5)-(9) and the direct relation matrix values are obtained using Formula (10). To this end, the boundaries of the linguistic term sets and the collective evaluations based on 2-tuple linguistic information with the optimistic and pessimistic values are presented in Tables 8 and 9.

TABLE 8. Boundaries.

	DI1			DI2			DI3		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
DI 1				$[m, vh]$	$[m, h]$	$[m, h]$	$[m, vh]$	$[s, h]$	$[m, vh]$
DI 2	$[n, h]$	$[s, vh]$	$[m, vh]$				$[m, vh]$	$[m, h]$	$[n, m]$
DI 3	$[n, m]$	$[m, vh]$	$[m, vh]$	$[h, vh]$	$[n, m]$	$[n, m]$			

TABLE 9. 2-tuple values.

	DI1		DI2		DI3	
	Oc	Pc	Oc	Pc	Oc	Pc
DI1			(h,.33)	(m,0)	(vh,-.33)	(m,-.33)
DI2	(vh,-.33)	(s,0)			(h,0)	(s,.33)
DI3	(h,.33)	(s,.33)	(h,-.33)	(s,0)		
Oc: Optimistic; Pc: Pessimistic						

TABLE 10. IVIFSs.

	DI1	DI2	DI3
DI1		((.60,.67), (.20,.40))	((.60,.73), (.20,.33))
DI2	((.60,.73), (.10,.20))		((.40,.60), (.20,.27))
DI3	((.60,.67), (.20,.27))	((.40,.53), (.10,.20))	

TABLE 11. Direct relation matrix (λ:0).

	DI1	DI2	DI3
DI1	.00	.70	.70
DI2	.75	.00	.60
DI3	.70	.65	.00

Table 10 shows the conversion of these evaluations into the IVIFSs. The optimistic and pessimistic values are converted into the IVIFs with the limits of 2-tuple linguistic values in five-point scales.

The direct relation matrix is generated by the values from the attitudinal expected score function with Equation (11) and the matrix is provided using Equation (12). Table 11 presents the relation matrix among the dimensions for the attitudinal value λ:0.

A normalization procedure is applied using Equation (13) and the results are given in Table 12.

Later, the total relation matrix is constructed using Equation (14) and the values of D and E, as well as the weights of the criteria, using Equations (15) and (16). The matrix and weighting results of dimensions are given in Table 13.

TABLE 12. Normalized direct relation matrix (λ:0).

	DI1	DI2	DI3
DI1	.00	.50	.50
DI2	.54	.00	.43
DI3	.50	.46	.00

TABLE 13. Total relation matrix (λ:0).

	DI1	DI2	DI3	Weights
DI1	14.51	14.17	13.83	.343
DI2	14.52	13.52	13.48	.331
DI3	14.49	13.83	13.17	.327

TABLE 14. Weights of criteria and dimensions (λ:0).

DI	Weights	CT	LW	GW
DI1	.343	CT1	.332	.114
		CT2	.328	.112
		CT3	.340	.117
DI2	.331	CT4	.335	.111
		CT5	.335	.111
		CT6	.330	.109
DI3	.327	CT7	.331	.108
		CT8	.331	.108
		CT9	.339	.111
LW: local weights; GW: global weights				

Finally, the local and global weighting results of the criteria and dimensions for the attitudinal value λ:0 are represented in Table 14.

According to the weighting results we can conclude that, financial (dimension 1) is the most important dimension in the dimension set, whereas physical conditions (dimension 3)

TABLE 15. Global weighting results with several attitudinal values.

CT	λ:0	λ:.1	λ:.2	λ:.3	λ:.4	λ:.5	λ:.6	λ:.7	λ:.8	λ:.9	λ:1
CT1	.114	.114	.114	.114	.114	.114	.113	.113	.113	.113	.113
CT2	.112	.112	.112	.112	.112	.111	.111	.111	.111	.111	.110
CT3	.117	.116	.116	.116	.115	.115	.115	.114	.114	.114	.113
CT4	.111	.111	.111	.111	.111	.111	.111	.111	.111	.111	.111
CT5	.111	.111	.111	.111	.111	.111	.111	.111	.111	.111	.111
CT6	.109	.109	.109	.109	.110	.110	.110	.110	.110	.110	.110
CT7	.108	.108	.108	.108	.109	.109	.109	.109	.109	.109	.109
CT8	.108	.108	.109	.109	.110	.110	.110	.111	.111	.112	.112
CT9	.111	.111	.111	.111	.111	.110	.110	.110	.110	.110	.110

TABLE 16. Evaluations for alternatives.

	CT1			CT2			CT3		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
AT 1	bw “f”-“g”	ms “f”	ls “f”	f	bw “f”-“g”	ls “p”	bw “p”-“g”	ms “f”	ms “f”
AT 2	bw “f”-“b”	bw “p”-“f”	ls “f”	f	bw “p”-“f”	bw “p”-“g”	bw “f”-“g”	bw “p”-“f”	ms “f”
AT 3	bw “p”-“f”	f	ms “g”	bw “p”-“f”	bw “f”-“g”	ls “f”	f	bw “f”-“g”	bw “f”-“g”
AT 4	bw “g”-“b”	bw “p”-“f”	bw “f”-“g”	b	bw “p”-“f”	G	bw “g”-“b”	bw “p”-“f”	ms “g”
AT 5	f	ls “f”	g	bw “f”-“g”	ls “f”	bw “p”-“f”	f	ls “g”	ms “f”
	CT4			CT5			CT6		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
AT 1	f	ls “g”	ls “f”	bw “p”-“f”	ls “g”	F	bw “p”-“f”	ls “g”	ls “f”
AT 2	ls “f”	ls “g”	ms “f”	bw “p”-“f”	ls “g”	bw “p”-“f”	bw “p”-“f”	ls “g”	bw “p”-“f”
AT 3	f	ls “g”	f	ls “f”	ls “g”	bw “f”-“g”	ls “f”	ls “g”	ls “f”
AT 4	b	bw “p”-“f”	g	ls “g”	ms “f”	ls “g”	bw “g”-“b”	ls “f”	ls “g”
AT 5	bw “p”-“g”	ms “f”	ms “f”	f	ms “f”	F	bw “p”-“f”	F	bw “p”-“g”
	CT7			CT8			CT9		
	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3	DEC1	DEC2	DEC3
AT 1	f	ls “g”	ms “f”	f	ls “f”	ms “g”	bw “p”-“f”	bw “p”-“f”	ms “g”
AT 2	ls “f”	bw “p”-“g”	bw “g”-“b”	bw “f”-“g”	ls “f”	bw “g”-“b”	bw “f”-“g”	ls “f”	bw “g”-“b”
AT 3	ms “f”	bw “p”-“g”	bw “p”-“f”	p	bw “p”-“g”	ls “f”	ms “f”	ls “f”	ms “g”
AT 4	b	ls “f”	bw “g”-“b”	b	ls “f”	bw “g”-“b”	B	ls “g”	bw “g”-“b”
AT 5	bw “p”-“f”	bw “p”-“f”	ls “f”	bw “p”-“f”	bw “p”-“f”	bw “g”-“b”	F	bw “p”-“f”	bw “p”-“f”

AT: alternatives; CT: criterion; DEC: decision makers; ls: at least; ms: at most; bw: between; gr: greater than; lw: lower than

is relatively weak. Regarding the customer expectations criteria, price fairness (criterion 1) obtains the best global weight with 11,4%, whilst working hours and hygiene (criteria 7 and 8 respectively) are the weakest criteria with 10.8% weight for the attitudinal value λ:0 of the expected score function.

TABLE 17. 2-tuple values of collective linguistic evaluations for alternatives.

	CT1		CT2		CT3		CT4		CT5	
	Oc	Pc	Oc	Pc	Oc	Pc	Oc	Pc	Oc	Pc
AT1	(f,.33)	(p,-.33)	(f,0)	(f,-.33)	(f,.33)	(w,.33)	(g,.33)	(f,.33)	(g,-.33)	(f,0)
AT2	(g,-.33)	(p,0)	(f,.33)	(p,.33)	(f,.33)	(p,0)	(b,0)	(f,.33)	(g,-.33)	(f,-.33)
AT3	(p,.33)	(p,0)	(g,0)	(f,-.33)	(g,-.33)	(f,0)	(g,-.33)	(f,.33)	(b,-.33)	(f,0,33)
AT4	(f,0)	(f,0)	(g,0)	(g,-.33)	(g,-.33)	(p,.33)	(g,0)	(g,-.33)	(g,.33)	(f,0)
AT5	(f,0)	(f,.33)	(g,0)	(f,-.33)	(g,-.33)	(f,-.33)	(f,.33)	(w,.33)	(f,0)	(p,.33)

	CT6		CT7		CT8		CT9	
	Oc	Pc	Oc	Pc	Oc	Pc	Oc	Pc
AT1	(g,.33)	(f,0)	(g,-.33)	(f,-.33)	(g,0)	(p,.33)	(f,.33)	(p,-.33)
AT2	(g,-.33)	(f,-.33)	(b,-.33)	(f,0)	(b,-.33)	(f,.33)	(b,-.33)	(f,.33)
AT3	(b,0)	(f,.33)	(f,.33)	(p,-.33)	(g,-.33)	(p,.33)	(g,0)	(p,-.33)
AT4	(b,0)	(g,-.33)	(b,0)	(g,0)	(b,0)	(g,0)	(b,0)	(g,.33)
AT5	(f,.33)	(p,.33)	(g,-.33)	(p,.33)	(g,-.33)	(f,-.33)	(f,0)	(p,.33)

TABLE 18. IVIFSs for alternatives.

	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9
AT1	((.40,.47), (.10,.13))	((.20,.40), (.20,.33))	((.40,.47), (.05,.07))	((.40,.67), (.40,.47))	((.40,.53), (.20,.40))	((.40,.67), (.20,.40))	((.40,.53), (.20,.33))	((.40,.60), (.20,.27))	((.40,.47), (.10,.13))
AT2	((.40,.53), (.10,.20))	((.40,.47), (.20,.27))	((.40,.47), (.10,.20))	((.60,.80), (.40,.47))	((.40,.53), (.20,.33))	((.40,.53), (.20,.33))	((.60,.73), (.20,.40))	((.60,.73), (.40,.47))	((.60,.73), (.40,.47))
AT3	((.20,.27), (.10,.20))	((.40,.60), (.20,.33))	((.40,.53), (.20,.40))	((.40,.53), (.40,.47))	((.60,.73), (.40,.47))	((.60,.80), (.40,.47))	((.40,.47), (.10,.13))	((.40,.53), (.20,.27))	((.40,.60), (.10,.13))
AT4	((.20,.40), (.20,.40))	((.40,.60), (.40,.53))	((.40,.53), (.20,.27))	((.40,.60), (.40,.53))	((.40,.67), (.20,.27))	((.60,.80), (.40,.53))	((.60,.80), (.40,.60))	((.60,.80), (.40,.60))	((.60,.80), (.60,.67))
AT5	((.20,.40), (.40,.47))	((.40,.60), (.20,.33))	((.40,.53), (.20,.33))	((.40,.47), (.05,.07))	((.20,.40), (.20,.27))	((.40,.47), (.20,.27))	((.40,.53), (.20,.27))	((.40,.53), (.20,.33))	((.20,.40), (.20,.27))

TABLE 19. Decision matrix for house of quality-based evaluation (λ:0).

	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9
AT1	.65	.50	.68	.50	.60	.60	.60	.60	.65
AT2	.65	.60	.65	.60	.60	.60	.70	.60	.60
AT3	.55	.60	.60	.50	.60	.60	.65	.60	.65
AT4	.50	.50	.60	.50	.60	.60	.60	.60	.50
AT5	.40	.60	.60	.68	.50	.60	.60	.60	.50

TABLE 20. Ranking results (λ:0).

AT	D+	D-	CCi	Ranking
AT1	.041	.065	.611	2
AT2	.017	.090	.842	1
AT3	.045	.061	.577	3
AT4	.084	.023	.211	5
AT5	.076	.031	.288	4

However, the sensitivity analysis of the weighting results can be also applied by considering the different attitudinal values of the expected score function. The global weighting results are illustrated with several attitudinal values between 0 and 1 in Table 15.

The global weighting results with several attitudinal values demonstrate that the criteria weights are consistent for all λ values between 0 and 1. This clearly shows that the weighting results can be used to rank the alternatives in the next stage.

C. STAGE 3: RANK THE TECHNICAL REQUIREMENTS OF NEW SERVICE DEVELOPMENT COMPETENCIES IN HEALTHCARE INVESTMENTS

In the last stage, the technical requirements of new service development competencies in healthcare investments are evaluated with the house of quality matrix. To this end, an extension of TOPSIS based on hesitant 2-tuple linguistic information and IVIFSs is considered. Table 16 shows the context-free evaluations of decision matrix.

TABLE 21. Comparative ranking results with different attitudinal values.

AT	λ:0	λ:.1	λ:.2	λ:.3	λ:.4	λ:.5	λ:.6	λ:.7	λ:.8	λ:.9	λ:1
AT1	2	2	2	2	2	2	2	2	2	2	2
AT2	1	1	1	1	1	1	1	1	1	1	1
AT3	3	3	3	3	3	3	3	3	3	3	3
AT4	5	5	5	5	5	5	5	5	5	5	5
AT5	4	4	4	4	4	4	4	4	4	4	4

In the following step, the extreme values of linguistic term sets are defined. Collective linguistic evaluations of decision makers are generated with the 2-tuple linguistic information by determining the optimistic and pessimistic limits of evaluations. Table 17 gives the results for the technical requirements of new service competencies in healthcare investments.

Decision matrix with IVIFSs is constructed as in Table 18.

Similarly, the defuzzified values of 2-tuple IVIFSs are computed with the attitudinal expected score function (Equation 11) and Table 19 presents the decision matrix for the house of quality-based evaluation (for the attitudinal value λ:0) with Formulas (17) and (18).

In the final step, both the closeness coefficient and the D+ and D− values are computed in order to rank the alternatives and define the technical requirements of new service development competencies in healthcare investments. Table 20 illustrates the results of D+, D−, CCi and shows the ranking order for λ:0. The ranking results are provided by listing the values of CCi in descending order.

The ranking performance of technical requirements are listed as technological infrastructure (alternative 2), organizational capacity (alternative 1), functionality (alternative 3), cost management (alternative 5), and operational convenience (alternative 4) respectively. HoQ-based evaluation results of new service development competencies in healthcare investments demonstrate that technological infrastructure (alternative 2) is the best technical requirement while operational convenience (alternative 4) is the worst/comes last. Additionally, the ranking results of the alternatives are given for other attitudinal values between 0 and 1 in Table 21.

The comparative results show that the rankings are same for all the attitudinal values. It is understood that the proposed model is considered coherent when used on the different values of the decision makers' attitudinal characteristics.

VI. CONCLUSION

This paper evaluates new service development competencies based on house of quality (HoQ) in the healthcare industry. For this purpose, a hybrid interval-valued intuitionistic decision-making approach is proposed with fuzzy linguistic information modelled by hesitant fuzzy linguistic term sets (HFLTSs) and linguistic 2-tuples. The findings demonstrate that financial expectation is the most crucial issue for demanders of healthcare services. Therefore, competitive pricing strategies should be improved to obtain consumer loyalty in the healthcare industry. Additionally, technological infrastructure is found as the best ranked technical requirement of new service development competencies.

VII. DISCUSSIONS

The findings illustrate that demanders of healthcare services consider the financial expectations to be the most important factor, while the physical conditions of health services is of significantly less importance. This clearly shows that healthcare firms should provide fair pricing policies together with several payment facilities for their healthcare services. Furthermore, competitive pricing strategies should be generated to obtain consumer loyalty in the healthcare industry. By applying the criteria of the financial expectations of patients and demanders of healthcare services, customer retention could be provided, and this also allows for sustainable growth in the healthcare industry. Frank and Lamiraud [7] focused on consumer behavior in healthcare industry. The health insurance market in Switzerland was taken into consideration in the analysis process, and the conclusion that pricing strategies should be fair to increase customer satisfaction in this area was reached. Winslow [9] also highlighted this situation in his study.

Technological infrastructure, however, is the best ranked technical requirement of new service development competencies, whereas operational convenience gets the worst results in the HoQ-based evaluation of healthcare investments. It is concluded that operational directions with high standards could increase the perceived quality of healthcare investments, which would also satisfy the needs of patients and demanders of health services. Fan *et al.* [22] focused on the Chinese healthcare sector and determined that operational mistakes should be minimized if customer satisfaction is to be improved in the healthcare industry.

The main limitation of this study is that the analysis has only been conducted in the health sector. In future studies, new service generation processes in different industries should also be evaluated. In addition to this issue, overall results could also widen for the country level analysis of healthcare industry. Moreover, in future research, different decision-making approaches, such as AHP, VIKOR and MOORA, could be applied to undertake a comparative evaluation.

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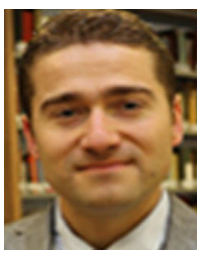

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