An Integration of QFD and Fuzzy-AHP approach in Hospital Services, case study: a Hospital in Iran

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Purpose

This paper shows a development of an integrated model to identify the customer needs and select the best solution to optimize the quality of healthcare systems, namely at hospitals.

Design/methodology/approach

After determining the patient's requirements by data gathering from experts and patients, a questionnaire was prepared to implement the Fuzzy Analytic Hierarchy Process (FAHP) method. Afterward, the requirement's weight has determined by the patients. Finally, the most important technical requirements were achieved applying the 3-phases Quality Function Deployment (QFD) model.

Findings

The results show that by adapting the FAHP on ideas of the patients and hospital's experts to determine the weights of patients' requirements, led to have more flotation in FAHP questionnaires in the hospital services. In this domain, adopting the decision-making tools help more precise ranking of patients' requirements.

Originality/value

Since high-quality urgent services are vital to the protection of human life, it is significant to precisely rank the patient’s requirements by novel methodologies. By the implementation of an integrated model using FAHP and QFD, we were able to show the improvement of the quality of an hospital in Iran. After precisely ranking the patient requirements, "increasing human resource" and "establishing requirements and instructions in initial measures and reducing medication errors", are obtained as the most important technical requirements.

Keywords: QFD, Voice of Customer, House of Quality (HOQ), Hospital Services, FAHP.

Paper type: Case study.

1. INTRODUCTION

The fast-growing and rapidly changing markets in today's competitive environment have made the product/service quality a key determinant for business success. In general, effective capturing of customer requirements (CRs) is a major advantage for product-oriented firms. In this regard, QFD is an efficient customer-oriented design tool that aims to meet customer expectations in a better way and enhance organizational capabilities while maximizing company goals. In 1972 in Japan, QFD emerged as a sufficient systematic tool in Mitsubishi heavy industry to translate CRs throughout the design, planning, and implementation phases of the product (Li et al., 2014). The QFD helps a company to make a trade-off between what the customer wants and what the company affords to produce. The fulfilment of customer needs depends on features of the product/service which can consider as engineering characteristics (ECs). It is important to determine the requirements that bring more satisfaction to the customer than others. Many industries have employed the QFD technique in various areas including transportation and communication, electronics and electrical utilities, software systems, manufacturing services, education and research, aerospace, agriculture, construction, environment protection, packaging, and so on (Chan and Wu, 2002). The relationship matrix in each stage between CRs and ECs is called the house of quality (HOQ) (Wu et al., 2020). The relationship between CRs and ECs reflects the impact of the fulfilment of the ECs on the satisfaction of the CRs. These relationships should be calculated by QFD team members. The relationship between CRs and ECs and the relationship between the ECs themselves are usually determined by linguistic variables. In other words, they are usually interpreted as symbols which should be converted into crisp numbers. The degree of these relationships is usually expressed on a scale system such as 0-1-3-9 or 0-1-3-5, representing linguistic expressions such as "no relationship", "weak/possible relationship", "medium/moderate relationship", and "strong relationship". Proper implementation of the QFD can lead to improvements especially in product and service build strength, quality, cost reduction, product and service development time, and engineering changes (Yang et al., 2012).

To develop the QFD technique for establishing a more precise ranking process, multi-criteria decision-making (MCDM) methods can be employed. Such methods evaluate a set of alternatives taking different criteria into account under a deterministic or uncertain decision environment.

Nowadays, the AHP method is popular in various decision areas. The triangular fuzzy numbers are used to construct a pairwise comparison matrix to evaluate the requirements as criteria in the AHP method (Alinezhad and Seif, 2020). Therefore, many researchers have used the AHP method as an integral part of implementing the QFD method in various issues. Since high-quality urgent services can save human life and healthcare organizations are one of the pivotal domains, it is vital to develop an integrated model to identify the patient's needs and select the best solution to optimize the quality of healthcare systems. Below we discuss the significant application of integrated QFD-MCDM techniques in service systems. Regarding education application, Bayraktaroğlu and Özgen (2008) presented an integrated method using the AHP, Kano model, and planning matrix of HOQ to evaluate the requirements of the library users. The authors considered the central library services of Dokuz Eylul University and evaluated and categorized the student requirements. Raharjo et al. (2011) proposed a systematic methodology to deal with customer needs' dynamics in terms of the relative weights in the QFD approach. First, the authors proposed a short-term forecasting method to model the dynamics of the AHP based importance rating. After that, it estimated the uncertainty degree of CRs. Then, a quantitative approach that considers the decision maker's attitude towards risk to optimize the QFD decision-making analysis is employed. Finally, the proposed method is adopted for improving education quality in a university in Singapore. Wang et al. (2016) presented a new hybrid group decision-making model based on hesitant 2-tuple linguistic term sets and an extended QUALIFLEX (qualitative flexible multiple criteria method) approach to handle the QFD problems under incomplete weight values. For this purpose, at the first stage, they integrated hesitant linguistic term sets into interval 2-tuple linguistic variables to express various uncertainties available in the assessment information of QFD team members. Using grey relational analysis (GRA), they formulated a multi-objective optimization model to determine the relative weights of CRs. Afterward, they extended the qualitative flexible multiple criteria method (QUALIFLEX) approach with an inclusion comparison method to rank the design requirements identified in the QFD. They validated their proposed methodology through the market segment selection data. To reduce the likelihood of poor and awkward body postures, Mistarihi et al. (2020) used a hybrid QFD-FANP method to assessing the modified wheelchair design. Multiple attribute decision making (MADM) is an approach employed to solve problems involving selection among a finite number of alternatives. A hybrid multiphase fuzzy QFD-MADM framework by integrating the QFD, AHP, decision-making trial and evaluation laboratory (DEMATEL), and analytical network process (ANP) along with fuzzy set theory has been developed by Ocampo et al. (2021) for sustainable product design. They applied the method in meat processing industry in Philippines.

Haber et al. (2020) developed an integrated method of the Kano model, QFD, and FAHP to improve medical haemodialysis devices. In this regard, they converted the CRs into receiver state parameters (RSPs) by the Kano model and applied the QFDforPSS which satisfies market expectations rather than traditional QFD by translating the CRs to product-service system (PSS) functionalities. The PSS models present the combination of product and service in a cohesive system to deliver the consumer functionality with taking into consideration of sustainability. Moreover, FAHP was adapted for reducing the vagueness regarding understanding the CRs. Considering the example of a hip replacement surgery aid device for elderly people, Neira-Rodado et al. (2020) proposed an integrated DEMATEL-AHP-QFD framework to translate the CRs to product features and rank the design alternatives. They employed the fuzzy Kano model to obtain how each CR affect the customer satisfaction.

The healthcare industry plays a vital role in ensuring the sustainable development of a country. Since maintaining people's lives and providing prompt, high-quality health care is more important than other service, it is vital to provide a coherent model for identifying patient needs. For this reason, researchers have been paying particular attention to the development of services in hospitals as one of the main pillars of health care. The growing demand for quality care has led to the need for modern modelling of sustainability for the health care system (Zhang et al., 2014). To provide fast and high-quality services by medical organizations, applying different methodologies to achieve comprehensive quality management can be an effective step. In recent years, QFD has been able to play a role in this field (Campos et al., 2013).

This paper aims to develop an integrated FAHP-QFD method for evaluating the weights of CRs are derived from patients using a series of matrixes of QFD. The importance of CRs is prioritized according to the patient's opinion based on the FAHP questionnaire. Afterward, from QFD matrixes and considering the ranked CRs, the most important ECs obtained to optimize the hospital services. This study brought up a real case study of a public hospital in Iran to implement a model and help managers of the health system to understand patients' requirements to provide prompt and high-quality services to protect human life. This paper is structured as follows. Section 2 discusses the proposed model of FAHP and QFD methodology. Section 3 discusses the FAHP approach. Section 4 will define the specific QFD steps in this study, and section 5 illustrates an example of a public hospital in Iran to validate the proposed integrated model. Section 6 concludes the paper. The appendix includes the related HOQ matrix in section 7.

2. PROPOSED AN INTEGRATED FAHP AND QFD MODEL IN HOSPITAL SERVICES

According to the discussed literature in the previous section, the integrated method of QFD and FAHP has not been used in the hospital services considering broad CRs. Therefore, this study tries to study the capability of this integrated method in assessing patients' requirements and identifying key processes to cover them in a hospital as a case study. The implementation of this model is depicted in Figure 1, includes the following steps:

Step 1: First, we tried to determine the criteria and requirements of hospital services by using library studies and searching in previous studies. In this regard, various tools applied such as tree diagram, Kano model, fishbone diagram, existing standards such as GOAL \ QPC criteria, experts in this field, and brainstorming.

QFD team members are represented different hospital units. Therefore, it has been tried to choose the most experienced people in medical affairs in 4 working groups through inquiries and review of work experience and resumes. Also, according to factors such as workload, intensity of impact on the performance of the hospital, as well as the number of staff in the four working groups, 2 people from the headquarters, 1 of the hospital educational supervisor team, 1 of the hospital accreditation team and 3 from the hospital emergency department who were selected as a total of QFD team members.

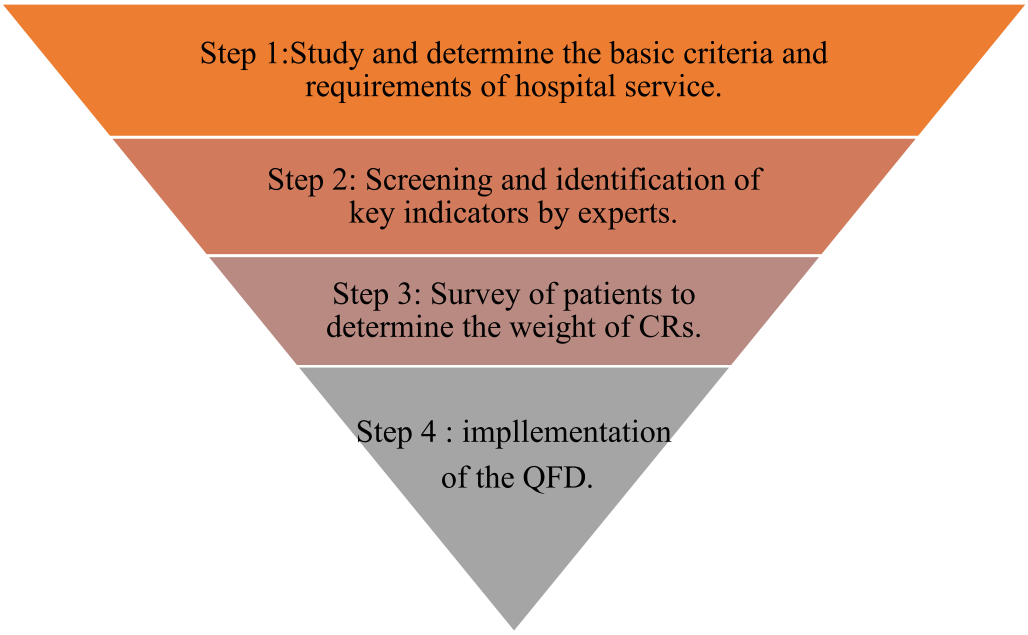

Figure 1– An overview of the proposed integrated FAHP in to QFD model.

Step 2: Prepare a questionnaire to score the main sub-indicators and indicators by experts and screen the most important ones.

Step 3: Form a questionnaire to implement the FAHP method and determine the weight of quality requirements by the customers.

Step 4: This step included the steps for implementing the QFD method, which are:

• Preparing a list of technical requirements by the QFD team members according to the opinion of hospital experts, reviewing related articles, brainstorming.

• Formation of HOQ matrix and measurement of any technical requirements considering the degree of fulfilment of related quality indicators and determination of important and sensitive technical requirements by the QFD team.

• Formation of the second QFD matrix to identify and prioritize executive plans to improve the quality criteria by the QFD team.

• Formation of the third QFD matrix to identify control factors in order to better and more accurately implement executive plans.

3. FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

The analytic hierarchy process is a ranking method based on pair-wise comparisons used as a powerful decision-making tool. Saaty (1990) has initially been introduced the AHP which is a decision support tool that can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pair-wise comparisons between criteria instead of their direct weighting is a main key point in this method and lead to increases in the accuracy of the weights. The AHP method can also examine the consistency of judgments, which is a unique feature of this method.

Guan et al. (2009) proposed a hybrid method based on Genetic Algorithm (GA) and AHP method for ranking and selecting multipurpose digital machines. Mangla et al. (2015) used AHP method for risk analysis in green supply chain. The AHP method is a ranking method based on pairwise comparisons in which the criteria and sub-criteria have a hierarchical structure, no matter how many layers are developing. To calculate the importance weights of the sub-criteria, should multiply two matrices ($W_{32} \times W_{21}$). The top of the pyramid is always the objective of the problem. Usually, this structure consists of two levels of criteria and sub-criteria. Since relative weights are based on pair-wise comparisons, the scale of 5 or 9 is normally used to show the degree of importance of criteria (or sub-criteria) compared to each other (Zebardast, 2001). Afterward, a set of questionnaires is designed to collect patients' opinions. The main structure of a questionnaire was developed to implement the FAHP method. Each set of sub-criteria of main criteria is compared in pairs. Finally, after forming a pairwise comparison matrix for each cluster in the hierarchical structure, it has done a set of calculations to obtain the priority vectors and the consistency ratio. Therefore, it is necessary to point out some mathematical equations related to triangular fuzzy numbers.

This monumental work has decades of applications, among them on decision-making under multiple criteria (Abdullah, 2013; Mardani et al., 2015). Let $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ two fuzzy triangular numbers, and λ is a crisp number. Then we can denote (Chang, 1996):

$$M_1 + M_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \quad [1]$$

$$M_1 \times M_2 = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2) \quad [2]$$

$$\lambda \times M_1 = (\lambda \times l_1, \lambda \times m_1, \lambda \times u_1) \quad [3]$$

$$M_1^{-1} = \left({}^{1}/_{u_1}, {}^{1}/_{m_1}, {}^{1}/_{l_1}\right) \quad [4]$$

According to the above preparations, the implementation of the FAHP method can summarise in the following steps:

3.1. Calculate the average of decision-makers opinions

After collecting the respondent's views which the detail will discuss in section 5, the average score on each question is calculated and the average weights with the formula below:

$$\overline{r_i} = \frac{1}{m} \times \sum_{i=1}^{m} r_{ij} \quad [5]$$

In this equation, i is the index of questions, j is the index of respondents, m is the number of respondents, and r_{ij} is the answer of the respondent j to the i question, which is itself a triangular fuzzy number of (l_{ij}, m_{ij}, u_{ij}). Also, the expression $\overline{r_i}$ can be represented as the following triangular fuzzy number:

$$\overline{r_i} = (\bar{l}_i, \bar{m}_i, \bar{u}_i) \quad [6]$$

According to Buckley (1985), three components can be calculated as follows:

$$\overline{l_i} = \frac{1}{m} \times \sum_{i=1}^{m} l_{ij} \quad [7]$$

$$\overline{m}_i = \frac{1}{m} \times \sum_{i=1}^{m} u_{ij} \quad [8]$$

$$\overline{u_i} = \frac{1}{m} \times \sum_{i=1}^{m} r_{ij} \quad [9]$$

3.2. Formation of pairwise comparison matrices

The next step is needed to form a matrix of pairwise comparisons for each cluster-criterion after calculating the average opinions of the respondents. The pairwise comparison matrix is a square matrix in which all elements of main diagonals are equal to one. In terms of value, symmetric elements are inverse to each other in this matrix. There is always an injective function between the questionnaire questions and the upper half elements of the pairwise comparison matrix. Therefore, the element of row i and column j (both i and j are criteria indices of the matrix) is related to the question in which the criterion preference i is questioned relative to criterion j.

3.3. Calculate priority vector

There are various methods for calculating the priority vector, including the principal Eigenvalue method, logarithmic least square method, least square method, line sum method, column sum method, arithmetic mean method, and geometric mean method (Saaty and Hu, 1998). One of the most widely used approaches in implementing FAHP is the method proposed by Chang (1996). To calculate the priority vector of each matrix, first the average of the elements of each row is calculated. Then, their normalized values are calculated and introduced as the weight of the corresponding criterion to the related row (Diabagate et al., 2017).

3.4. Inconsistency rate of the answers

To ensure the stability of the respondents' pair comparison, the inconsistency rate of each matrix is calculated. The acceptable numerical consistency rate is less than 0.1. The equations below are mentioned to calculate the inconsistency rate of the answers:

$$IR = II/RI \quad [10]$$

$$II = (\lambda - n)/(n - 1) \quad [11]$$

The II shows the inconsistency index, the IR inconsistency rate, n is the number of items compared in the matrix and, λ is the maximum weight of the pair comparison matrix. Also, RI is a conventional value for matrices with different dimensions, which is called the Random Consistency Index. If the answers are inconsistent for each of the matrices, the following set of actions is recommended:

3.4.1. Calculate the inconsistency rate of the answers for each respondent by performing 3.2 to 3.4.

3.4.2. Descend ordering of data on respondents' inconsistency rates.

3.4.3. Remove the answers related to the respondent with the highest inconsistency rate from the set of responses and then calculate the responses' inconsistency rate using the average of the remaining respondents.

Repeat the three phases above (i.e., eliminating the answers with the highest inconsistency rate from the data set) until the inconsistency rate is less than 0.1.

3.5. Calculate the final fuzzy weight of the sub-criteria

To obtain the final weight of the sub-criteria, it is sufficient to multiply the importance weights of the criteria hierarchically. According to the criteria hierarchy (three-layer structure), by multiplying the relative weight of each sub-criterion by the weight of its parent criterion, the final weight of all sub-criteria will be obtained. Note that after calculating the final weight of the sub-criteria, the sum of all these weights will be equal to one.

3.6. De-fuzzition weight of sub-criteria and determine their final crisp weight

One of the concepts proposed in the Chang method is to calculate the magnitude of a triangular fuzzy number compared to another one. The value of a fuzzy number compared to another one will be obtained in equations 12 and 13. Where $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers. If $m_1 \geq m_2$

Then, can be expressed as follows:

$$V(M_1 \geq M_2) = 1 \; Otherwise \;\; V(M_1 \geq M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \qquad [12]$$

Also, the magnitude of a triangular fuzzy number compared to k triangular fuzzy numbers has resulted from the following formula:

$$V(M_1 \geq M_2, \ldots, M_k) = min\{V(M_1 \geq M_i); i = 2, \ldots, k\} \qquad [13]$$

4. THE QFD STEPS

Nowadays, organizations use a variety of quality topics to produce their product or service, which leads to meeting the customer requirements and ultimately customer satisfaction. The QFD method is a customer-oriented product development tool to translate effectively customer needs to design and implementation requirements in different aspects of the product or service. The three-matrix structure QFD is recognized as one of the most widely applied models in medical centers, hospitals, and service organizations (Venkateswarlu and Birru, 2012). Therefore, the three-matrix QFD method has been adapted to implement the model, which has the following steps:

4.1. Formation of the HOQ

The HOQ matrix is known as the most common part used in QFD. This house contains elements related to the customer requirements called "WHATs" placed in the rows of the matrix. The technical characteristics are called "HOWs" placed in columns. Nevertheless, the common elements with details and a set of actions that must implement are depicted in Figure 2.

The QFD and the HOQ matrix start with the customer's needs regarding the product. For this purpose, using Benchmarking methods, evaluation of competitors, interviews, focus groups, observing how providing services, staff opinions, reviewing the records of complaints and non-compliance, the customer expectation from desired product or service is determined. Then it needed to rate customers' requirements in terms of importance. There are several manners to weigh these criteria. It is possible to use a range of discrete numbers such as "1 to 5" or "1 to 10". For this purpose, to increase the accuracy of the importance ratings, the FAHP method has been used. The QFD team members must develop a set of technical characteristics to meet these CRs after the identification by the customers. A list of ECs can be extracted by experts, it can expect for an EC to meet more than one CR with different levels of importance. It is important to note that all ECs must be measurable and clearly stated transparently and unambiguously.

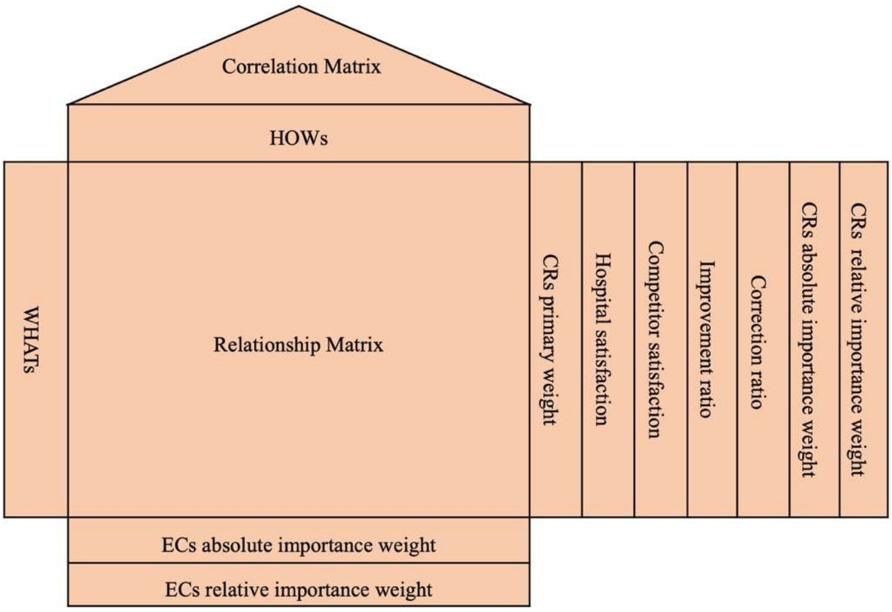

Figure 2 – The main components of the HOQ matrix.

Organizations that want to compete in the market must know what position and rank their product or service from the customer's perspective. According to fulfilment of activities, they want to compare with other competitors; For taking account of this in the HOQ, on the right side of the HOQ matrix, the product or service is evaluated with a similar product or service from competitors. In this step, we designed a questionnaire for data collection from the statistical population of patients in the related hospital and the competitor to evaluate the hospital service performance " (the questionnaire not presented) ". The scoring range of 1 (for the worst condition) to 10 (for the best condition) was used to show the hospital performance in the related criteria. The information collected in this step is in the "Hospital Status" and "Competitor Status" columns in Figure 2, respectively. By obtaining the result of these two columns, the information of the "Improvement ratio" column can also be obtained by dividing the elements of the "Competitor status" column by the "Hospital status" column.

To further emphasize some of the CRs, a coefficient called "Correction ratio" is assigned to them. Therefore, the rate of 1.5 is given to some criteria which bring higher importance for the customer, satisfy them at a higher level, and motivate the customers to use the organization service. Items satisfying the customer but not as much as the first category, get a rate of 1.2. Other criteria that do not need further correction and emphasis are assigned a value of 1.

Afterward, the elements of the three columns consist of " CRs primary weight", "Improvement ratio" and "Correction ratio" are specified. By multiplying the value of these three columns, the " CRs absolute importance weight" column resulted. Finally, by normalizing the absolute weights from the previous step, the" CRs relative importance weight" column be obtained.

The absolute weight of each EC calculates according to the relationship between the corresponding EC and the CR in the following equation:

$$w_i = \sum_{\forall j} c_j \, d_{ij} \qquad [14]$$

Where i represents an EC and j is the index related to criterion (CR), w_i is the absolute weight of the ith EC. The c_j is the index of jth criterion relative importance weight, and d_{ij} represents how the criterion index j is satisfied by the ith criterion. Finally, for the simplicity of comparing the ECs, the relative importance weight of each of them is obtained by normalizing the absolute weights. The HOQ matrix from case study broadly will depicted in section 7.

4.2. Service process deployment

After determining the weights of CRs from the previous stage, it is time to design a set of executive plans to meet these requirements. First, the prior ECs obtained from the HOQ matrix are placed as the rows of the second matrix, and the necessary processes to achieve them are designed. To select the ECs to be transferred to the second matrix due to their large number, those ECs in the fourth quadrant were selected and placed in the rows of the second matrix.

4.3. Evaluate control factors and action plans

The basic requirements of critical processes are determined. The possible operations on these requirements are performed at this stage. Finally, the operations that have been recognized by the organization from customer satisfaction (the expectations expressed in the first stage) will be extracted. Also, we create the control parameters required for execution in this step. Several columns of service operations of the service process deployment matrix are considered rows of the process control planning and action plans matrix (The figure 4 shows this matrix). Afterward, for each of the rows of the matrix with ranges 1 (non-critical), 2 (critical), and 3 (very critical), the four evaluation criteria are determined as follows: 1. The difficulty of the control, 2. Frequency of the problem, 3. The severity of the potential problem, 4. Ability to diagnose the problem.

By Multiplying the weights of the above four factors, the "operation evaluation" indicator, which will be a number between 1 and 81, is calculated for every row in the matrix. The higher value shows the process is more critical and needs action plans. The main objective of this step is to control and monitor the key characteristics of the process and emphasize the amount of control required. Critical processes and operations in the rows have determined. Then, the requirements for controlling are identified in the columns of the process control planning matrix to prevent errors and failures. Figure 3 shows the approach used in the three-matrices QFD.

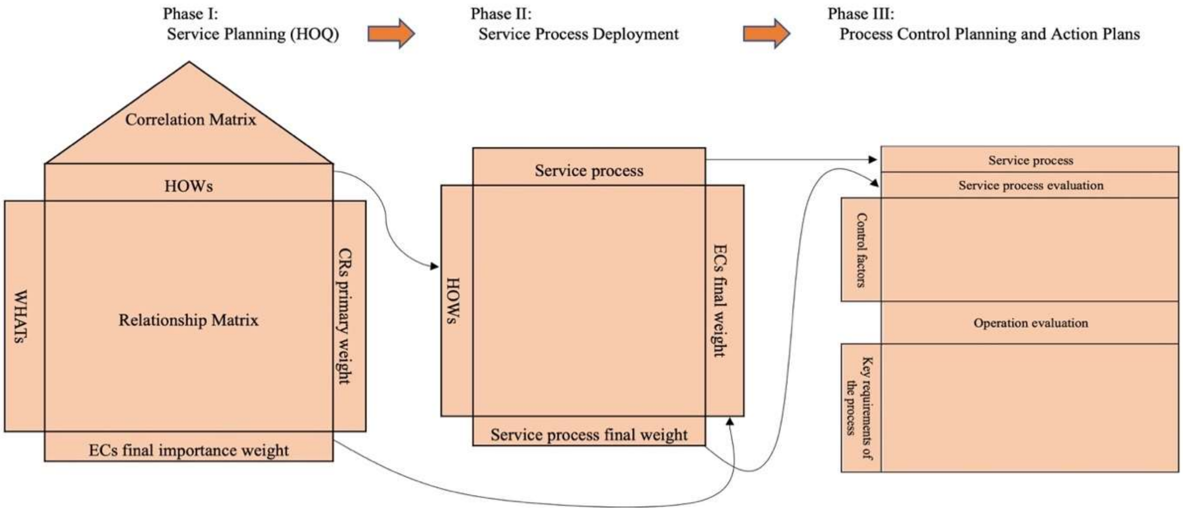

Figure 3 – The three-matrices QFD approach.

5. IMPLEMENTATION OF THE PROPOSED APPROACH

After explaining the general structure of the proposed model, the model is developed in a public hospital in Bojnord, in the North Khorasan state of Iran. This hospital is the first hospital in the state with more than 50 years old after renovation. Recently, it has been upgraded to 225 beds and is the largest hospital in the North Khorasan state which consist of 10 wards and clinical and paraclinical sections. It serves 15000 people per month. In the following sections, steps of the implementation process are presented with the relevant details.

5.*1. Experts survey*

The set of criteria and sub-criteria were designed in a questionnaire format and then provided to the experts. Experts of the organization consist of members of different hospital units such as the management, hospital educational supervising team, quality improvement team, and hospital emergency team. According to Morgan table should have a sample size of 48 for a statistical population of 55 people (Krejcie and Morgan, 1970). After determining the sample size using the random sampling method, we have distributed the questionnaire among the experts. This questionnaire is presented in table 1.

Table 1 – An example of questionnaire options for expert opinion about quality criteria.

Question: How do you assess the importance of the following quality criteria as a measure of patient satisfaction with hospital services?						
Number	Sub-Criterion	Very important	Somewhat Important	Neutral	Somewhat Unimportant	Very unimportant
1	Rapid and on-time response					

The value of Cronbach's alpha for the questionnaire was 0.94, which indicates a high-reliability rate. The center of gravity method has been used to de-fuzzy the triangular Fuzzy numbers. Following equation shows how to calculate the non-fuzzy value of the $M = (l, m, u)$ in the center of gravity method:

$$M = \frac{l+2m+u}{4} \quad [15]$$

5.2. Patients survey to calculate the sub-criteria weight

An average of 1100 patients registered according to the scope of 6 months from June 2018 to December 2018 and considering the available statistical data in the hospital. Considering Morgan's model, the number of samples is 285 patients (Krejcie and Morgan, 1970). After determining the sample size, we have distributed the questionnaire among the patients. This questionnaire showed in table 2.

For example, to evaluate the importance of the two sub-criteria of " Rapid and on-time response " and " Experienced medical team" in the main criterion of "medical", how to answer the questionnaire depends on the respondent. In one of example:

If from the respondent's point of view, the importance of the sub-criterion of " Rapid and on-time response" is more than the criterion of "Experienced medical team" and the level of importance in the range of 1 (equal preference), 2 (low preference), 3 (medium preference), 4 (High preference), 5 (very high preference), number 5 is completed as follows and shows the very high preference of left sub-criterion than right sub-criterion:

Table 2 – Sample of AHP method questionnaire for the determining the final structure of quality criteria by patients.

Rapid and on-time response	5	4	3	2	1	2	3	4	5	Experienced medical team

Due to the different distribution of patients in various wards, the Stratified sampling method is developed. The hospital wards and distribution of beds showed in table 3.

Table 3 – Distribution of beds in various units of hospital.

	Hospital unit	Number of beds
1	Pediatrics	50
2	Internal diagnosis	38
3	Neurology	18
4	Intensive Care Unit (I.C.U.)	8
5	Infectious disease	8
6	Psychiatric	22
7	Accident and Emergency (A&E)	25
8	Cardiovascular	19

9	Coronary Care Unit (C.C.U.)	11
10	Subspecialty	20

Also, the average inconsistency rate was 0.285, and using the equations of FAHP in section 3, the stages of section 3 implemented to determine the final weights of the criteria are obtained as shown in table 4 according to the questionnaire by experts (after the deadline and reaching the required number of questionnaires) and another questionnaire (patient opinions) distributed it among the statistical population of patients according to the model.

Table 4 – Final weights of sub-criteria in the hospital services using FAHP method.

Weight	Sub-Criteria	Sub-Criteria	Weight
–	Welfare	Medical	–
0.007	Indoor condition (ventilation, light, temperature)	Rapid and on-time response	0.212
0.006	Convenient medical transportation services		
0.003	Entertainment in each room (TV, Books, etc.)	Experienced medical team	0.155
0.004	Communication channels, media, and devices in the room	Hospital equipment	0.097
0.003	Existence of welfare facilities for patients	Ability to communicate with patients effectively	0.019
0.002	Existence of welfare facilities for patient care assistant	Administrative and service	–
		Documentation issuing time	0.044
0.001	Hospital Signage Boards	Hospital environmental hygiene	0.062
0.001	A healthy-eating menu	Timely supply of clean linen and bedsheets	0.026
0.008	sufficient quiet and silence rooms		
–	Psychological support	Personal hygiene, health, and professional appearance	0.015
0.183	Respect for patients by the staffs	Ease of hospital discharge	0.005
0.025	Respecting the Religious and Cultural needs of patients		
0.112	The response rate to patient questions (by doctors and nurses)		

5.3. Identification of engineering characteristics and implementation of QFD

After considering the CRs, to fulfill these demands the ECs are determined by the QFD team. These ECs are located at the top wall of the HOQ and form the columns of the house. In this regard, it has been tried that each EC has a strong relationship with at least one CR.

- **Relationship matrix:** by summing the weight of the sub-criteria and, the evaluation of another hospital in North Khorasan state in Bojnord as a competitor. The relationship matrix (HOQ) is presented in section 7.

- **Process control planning and action plans matrix:** After determining the critical processes and operations in the rows, the requirements for controlling them are determined in the process control planning and action plan matrix columns to prevent errors and failures. Figure 4 shows the process control planning.

		Purchasing advanced cleaning devices	Strengthening the capacity of Human Resources	Recruitment of medical staff	Healthcare assistant training	Arrange psychological courses for staff (specifically for nurses) regarding how to treat patients	Healthcare assistant hiring	Arrange specialized courses in up-to-date treatment methods	Developing instructions and obligations for primary care and reducing medication errors
		9.7	**16.4**	**23**	**7.2**	**11.3**	**10.9**	**8.2**	**13.8**
Control factors	*Difficulty of the control*	*1*	*3*	*3*	*2*	*2*	*1*	*2*	*2*
	Frequency	*2*	*2*	*1*	*1*	*1*	*2*	*1*	*2*
	Severity	*2*	*2*	*3*	*1*	*1*	*1*	*2*	*3*
	Ability to diagnose	*1*	*3*	*2*	*2*	*2*	*2*	*2*	*2*
	Multiplication	*4*	*36*	*18*	*4*	*4*	*4*	*8*	*24*
Key requirements of the process	Various proficiency interviews before hiring			✱			✱		
	Background check for employment			✱			✱		
	Direct supervision over the educational workshops		✱		✱	✱		✱	
	Determining indicators to measure service quality		✱						✱
	Analysis of existing processes		✱	✱	✱				
	Set up a maintenance department	✱							
	Inspection of purchased equipment	✱							
	Develop and implement the necessary measures to prevent failure								✱

Figure 4 – Process control planning and action plans matrix.

6. CONCLUSION

There are always problems when implementing a QFD that team members may encounter at first during the project. These problems are exacerbated when the QFD team seeks to improve service quality. Lack of service quality measurement systems, and lack of measuring tools are among the critical problems in service organizations. Therefore, the QFD team should try to find how to measure service quality and design new methods and tools to measure criteria. In some service organizations, the service delivery process does not have a clear process, in such organizations, analysing the service outputs of the organization is difficult and time consuming.

One of the limitations in collecting information was the inability of some patients to answer questions and the absence of their care assistants then had to be asked each question orally. In some cases, due to the medical care provided to the patient, the interview was forced to be interrupted, which caused a long process of data collection. Some patients did not fully understand the questions and had difficulty receiving the requirements of the questionnaire, and sometimes they were misunderstood. Other problems include congestion and stress on patients and their companions in some wards such as the emergency ward. The implementation of the QFD method led to obtain the voice of customers and their hidden demands that were not identified previously. For example, the item "Respect for patients by the staff", which does not seem to affect the medical criteria has a strong relationship with patients 'satisfaction with the hospital. Also, the item "Hospital environmental hygiene" is not the main factor considered in medical criteria and is one of the most important CRs. According to the HOQ, the most priority CRs concluded the following, respectively: Rapid and on-time response, Respect for patients by the staff, Experienced medical team, and Response rate to patient questions (by doctors and nurses), Hospital Equipment, Hospital environmental hygiene.

In this study, by the integration of QFD and FAHP, CRs were identified and prioritized. Afterwards, a set of action plans to improve the quality of hospital services defined. This method has two advantages. First, pairwise comparison, and second, applying the fuzzy theory. After implementing the integrated model, two ECs "Strengthening the capacity of human resources" and "Developing instructions and obligations for primary care and reducing medication errors" as the most significant technical control requirements in a case study in a public hospital in North Khorasan state in Iran have obtained. Finally, the importance of "Determining indicators to measure service quality", "Direct supervision over the educational workshops", "Analysis of existing processes" and "Developing and enforcing the necessary measures to prevent failure" were recognized as the most important for these key requirements of the process. Future studies can focus more on the following:

- Fuzzy variables can be used by the QFD team in matrices due to improve the accuracy instead of the use of discrete symbols of weights.
- In this study, to weigh the criteria and sub-criteria, the ANP method can be used instead of AHP. Unlike AHP, it considers the advantage of the ANP method over AHP in creating correlation and interaction.
- Due to the use of signs on the roof in the HOQ, which has only a control and warning aspect to control the ECs, these elements can be upgraded to a score that achieves quality requirements and mathematical correlation between ECs.

7. APPENDICES

As mentioned in sub-section 4.1, the relationship between CRs and ECs determines the relationship between quality criteria and technical characteristics in the HOQ matrix. Each strong link has a score of 9, the medium link has a score of 3 and, a weak link has a score of 1. For example, the "Electronic medical record system" is strongly related to the "Documentation issuing time", since if the patient has already been referred to this hospital and has a record, documentation issuing will be easier and faster. Otherwise, the normal procedure for issuing the documents is ongoing. Figure 5 shows the HOQ of the public hospital in Bojnord.

Group	CRs \ ECs	Average wait time to see the doctor <10 min	Preliminary help pending arrival of doctor	Patience of the staff	Number of nursing personnel	Number of medical staff	Laboratory and radiographic equipment	Advanced Call button beside the patient's bed	Patient discharge rules	Patient admission procedure	Average time of admission process	Cleaning plan	arranging commute in hospital	Number of healthcare assistants	Guidance on uniforms	Elevators and ramps	Arrange psychological courses for nurses	Transport stretcher trolley	Observance of the room's silence
Medical	Rapid and on-time response	●	●	△	●	●	○	○		○	○	△		○		○		△	
Medical	Experienced medical team		○	○	○	●													
Medical	Hospital equipment						●												
Medical	Ability to communicate with patients effectively		○		●	○		●						△			●		
Administrative and service	Documentation issuing time	○	○							●	●								
Administrative and service	Hospital environmental hygiene											●		●					
Administrative and service	Timely supply of clean linen and bedsheets											●		●					
Administrative and service	Personal hygiene, health, and professional appearance											●			●				
Administrative and service	Ease of hospital discharge					●			●										
Welfare	sufficient quiet and silence rooms			○									○						●
Welfare	Indoor condition (ventilation, light, temperature)																		
Welfare	Convenient medical transportation services															○		●	
Welfare	Entertainment in each room (TV, Books, etc.)																		
Welfare	Communication channels, media, and devices in rooms																		△
Welfare	Existence of welfare facilities for patients																		
Welfare	Existence of welfare facilities for patient care assistants							○											
Welfare	Hospital Signage Boards																		
Welfare	A healthy-eating menu																		
Psychological	Respect for patients by the staffs			●								●					●		
Psychological	Respecting the Religious and Cultural needs of patients																		
Psychological	The response rate to patient questions (by doctors and nurses)			●										●			●		
	Absolute weight	1.983	2.565	3.183	2.571	3.528	1.602	0.819	0.045	0.981	0.981	2.691	0.018	2.473	0.09	0.639	2.628	0.054	0.058
	Relative weight	0.062	0.080	0.099	0.080	0.110	0.050	0.026	0.001	0.031	0.031	0.084	0.001	0.077	0.003	0.020	0.082	0.002	0.002

Group	CRs \ ECs	Minimize the light bulb burnt out	Ventilation system	Adequate refrigerator and wardrobe in each room	Electronic medical record system	Providing games and entertainment	Religious and cultural competence procedure	Specialized employee training	Use of cellular telephones in each room	Restroom in each room	Average number of patients in each room	Privacy of the patient	Patient care assistant room	Companion Bed	Existence of signboards	Parking marks and traffic regulation signage	Proper performance of the facility unit	Patient diet adaptation and alternative feeding	Importance	Hospital evaluation	Competitor evaluation	Improvement ratio	Correction ratio	Absolute weight	Relative weight
Medical	Rapid and on-time response				○			●											0.212	8	7	0.88	1.5	0.28	0.207
Medical	Experienced medical team							○											0.155	8	8	1.00	1.5	0.23	0.173
Medical	Hospital equipment							○											0.097	9	9	1.00	1.5	0.15	0.109
Medical	Ability to communicate with patients effectively							●							△				0.019	5	6	1.20	1.2	0.03	0.021
Administrative and service	Documentation issuing time				●														0.045	8	8	1.00	1.2	0.05	0.040
Administrative and service	Hospital environmental hygiene									○	△								0.062	7	8	1.14	1.5	0.11	0.080
Administrative and service	Timely supply of clean linen and bedsheets										○								0.027	9	9	1.00	1.2	0.03	0.024
Administrative and service	Personal hygiene, health, and professional appearance																		0.015	7	6	0.86	1	0.01	0.010
Administrative and service	Ease of hospital discharge				△														0.006	10	8	0.80	1.5	0.01	0.005
Welfare	sufficient quiet and silence rooms		○						△		●								0.008	7	6	0.86	1.2	0.01	0.006
Welfare	Indoor condition (ventilation, light, temperature)	●	●							△	○						●		0.007	7	6	0.86	1.5	0.01	0.007
Welfare	Convenient medical transportation services																		0.006	7	7	1.00	1.2	0.01	0.006
Welfare	Entertainment in each room (TV, Books, etc.)					●													0.004	5	5	1.00	1	0.00	0.003
Welfare	Communication channels, media, and devices in rooms								●										0.005	4	4	1.00	1	0.01	0.004
Welfare	Existence of welfare facilities for patients			●		○				○		○			○				0.004	6	8	1.33	1	0.01	0.004
Welfare	Existence of welfare facilities for patient care assistants					△							●	●	○	●			0.003	6	8	1.33	1	0.00	0.003
Welfare	Hospital Signage Boards														●	○			0.002	4	4	1.00	1.2	0.00	0.001
Welfare	A healthy-eating menu																	●	0.001	8	9	1.13	1.2	0.00	0.001
Psychological	Respect for patients by the staffs																		0.184	6	5	0.83	1.5	0.23	0.171
Psychological	Respecting the Religious and Cultural needs of patients						●												0.025	6	7	1.17	1.2	0.04	0.027
Psychological	The response rate to patient questions (by doctors and nurses)																		0.113	8	8	1.00	1.2	0.14	0.100
	Total																							1.34	1
	Absolute weight	0.063	0.081	0.086	0.986	0.042	0.243	2.898	0.042	0.259	0.227	0.012	0.027	0.027	0.051	0.03	0.063	0.009	32.055						
	Relative weight	0.002	0.003	0.003	0.031	0.001	0.008	0.090	0.001	0.008	0.007	0.000	0.001	0.001	0.002	0.001	0.002	0.000	1						

Figure 5 – The HOQ matrix of the hospital.

△Weak (1) ○Medium (3) ● Strong (9)

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