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Model Development Using Fuzzy Quality Function Deployment (FQFD) to Assess Student Requirement in Engineering Institutions: An Indian Prospective

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Abstract- Quality is a complex and multifaceted concept. It is being increasingly recognized that high quality of products and services and their associated customer satisfaction are the key elements for survival of any organization. It is the basis that differentiates between a mediocre and an excellent organization. This concept is equally important for an engineering education system. The present paper hybridizes QFD with fuzzy dominance order to assess the student requirements in engineering education system. It uses content analysis and nominal group technique (NGT) to identify requirements. Fuzzy dominance order has been used to establish democratic wisdom to identify customer requirements. Relation matrix used in traditional QFD has been replaced with aggregated fuzzy relation matrix to justify subjective responses. The results obtained by this approach and traditional QFD approach are compared using Interpretive Structural Model (ISM) for deployable elements of technical requirements as yardstick.

Index Terms: **Quality assurance, Fuzzy dominance, Fuzzy Quality Function Deployment (FQFD), Cost to Company (CTC). Interpretive Structural Model (ISM).**

I. INTRODUCTION

QFD was developed in Japan during the 60s by Akao and Mizuno as a method of product development, which aims at fulfilling customer demands. The primary objective of this method is to assure quality from the earlier stages of the project development. The QFD concept is broken down into the two main objectives: Product quality deployment and deployment of the quality function. Product quality deployment translates the "voice of the customer" in to the product control characteristics. Whereby, deployment on the quality function activities needed to assure that customer required quality is achieved. Deployment of the quality function examines the company's response to the customer voice through an organized team approach [1].

According to Cohen and Han [2, 3] there are six stages of hierarchical framework of QFD as in Table I.

Many attempts have been made in order to provide a mathematical background to QFD. The approaches based on probability theory require that sufficient data be collected [Denis Gien 9]. However, in real world situation where human preference and logic is involved the opinions often follow subjectivity thereby bringing element of fuzziness in the system. QFD methodology does address such fuzziness in its relationship between customer and technical requirements. It therefore, seems logical if fuzzy set approach is utilized in QFD technique in order to obtain a more realistic solution.

Table I Hierarchical Framework of QFD

Stage		
1	Voice of the customer	Developing categorizing and prioritizing customer requirements
2	Competitive Analysis	Comparing the performances with competitors and set target levels for customer requirements.
3	Voice of Organization	Translating the voice of the customer to the voice of organization.
4	Design Targets	Specifying targets value for design requirement and determining the project cost.
5	Relationship matrix	Evaluating impact of design requirements on customer requirements.
6	Correlation matrix	Specifying tradeoffs and selecting the appropriate design requirement.

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II. ENGINEERING EDUCATION SYSTEM

Engineering education world over is currently under tremendous strain as it is trying to cope up with the educational aspects of globalization of economy, rapid technological advances, emergence of totally new technologies, and continuing shortening of half life of engineers effectiveness. [7, 9]

Process improvement must begin and end with customer in any production system. This concept is equally important in case of engineering education system. One can identify many customers for the product i.e. student education in an educational system. They are the student themselves; for they must live with the product for the rest of their lives, their parents; for they, too much live with the product and they are the ones, who in general pay for it, future employers, who will have to pay to obtain the benefits of the student's education.

Customer satisfaction does not come about overnight or by accident in engineering education system. It requires careful planning and cautious execution. The process of satisfying customers or outperforming their expectations starts with effectively understanding their genuine needs.

A. Identifying Customer requirements through NGT

In order to identify customer requirement as part of their need in an engineering education system for quality deployment. Nominal Group Technique (NGT) has been utilized to obtain overall integrated descriptive customer requirements through a consensus – driven interactive-iterative process.

Three workshop sessions in two stages were organized to prepare the integrated list of customer requirements. It consisted of 15 domain experts derived from academia, student population, experts in administration of engineering education planning and finance including the authors. During the first stage lists of customer requirements were prepared from primary and secondary sources. These compiled lists were further clarified, merged, edited, coded and key worded. In all 10 elements have been considered. [Table-II

Table II Customer Requirement

S.No	Customer requirement	Code
1	Placement	C_1
2	Regular course update	C_2
3	Modernization of Lab	C_3
4	Competent faculty and supporting staff	C_4
5	Optimal Infrastructure	C_5
6	Health conscious canteen facility	C_6
7	Modernization of Library	C_7
8	Sufficient sports and cultural activities	C_8
9	Optimal fee structure	C_9
10	Transparent Evaluation system	C_{10}

B. Identifying Technical requirements through NGT

During this stage, identified customer requirements were translated into technical requirement. The objective is to translate each customer requirement into one or more technical requirements. Eight important technical requirements were identified to meet customer requirements with the help of the chosen set of domain experts. Table-III shows the list of technical requirements.

Table III Technical Requirements

S.No	Technical requirement	Code
1	Active Placement cell	T_1
2	Curriculum development cell	T_2
3	Allocation/ acquisition of funds	T_3
4	Administrative skills and Vision	T_4

5	Non democratic approach/student friendly	T_5
6	Implementability	T_6
7	Vision and mission	T_7
8	Competent and dedicated faculty and staff	T_8

The experts also agreed on the following explanation for the technical requirements to give a clear picture of the issue under consideration. This list of such explanation is given in table-IV.

Table IV Technical Requirements and Their Explanation

Technical Requirement	Explanation
Dynamic Placement Cell	An operating sub system of an engineering institution to place the admitted students to reputed organizations with an attractive CTC/ package/pay/remuneration and perks.
Curriculum conformance	A balanced and updated matching of industrial/ organizational requirements of knowledge.
Resource mobilization and distribution	A characteristic of acquiring needful financial and other resources through dynamic planning of resource generative programs and their implementation and utilizing the mobilized resources in an optimal and profitable way.
Administrative Skill	An operative characteristic of an engineering institution to drive the strategic, medium and short term planning for in time execution of the predetermined goals.
Honest democratic and cooperative approach	An approach of building good relationship between the industries, institutions and public through building rapport and repute of building knowledge, creativity and innovativeness in order to achieve excellence. This approach ensure healthy competitive, cooperative general and academic environment.
Implementability	An X-ability of an engineering institution of adapting the changes quickly and acting upon execution of planned work for total quality of education.
Vision and Mission	A descriptive statement of long term perspective to have a better plan and implementation for achieving them
Competent and dedicated faculty and Supporting Staff	A team of qualified, conversant personal dedicated and committed to the organizational vision and mission through self motivation, enthusiasm and cooperative attitude to have academic excellence to give complete satisfaction to student and other stake holders.

C. QFD: Traditional Approach

For an engineering institution it may not possible to satisfy all its customers' requirement. Therefore it is necessary to rank the customer requirements in order to enhance the satisfaction level of customer. For this purpose responses from 100 stakeholders (i.e.25 from each categories of customers namely students, employer parents and persons from society) were collected through a developed questionnaire on a five point scale of importance. Those requirements which bore maximum vote for a specific scale were assigned that value of importance/weightage. Table V shows the scale of importance to which the stakeholders responded.

Table V Importance Scale

1	Not important to the customer
2	Minor importance to the customer
3	Moderate importance to the customer
4	Very important to customer
5	Highest importance to the customer

Further a relationship between customer requirements and technical requirements have also been obtained which is given in table VI.

Table-VI Relationship Matrix between Customer and Technical Requirements

	Importance		T1	T2	T3	T4	T5	T6	T7	T8	Row Sum
C1	5		45	25	45	45	25	45	45	9	284
C2	4		36	36	4	36	20	36	36	25	199
C3	4		36	20	36	36	4	36	36	36	240
C4	5		45	45	25	45	45	25	45	45	365
C5	4		20	4	36	36	36	20	20	4	176
C6	3		3	0	15	27	15	27	15	3	105
C7	4		20	36	36	36	36	36	36	20	256

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C8	4		4	4	36	36	20	20	20	20	160
C9	5		5	0	5	25	5	45	45	5	135
C10	4		20	20	20	36	36	36	36	36	240
	Column Sum		**234**	**190**	**258**	**358**	**242**	**326**	**334**	**203**	**2160**

To identify tradeoff of technical requirements correlation coefficient has also been obtained, which is shown in table VII.

Table VII Correlation Coefficient for Technical Requirement

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
T_1	x	0.793	0.194	0.826	0.327	0.250	0.367	0.572
T_2		x	0.919	0.705	0.592	0.181	0.297	0.744
T_3			x	0.6003	0.603	0.180	0.145	0.744
T_4				x	0.612	0.029	0.330	0.550
T_5					x	.4114	0.172	0.353
T_6						x	0.315	0.0671
T_7							x	0.326
T_8								x

Finally very strong to moderate relationship between technical requirements were obtained as depicted in table VIII.

Table VIII Co-relationship between Technical Requirements

Relationship	**Technical Requirements**
Very strong (++)	T_3-T_8,T_1-T_2, T_1-T_4, T_2-T_4,T_2-T_8
Strong (+)	T_3-T_4,T_3-T_5,T_4-T_5
Moderate (--)	T_2-T_5,T_4-T_8,T_1-T_8

Govers [4] explained three categories that may develop conditions leading to failure of QFD. They may be methodological problem like risk of too much detail, organizational problem like lack of communication among cross functional processes and product policy like market information. Some of these problems may well be addressed provided subjective information is directly incorporated in QFD process. This will help respondents give a better communication strategy without losing focus on detail. Hybrid QFD approach has therefore been incorporated to overcome such difficulty.

III. HYBRID QUALITY FUNCTION DEPLOYMENT

In this method the weighted importance of customer requirement was obtained on the basis of fuzzy dominance. Five features namely quality, utility, aesthetics, performance and serviceability were selected with the help of domain experts. Stake holders were asked to compare all customer requirements on each feature in the form of linguistic variables like A-very good, B- good, C- average, D- below average and D- poor. 100 customers were asked to fill such questioner in the form of 5x10 position matrices. In all 100 such position matrices were obtained. A sample position matrix is given in table-IX.

Table IX Sample Position Matrix

Features	1	2	3	4	5	6	7	8	9	10
Quality	A	B	A	A	B	C	A	A	A	A
Utility	A	A	A	C	C	B	B	B	C	A
Aesthetics	C	C	C	C	A	A	A	B	B	A
Performance	A	A	A	A	A	A	B	B	A	A
Serviceability	A	A	A	C	A	A	A	A	C	B

Each matrix was then quantified. The membership values are shown in table-X. The quantified position matrices were aggregated as shown in table XI. Dominance order on all features for customer requirements is given in table-XII. The weights were assigned as per the decreasing dominance order. The requirement of dominance order of 1 bore a weight of 10

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Table X Fuzzy membership function

Very good	0.9
Good	0.7
Average	0.5
Below average	0.3
Poor	0.1

While a dominance order of 10 bore a weight of 1. These weights were further normalized with a scale 0-1. These normalized weights are given in table XII

Table XI Aggregated Position Matrix

Features	1	2	3	4	5	6	7	8	9	10
Quality	0.84	0.53	0.50	0.86	0.85	0.32	0.54	0.29	0.88	0.47
Utility	0.75	0.39	0.65	0.68	0.88	0.28	0.68	0.32	0.68	0.18
Aesthetics	0.67	0.20	0.48	0.28	0.68	0.32	0.48	0.18	0.18	0.24
Performance	0.86	0.56	0.88	0.88	0.86	0.48	0.28	0.22	0.32	0.48
Serviceability	0.74	0.59	0.74	0.85	0.84	0.28	0.72	0.28	0.28	0.52

Table -XII Dominance Orders of Customer Requirements

Dominance order	Customer requirement C Customer requirement	Weightage
I	Optimal Infrastructure	0.113
II	Placement	0.169
III	Competent faculty	0.132
IV	Modernization of lab	0.150
V	Regular course update	0.150
VI	Health conscious canteen	0.094
VII	Modernization of Library	0.075
VII	Optimal fees structure	0.037
IX	Transparent Evaluation System	0.018
X	Sufficient sports and cultural activities	0.056

Fuzzy relation matrix [Table XIII] between customer requirement and technical requirement was obtained in the form of linguistic variables, whose membership function is given in figure-1.

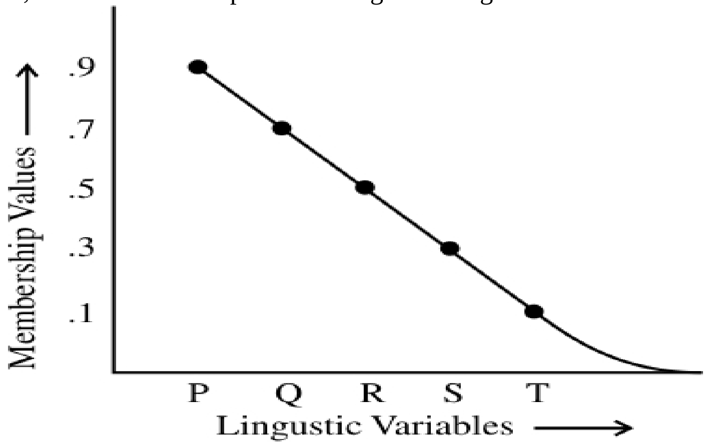

Fig. I Linguistic variables and their membership values

Table XIII Fuzzy relation matrix

	Importance	T1	T2	T3	T4	T5	T6	T7	T8
C1	0.169	P	R	P	P	R	P	P	T
C2	0.150	P	P	T	P	R	P	P	R
C3	0.150	P	R	P	P	T	P	P	P
C4	0.132	P	P	R	P	P	R	P	P
C5	0.113	R	T	P	P	P	R	R	T

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C6	0.094	T	0	R	P	R	P	R	T
C7	0.075	R	P	P	P	P	P	P	R
C8	0.056	T	T	P	P	R	R	R	R
C9	0.037	T	0	T	R	P	P	P	P
C10	0.018	R	R	R	P	P	P	P	P

These matrices were quantified and aggregated. The aggregated relation matrix is given in table-XIV. Each cell entry was multiplied with importance factor by scalar multiplication.

Table XIV Fuzzy aggregated relation matrix

	Importance	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	
C_1	0.169	0.133	0.104	0.139	0.132	0.088	0.148	0.127	0.044	0.148
C_2	0.150	0.123	0.117	0.033	0.132	0.072	0.129	0.132	0.081	0.132
C_3	0.150	0.117	0.078	0.126	0.117	0.027	0.126	0.129	0.129	0.129
C_4	0.132	0.108	0.11	0.063	0.110	0.108	0.063	0.110	0.111	0.110
C_5	0.113	0.058	0.020	0.094	0.097	0.094	0.058	0.058	0.020	0.097
C_6	0.094	0.016	0.015	0.048	0.082	0.048	0.082	0.045	0.022	0.082
C_7	0.075	0.036	0.056	0.058	0.061	0.063	0.064	0.061	0.039	0.064
C_8	0.056	0.014	0.010	0.045	0.029	0.030	0.029	0.026	0.030	0.045
C_9	0.037	0.006	0.055	0.006	0.031	0.031	0.030	0.032	0.031	0.031
C_{10}	0.018	0.011	0.0008	0.009	0.014	0.015	0.015	0.154	0.015	0.158
	AR	0.133	0.117	0.139	0.132	0.108	0.148	0.132	0.129	
	RR	III	VI	II	IV	VII	I	IV	V	

In order to find out the relative importance between technical and customer requirements maxima of each row entry and column entry was taken instead of row sum and column as in traditional QFD. Since each column of matrix represents a fuzzy vector therefore, fuzzy Euclidean distance between columns vector were obtained to find out closeness between two technical requirements given preferences of customer requirements.

Table XV Euclidean matrix for Technical Requirement

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
T_1	x	0.0994	0.217	0.899	0.903	0.124	0.0505	0.901
T_2		x	0.150	0.0821	0.746	0.213	0.542	0.0898
T_3			x	0.1356	0.876	0.862	0.216	0.0836
T_4				x	0.122	0.836	0.136	0.216
T_5					x	0.145	0.856	0.126
T_6						x	0.0643	0.248
T_7							x	0.1092
T_8								x

IV. THE ISM PROCESS

ISM provides a method for making the elements of a complex issue into an agreed diagrammatic structure. The structure may be obvious as in management organizations or may be less obvious as in the value structure of a decision maker. Concept elements are no exception to such vagueness. ISM has its roots in the systematic application of some elementary notions of graph theory, set theory, mathematical logic and matrix theory. Theoretical, conceptual and computational leverage is exploited to efficiently construct a directed graph of complex system under a specified contextual relationship among a set of elements of the system.

A. Structural Self Interaction Matrix (SSIM)

SSIM on the contextual relation affects have been developed for identified concept elements as in Table IV. Each element of the ranked list was compared with another and the group responses were symbolically put in the form of V, A, X, O according to the following rules. If Xi be the upper element and Xj be the lower element in SSIM then put V,If XiRXj and Xj does not relate Xi put A, If Xi is not related Xj and Xj related Xi put O, If Xi is not related Xj in either direction then put X. The final agreed SSIM for Technical Requirement is shown in figure-2.

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T_1	V	Λ	Λ	Λ	Λ	V	V	Λ	T_1
T_2	V	V	Λ	Λ	Λ	X	Λ	T_2	
T_3	V	V	V	Λ	Λ	V	T_3		
T_4	V	V	V	Λ	X	T_4			
T_5	X	V	V	Λ	T_5				
T_6	V	V	X	T_6					
T_7	V	Λ	T_7						
T_8	V	T_8							

Fig. II SSIM for rank ordered Technical Requirements

The SSIM has been converted into reachability matrix by replacing symbols into 1 and 0 in it's (I, j) th entry.

Table-XVI Reachability Matrix for Technical Requirements

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
X	0	1	1	0	0	1	1	1
1	X	0	0	0	0	0	0	1
0	1	X	1	0	0	1	1	1
0	0	0	X	1	0	1	1	1
1	1	1	1	X	1	1	1	1
1	1	1	1	1	X	1	1	1
0	1	0	0	1	1	X	1	1
0	1	0	1	0	0	0	X	1
0	0	0	0	0	0	0	0	X

Partitions on the reachability matrix were done, cycles identified and it was converted into canonical form, which was appended to give ISM. The ISM of technical requirement so obtained is given in figure 3.

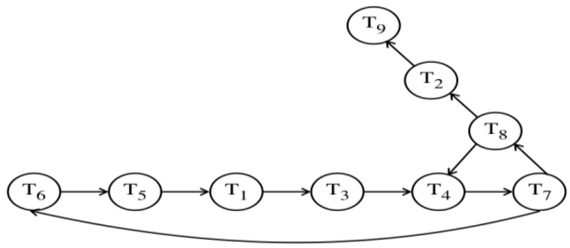

Fig. III ISM for Technical Requirements

V. CONCLUSION

It is evident from the ISM of technical requirements that requirements like T6 (Implementability), T5 (Non beaurocatic approach), T3 (Allocation/ acquisition of funds) T7 (Vision and mission) and T8 (Competent and dedicated faculty and staff) form strong cycles and are acting as grass root elements and therefore, they closely affect each other. All these technical requirements affect a single technical requirement T2 at its next hierarchical level, which in turn affects technical requirement T9 which is the top most element and stand as the basic objective. For any QFD it becomes imperative that the order of deployment must move from the grass root level of hierarchy to other higher levels. If the order of deployment of technical requirements from traditional QFD is compared with the proposed hybrid QFD it is found that the order of deployment in traditional QFD although goes from bottom level to the hierarchy yet the choice of order is not well ordered as depicted by the cycles in the bottom level elements of ISM. However, the order of deployment in case of hybrid OFD follows almost the same order as that obtained in the ISM. It clearly signifies that the decision obtained through hybrid QFD approach is more systematic and satisfying as far as the stakeholders are concerned. Hence this methodology seems to provide a better functional approach.

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Further, regarding the importance of weights obtained in case of traditional QFD for customers requirements, it is observed that it has more ties as compared to the proposed approach where it is none. It is because of the fact that in hybrid QFD customer requirements has been judged on the basis of selected features and gives overall dominant opinion of the stakeholders in terms of their linguistic perceptions. This gives better clarity in deciding the level of importance of customer requirements and hence assigning distinct weights

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