INTEGRATION OF BLITZ QUALITY FUNCTION DEPLOYMENT AND FUZZY ANALYTICAL HIERARCHY PROCESS IN PRODUCT DEVELOPMENT

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Abstract: The development of excellent products is the key of any organization's success, especially in a dynamic environment where technology changes rapidly making existing products obsolete. One of the techniques that helps in developing products that truly meet customer's requirements is Quality Function Deployment (QFD). However, the traditional QFD takes long time to be developed and hinder the organizations' ability to shorten the product development cycle. In this paper, the researchers proposed a detailed guideline with explained calculations to implement Blitz Quality Function Deployment, a faster and leaner model than the traditional one. Fuzzy logic has been integrated in order to solve the vagueness in Voice of Customer (VoC) and to provide more accurate results.

Keywords: Quality Function Deployment (QFD), Analytical Hierarchy Process (AHP), Fuzzy Logic, Product Development.

I. INTRODUCTION

Quality Function Deployment (QFD) is a technique which can be used to assure that a product is designed and manufactured to exceed customer expectations[1]. ISO 16355-1 defines QFD as managing of all organizational functions and activities to assure product quality[2]. QFD utilizes market research of customer requirements, engineering's technical description of that information and competitive analysis from both customer and technical viewpoints.

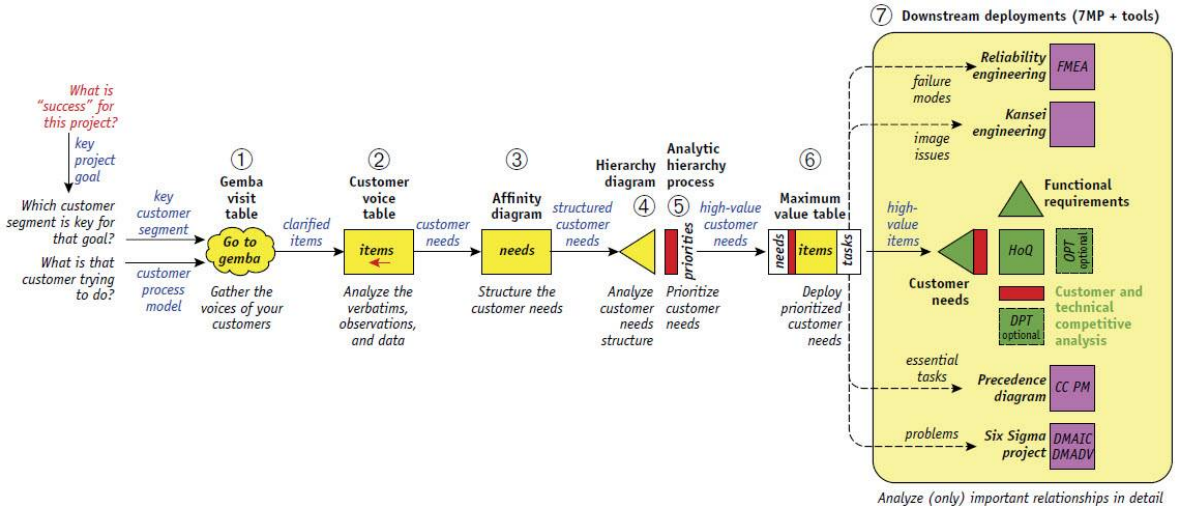


Figure 1 Blitz Quality Function Deployment Process

In traditional product development process, product concept developed by design team, tested, produced and marketed, then redesigned until customer needs are accommodated, which leads to a great waste of effort and time[3]. On the other hand, QFD initiates the process by identifying customer needs or Voice of Customers (VoC) and transfers these needs through all following stages, resulting in a product that achieves customers' requirements better and make them more satisfied[4]. Some of the advantages of QFD that have been reported aredecreasing the required number of engineering modifications, decreasing the required time to develop the product, declining start-up costs, and boosting customer satisfaction[5][1].

On the other hand, there are some difficulties in applying QFD; the most reported are it requires a lengthy time to develop a QFD chart entirely andit depends on VoC which contains vague expressions that make itchallenging to figure out the relation between customer requirements and technical characteristics [5][6]. The Blitz QFD approach developed by Richard Zultner in the mid-1990 to develop a faster approach to QFD for time-to-market sensitive project[7]. Blitz QFD offers improvements over traditional QFD as it speeds the analysis and makes it more efficient by prioritizing the most critical customers' needs [8].Fifure 1 shows the process flow of Blitz QFD[8].

In 1965, Prof. Zadeh introduced Fuzzy logic as a mathematical techniqueto deal with uncertainty[9]. To achieve that, fuzzy logic implements an inference structure that can help to interpret the potential of human reasoning. On the contrary, the traditional binary set theory describes crisp events, events that either do or do not occur. The fuzzy logic theory isbuilton the relative graded membership concept and the functions of cognitive process.

If set X={x}, a fuzzy set F on x consists of two parts, a value and membership degree $MFF = \{\{x, MF(x) | x \in X, MF(x) \in [0,1]\}$

Therefore, a classic set is a fuzzy set with all the degrees of membership equal to 1[10].

Abdolshah et al. argued that using crisp numbers regarding the application of lingual variables leads to lose information[11]. While Liu et al.have reported that the fuzzy set theory provides a sound theoretical basis for ranking VoC in QFD[12].

II. METHODLOGY

2.1. Project Definition

The first critical difference between Blitz QFD and Traditional QFD is that the Blitz process must start with Project Definition in order to assure end to end quality[8]. The Project Definition should cover the following: 1) Basic Information about the company and the product to be developed 2) Clear and understood Strategic Targets 3) Company points of strength 4) Customer Segments[13]. Some of the tools that help with prioritizing the targets are Balanced Scorecard and Analytical Hierarchy Process (AHP)[2]. The researchers will use the AHP technique which was developed by Saaty[14] for supporting decisions and ranking the available options by comparing each two of them together. The steps to implement this technique are indicated in Draw a matrix and fill the first row and the first column with agreed targets. Compare each target in each row to the corresponding targets in each column by using the values from 0.11: Very much less important to 9: Very much more important, while 1: the row is equally important as the column.Then, calculate the summation of each column, and normalize the assessment by dividing each cell by the sum of its column.Finally, calculate the absolute weight by calculating the summation of each row of the normalized assessment, and calculate priority by dividing the absolute weight by no of targets.

2.2. Customer Analysis

Analysis of customer request is the fundamental step of both Blitz and Traditional QFD. Vinayak and

			Strategic Targets								Absolute weight	Priority
			A	B	C	D	A	b	c	d		
			Target 1	Target 2	Target 3	Target 4	Normalized assessment					
Strategic Targets	1	Target 1	1	3	3	9	0.56	0.5	0.58	0.45	2.09	52.25%
	2	Target 2	0.33	1	1	5	0.19	0.17	0.19	0.25	0.8	20%
	3	Target 3	0.33	1	1	5	0.19	0.17	0.19	0.25	0.8	20%
	4	Target 4	0.11	1	.2	1	0.06	0.17	0.04	0.05	0.32	8%
∑			1.77	6	5.2	20	1	1	1	1	4	100%

Table 1. AHP strategic targets matrix

Kodali[15] reported that identifying customer requirements have the maximum attention from researchers when implanting QFD. In order to gain VoC, different tools could be used. Typically, these tools can be grouped into two divisions; qualitative tools and quantitative tools[16]. According to Blitz generic model, Gemba Visits is used as a qualitative tool. Gemba visits is the first step of obtaining the VoC in Blitz QFD [8]. The process to implement gemba visits can divided into 3 sections; before, during and after the visits[13]. Before making the visits, a specific category of customers has to be identified. This can be done by following the results gained from customer segmentation step discussed earlier. Hauser and Griffin[17] reported that conducting 25-30 visits are enough to capture customer requests. However, Maritan[13] argued that 10-15 visits are sufficient to obtain huge information. During the visits, the interviewer should start with explaining the purpose of the visit and how important it is for improving customer satisfaction. Then typically the interviewer asks open questions to capture specific information. It is very recommended that the interview is recorded with a digital camera in order to capture customer's facial expressions. The 3rd and last step is to summarize the notes gained from the visits. 5W1H model can be used to represent that[13]. Jiro Kawakita (KJ) method is a powerful tool that can work as a bridge between the data gained in 5W1H table and the required closed questions to asked in a questionnaire[18]. Its objective is to re-write the sentences collected during the visits into specific requirements. The steps to conduct this method are 1) Introduction and explaining the objective 2) Distribution of sticky notes where each participant individually writes only

one sentence on each card to describe a demand quality 3) Collection and revision of sticky notes by the whole team 4) Grouping sticky notes into categories of up to three level as shown in Figure 2.

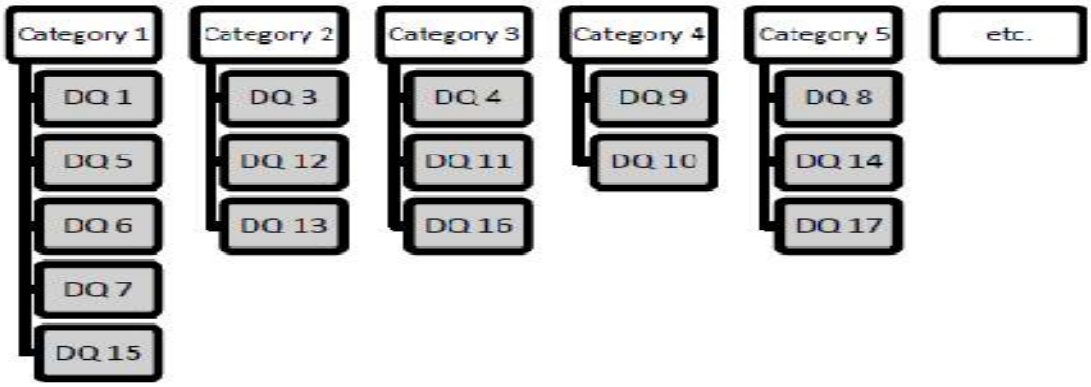


Figure 2 Affinity diagram, the result of JK method

Using the 1st level of the affinity diagram, the questionnaire can be divided into two parts. First asking about the importance of these characteristics. Second asking for rating how each company satisfy these characteristics as shown in Figure-3

Help Us Developing the Best Product for You Please take 5 minutes to complete this questionnaire!															
How much important these characteristics to you? (1 = not important at all : 5 = extremely important)															
W_1	1	2	3	4	5										
W_2	1	2	3	4	5										
W_3	1	2	3	4	5										
W_4	1	2	3	4	5										
W_5	1	2	3	4	5										
W_n	1	2	3	4	5										
How do these companies satisfy the previous characteristics? (1 = very bad : 5 = very good)															
Company	C1					C2					C3				
W_1	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W_2	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W_3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W_4	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W_5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W_n	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Thank you for completing the questionnaire!															

Figure-3 Questionnaire Form

All the answers from questionnaires have to be summarized in order to easily preform the required analysis on them as shown in

Question / Customer	W_1	W_2	W_3	W_n
1	4	5	1	
2	4	5	3	
3	5	3	4	
4	4	2	3	
5	5	2	4	
n				

Question / Customer	W_1			W_2			W_3			W_n
Company	Us	C1	C2	Us	C1	C2	Us	C1	C2	
1	3	2	5	5	2	3	5	5	3	
2	3	2	4	4	2	3	4	4	3	
3	2	1	5	5	1	2	5	5	2	
4	4	2	3	3	2	4	3	3	4	
5	2	3	5	4	3	2	5	5	2	
n										

Table 2 Summarizing questionnaire data

Starting from this step, the fuzzy logic will be used instead of classical logic. In this step, every answer value from questionnaire will be assigned to a fuzzy value. The reason for doing that is that it is not reasonable to use a precise and definite number to represent subjective assessment, a better way is to use fuzzy numbers which can capture the vagueness[19]. The assigned triangular fuzzy number (TFN) for each crisp value are indicated in

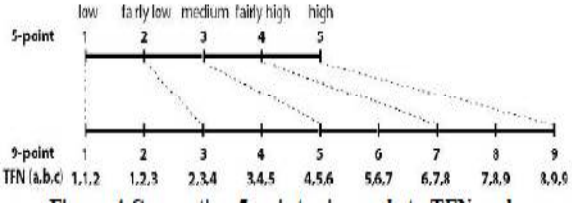


Figure 4 Converting 5-point crisp scale to TFN scale

Table-2will be converted to the new TFN as in Table 3,, then the average will be calculated.

Question / Customer	W_1	W_2	W_3	W_n
1	4 (6, 7, 8)	5 (8, 9, 9)	1 (1, 1, 2)	
2	4 (6, 7, 8)	5 (8, 9, 9)	3 (4, 5, 6)	
3	5 (8, 9, 9)	3 (4, 5, 6)	4 (6, 7, 8)	
4	4 (6, 7, 8)	2 (2, 3, 4)	3 (4, 5, 6)	
5	5 (8, 9, 9)	2 (2, 3, 4)	4 (6, 7, 8)	
AVG	4.4 (6.8, 7.8, 8.4)	3.4 (4.8, 5.8, 6.4)	3 (4.2, 5, 6)	

Question / Customer	W_1			W_2			W_3			W_n
	Us	C1	C2	Us	C1	C2	Us	C1	C2	
1	3 (4, 5, 6)	2 (2, 3, 4)	5 (8, 9, 9)	5 (8, 9, 9)	2 (2, 3, 4)	3 (4, 5, 6)	5 (8, 9, 9)	5 (8, 9, 9)	3 (4, 5, 6)	
2	3 (4, 5, 6)	2 (2, 3, 4)	4 (6, 7, 8)	4 (6, 7, 8)	2 (2, 3, 4)	3 (4, 5, 6)	4 (6, 7, 8)	4 (6, 7, 8)	3 (4, 5, 6)	
3	2 (2, 3, 4)	1 (1, 1, 2)	5 (8, 9, 9)	5 (8, 9, 9)	1 (1, 1, 2)	2 (2, 3, 4)	5 (8, 9, 9)	5 (8, 9, 9)	2 (2, 3, 4)	
4	4 (6, 7, 8)	2 (2, 3, 4)	3 (4, 5, 6)	3 (4, 5, 6)	2 (2, 3, 4)	4 (6, 7, 8)	3 (4, 5, 6)	3 (4, 5, 6)	4 (6, 7, 8)	
5	2 (2, 3, 4)	3 (4, 5, 6)	5 (8, 9, 9)	4 (6, 7, 8)	3 (4, 5, 6)	2 (2, 3, 4)	5 (8, 9, 9)	5 (8, 9, 9)	2 (2, 3, 4)	
AVG	**2.8 (3.6, 4.6, 5.6)**	**2 (2.2, 3, 4)**	**4.4 (6.8, 7.8, 8.2)**	**4.2 (6.4, 7.4, 8)**	**2 (2.2, 3, 4)**	**2.8 (3.6, 4.6, 5.6)**	**4.4 (6.8, 7.8, 8.2)**	**4.4 (6.8, 7.8, 8.2)**	**2.8 (3.6, 4.6, 5.6)**	

Table 3Questionnaire Analysis using both Crisp and TFN

2.3 Preplan Matrix

The average of importance and the average of benchmarking gained from the previous step will be inserted into the Preplan matrix in order to prioritize customer requests [20]. The following steps describe calculations for filling the preplan matrix inTable[13].

1. Insert Customer Requirement (What) and the TFNs of Importance and Benchmarking as obtained from the previous step.

2. Calculate Quality Target (by making b_{target} = the maximum number in all benchmarking)

$$b_{target} = 8.2$$

$$a_{target} = b_{target} - 1$$

$$c_{target} = b_{target} + 1$$

3. Calculate Rate of Improvement (where Rate of Improvement = Target/Our Score)according to mathematics of fuzzy logic [10]

$$a_{improve} = \frac{a_{target}}{C_{us}}$$

$$b_{improve} = \frac{b_{target}}{b_{us}}$$

$$c_{improve} = \frac{c_{target}}{a_{us}}$$

4. Determine Sales Point: (Strong, Medium or Weak)

5. Calculate Absolute Weight (by multiplying Importance * Rate of Improvement * Sales Point)

6. Calculate Priority (by dividing each Absolute Weight number over the maximum number in all Absolute Weight numbers)

What	Importance	Benchmarking			Plan			Weight	
		Us	Comp 1	Comp 2	Target	Rate of improvement	Sales points	Absolute	Priority
W_1	6.8, 7.8, 8.4	3.6, 4.6, 5.6	2.2, 3, 4	6.8, 7.8, 8.2	7.2, 8.2, 9.2	1.3, 1.8, 2.6	1, 1, 1	8.8, 14, 21.8	0.4, 0.6, 1
W_2	4.8, 5.8, 6.4	6.4, 7.4, 8	2.2, 3, 4	3.6, 4.6, 5.6	7, 8, 9	0.9, 1.1, 1.4	1, 1, 1	4.3, 6.4, 9	0.2, 0.3, 0.4
W_3	4.2, 5, 6	6.8, 7.8, 8.2	6.8, 7.8, 8.2	3.6, 4.6, 5.6	7.2, 8.2, 9.2	0.9, 1.1, 1.4	1.25, 1.5, 1.5	4.7, 8.3, 12.6	0.2, 0.4, 0.6
W_4									
W_5 W_n									

Table4 Preplan Matrix

2.4 HoQ

HoQ is the central element of both Blitz and Traditional QFD [6]. Its objective is to correlate customer requirements to engineering characteristics (ECs) and prioritize those ECs depending on the importance of CRs. That can be done by the following steps[13].

1. Insert Customer requirements (What) and the TFNs of Customer Requirement Priority as shown in
2. Fill 1st row with Technical Requirement which are determined by Development Team by using Jiro Kawakita method.
3. Correlate each Technical Requirement with each Customer Requirement (What) by using the following values: -

Strong correlation = (4, 9, 9)
Medium correlation = (1, 3, 5)
Weak correlation = (0, 1, 2)

4. Calculate Technical Requirement Weight (by ∑ each Customer Requirement Weight * Correlation)

- $For\ D_1: a_{absolute} = \sum a_{weight} * a_{corelate} = (0.4 * 4) + (0.2 * 0) = 1.6$
- $For\ D_1: b_{absolute} = \sum b_{weight} * b_{corelate} = (0.6 * 9) + (0.3 * 1) = 5.7$
- $For\ D_1: c_{absolute} = \sum c_{weight} * c_{corelate} = (1 * 9) + (0.4 * 2) = 9.8$

5. Calculate Priority (by dividing each number of AbsoluteWeight over the maximum number in all AbsoluteWeight numbers)
6. Calculate the Crisp Value of Priority (i.e. Defuzzifying the TFNs) by using the Center of Gravity method[21]
   - $Crisp\ Value = b_{priority}$
7. Fill Technical Benchmarking data
8. Determine the Technical Targets (where Technical Targets ≥ best competitors' values)
9. Determine Difficulty by using the values from 1: Very easy to 5: Very difficult

What	Weight	Technical requirements							
		Category 1			Category 2		Category 3		
		D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_n
W_1	0.4, 0.6, 1	4, 9, 9	4, 9, 9	1, 3, 5			0, 1, 2		
W_2	0.2, 0.3, 0.4	0, 1, 2		4, 9, 9			0, 1, 2	0, 1, 2	
W_3	0.2, 0.4, 0.6				4, 9, 9	4, 9, 9			
W_4									
W_5									
W_n									
Technical benchmarking: Unit of measurement		KM/H	Meter	KG	No. of color	Hour	Year	No. of centers	
Technical benchmarking: Us		60	4	500	3	120	2	1	
Technical benchmarking: Comp 1		70	5	400	5	200	2	4	
Technical benchmarking: Comp 2		65	5	420	5	80	1.5	2	
Technical benchmarking: Technical Targets		72	3	600	6	300	2.5	5	
Technical benchmarking: Difficulty		3	3	5	1	3	3	5	
Absolute Weight		1.6, 5.7, 9.8	1.6, 5.4, 9	1.2, 4.5, 8.6	0.8, 3.6, 5.4	0.8, 3.6, 5.4	0, 0.9, 2.8	0, 0.3, 0.8	
Priority		0.2, 0.6, 1	0.2, 0.6, 0.9	0.1, 0.5, 0.9	0.1, 0.4, 0.6	0.1, 0.4, 0.6	0, 0.1, 0.3	0, 0, 0.1	
Crisp Value		0.6	0.6	0.5	0.4	0.4	0.1	0	

Table 5 HoQ Matrix

2.5 Bottleneck Analysis

The trade-off between how important a technical requirement is and how difficult to implement can be presented in a chart where the priority of the technical requirement on the x-axis and the difficulty on the y-axis as shown in Figure 5

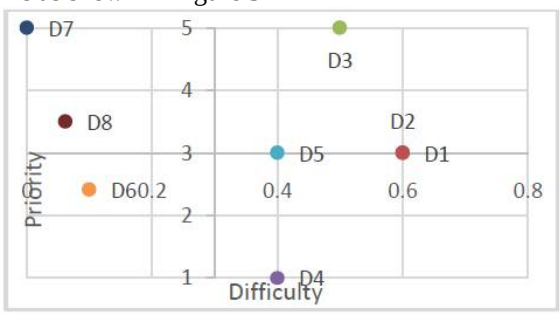


Figure 5 Bottleneck Analysis

The right-bottom section is the one to be concentrated on first as it includes easy-high priority requirements.

CONCLUSIONS

In this study, the researchers implemented the Biltz QFD and demonstrated the differences between it and the traditional one. Blitz QFD aims to tackle the drawbacks of Traditional QFD by implementing the lean thinking through the model, first by clearly identifying the objectivesof the project, then by prioritizing the most critical VoC using some techniques like AHP, which leads to increasing the speed of analysis and therefore shorten the production development cycle to meet the rapid release of products in these days. The integrations of Fuzzy Logic through the model was used to reduce the ambiguity of VoC, and thus developing a product that meet the customers' requirements better. The researchers used more simple methods to convert between fuzzy numbers and crisp numbers in order to provide a non-complex model which can be done by any small company. However, the researchers suggest testing other techniques and comparing between them in order to choose the most suitable one for the specified application.

REFERENCES

[1] C. D. Gevirtz, Developing New Products with TQM, McGraw-Hill, 1993.
[2] ISO 16355-1 General principles and perspectives of Quality Function Deployment (QFD), ISO, 2015.
[3] J. R. Evans and W. M. Lindsay, The Management and Control of Quality, South-Western College Pub, 1999.

[4] Yoji and G. H. Mazur, "The leading edge in QFD: past, present and future," International Journal of Quality & Reliability Management, vol. 20, no. 1, pp. 20-35, 2003.
[5] E. S. Jaiswal, "A Case Study on Quality Function Deployment (QFD)," IOSR Journal of Mechanical and Civil Engineering, vol. 3, no. 6, pp. 227-35, 2012.
[6] M. Xie, K.-C. Tan and T. N. Goh, Advanced QFD Applications, ASQ Quality Press, 2003.
[7] E. R. Zultner, "Project QFD Managing Software Development Projects," Transactions of the 9th symposium on QFD, 1997.
[8] G. H. Mazur, "Blitz QFD - the lean approach to product development," in ASQ World Conference on Quality and Improvement, Anaheim CA, 2012.
[9] L. A. Zadeh, "Fuzzy Logic = Computing with Words," IEEE transactions on fuzzy systems, vol. 4, no. 2, pp. 103-111, 1996.
[10] B. Bede, Mathematics of Fuzzy Sets and Fuzzy Logic, Springer, 2013.
[11] M. Abdolshah and M. Mohsen, "Fuzzy quality function deployment: an analytical literature review," Journal of Industrial Engineering, vol. 2013, 2013.
[12] J. Lie, Y. Chen, J. Zhou and X. Yi, "An Exact Expected Value-Based Method to Prioritize Engineering Characteristics in Fuzzy Quality Function Deployment," International Journal of Fuzzy Systems, vol. 18, no. 4, pp. 630-646, 2016.
[13] D. Maritan, Practical Manual of Quality Function Deployment, Springer, 2015.
[14] T. L. Saaty, "The Analytical Hierarch Process," European Journal of Operational Research, no. 48, pp. 9-26, 1990.
[15] K. Vinayak and R. Kodali, "Benchmarking the quality function deployment models," Benchmarking: An International Journal, vol. 20, no. 6, p. 825 854, 2013.
[16] T. Proctor, Essentials of Marketing Research, Prentice Hall, 2005. Griffin and J. R. Hauser, "The Voice of the Customer," Marketing science, vol. 12, no. 1, pp. 1-27, 1993.
[17] J. Kawakita, "The use of a holystic presentation of “Key Problem Approach” in a technical cooperation project for a Himalayan Hill Area," MAB/CONF-81/5/6 UNESCO-ICSU Conference-Exhibit: Ecology in Practice, pp. 22-29, Sept. 1981.
[18] L.-K. Chan and M.-L. Wu, "A systematic approach to quality function deployment with a full illustrative example," Omega, vol. 33, no. 2, pp. 119-139, 2005.
[19] Y. Akao, "Quality Function Depolyment (QFD) integrating customer requirements into product design," in Productivity Press, Portland, 1990.
[20] S.-J. Chen and C.-L. Hwang, Fuzzy Multiple Attribute Decision Making, Methods and Applications, Springer-Verlag, 1992.

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