http://dx.doi.org/10.21172/ijiet.261.02

Application of Quality Function Deployment for the Design and Development of a Novel High Effective Charcoal Stove

Kritsda Khajarern
Department of Food Technology and Innovation,
Faculty of Interdisciplinary studies, Khon Kaen University, Nong Khai Campus,
Nong Khai 43000 Thailand

Abstract- Quality function deployment technique (QFD) was applied for designing and developing a new high effective Thai charcoal stove with 7 steps of house of quality (HOQ) construction. The first step, voices of customer were elicited using focus group discussion (N=3, n=8) caused to 19 voices as the items for questionnaire construction. The second, the important degree of each item were rated using consumer panels (N=100). The result showed first three of customers' voices (Charcoal saving, durability and performance of thermal insulator) which had high important degree. The third was comparison between the traditional charcoal stove (TCS) and the original high effective charcoal stove (OHECS) for the degree of customer satisfaction (N=100) in each voice. The result showed higher level of all voices for OHECS than TCS. The fourth, 18 OHECS's technical terms were investigated using documental study and their specific value were fixed. The fifth, technical experts (N=3) were invited to fix the correlation signs (+, -) among these technical terms. The sixth, the correlations between customers' voices and technical terms were rated. The result showed that charcoal saving and durability related to thickness increasing of stove and its rack include highness decreasing of stove. Finally, the important degree of all technical terms was fixed by considering the important degree of voice of customer and then the specifications of these technical terms were indicated to use for high effective stove design and development. Thus, a new high effective stove had to increase a thickness of stove from 6.5 cm to 7 cm, increase a thickness of rack from 4 cm to 4.5 cm and decrease a highness of stove from 25 cm to 22 cm.

Keywords – QFD, HOQ, TCS, OHECS

I. INTRODUCTION

Charcoal stove is a traditional cooking brazier which most Thai household in countryside areas [1] frequently used it for their cooking food as long as the period [2]. Charcoal is an energy from wood [3] which was used as the cooking fuel source due to because it is more affordable than cooking gas [4], and is also available in the areas. In recent year, cost of wood is higher, the traditional charcoal stove (TCS) is improved and developed as an original high effective charcoal stove (OHECS) for increasing its performance especially for high energy with less fuel [5]. This OHECS can reduce the cost of charcoal more than 750 baht per family per year [4].

However, it is necessary for entrepreneurs or manufacturers to improve and develop more quality of OHECS. The importance of product design and development has to use the voices of consumer as a guide to be achieved using the QFD with HOQ construction [6]. [7] claimed to have proposed QFD for the first time in Japan in 1966. And this technique was devised by himself with using the house of quality diagram, which was introduced to Mitsubishi Heavy Industries in 1972. This prompted a rapid spread of QFD applications in Japan, followed by its introduction in the United States in the early 1980s. Most of industrial manufacturers used this technique to design and develop their products successfully [8] using the relationship between voices of consumer and technical data systematically.

It's been utilized in the food industry since 1987 [9]. [10] has used QFD in chocolate industry and [11] has used it for puff snack development research.

Currently, a group of local entrepreneurs (Ban Si Kye community enterprise entrepreneur group of Nong Khai province, Thailand) has been making TCS based on the local wisdom for a long time. This product is a part of One Tambon One Product (OTOP) project by Thai government policy. They requested that educational institutions near this area, such as Khon Kaen University, Nong Khai Campus, which is one of government sectors that assists their group in improving and developing their charcoal stove products. It is interesting to improve and develop OHECS using the QFD technique with HOQ construction method. Thus, the ultimate goal of this research is to design and produce a new version of HECS for them.

II. METHODOLOGY

Seven basic sections of the HOQ construction were used for QFD technique to analyze and translate the voices of customer (What's) into technical specifications (How's) [12]. The basic structure of the HOQ was presented in Figure 1 [13]. The HOQ matrix was constructed for improving and developing HECS as following;

Step 1: Voices of customer elicitation

Focus group discussion technique was used to elicit voices of customer [14]. Three focus groups (8 participants per a group) were recruited using purposive sampling from food outlets both inside and outside Khon Kaen University, Nong Khai Campus. They were 12 males and 12 females between the ages of 24 and 58, who cooked on a TCS on a regular basis. They were willing to participate in this study.

The introduction was created for 10 minutes. Then, all voices of customer (The characteristics of the HECS that they desired) were asked and recorded by the research moderator. The groups opened with a discussion on customer requirements which lasted for one hour per a session. The proceedings of the groups were video- and audio-recorded. All descriptors were written down on a board.

The focus group results were transcribed from the VDO/audio tape recording and summarized, deriving a list of characteristics of the HECS that they desired. The most desirable characteristics (the highest frequency of answers) [15] were recorded on the first part of HOQ (All characteristics were sorted in descending order).

Step 2: The important degree of each customer voice evaluation

Based on the fundamental data collected in the first step, two additional questionnaires were created to convey the significance degree of important and the level of satisfaction with the TCS when compared to an OHECS. Each questionnaire included 100 consumer panels and focused on two primary categories: product format and substance. Each of consumer panels was given an evaluation scale of 1 to 5 point, with 5 being the most important and 1 being least important. The core data from these two questionnaires was calculated using the mean scores [16]. To fulfill this work, the needs' importance weights were multiplied by the improvement ratio values, resulting in the important. Mean important scores of each item were recorded on the second part of HOQ.

Step 3: The comparison of consumer satisfaction between the TCS and the OHECS

The degree of customer satisfaction of the TCS and OHECS were compared for all customer voices using 5-point satisfaction scale (1 = least satisfied to 5 = most satisfied) by 100 consumer panels. The target value of each customer voice was mean satisfaction score of the OHECS. For the improvement ratio for each customer voice was evaluated by dividing the target value (mean satisfaction score of OHECS) with the mean satisfaction score of OHECS for this research. All data from this step were recorded on the third part of HOQ.

Step 4: The investigation of high effective stove's technical terms

Documental study was used to investigate technical specifications of OHECS (an expanded list of how's to be done to the product to fulfill the customer voices). These technical specifications of OHECS were available in [5]. As a result, the target value of the technical requirements was set to measure and determine the direction of the goal of improvement. 18 OHECS's technical terms were recorded on the fourth part of HOQ. Then, technical experts (n = 3) were asked to establish a symbol on each technical term (O = No need to decrease or increase, ↑ = increasing it will be good, and ↓ = decreasing it will be good).

Step 5: The indication of correlations among the technical specifications.

The technical correlation matrix, which was more often referred to as the roof, was used to aid in developing relationships among technical specifications [17] and to identify where these units must work together; otherwise, they were in a design conflict. Technical experts (n = 3) were asked to establish a symbol to represent the type of impact each technical specification had on the other. (+ = positive, and - = negative relationships). Each of the symbols was recorded on the fifth part of HOQ.

Step 6: The correlations between voices of customer and technical specifications

This matrix highlights the correlations between the voices of customer and the technical specifications. It must also be remembered to include the technical and regulatory specifications in the correlation. Technical experts (n = 3) were asked to seek consensus on these evaluations, basing them on expert technician experience, consumer panel responses and controlled experiments. There will be varying degrees of the strength of the relationships and so a set of digits was used to identify the significance on the sixth part of HOQ. The digits used were: 9 = strong relationship, 5 = medium relationship, 3 = weak relationship and 0 = no relationship [18].

Step 7: Establishing technical targets and ratings

Once the relationships (correlations and conflicts) had been established, the next stage was to determine target values for the technical specifications, a rating of the degree of difficulty for achieving that technical target value and an importance rating for the technical specifications.

Determine the important degree of each technical specification was fixed by considering the importance degree of customer voices using 3 HECS production experts. And then, these technical specifications were indicated their technical target value to use for a new HECS development and improvement. HECS production team had to develop

its own approach and decide on the degree of technical difficulty. These data were recorded on the seventh part of HOQ. Finally, all data in HOQ matrix was used to design and produce a new version of HECS product prototype.

III. RESULT AND DISCUSSION

For the HOQ matrix of the HECS result, it was shown in Figure 2. Each part of the HOQ was described. In the first part, a list of 19 voices of customers (100 consumer panels) of HECS was shown. And the importance of each requirement was shown in the second part. For this part, the first three important requirements were “less charcoal usage”, “higher durability of stove’s body” and “higher durability of stove’s rack”.

In the third part, the satisfaction degree of each customer voice was compared between TCS and OHECS. The mean satisfaction scores for all requirements of OHECS were higher than TCS particularly for “two-year warranty”, “energy savings with insulator”, “less charcoal usage” and “higher durability of stove’s body”, respectively. These requirements had higher mean satisfaction scores, though not the highest, and may be developed continuously.

For the fourth part of HOQ, all technical specifications or HECS’s technical requirements were placed and marked with their target values using symbols. The results showed that “saving charcoal” and “smaller space for charcoal input” met a specified technical target value. “Thickness of the stove’s rack” and “less energy loss” increased the target value, but “diameter” and “height” of the stove decreased the target value.

In the fifth part of the HOQ, the roof, the positive and negative relationship among technical specifications was indicated. The result showed that “energy saving”, “small space for charcoal input”, and “holds of the stove’s rack” related to heat energy increase.

The sixth part of the HOQ contained the levels of relationship between customer voices and technical specifications, as measured by mean relationship scores. The result showed that “less charcoal usage” and “higher stove durability” were related to “thickness of the stove’s wall” and “thickness of the stove’s rack”.

Finally, the seventh part of the HOQ displayed the technical target values and level of technical difficulty for all technical specifications chosen by the production expert team to improve and produce a novel HECS product prototype (Figure 3).

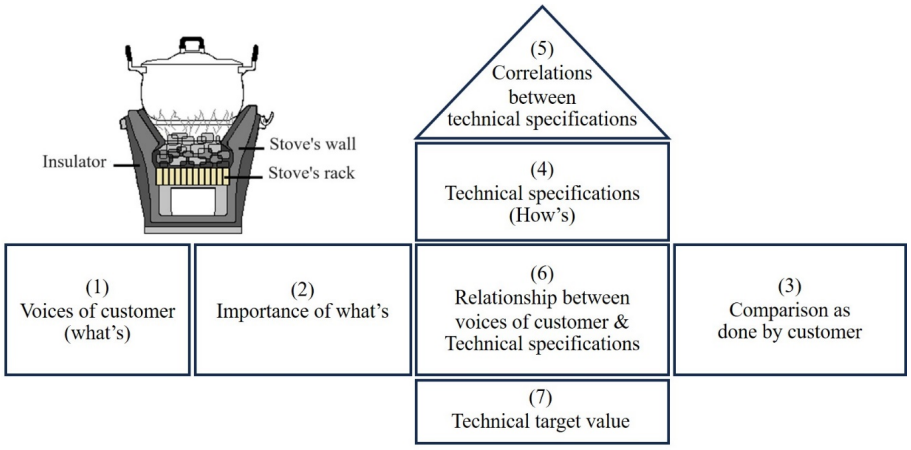
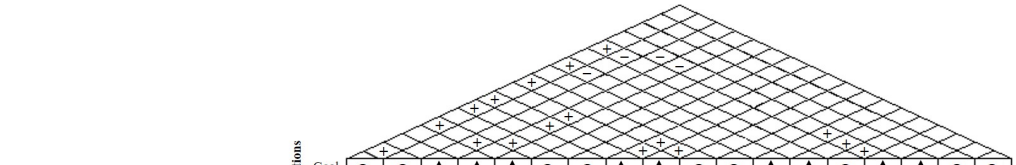


Figure - 1 Illustration of the House of Quality [12].



Voices of customer	Technical specifications	Degree of importance	30-40 % charcoal saving	Small rack holes	Thick stove body	Thick stove rack	Less heat loss	2 years warrantee	Service life > 2 yrs.	Heat 1000-1200°C	Rack absorbs air well	Short cooking time	Support pot 9 sizes	Stove diameter	Height of stove	Depth of stove	Weight of stove	Numbers of colors	Rack cleaning	Body stove cleaning	High effective stove	Traditional stove	Target value	Improvement ratio
	Goal		O	O	↑	↑	↑	O	O	↑	↑	O	O	↑	↑	O	↑	↑	O	O				
Less charcoal usage	1	4.44	9	9	9	9	9			9	9	9		9	9	9					4.42	3.72	4.42	1
Durable stove	2	4.53			9	9		9	9												4.29	3.60	4.29	1
Durable stove rack	3	4.17	9			9	9			9	9	9									4.30	3.58	4.30	1
Stove body decays slowly	4	4.01			9		9	9	9	5											4.23	3.51	4.23	1
Long lasting insulation	5	4.36	9				9			9		5									4.43	3.61	4.43	1
Long warranty period	6	4.18			9	9		9	9												4.94	3.47	4.94	1
The price of the stove is reasonable	7	4.29						5	5												4.22	3.54	4.22	1
Less heat loss	8	4.32	9				9			9	9	9			9	9	9				4.40	3.54	4.40	1
Save cooking time	9	4.31	9				9			9	9	9			9	9	9				4.34	3.50	4.34	1
Support the weight of pots for many sizes	10	4.28											9								4.18	3.74	4.18	1
Long service life	11	4.34			9	9		9	9												4.35	3.56	4.35	1
Easy to move	12	4.10												9	9						4.06	3.55	4.06	1
Diameter of stove is suitable	13	3.95											9	9							3.95	3.58	3.95	1
Height of stove is suitable	14	4.25													9						4.19	3.72	4.19	1
Weight of stove is suitable	15	3.89			9	5											9				4.00	3.42	4.00	1
Stove color is attractive	16	4.23																9			3.95	3.51	3.95	1
Trusted brand	17	3.85	5		5	5		5	5				5								3.98	3.54	3.98	1
Easy to clean inside	18	3.96		5		5										9			9		3.97	3.66	3.97	1
Easy to clean outside	19	4.01												9	9					9	3.95	3.64	3.95	1
Technical comparisons	High effective stove		30-40	15.5	6.5	4	30-40	yes	yes	1000-1200	61	20	9	30.5	25	14.5	10.4	1	yes	yes				
	Traditional stove		0	15.17	3	2	0	no	no	500-600	19	35-40	1-2	27.5	24	11	6	5	yes	yes				
	Measurement units		%	Cm.	Cm.	Cm.	Degree	yes	year	Degree	Holes	Min.	Sizes	Cm.	Cm.	Cm.	Kg.	Colors	yes	yes				
Technical difficulty			2.66	3.00	1.66	2.66	2.66	1.00	1.00	3.00	3.00	3.00	2.33	2.66	2.66	2.66	2.66	1.33	1.33	1.33				
Technical target values			35-45	15.5	6.5	4	30-40	yes	yes	1000-1200	61	20	9	30.5	25	14.5	10.4	1	yes	yes				

FIGURE - 2 HOQ MATRIX OF HECS.

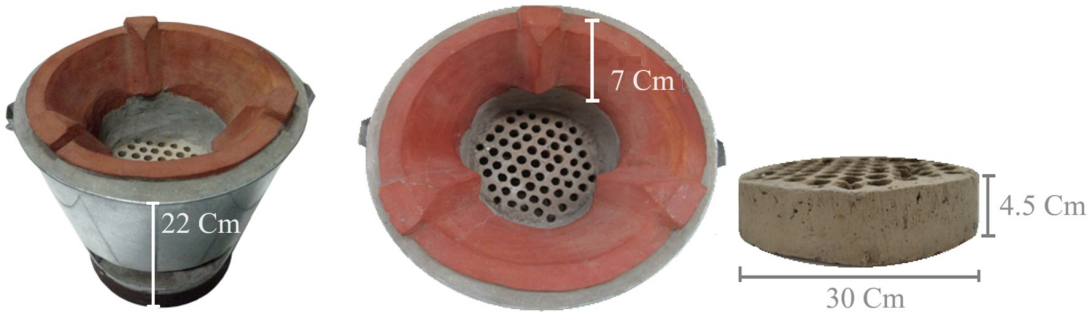


Figure - 3 A novel HECS which was improved.

IV.CONCLUSION

The important value of all technical specifications was determined by taking into account the importance level of customer voices, and the technical targets of these technical specifications were identified for use in future HECS design and development. Finally, a revolutionary HECS product prototype required increasing the “thickness of the stove's wall” from 6.5 cm to 7 cm, increasing the “thickness of the stove's rack” from 4 cm to 4.5 cm, and lowering the “stove's height” from 25 cm to 22 cm (Figure 3). Furthermore, these upgrades also reduce the weight of the stove.

V. REFERENCE

[1] P.D. Dunn, P. Samootsakorn, N. Joyce. "The performance of Thai charcoal stove". *Proceedings of the Indian Academy of Sciences,* Vol. 5, pp. 361-372, 1982.

[2] A. Chomcharn, "Improved Biomass Cooking Stove for Household Use", National Energy Administration Ministry of Science, Technology and Energy, Bangkok, 1984.

[3] A. Chomcharn, "Energy from Wood: Testfor Efficiency of Fuel and Bucket Stove", ForestryMeeting Annual Report, Forest Products Research Division, Bangkok, 1981.

[4] K. Kamanee, "Costs and Returns on Producing Energy-Saving Braziers in Amphoe Hang Dong, Changwat Chiang Mai", Chiang Mai University, Chiang mai, 2011.

[5] Department of Alternative Energy Development and Efficiency, "Biomass Energy", Ministry of Energy, Bangkok, 2003.

[6] G.L. Vairaktarakis, "Optimization tools for design and marketing of new/improved products using the house of quality", *Journal of Operations Management,* Vol. 17, pp. 645-663, 1999.

[7] Y. Akao, "Quality Function Deployment: Integrating Customer Requirements into Product Design", Translated by Glenn Mazur Cambridge. Productivity Press, M.A., 1990.

[8] K. Bergquist, J. Abeysekera, "Quality function deployment (QFD) - A means for developing usable products", *International Journal of Industrial Ergonomics,* Vol. 18, pp. 269-275, 1996.

[9] A.I.A. Costa, M. Dekker, W.M.F. Jongen, "Quality functiondeployment in the food industry:a review", *Trends in Food Science & Technology*, Vol. 11, pp. 306-314, 2001.

[10] J. Viaene, R. Januszewska, R. "Quality function deployment in the chocolate industry". *Food Quality and Preference,* Vol. 10, pp. 377-385, 1999.

[11] W. Wangcharoen, T. Ngarmsak, B.H.P. Wilkinson, "The Product Design of Puffed Snacks by Using Quality Function Deployment (QFD) and Reverse Engineering (RE) Techniques", *Kasetsart Journal - Natural Science,* Vol. 40, pp. 232-239, 2006.

[12] C. Homkhiew, T. Ratanawilai, K. Pochana, "Application of a quality function deployment technique to design and develop furniture products", *Songklanakarin Journal Science and Technology,* Vol. 34, pp. 663-668, 2012.

[13] F.Y. Partovi, R.A. Corredoira, "Quality function deployment for the good of soccer", *European Journal of Operation Research,* Vol. 137, pp. 642-656, 2002.

[14] R. Krueger, M. Casey, "Focus Groups: A Practical Guide for Applied Research", Sage Publications, Thousand Oaks, CA, 2009.

[15] K. Khajarern, "Fatigue Measurement Scale Evaluation in Cross Cultural", Graduate School, Khon Kaen University, Khon Kaen, 2009.

[16] A. Kengpol, "Concurrent Engineering". King Mongkut's Institute of Technology North, Bangkok, 2004.

[17] M. Benner, A.R. Linnemann, W.M.F. Jongen, P. Folstar, "Quality function deployment (QFD) – can it be used to develop food products?", *Food Quality and Preference,* Vol. 14, pp. 327-339, 2003.

[18] A. Pinta, "The improvement of product by using quality function deployment (QFD) technique: a case study of an educational wood toy factory", Master Thesis, King Mongkut Institute of Technology North Bangkok, Bangkok, 2002.