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A TREATISE ON AHP-QFD MODEL FOR HEALTHCARE INSTITUTE SELECTION: A CONSPECTUS CONSILIENT APPROACH

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ABSTRACT

The explosion of knowledge sharing, cloud computing, artificial intelligence and machine learning(AI and ML), digital integration, internet of things(IOT), advancement in medical technology and telemedicine leads patient and patients party across the world to avail the best healthcare services under utopian environment. Patients have high expectation regarding their speedy recovery and similarly the service providers have high responsibility to meet the desired level of satisfaction of patients. Choosing a healthcare institute for medical treatment is an epochal task. Inappropriate selection can have a detrimental effect on health of an individual. Several criteria must be taken into account in order to select the most robust healthcare institute. This paper aims to develop an integrated model by linking AHP with QFD to determine the performance score of healthcare institute and select the best among them based on patient and patients' party demand and technical criteria of healthcare institute. The proposed approach highlights technical criteria of healthcare institute based on patient and patients' party requirement perspective. Including cost-factor elements in the proposed model justifies healthcare institute selection from an economic perspective. A case study has been carried out in Kolkata to apply the proposed integrated AHP-QFD model and select the optimal healthcare alternative. It also addressed both subjective and objective factors taken together in a conspectus consilient ways.

Keywords: Multi-criteria analysis; Analytical hierarchy process; Quality function deployment; Healthcare Institute selection; Decision-making

I. Introduction

The entire world has undergone a significant transformation due to the current trend of digitalisation. In the present highly competitive environment, service quality is a decisive factor to achieve success in service sector industries by retaining existing customers and gaining new customers. It is substantial to figure out the needs that bring more contentment to the customer. Identifying customer needs and meeting their expectation is very significant aspect to achieve success in the present market scenario.

An essential component of human growth is health. Health systems are composed of various interrelated elements, such as individuals, institutions, and activities. They carry out a number of tasks, including providing healthcare services, preserving and enhancing health, shielding families from the financial burden of disease, facilitating revenue generation, and influencing social values and standards. An economical and accessible healthcare provider is crucial for providing quality care to the people. Every healthcare provider throughout the world is battling with increasing expenses and inconsistent quality. The healthcare sector is an integral part for sustainable growth of a nation. The healthcare sector is a patient-focused service sector [1]. Healthcare providers must prioritize both medical care and patients' satisfaction. Their goals include providing high-quality and safe healthcare services, boosting efficiency and competitiveness, meeting patient demand, and improving level of satisfaction. Improving service quality is a crucial management concern for healthcare providers. The increasing demand for healthcare services is a significant challenge for states. Healthcare services are in high demand, despite limited resources. There is an urgent need to look into and pinpoint the essential elements of healthcare services to provide users with high-quality care. One of the primary goals of healthcare quality improvement is to provide better care. It aims to make healthcare more patient-centered, decisive, affordable, and secure in addition to raising the

standard of care. The healthcare providers needs to pay attention to patient requirements and get opinions regarding their satisfaction in order to promote ongoing quality improvement [2].
We are all aware about the adverse effects of covid-19 in the last few years. In the present scenario, people are more conscious about health. The health care providers should ensure that people availing their facility are completely satisfied with the service quality once they visit the healthcare. Selecting an optimal healthcare institute for medical treatment is an intricate task as it is related to the physical health of an individual. The decision should be made collaboratively by patient and patients' party and healthcare provider to ensure the most appropriate treatment. Service quality is one of the leading criteria for optimal healthcare institute selection. There are several service quality assessment tool developed by various researchers for optimal selection of healthcare institution.
The purpose of healthcare institute selection is to assist people in selecting an appropriate healthcare provider by highlighting important aspects to take into account including the standard of care, cost, convenience, and wellness needs. It also highlights the significance of making sound choices to ensure the best possible access to healthcare institute. Healthcare decision-making is a challenging procedure and requires clear and effective methodologies for assuring uniformity and clarity of factors. An extensive variety of societal, ethical, financial, medical, and technological factors are essential for effective decision making.

II. Literature

II. 1. Bibliometric Review of Literature

A bibliometric study of previous literature is conducted between 2005 and 2024 using SCOPUS database. The search concentrated largely on applications of Analytical Hierarchy Process (AHP) and Quality Function Deployment (QFD). The search was restricted to articles in document type, journals in source type, English in language and final in publication stage. The total number of papers reviewed is 273.

Figure: 1- Ten leading nations for research in the field of AHP and QFD

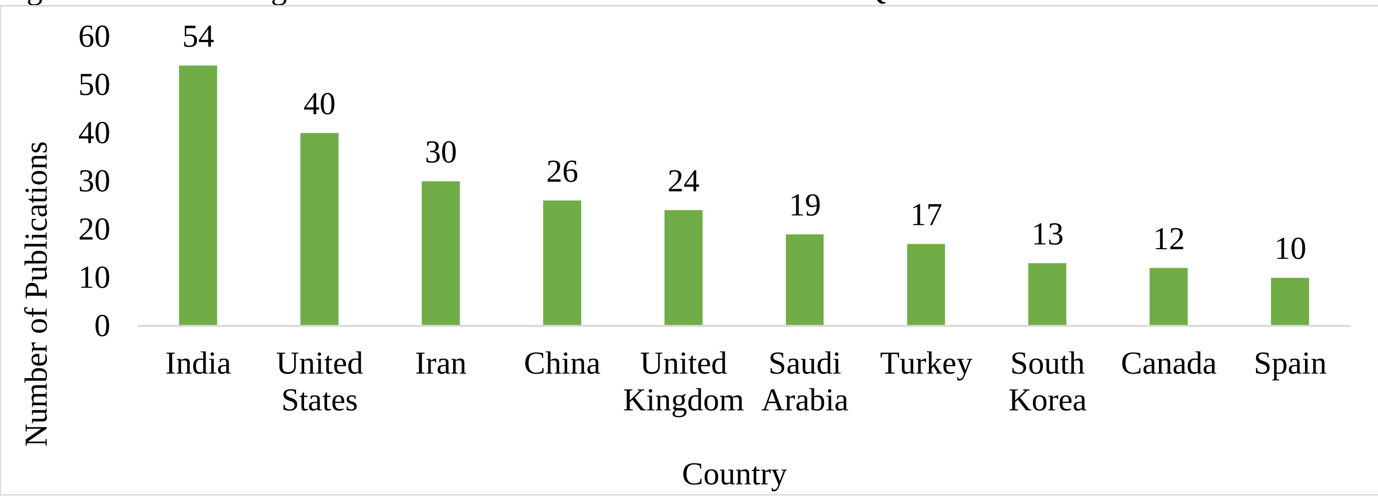

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Figure: 2- The trend of publications of AHP and QFD studies

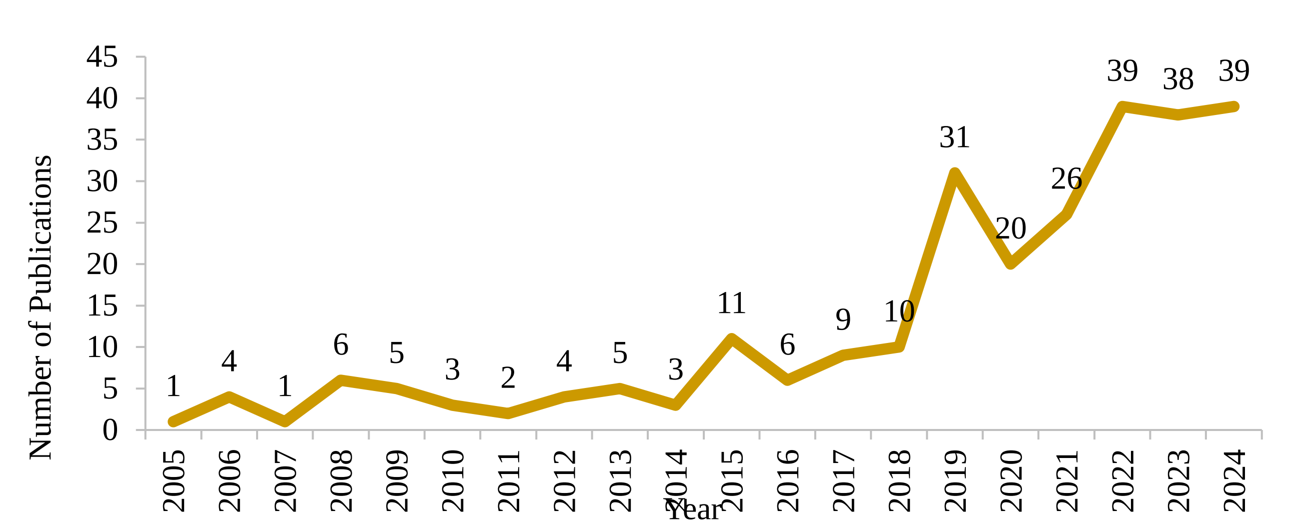


Figure: 3- Ten topmost authors in the field of AHP and QFD

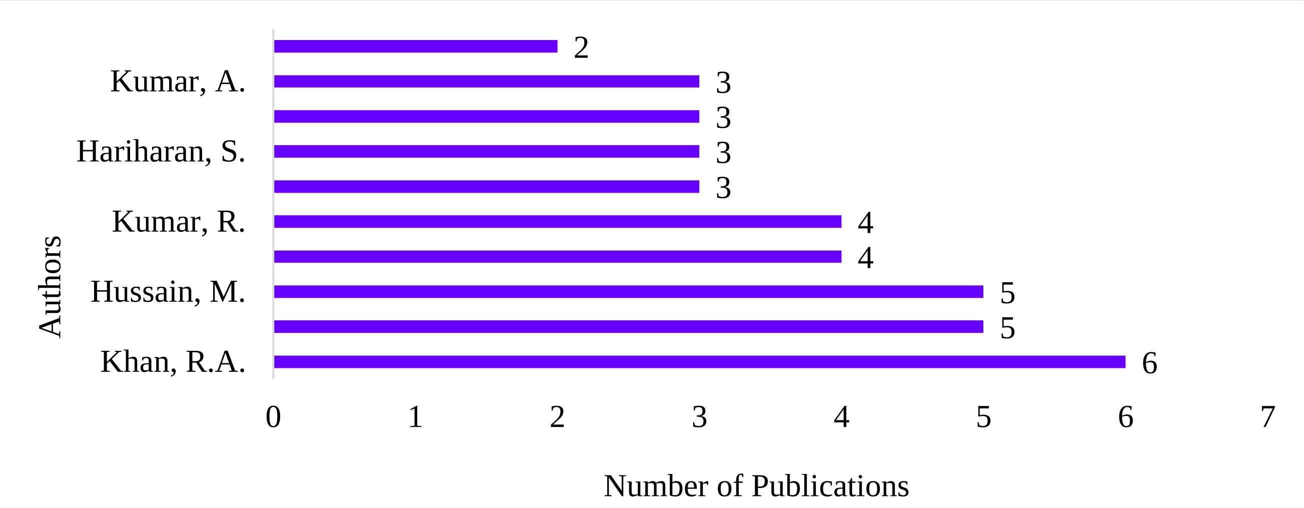
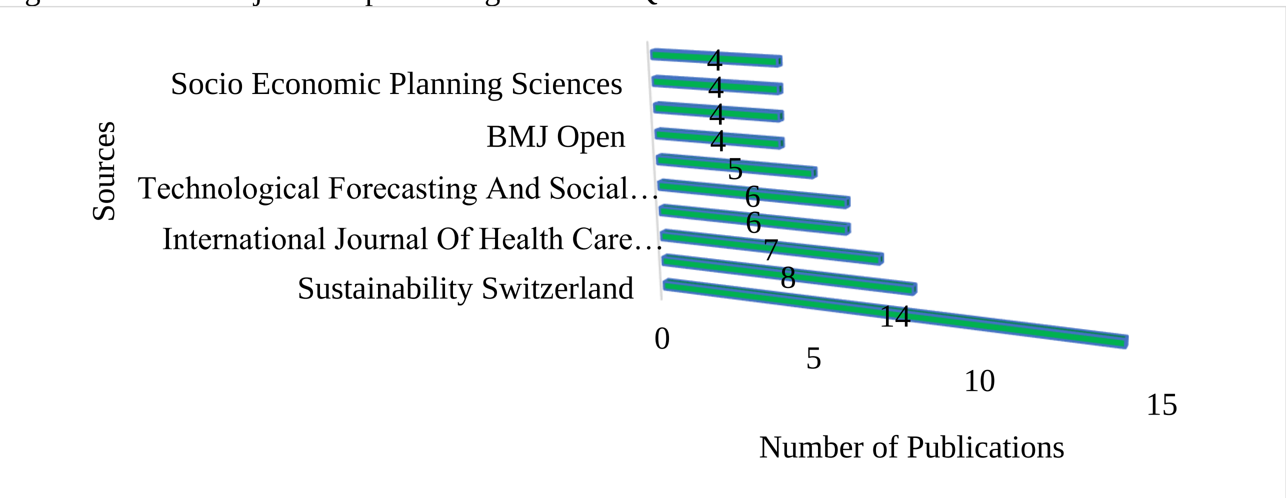


Figure: 4- Ten elite journals publishing AHP and QFD research



Co- occurrence analysis of author keywords

VOS viewer is used to for co- occurrence analysis of keywords that author have so far utilized in their research as illustrated in Figure 5. 1042 keywords were utilized in the articles pertaining to the studies on AHP and QFD. There were 271 links of 61 items grouped in 8 clusters of all keywords with a total link strength of 469.

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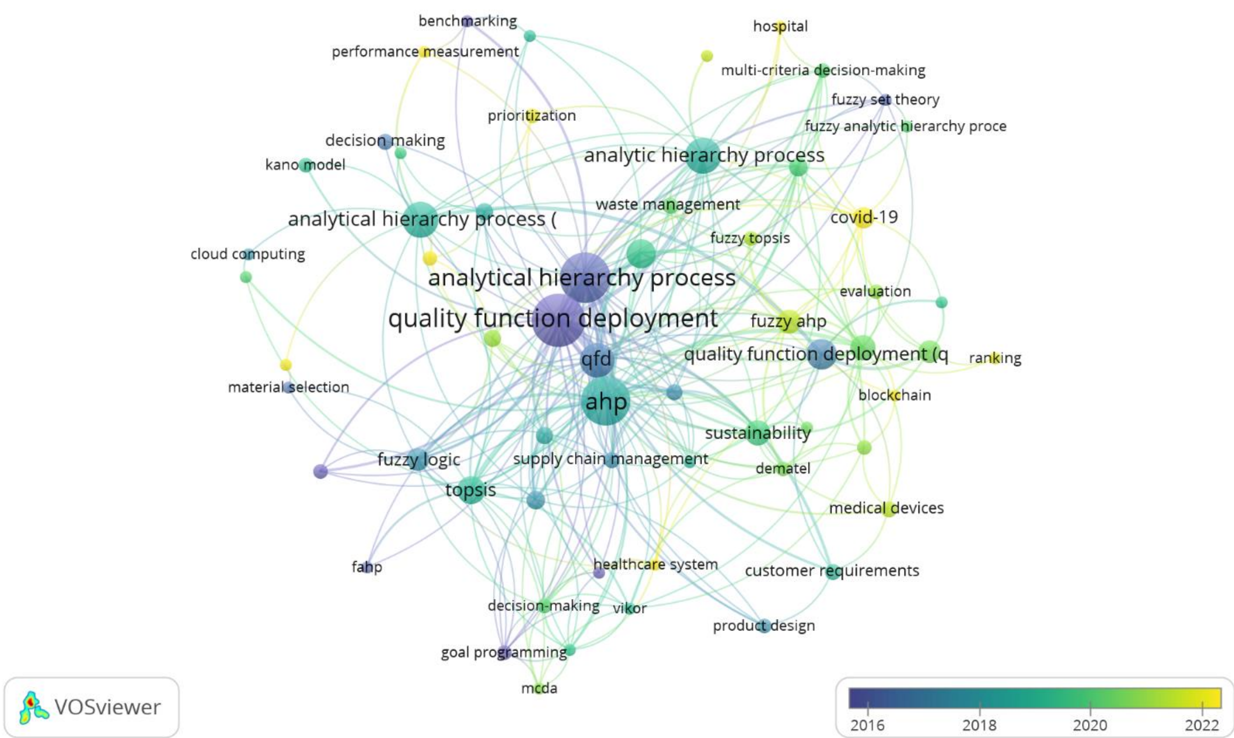
Figure: 5- Co- occurrence analysis of author keywords



II.2. Systematic Review of Literature

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a decision-making technique for ranking alternatives when several factors need to be taken into account. It was expounded and propounded by Thomas L. Saaty [3-6] AHP to deal with intricate, unorganised, and multi-criteria opinions [7-9]. The primary functions of the AHP are consistency validation, prioritisation assessment, and hierarchy design. AHP is broadly applied for decision making in agricultural, environmental, industrial and healthcare fields [7, 10]. The AHP approach was used for risk assessment in a sustainable supply chain [11]. Various researchers have addressed the methodology of the Analytical Hierarchy Process (AHP) in a wide range of medical decision-making and healthcare applications. AHP was initially used in health economics research [12, 13], healthcare decision support systems [14, 15] and healthcare project selection [16].

Quality Function Deployment (QFD)

Quality Function Deployment (QFD) is an effective and well known customer-focused design tool that aims to design customer-oriented services and products and achieve organisational goals, upgrade managerial abilities, and effectively fulfil the expectations of customers [17-19]. QFD originated in 1972, when Takayanagi Nishimura and his engineers submitted a quality chart for a shipyard in Kobe, Japan. It has diverse application in various fields. It has recently been used in process selection [20, 21], product design planning [22], shipping investment decision-making [23] and selection of ERP systems [24]. Quality Function Deployment has been rarely implemented in the field of healthcare [25-34], however research in this field is escalating [35-51]. Quality Function Deployment is adopted for continuous quality improvement of healthcare service delivery [37]. A personalised QFD is presented to design computer network service [38] and examining radiation safety management in healthcare [46]. A modified QFD by using the ANP theory and Kano's model is developed to enhance outpatient care for senior citizens in Taiwan [51].

AHP integrated with QFD

Analytical Hierarchy Process integrated with Quality Function Deployment are commonly used in product design decisions [52-59] and healthcare [60-79]. A combined AHP-QFD approach is employed to assess and elect multi-functional groups [80]. The facility location issue is addressed by utilizing the combined AHP–QFD technique [81]. In order to assess the degree of synergistic effects between the two consecutive HOQs (House of Quality) for the advantage of soccer sport, a combined AHP–QFD technique is implemented [82]. A hybrid AHP-QFD approach for designing of products is proposed [83]. A framework that incorporates ANP for the intrinsic reliance in the QFD method is presented [84].The integrated AHP–QFD strategy is used for assistance in robot selection [85]. A blended AHP-QFD approach is propounded to assess and choose a facility location for a firm that manufactures automated mass measurement devices for industrial service [86]. A hybrid AHP-QFD technique is suggested for selecting rapid hard tooling process [87]. AHP/ANP, QFD and TRIZ is integrated to create a customer-manufacturer-competitor (CMC) framework [88]. The framework examines manufacturers, customers and competitors perspective, as well as related concerns throughout the Product Life Cycle (PLC). The combined AHP, Kano, and QFD model was implemented to the central library facilities of Dokuz Eylul University (DEU) in Turkey to figure out the requirement of students and library patrons [89]. It is contended that prior studies employing ANP are limited and a broad network structure for ANP with five clusters which includes objective, desired quality, novel product design threat, quality features and adversaries is suggested [90]. A four-dimension House of Quality does a trio of translation in a multi-criteria decision making paradigm based on ANP [91]. Here, House of Quality facilitates a more seamless decision-making process. An AHP-QFD model is propounded for creating a tourism service that addresses travelers' requirements [92]. QFD in combination with AHP and artificial neural network is employed to identify the main components for a new product design and planning [93]. For optimal third-party logistics service provider selection in modern supply chain management, an integrated AHP-QFD strategy is devised [94]. An integrated method based on AHP and Genetic Algorithm for digital machines selection is suggested [95]. A trio cluster ANP system to estimate the initial significant weights for House of Quality is proposed [96]. The significance levels in the House of Quality is estimated by implementing ANP [97]. Other strategies, such goal programming, are also incorporated into the holistic approach for a specific objective. A combined AHP-QFD strategy to raise the standard of education at a university in Singapore is recommended [98]. The improved wheelchair design using an integrated QFD-FANP approach is evaluated [99]. A novel approach to improve medical haemodialysis systems by integrating QFD, FAHP and the Kano model is proposed [100]. A unified DEMATEL-AHP-QFD model for transforming customer requirements into attributes of products to grade design options is suggested by considering an illustration of a joint replacement surgery assistance technology for senior citizens [101]. The fuzzy Kano model is used to obtain the impact of each customer requirements on customer satisfaction. A multistage integrated fuzzy QFD-MADM structure for sustainable design of products is created by combining fuzzy set theory with the QFD, AHP, ANP and decision-making trial and evaluation laboratory (DEMATEL) and applied to meat processing sector in Philippines [102].

III. Research Gap and objectives of the study

It has been confirmed from the previous studies that the unified AHP-QFD technique is an effective instrument for quality accomplishment. There are rare studies on employing this technique in the field of health care. None of the prior cited articles address selection of healthcare institution from the viewpoint of patients and patients' party requirements and technical criteria. A novel approach must be adopted for selecting a healthcare institute that meets both technical criteria and patients' and patients party needs. The current study presents a novel approach to develop a blended model by integrating AHP and QFD to address healthcare selection issues. This study provides an innovative way to aid decision-making in healthcare sector under multiple criteria. It incorporates technical criteria with patients and patients' party requirements in healthcare institute (HI) without cumbersome computations. It offers a framework by examining technical criteria that may result in developing a system for selecting the optimal healthcare institute that is focused on the needs of the patients and patients' party. The present research determines the optimal healthcare institute by investigating and comprehending patients and patients' party requirements of the current service quality by healthcare institute (HI).

IV. Proposed Methodology

The following steps constitute the proposed approach for healthcare institute selection problem incorporating AHP and QFD

Step-1:- A QFD expert committee of decision makers is constituted.

Step-2:- The QFD expert team identifies patients and patients' party requirements and technical criteria of healthcare institute to construct the central relationship matrix or QFD matrix.

Step 3:- The significance level of patient and patients' party requirements is reckoned using AHP and the significance level of technical criteria for healthcare institute selection is calculated using equation-1.

$$w_y = \sum_{x=1}^{i} S_{xy}\, e_x \qquad (1)$$

where w_y is the significance level for the yth technical criteria (y= 1, 2 ….j); S_{xy} is the computed relationship in the central relationship matrix between the xth patient and patients party requirements and the yth technical criteria of healthcare institute; and e_x is the important weights of the xth patient and patients party requirements.

Step 4:- The significance level of technical criteria for healthcare institute is normalised using equation-2.

$$Nw_y = \frac{w_y}{\sum_{y=1}^{j} w_y} \times 100 \qquad (2)$$

Step 5:- A pairwise comparison matrix considering each technical criteria of healthcare institute is devised by applying scale of relative importance as shown in table –1 which was propounded by Thomas L. Saaty [3, 6].

Table: 1- Nine point scale of relative importance

Description	Scale of relative importance
Equally Significant	1
Moderately Significant	3
Essentially Significant	5
Very strongly Significant	7
Extremely Significant	9
Intermediate Significance	2,4,6,8

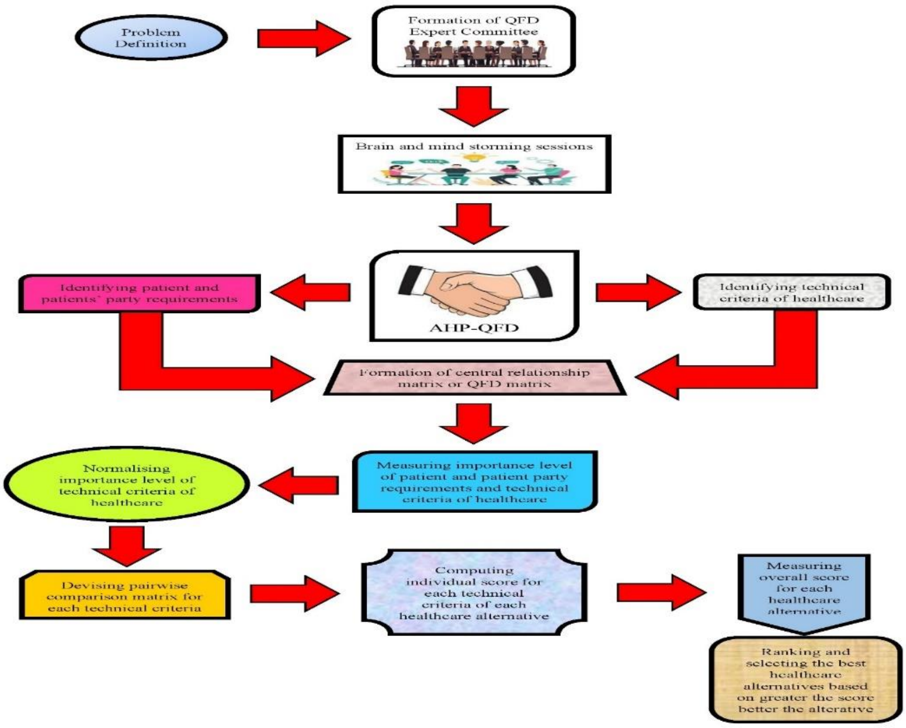
Step-6:- Individual score s_{xy} for each technical criteria for each healthcare alternative is computed and finally overall score is measured by using equation-3

$$OS_y = \sum_{y=1}^{j} Nw_y\, s_{xy} \qquad (3)$$

where, OS_y is the overall score for yth healthcare institute (y=1, 2…); Nw_y is the normalised significance level of yth technical criteria (y= 1, 2…j); and s_{xy} is the measure of priority vector of yth alternative on xth technical criteria.

Step-7:- The healthcare institutes are ranked based on the overall score by using the metaphor "the greater the score, the better the alternative" [81].

Figure: 6 - Flowchart of the proposed methodology



V. A case study

A case study is provided to demonstrate the effectiveness and convenience of the proposed method. Four healthcare institutes located in Kolkata has been selected with a goal to identify and rank the most robust healthcare institute based on patients and patients' party requirements and technical criteria of each healthcare institute. A QFD expert committee of decision makers consisting of three healthcare experts and two academic researchers were constituted where brain and mind storming sessions were held among the different experts to identify the patients and patients' party requirements and technical criteria of healthcare institute as illustrated in Table 2 and 3.

Table: 2- Patient and patients party requirements for healthcare institute selection

Sl no	**Patient and patients party requirements**
01	Accurate diagnosis (PPPR-1)
02	Quality of doctors, nurses and clinical staff (PPPR-2)
03	Patients safety(PPPR-3)
04	Less waiting time for treatment (PPPR-4)
05	Cost of treatment (PPPR-5)
06	Infrastructure (PPPR-6)
07	Hygiene and cleanliness(PPPR-7)

Table: 3- Technical criteria for healthcare institute selection

Sl no	**Technical criteria for healthcare institute selection**
01	Modern and updated medical equipment for diagnosis and treatment (TC-1)
02	Availability of beds for patients and waiting halls for visitors (TC-2)
03	Highly qualified, experienced and skilled doctors, nurses and clinical staffs(TC-3)
04	Sufficient security and CCTVs and availability of safety features like elevators, handrails and ramps (TC-4)
05	Health insurance which covers medical reimbursement(TC-5)
06	Adequate hygiene and cleanliness to prevent infections (TC-6)
07	Healthcare is capable to take appropriate care of their patients in a systematic way (TC-7)

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The following decision matrix is formulated based on patient and patients' party requirements

$$M=\begin{bmatrix} 1 & 7 & 3 & 5 & 4 & 9 & 7 \\ \frac{1}{7} & 1 & \frac{1}{5} & \frac{1}{2} & \frac{1}{2} & 4 & 2 \\ \frac{1}{3} & 5 & 1 & \frac{1}{2} & 3 & 6 & 5 \\ \frac{1}{5} & 2 & 2 & 1 & \frac{1}{3} & 5 & 2 \\ \frac{1}{4} & 2 & \frac{1}{3} & 3 & 1 & 4 & 3 \\ \frac{1}{9} & \frac{1}{4} & \frac{1}{6} & \frac{1}{5} & \frac{1}{4} & 1 & \frac{1}{5} \\ \frac{1}{7} & \frac{1}{2} & \frac{1}{5} & \frac{1}{2} & \frac{1}{3} & 5 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 7 & 3 & 5 & 4 & 9 & 7 \\ 0.143 & 1 & 0.200 & 0.500 & 0.500 & 4 & 2 \\ 0.333 & 5 & 1 & 0.500 & 3 & 6 & 5 \\ 0.200 & 2 & 2 & 1 & 0.333 & 5 & 2 \\ 0.250 & 2 & 0.333 & 3 & 1 & 4 & 3 \\ 0.111 & 0.250 & 0.167 & 0.200 & 0.250 & 1 & 0.200 \\ 0.143 & 0.500 & 0.200 & 0.500 & 0.333 & 5 & 1 \end{bmatrix}$$

The QFD expert team devised central relationship matrix or QFD matrix as illustrated in table-4

Table: 4- Central relationship matrix or QFD matrix for healthcare institute selection problem

		Technical criteria for Healthcare Institute selection(TC)							
		Modern and updated medical equipment for diagnosis and treatment	Availability of beds in wards and cabins for patients and waiting halls	Highly qualified, experienced and skilled doctors, nurses and clinical staffs	Sufficient security and CCTVs and availability of safety features like elevators, ramps etc	Health insurance which covers hospitalisation costs and medical reimbursement facility	Adequate hygiene and cleanliness to prevent infections	Healthcare is capable to take appropriate care of their patients in a systematic way	Importance weights of patient and patients party requirements
Patient and patients party requirements (PPPR)	1.Accurate diagnosis	■		■				▲	0.428
	2. Quality of doctors, nurses and clinical staff	▲		■				▲	0.066
	3. Patients safety	▲	■	▲	■	▲	■	■	0.185
	4. Less waiting time for treatment	■	●		●			●	0.115
	5. Cost of treatment	●	▲	●		■	▲		0.129
	6. Infrastructure	▲	■		▲		▲	▲	0.024
	7. Hygiene and cleanliness		■				■		0.053
	Significance level	6.391	3.118	5.500	1.900	2.086	2.907	4.37	
	Normalised significance level	24.33	11.87	20.94	7.23	7.94	11.06	16.63	

■ : Strong relation=9; ▲ : Moderate relation=5; ● : Weak relation= 1; Blank: No relation=0

The inconsistency level present in the information of patient and patients' party requirement matrix and each technical criteria of healthcare institute matrix is acceptable as inconsistency ratio is less than 10 percent for all parameters.

Table: 5- Ranking of healthcare institute based on technical criteria

TC	Weights	HI-1	HI-2	HI-3	HI-4	HI-5
01	24.33	0.555	0.093	0.186	0.101	0.065
02	11.87	0.523	0.090	0.131	0.211	0.045
03	20.94	0.306	0.404	0.061	0.146	0.083
04	7.23	0.066	0.053	0.265	0.118	0.498
05	7.94	0.438	0.167	0.166	0.063	0.166
06	11.06	0.088	0.263	0.398	0.192	0.059
07	16.63	0.092	0.091	0.199	0.530	0.088
Overall score		0.32577	0.17922	0.18303	0.20311	0.10888
Rank		**1**	**4**	**3**	**2**	**5**

From table 5, it is clear that HI-1 >HI-4 >HI-3 >HI-2 >HI-5. Since, healthcare HI1 has the maximum overall score, it is preferred.

Including cost factor elements

Healthcare institute selection should include the elements of cost factor to escalate the robustness of the present integrated AHP-QFD methodology. The elements of the cost factor are illustrated in Table 6 for five different healthcare institute.

Table: 6- Ranking of healthcare institute based on cost factor elements

Cost factor elements	HI-1	HI-2	HI-3	HI-4	HI-5
1. Cost of accommodation	3000	2500	2800	3200	3500
2. Cost of medical test and procedures	2630	2800	2470	2750	2500
3. Cost of surgeries	25000	27400	30000	22600	28100
4. Cost of medicines and bodily fluids	2440	2675	2860	2554	3000
5. Cost of ward girl/boy	1000	800	850	650	750
Total	34070	36175	38980	31754	37850
Selection Index (SI)	22.543	12.427	12.686	14.084	7.571
Rank	**1**	**4**	**3**	**2**	**5**

A mathematical framework was devised that combines cost-factor elements with priority values obtained from AHP [103-105]. The underlying equation of the stated framework is

$$SI_x = [(\alpha\ SFM_x) + (1-\alpha)\ OFM_x] \qquad (4)$$

where

$$OFM_x = \left[OFC_x \times \sum_{x=1}^{j} \frac{1}{OFC_x}\right]^{-1} \qquad (5)$$

where, *SI* = Selection Index, *SFM* = Subjective Factor Measure, *OFM* = Objective Factor Measure, *OFC* = Objective Factor Cost, α = Objective factor decision weight, and *j* = number of alternative. The *SFM* values are the overall scores found from table 2. *OFC*s are the total costs of each healthcare institute. The choice of α is a serious issue. The value of α relies on the decision-maker's opinion on priority regarding the importance subjective and objective factor measures.

Using equation (4) and assuming α= 0.69, the healthcare institutes are ranked as HI-1 >HI-4 >HI-3 >HI-2 >HI-5 which is similar to that found from table-5.

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Figure: 7- Sensitivity analysis

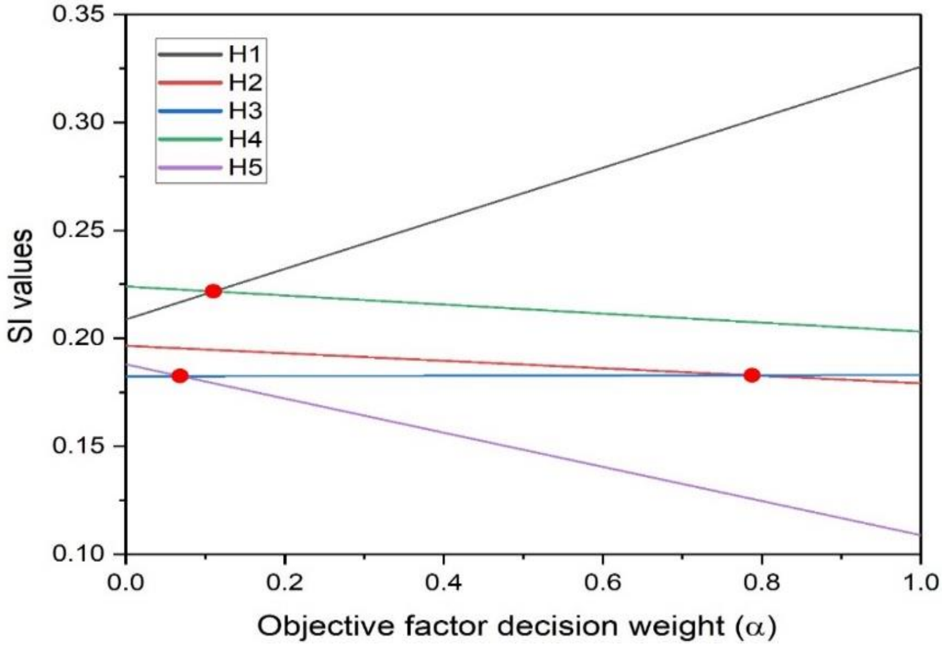

Table: 7- Results of sensitivity graph

Healthcare Institute	Correlation	Optimal range of α
HI-1	Between HI1 and HI4	$0.1106 \leq \alpha \leq 1.000$
HI-4	Between HI1 and HI4	$0.000 \leq \alpha \leq 0.1106$
HI-2	Between HI2 and HI3	$0.000 \leq \alpha \leq 0.7879$
HI-3	Between HI2 and HI3	$0.7879 \leq \alpha \leq 1.000$
HI-3	Between HI3 and HI5	$0.0685 \leq \alpha \leq 1.000$
HI-5	Between HI3 and HI5	$0.000 \leq \alpha \leq 0.0685$

The findings of sensitivity graph displayed in figure (7) are compiled in table 7 which signifies that the convenient value of α should be preferred conscientiously. The supremacy of α will be greater for SFM_x values and lower for cost factor elements.

VI. CONCLUSION

The increasing demand for high-quality healthcare services makes it more difficult to select the best healthcare institute for treatment. Analytical hierarchy process and quality function deployment has gained noteworthy success globally in a diverse range of service selection. This is due to its methodical coupling of customer needs. Appropriate selection of healthcare from patients and patients' party perspective is a serious and intricate task as it involves physical health of an individual. It calls for incredibly discrete decision-making and exhaustive assessment of the idea and approach on the alternatives for effective selection. The integrated AHP-QFD model proposes a robust methodology to develop a decision making process for healthcare selection by considering patients and patients' party requirements and technical criteria of healthcare. This paper aimed to demonstrate the efficiency of the proposed methodology. In this paper, the QFD approach is implemented to figure out the technical criteria. AHP is utilised to determine the importance of each technical criteria. AHP is also applied to find the importance of each healthcare institute based on the technical criteria. Including cost-factor elements in the proposed model justifies healthcare selection from an economic perspective.

The proposed approach can offer an impartial way to choose a healthcare institute that meets the overall patients and patients' party requirements. This approach is an effective solution to apply in a multi-criteria, unorganised and conflicting environment.

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