Customer Needs and Technology Analysis in New Product Development via Fuzzy QFD and Delphi

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Abstract: - The advanced technology in terms of interaction between human and machine as well as considerable Emotion Interaction Products (EIP) promoted by companies have facilitated a new era. For example, voice recognition and synthesis, hand writing and hand signal identification and virtual reality technologies have enabled the connection between human and computer interaction. Moreover, the application is expended from PC, Personal Digital Assistant (PDA) to mobile phone. Future technological products are expected to respond human emotion and improve human life quality. This research centers on EIP and compares 20 customer needs and 14 technologies using Quality Function Deployment (QFD). Additionally, experts and professionals are invited to express their opinions towards EIP through Fuzzy Delphi Method (FDM) to discuss the dimensions and criteria to be fulfilled. The results demonstrate which customer needs and technologies should be heavily focused, and contribute to design and manufacture EIP effectively.

Key-Words: - Emotion Interaction Product (EIP), Human Machine Interaction, Quality Function Deployment (QFD), Fuzzy Delphi Method (FDM)

1 Introduction

Numerous electronic firms have devoted their attention to the research and development of Emotional Interaction Product (EIP). The increasing digital devices become available in the market to emphasize artificial intelligence as well as emotional interaction, which boosts more purchasing. More firms also produce technological toys with the characteristics such as human-like appearance, high interaction, multiple reaction, education and emotional intelligence. It seems a promising market in the future. The market scale of technological toys and electronic pets was up to 38 billion US dollars in 2008, which firstly surpassed traditional toys in a scale of 36.4 billion US dollars. Electric Pets provide a new development and stress on emotion involved instead of fun based cheap products. It is estimated that artificial intelligence would lead the future trend. For example, Foxconn also produced a popular dinosaur toy named Pleo in 2007 and expect to bring 30 billion revenue. In this context, Foxconn set up new department of robot and well prepare to take advantage of the great business opportunity. Besides Foxconn, BenQ, MSi and ASUS also participate in the robot industry and hopefully create another diversity strategy other than declining OEM. Taiwanese high-tech industry has converted from OEM to ODM and OBM, they have abilities to produce the major components for EIP, such as semiconductor, communications kit, information kit, electronic components and material except the critical core technology. There is a need for Taiwanese high-tech industry to assess the optimal solution for EIP.

The aim of the research is using QFD to transform customer needs to technology, and undertaking Fuzzy Delphi Method (FDM) to analyze EIP in terms of relative importance among dimensions and criteria. The results can contribute to policy decision making and product development strategy.

QFD is based on the concept of the House of Quality. Several studies used AHP to determine consumer's weight in terms of relative importance (Armacost et al. 1994; Park & Kim 1998) [[1], [24]]. There are also some surveys addressed fuzzy measures to represent imprecise decision process (Chan et al. 1999; Vanegas & Labib 2001; Chan & Wu 2005; Fung et al. 2006) [[4], [32], [3], [10]]. Other researches adopted fuzzy set, fuzzy computation or defuzzy technique to solve the imprecision and complex in QFD (Khoo & Ho 1996; Zhou 1998; Wang 1999; Kim et al. 2000; Shen et al. 2001; Kahraman et al. 2006; Chen et al. 2006) [[16], [37], [33], [17], [27], [14], [6]]. Karsak (2004) [[15]] and Chen & Weng (2006) [[5]] utilized linguistic scales to measure the importance level, relationship intensity and correlation intensity, and subsequently created a fuzzy multi-goal programming to identify implementation of design requirements. This study associates QFD with FDM to survey expert opinions towards EIP and their importance based on customer needs and technology assessment.

Section 2 illustrates the perception in relation to emotional interaction and literature review. Section 3 describes research method. Section 4 establishes research model. Section 5 explains the analysis and results in terms of customer needs and technology respectively. Section 6 concludes this research and suggestions are also included.

2 Literature Review

The first part reviews emotional interaction perception and related issues. It is followed by comparing and analyzing the assessment criteria of EIP in terms of customer needs and technology. The rest of this section discusses current market scale of technological toys.

2.1 Emotional interaction perception

Developing consumer electronic products with emotion like human has been the major goal in the area of interaction between people and computer. Laurel (1990) [[18]] and Sproull et al. (1996) [[29]] pointed out interface with human nature can convey easy-to-use and comfortable feeling easily, and raise user satisfaction throughout the interaction. Besides complex computation via artificial intelligence, Social Cues provides another alternative to be easier and more feasible. This technology is used to make people feel virtual reality and human-like feature of digital product in middleware design. Many studies showed people not only regard computer as a tool, but also another interaction of social emotion (Reeves & Nass 1996) [[26]]. The hot topics in human-computer interaction have shifted from the usage to social support and emotion (Picard & Wexelblat 2002; Short et al. 1976) [[25],[28]]. Through the feeling of virtual reality, computer can facilitate social relationship rather than human-computer relationship, and can be helpful for the closeness between people and computer.

There is also more emotional product research in the area of product design, such as international conference on design and emotion, DPPI (conference on designing pleasurable products and interfaces), emotional engineering symposium and so forth. Some study argued that the emotional response and interaction with users not only bring people different feeling, but also influence their work performance and ability of solving problem (Desmet 2002; Overbeeke et al. 2002; Wensveen et al. 2000) [[9],[23],[35]]; Isen 1993; Norman et al. 2003; Norman 2004) [[12],[21],[22]]. Therefore, the emotional feeling towards product can be connected with usability and performance (Norman et al. 2003; Tractinsky 1997) [[21], [31]]. The role of product design has gone beyond pure tool, and becomes part of human life. Users have created different expectation on EIP on the basis of market observation.

2.2 The assessment criteria for customer needs and technology

EIP applies a number of high-tech technologies on the functions and appearance of product. For example, electronic toy (named AIBO) created by SONY, model with dressing concept can function to show users' feeling designed by Philip (Bubelle & Frison), electronic dinosaur (named PLEO) invented by UGOBE, talking Mickey Mouse robot made by SEGA, emotional interaction mouse (named MD300) invented by BenQ, Electronic Drum Kit Shirt invented by Thinkgeek, interactive Nabaztag produced by Violet, and Emotion Sensor necklace designed by VIBE.

2.3 The market scale of technological toys

Taiwanese firms provide approximately 90% medium and low end toy IC, and they still remain active under fast market change. From the viewpoint of the sales of components and IC, Taiwan contributed 1 billion US dollars in toy industry in 2007. Currently the proportion of electric toy like Pleo, SD card, Wi-Fi, sensor and servo motor of

ICT is higher. Taiwanese firms can foster the development of technological toy or electronic toy based on their electronic manufacturing ability and experience on traditional toys. It is expected there are more high-tech firms participate this market and develop high end components in the future.

2.4 Summary

In terms of customer needs, 5 dimensions and 20 criteria have been induced by above review. Namely, five dimensions of entertainment, education & learning, perceptual feedback, health & security and operation mechanism. Twenty criteria include vivid interaction, novel content, serial story, personification behavior, learning & growth, digital video, memory aided, multilingual translation, voice recognition & response, script display, diagram interface, warm reply, risk sensor, stress down device, emotion management, physiological test, portability, convenient operation, friendly design and identification. Furthermore, there are four dimensions and fourteen criteria in dimension of product manufacture technology. The four dimensions contain appearance design, human-machine interaction, artificial intelligence and communications technology. The fourteen criteria consist of appearance design, human engineering, physical trait, facial expression sensor, posture recognition, voice distinguishing, touch perception, environment perception, temperature perception, emotion recognition, emotional expression, learning intelligence, natural language process and wireless communications.

3 Research Method

The construction of research method starts with literature review which builds up a comprehensive understanding towards previous research, and then develops QFD model between customer needs and technology. Questionnaire uses Fuzzy Delphi Method (FDM) to collect experts' opinion in relation to the relative importance among various customer needs of EIP, and proceed correlation analysis between customer needs and technologies.

3.1 Literature review

To ensure the central theme of this study, theoretical underpinning is carried out to understand the characteristics of EIP and collect valuable experience and useful information from experts. The analytical framework is established with the help of expert interview, and combines 20 customer needs with 14 technology requirements. There are 5 fundamental steps for literature review, namely, generalization, induction, abstract, criticism and suggestion. The source from previous research can be categorized into primary information, secondary information and bibliographic instruments.

3.2 QFD

Quality Function Deployment (QFD) was indicated by Mitsubishi's Kobe Shipyard Site in Japan to promote quality from 1966 to 1972. Bossert (1991) [[2]] regarded QFD as a structural method to establish organizational quality institution and more understand customer needs. QFD can convert customer needs to appropriate production technology in every single product development stage. It also combine R&D, manufacture, management, customer needs, engineer features and product design quality to deploy product component quality as well as engineer elements (Sullivan 1986; Wasserman 1993) [[30],[34]]. Hauser & Clausing (1988) [[11]] presented that QFD is a structural approach to associate customer requirements with product development. They especially outlined House of Quality is the basic design tool of QFD. Based on this concept, product design should reflect customer needs. Therefore, business professionals including marketing, R&D, manufacturing should cross-department plan and communicate customer needs through the House of Quality at very beginning stage of product development. In other words, QFD uses systematic method to proceed all kinds of processes such as design, component, manufacture and costing. The transformation is undertaken by binary matrix technology to facilitate customer needs oriented product development. No matter what kind of product is created by industries, the end users are customers. Only by listening to the voice of customers, organizations can increase competitive advantage, sustain their business and grasp business opportunities. QFD can integrate customers' voice and requirements with the design, component, component, manufacture and cost processes, so that engineers can understand the association and importance easily and quickly. Bossert (1991) [[2]] explained the structure of House of Quality as shown in Figure1.

The essential structure of House of Quality is principally divided into six parts. Namely, Voice of Customer (VOC), Voice of Engineering (VOE), Correlation Matrix, Correlation Analysis, Benchmarking and Priority.

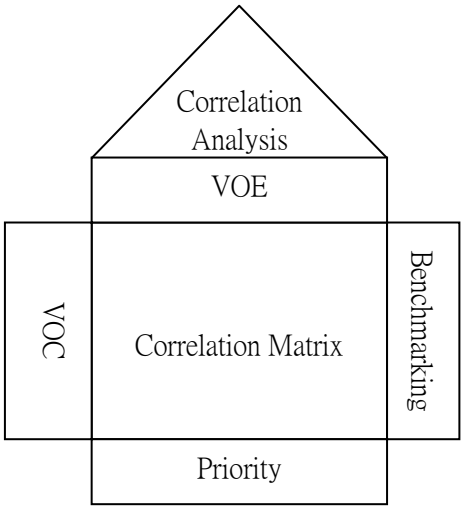

Figure 1. Structure of House of Quality (Bossert, 1991)

(1) VOC: it describes the requirements and expectations of customers. The information can collect from questionnaire and interview.
(2) VOE: it is the strategy or technology service planned, communicated and in tune with related departments within organization.
(3) Correlation Matrix: it interprets the relationship between VOC and VOE.
(4) Correlation Analysis: the relationship among VOE.
(5) Benchmarking: compare in-house product with other competitors.
(6) Priority: it can understand which technologies are more critical through the ranking of VOE, and use this basis to introduce new technology and resource allocation.

3.3 Fuzzy Delphi

Delphi was proposed by Dalkey and Helmer (1963) [[8]] as a method to express experts' opinions systematically. Murray, et al. (1985) [[20]] first combined Fuzzy Set with Delphi. Ishikawa et al. (1993) [[13]] utilized the concepts of accumulated frequency distribution and fuzzy integral to integrate experts' opinions with fuzzy set titled Fuzzy Delphi Method (FDM). FDM can be one of criteria measurement tools with more advantages than traditional Delphi: (1) decrease the times of investigation; (2) express experts' opinions more completely; (3) the experts' knowledge can be more rational and meet user requirements through the application of fuzzy theory and (4) more economic in terms of time and cost. Basically, there are three procedures to adopt FDM: (1) establish a set of assessment factors to influence decision-making; (2) collect experts' or decision groups' opinions; (3) calculate assessment value using FDM. Conventional Delphi Method is a prediction approach based of experts' judgments. It belongs to the area of group decision and is subjectively forecasted by experts' judgments through questionnaire survey and meeting (Linstone 1978) [[19]]. The basic principles are based on structural information distribution, anonymous group decision and experts' judgments. FDM filters assessment criteria for the purpose of understanding the agree level of experts, and then prioritize it using Analytical Hierarchy Processing (AHP). AHP has been widely used to measure various issues recently. Its advantage is to decompose complicated problems into logic and hierarchical framework carefully. AHP also can quantify desired goals, abstract experience and social value by way of comparison, and filter useful questionnaire through consistent test to control validity. Researchers integrate and sort the opinions from experts every time, and feedback to experts for their new judgments to come up with new statement. Repeating this process many times, the quality of experts' judgments can be achieved. However, conventional Delphi approach usually spends a long time with a high cost during the process of collecting and integrating experts' opinions repeatedly. At times questionnaires with low return rate or unable returned will influence the quality of judgments, even twist experts' intentions. This is one of the barriers of traditional Delphi. In this context, this research adopts Fuzzy Delphi Method (FDM), which has higher stability with small sample and triangle fuzzy set used by Huang et al (2001) to overcome the drawback of Delphi. Triangle fuzzy set is used to represent the fuzzy function of decision consensus. It also uses the maximum and the minimum of average function as the two points of triangle fuzzy set stands for the common view of experts. Geometric average represents the majority consensus by decision makers, the definitions are as follows.

U : The maximum of decision consensus
L : The minimum of decision consensus
X_0 : Geometric average

Figure 2 shows the triangle fuzzy function of decision consensus. This triangle function covers the opinions toward issue by decision group. The highest point means the greatest evaluation by decision group (U point). In other words, there is no possibility to have better evaluation than this point. The lowest point means the smallest evaluation by decision group (L point). In other words, there is no possibility to have worse

evaluation than this point. Therefore, the evaluation by decision group is within the highest and the lowest points. The advantages of FDM contain individual opinion would be considered, decrease the repetitive survey and reduce time and cost. The formulas of fuzzy triangle functions are as follows.

$$\mu_A^{\sim} = (L_A, M_A, U_A) \quad (1)$$

$$L_A = Min(X_{Ai}), i = 1,2,3...n \quad (2)$$

$$M_A = (X_{A1}, X_{A2}, ..., X_{An})^{1/n} \quad (3)$$

$$U_A = Max(X_{Ai}), i = 1,2,3...n \quad (4)$$

$$\mu_A^{\sim}(x) = \begin{cases} (x-L)/(M-L) & IF \quad L \le x \le M \\ (U-x)/(U-M) & IF \quad M \le x \le U \\ 0 & otherwise \end{cases} \quad (5)$$

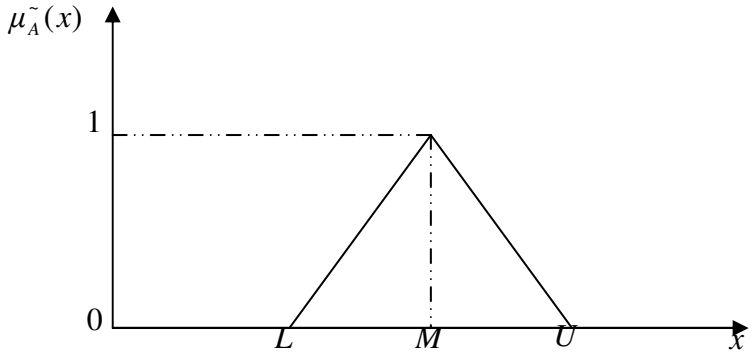

Figure 2: Triangle fuzzy function stands for decision consensus

A means evaluation criteria, i means expert, $\mu^{\sim}$ means fuzzy set of importance, X_{Ai} means the evaluation towards criteria A by ith expert, L_A means the minimum evaluation towards criteria A, M_A means the geometric average evaluation towards criteria A, U_A means the maximum evaluation towards criteria A.

3.4 Fuzzy linguistic variable

It is quite complex and difficult to identify and state fuzzy situation by traditional quantification methods, so that it is essential to have artificial language variable in fuzzy environment (Zadeh 1975) [[36]]. Fuzzy meaning variable can correspond different meanings by human language. The objective of fuzzy meaning is to measure the intensity of preference towards criteria by participants. That is, the measurement of nominal scale is represented by the meaning intensity of fuzzy theory. The scale can be classified into 5 levels, namely, low relevant, slightly low relevant, medium relevant, slightly high relevant and high relevant. This research even uses 9 point scale to be more precise, namely, very low relevant, lower relevant, low relevant, slightly low relevant, medium relevant, slightly high relevant, high relevant, higher relevant, very high relevant. The distribution of membership function for 9 point scale is shown in Figure 3.

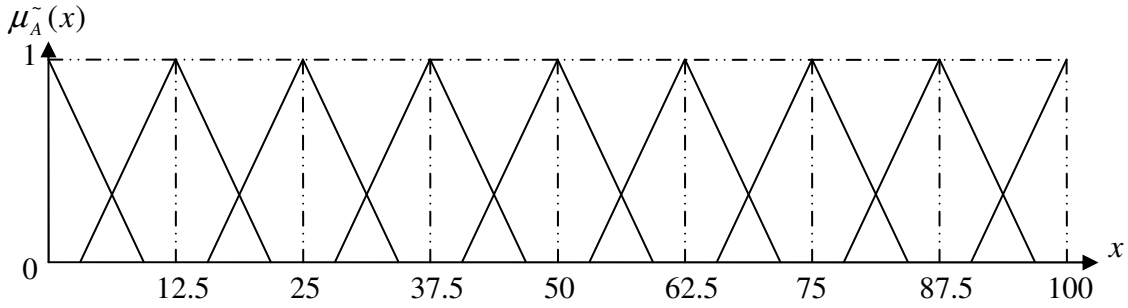

Figure 3: Membership function of 9 point scale

The number calculated by above procedures is still fuzzy set. To compare the correlation ranking among criteria conveniently, the procedure of Defuzzy is required. Therefore, this research adopts Center of Area (COA) to transfer fuzzy set to Nonfuzzy Value. That is, this non fuzzy synergy is so-called the value of BNP (Best Nonfuzzy Performance) for the purpose of ranking. In terms of (LR_i , UR_i , MR_i), the computation of BNP is as follows (Chiou & Tzeng, 2002)[[7]]. Finally, according to the results of above calculation, input QFD model for ranking criteria and ensure their correlation.

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i \forall i \quad (6)$$

4 Research Methodology

This paper is based on research objectives to indentify direction and focus, and integrate literature review and chosen research methods to establish research methodology. Section 4.1 explains how to organize measurement criteria for EIP. Section 4.2 illustrates the processes of research methodology and provides the operation basis for section 5 accordingly.

4.1 Identifying assessment criteria

Several technologies can be applied on EIP. Through the analysis done in section 2 in terms of customer needs and technology, five dimensions and twenty criteria are obtained. That is, five dimensions include entertainment, education & learning, perceptual feedback, health & security and operation mechanism. Twenty criteria consist of vivid interaction, novel content, serial story, personification behavior, learning & growth, digital video, memory aided, multilingual translation, voice recognition & response, script display, diagram interface, warm reply, risk sensor, stress down device, emotion management, physiological test, portability, convenient operation, friendly design and identification. In terms of production technology, four dimensions and fourteen criteria are acquired. The dimensions contain appearance design, human-machine interaction, artificial intelligence and communications. The criteria includes appearance design, human engineering, physical trait recognition, facial expression sensor, posture recognition, voice distinguishing, touch perception, environment perception, temperature perception, emotion recognition, emotional expression, learning intelligence, nature language process and wireless communications.

4.2 Establishing research model

This model is first concluded by literature review and experts' suggestions to have a set of criteria. QFD, fuzzy theory and fuzzy linguistic scale are then used to conduct FDM based questionnaire. We combine this questionnaire with triangle function of experts' evaluations to build up fuzzy weights toward various criteria. The last step is using QFD model to analyze criteria measurements and correlation ranking as shown in Figure 4.

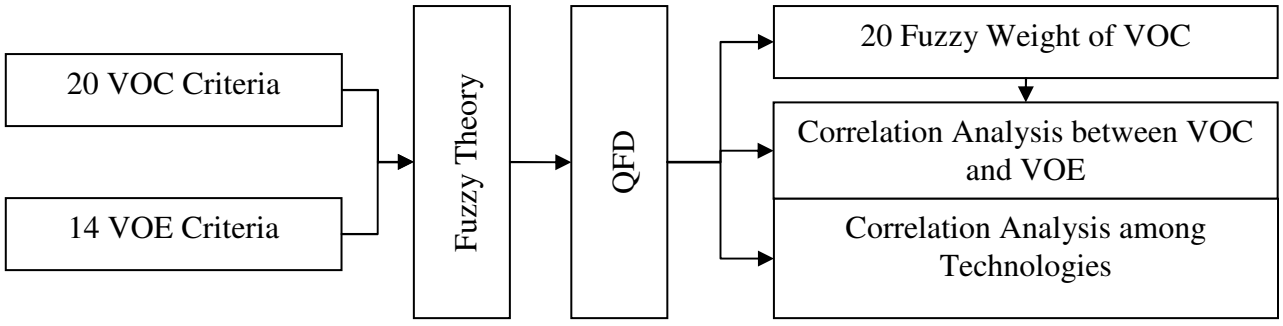

Figure 4. Research Model

5 Empirical Analysis

According to the research model built in section 4, this section demonstrates the empirical analysis. Firstly, we use QFD and FDM through questionnaire survey to consult 10 experts in the area of EID. The importance level and consensus regarding dimension and criteria of EID is acquired, and then rank them in

terms of customer requirement and technology with four steps. Step 1: sort and analyze five dimensions and four criteria in terms of function and feature by returned questionnaire. Step 2: analyze and transform the fuzzy weight of twenty criteria. Step 3: use QFD to discuss the correlation analysis and ranking between customer requirements and existing technology. Step 4: analyze the correlation between technologies.

5.1 Five Dimensions

Through the FDM and questionnaire to 10 experts we regard the importance of five dimensions including entertainment, education & learning, perceptual feedback, health & security and operation mechanism. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The results show the dimension of perceptual response has the highest score (74.4), while the dimension of education & learning has the lowest one (47.5). As a result, the perceptual response is highly emphasized and followed by entertainment. On the other hand, education & learning is less important. The calculation is shown in Table 1.

Table 1. Analysis of five dimensions

Dimension / Expert No.	Entertainment			Education & Learning			Perceptual Feedback			Health & Security			Operation Mechanism		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
001	65	70	75	53	59	65	75	80	85	65	70	75	75	80	85
002	65	75	85	57	66	75	65	75	85	32	40	48	32	40	48
003	58	68	78	8	18	28	78	88	98	38	48	58	78	88	98
004	57	66	75	57	66	75	57	66	75	57	66	75	57	66	75
005	77	87	97	55	65	75	77	87	97	77	87	97	77	87	97
006	30	40	50	40	50	60	50	60	70	20	30	40	40	50	60
007	45	50	55	37	45	53	75	85	95	55	65	75	37	45	53
008	65	75	85	57	66	75	75	85	95	65	75	85	33	40	47
009	78	83	88	20	25	30	50	55	60	20	25	30	78	83	88
010	85	90	95	75	80	85	75	80	85	55	65	75	85	90	95
W_i (fuzzy weight)	30	68.6	97	8	49.6	85	50	75.2	98	20	53.3	97	32	63.6	98
S_i (Defuzzy value)	65.2			47.5			74.4			56.8			64.5		

P.S.: the range of i is from 1 to 5 and stands for each dimension.
L: minimum, M: medium, U: maximum

5.1.1 Entertainment Dimension

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in entertainment dimension. The criteria include vivid interaction, novel content, serial story and personification behavior. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The results show the personification behavior has the highest score (69.6), while serial story has the lowest one (59.8). As a result, the personification behavior is highly emphasized and followed by novel content. On the other hand, serial story is less important. The calculation is shown in Table 2.

5.1.2 Education & Learning Dimension

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in education & learning dimension. The criteria include learning & growth, digital video, memory aided and multilingual translation. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The results show the digital video has the highest score (58.2), while multilingual translation has the lowest one (48.6). As a result, the digital video is highly emphasized and followed by learning & growth. On the other hand, multilingual translation is less important. The calculation is shown in Table 3.

Table 2. Criteria for entertainment dimension

Criteria / Expert No.	Vivid Interaction			Novel Content			Serial Story			Personification Behavior		
	L	M	U	L	M	U	L	M	U	L	M	U
001	53	59	65	53	59	65	65	70	75	75	80	85
002	65	75	85	65	75	85	65	75	85	65	75	85
003	58	68	78	58	68	78	58	68	78	78	88	98
004	63	73	83	63	73	83	63	73	83	77	87	97
005	55	65	75	77	87	97	55	65	75	55	65	75
006	30	40	50	40	50	60	30	40	50	40	50	60
007	37	45	53	45	50	55	45	50	55	55	65	75
008	57	66	75	65	75	85	65	75	85	65	75	85
009	78	83	88	60	65	70	70	75	80	50	55	60
010	75	80	85	85	90	95	55	65	75	75	80	85
W_i (fuzzy weight)	30	63.9	88	40	67.9	97	30	64.5	85	40	70.9	98
S_i (Defuzzy value)	60.6			68.3			59.8			69.6		

P.S.: the range of i is from 1 to 4 and stands for each criteria of entertainment dimension.
L: minimum, M: medium, U: maximum

Table 3. Criteria for education & learning dimension

Criteria / Expert No.	Learning & Growth			Digital Video			Memory Aided			Multilingual Translation		
	L	M	U	L	M	U	L	M	U	L	M	U
001	75	80	85	65	70	75	53	59	65	45	49	53
002	57	66	75	65	75	85	32	40	48	32	40	48
003	67	76	85	67	76	85	67	76	85	58	68	78
004	77	87	97	35	44	53	35	44	53	57	66	75
005	25	34	43	65	75	85	18	28	38	33	43	53
006	50	60	70	30	40	50	30	40	50	30	40	50
007	45	50	55	37	45	53	17	27	37	17	27	37
008	33	40	47	57	66	75	57	66	75	33	40	47
009	20	25	30	40	45	50	20	25	30	20	25	30
010	85	90	95	75	80	85	55	65	75	53	60	67
W_i (fuzzy weight)	20	56.3	97	30	59.6	85	17	43.7	85	17	43.5	78
S_i (Defuzzy value)	57.8			58.2			48.6			46.2		

P.S.: the range of i is from 1 to 4 and stands for each criteria of education & learning dimension.
L: minimum, M: medium, U: maximum

5.1.3 Perceptual Feedback Dimension

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in perceptual feedback dimension. The criteria include voice recognition & response, script display, diagram interface and warm reply. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The results show the warm reply has the highest score (75.8), while script display has the lowest one (52.7). As a result, the warm reply is highly emphasized and followed by voice recognition & response. On the other hand, script display is less important. The calculation is shown in Table 4.

Table 4. Criteria for perceptual feedback dimension

Criteria / Expert No.	Voice Recognition & Response			Script Display			Diagram Interface			Warm Reply		
	L	M	U	L	M	U	L	M	U	L	M	U
001	75	80	85	53	59	65	85	90	95	75	80	85
002	57	66	75	25	34	43	32	40	48	65	75	85
003	67	76	85	67	76	85	67	76	85	78	88	98
004	77	87	97	35	44	53	35	44	53	77	87	97
005	33	43	53	25	34	43	77	87	97	77	87	97
006	60	70	80	30	40	50	40	50	60	50	60	70
007	45	50	55	37	45	53	35	40	45	55	65	75
008	33	40	47	57	66	75	57	66	75	75	85	95
009	50	55	60	50	55	60	78	83	88	78	83	88
010	85	90	95	35	44	53	75	80	85	85	90	95
W_i(fuzzy weight)	33	63.3	97	25	48.0	85	32	62.6	97	50	79.4	98
S_i(Defuzzy value)	64.4			52.7			63.9			75.8		

P.S.: the range of *i* is from 1 to 4 and stands for each criteria of perceptual feedback dimension.
L: minimum, M: medium, U: maximum

5.1.4 Health & Security Dimension

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in health & security dimension. The criteria include risk sensor, stress down device, emotion management, physiological test. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The results show the stress down device has the highest score (61.3), while physiological test has the lowest one (57.5). As a result, the stress down device is highly emphasized and followed by emotion management. On the other hand, physiological test is less important. The calculation is shown in Table 5.

Table 5. Criteria for health & security dimension

Criteria / Expert No.	Risk Sensor			Stress Down Device			Emotion Management			Physiological Test		
	L	M	U	L	M	U	L	M	U	L	M	U
001	65	70	75	75	80	85	75	80	85	53	59	65
002	65	75	85	65	75	85	65	75	85	57	66	75
003	67	76	85	58	68	78	58	68	78	67	76	85
004	63	73	83	77	87	97	77	87	97	63	73	83
005	77	87	97	77	87	97	55	65	75	77	87	97
006	40	50	60	50	60	70	60	70	80	30	40	50
007	45	50	55	55	65	75	45	50	55	37	45	53
008	57	66	75	57	66	75	65	75	85	33	40	47
009	20	25	30	20	25	30	20	25	30	20	25	30
010	35	44	53	85	90	95	85	90	95	75	80	85
W_i(fuzzy weight)	20	58.4	97	20	66.9	97	20	65.1	97	20	55.4	97
S_i(Defuzzy value)	58.5			61.3			60.7			57.5		

P.S.: the range of *i* is from 1 to 4 and stands for each criteria of health & security dimension.
L: minimum, M: medium, U: maximum

5.1.5 Operation Mechanism Dimension

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in operation mechanism dimension. The criteria include portability, convenient operation, friendly design and identification. The fuzzy weight (W_i) and defuzzy value (S_i) are calculated based on expert's answers. The result shows the friendly design has the highest score (73.4), while identification has the lowest one (57.3). As a result, the friendly design is highly emphasized and followed by convenient operation. On the other hand, identification is less important. The calculation is shown in Table 6.

Table 6. Criteria for operation mechanism dimension

Criteria / Expert No.	Portability			Convenient Operation			Friendly Design			Identification		
	L	M	U	L	M	U	L	M	U	L	M	U
001	75	80	85	85	90	95	85	90	95	65	70	75
002	57	66	75	65	75	85	65	75	85	32	40	48
003	67	76	85	78	88	98	78	88	98	67	76	85
004	77	87	97	77	87	97	77	87	97	63	73	83
005	65	75	85	77	87	97	77	87	97	33	43	53
006	40	50	60	40	50	60	50	60	70	40	50	60
007	55	65	75	45	50	55	45	50	55	37	45	53
008	57	66	75	65	75	85	65	75	85	33	40	47
009	78	83	88	78	83	88	78	83	88	60	65	70
010	75	80	85	85	90	95	85	90	95	55	65	75
W_i(fuzzy weight)	40	72.0	97	40	75.8	98	45	77.2	98	32	55.0	85
S_i(Defuzzy value)	69.7			71.3			73.4			57.3		

P.S.: the range of *i* is from 1 to 4 and stands for each criteria of operation mechanism dimension.
L: minimum, M: medium, U: maximum

5.2 Fuzzy weight transformation of 20 criteria

Through the FDM and questionnaire to 10 experts we regard the importance of 4 criteria in each dimension. The study normalizes defuzzy value (Si) and obtains the rankings of 20 criteria. The results show the highest weight is warm reply (0.061), and followed by friendly design (0.059) and convenient operation (0.058), while multilingual translation has the lowest one (0.037). As a result, the warm reply is highly emphasized and followed by friendly design and convenient operation. On the other hand, multilingual translation is less important. The transformation is shown in Table 7.

Table 7. The transformation of fuzzy weight for 20 criteria

Criteria\Weight	S_i(Defuzzy Value)	Weight	Weight Ranking of Dimension
Vivid Interaction	60.6	0.049	11
Novel Content	68.3	0.055	6
Serial Story	59.8	0.048	12
Personification Behavior	69.6	0.056	5
Learning & Growth	57.8	0.047	15
Digital Video	58.2	0.047	14
Memory Aided	48.6	0.039	19
Multilingual Translation	46.2	0.037	20

Table 7. The transformation of fuzzy weight for 20 criteria (cont'd.)

Criteria\Weight	S_i(Defuzzy Value)	Weight	Weight Ranking of Dimension
Voice Recognition and Response	64.4	0.052	7
Script Display	52.7	0.043	18
Diagram Interface	63.9	0.052	8
Warm Reply	75.8	0.061	1
Risk Sensor	58.5	0.047	13
Stress Down Device	61.3	0.050	9
Emotion Management	60.7	0.049	10
Physiological Test	57.5	0.047	16
Portability	69.7	0.056	4
Convenient Operation	71.3	0.058	3
Friendly Design	73.4	0.059	2
Identification	57.3	0.046	17

P.S.: the range of *i* is from 1 to 20 and stands for 20 criteria. The calculation of weight uses mathematical average approach.

5.3 Correlation analysis between customer needs and existing technology

This study uses QFD to discuss the relationship between customer needs and existing technology. In term of customer needs, the results show friendly design has the highest relational ranking (793), and followed by convenient operation (788) and personification behavior (754), while multilingual translation has the lowest one (461). As a result, from the perspective of customer needs, friendly design is more important, and followed by convenient operation and tree down device. On the other hand, multilingual translation is less important. In terms of existing technology, the results show human engineering is ranked the highest (1089), and followed by appearance design (1078) and emotion expression (1042), while temperature sensor is ranked the lowest (751). As a result, from the aspect of existing technology, human engineering should be the first priority, and followed by appearance and emotion expression, while temperature sensor is later considered. The calculation is shown in Table 8.

Table 8. Correlation analysis between customer needs and existing technology

Customer Needs \ Existing Technology	Appearance Design	Human Engineering	Physical Trait	Facial Expression Sensor	Posture Recognition	Voice Distinguishing	Touch Perception	Environment Perception	Temperature Perception	Emotion Recognition	Emotional Expression	Learning Intelligence	Natural Language process	Wireless Communications	Total	Ranking
Vivid Interaction	59	67	30	50	42	43	60	50	47	54	57	47	41	44	691	7
Novel Content	59	53	36	38	27	28	35	38	31	55	62	51	45	40	598	14
Serial Story	46	41	28	34	33	40	36	38	30	44	54	53	41	32	550	17
Personification Behavior	74	66	45	50	52	52	55	54	37	60	72	56	50	31	754	3
Learning & Growth	41	44	35	36	40	49	37	34	32	50	51	74	57	49	629	12
Digital Video	46	36	22	27	26	38	35	34	32	35	57	48	36	60	532	18

Table 8. Correlation analysis between customer needs and existing technology (cont'd.)

Customer Needs \ Existing Technology	Appearance Design	Human Engineering	Physical Trait	Facial Expression Sensor	Posture Recognition	Voice Distinguishing	Touch Perception	Environment Perception	Temperature Perception	Emotion Recognition	Emotional Expression	Learning Intelligence	Natural Language process	Wireless Communications	Total	Ranking
Memory Aided	38	44	23	35	26	43	33	24	20	39	39	69	49	33	515	19
Multilingual Translation	24	28	17	25	20	59	21	21	18	28	27	59	67	47	461	20
Voice Recognition and Response	37	46	33	42	33	82	29	32	24	63	55	66	79	47	668	8
Script Display	48	45	25	40	36	44	35	42	32	43	60	53	56	34	593	15
Diagram Interface	69	61	31	47	38	45	43	40	34	40	60	58	44	32	642	11
Warm Reply	69	69	45	54	47	59	51	44	44	55	70	58	50	37	752	4
Risk Sensor	40	52	57	44	58	42	59	69	54	53	38	22	22	58	668	8
Stress Down Device	56	53	59	68	55	57	56	54	56	72	61	33	32	28	740	5
Emotion Management	52	56	56	59	48	45	41	34	37	72	71	35	34	28	668	8
Physiological Test	51	61	78	49	60	43	57	49	64	68	43	35	22	51	731	6
Portability	76	73	46	36	36	33	47	34	34	31	24	25	26	37	558	16
Convenient Operation	76	75	51	58	57	61	57	54	46	57	46	47	55	48	788	2
Friendly Design	76	78	57	58	55	52	58	52	47	60	62	47	55	36	793	1
Identification	41	41	67	54	39	62	35	40	32	44	33	37	31	49	605	13
Total	1078	1089	841	904	828	977	880	837	751	1023	1042	973	892	821		
Ranking	2	1	10	7	12	5	9	11	14	4	3	6	8	13		

5.4 Correlation analysis between technologies

This study uses QFD to discuss the relationship and ranking between 14 existing technologies. The results show emotion recognition is ranked the highest (766), and followed by human engineering (699) and learning intelligence while wireless communications is ranked the lowest (488). As a result, technically the emotion recognition has more impact and requires to be developed first or acquire key technology. The ranking is followed by human engineering and learning intelligence, while wireless communications has smaller impact. The calculation is shown in Table 9.

Table 9. Correlation Analysis between Technologies

Expert No. \ Existing Technology	Appearance Design	Human Engineering	Physical Trait	Facial Expression Sensor	Posture Recognition	Voice Distinguishing	Touch Perception	Environment Perception	Temperature Perception	Emotion Recognition	Emotional Expression	Learning Intelligence	Natural Language process	Wireless Communications
001	73	79	73	73	49	61	63	57	57	80	82	65	59	43
002	82	79	64	78	72	79	70	74	58	83	84	77	69	63
003	76	74	72	73	72	71	71	72	71	72	72	51	48	49
004	9	77	33	24	23	32	25	24	31	75	0	9	17	71
005	83	102	75	69	49	64	73	65	46	72	59	61	14	28
006	45	42	48	39	41	43	44	43	44	49	43	43	43	39
007	87	63	88	82	86	84	90	84	74	93	94	75	71	63
008	79	94	90	93	93	97	98	87	81	94	99	93	86	82
009	14	14	28	14	21	37	26	33	14	55	19	79	30	14
010	65	75	77	60	54	57	66	90	52	93	99	100	72	36
Correlation Value	613	699	648	605	560	625	626	629	528	766	651	653	509	488
Ranking	9	2	5	10	11	8	7	6	12	1	4	3	13	14

5.5 Discussion

Based on above analysis and computation, it can be noted that perceptual feedback and entertainment are highly stressed among five dimensions. In customer dimension, warm reply, friendly design and convenient operation are most emphasized among twenty criteria. In terms of correlation analysis between customer needs and technology, friendly design, convenient operation and personification behavior are ranked higher. As a result, friendly design, convenient operation and personification behavior should be highlighted to look after customer needs. The correlation ranking between technology and customer needs reveals human engineering, appearance design and emotion expression as the top priorities. As a result, the R&D technology should focus on those three functions. Regarding the correlation analysis between technologies, emotion recognition, human engineering and learning intelligence are ranked the highest, so that these technologies should develop as soon as possible.

6 Conclusions and Suggestion

This section contains the research outcomes and contribution, suggestions, future research and limitation.

6.1 Conclusion

This study applied QFD to establish a research framework and converted customer needs into technology development strategy, so that firms can master a future leading edge. It can be concluded that friendly design, convenient operation and personification behavior should be heavily focused to facilitate the EID production and meet customer requirements among 20 customer needs and 14 technologies. From the viewpoint of relationship between 14 technologies and 20 customer needs, human engineering, appearance design and emotion expression should be first developed. With regard to the relationship among 14 technologies, emotion recognition, human engineering and learning intelligence have major impacts and should be acquired urgently

6.2 Suggestion

There are several points are suggested by this research. (1) The important functions and features required by customers have significant impacts on QFD weight and correlation ranking between criteria. Future research can be based on this framework to investigate different products and consumers. With a broader sampling and statistic testing procedure, the

deviation in different market can be highlighted. (2) This survey doesn't include high-tech companies. Actually high-tech companies can consult this model to analyze the functions and features required by customers, and set up business strategy to deploy market segment. The analysis also can be used to benchmark competitors' strategy and come up with different strategic planning of competitive advantage. (3) Taiwanese high-tech firms has been shifted from OEM oriented to ODM and OBM oriented, they have production ability on the EIP components such as semiconduction, communications kit, information kit, electronic component and material. If the core technology of emotion perception and algorithms are required to develop themselves or acquire from overseas, there is a need to assess the optimal benefit solution carefully. (4) Taiwanese firms are more competitive on information key components and production technology, while less competitive on brand and channel. Therefore, Taiwanese firms can align with Chinese firms strategically using policy negotiations, so as to obtain EIP related patents, brand, channel, R&D and personnel to promote the competitive advantage of Taiwanese high-tech firms.

6.3 Future Research

In the aspect of correlation analysis between customer needs and technology, criteria and technology assessment to each company can be done based on the requirement of criteria and technology relationship. In this way, the mainstream product, level of customer satisfaction and technology advantage as well as maturity can be enhanced. In the aspect of technology relationship, patent database can be applied to cross analyze technology and patent, and add on the technology and function used for mainstream product. The patent map of industrial technology, trend development of mainstream technology can be planned, which can be the basis of establishing Taiwan's technology policy and firm's industrial strategy. Furthermore, the market segment can be analyzed through the information and quantified QFD by market survey to come up with different ranking of diversified business strategy.

6.4 Limitation

This study has been striving for objective and careful research, some limitation still needs to be addressed. That is, the content of questionnaire might have bias resulted from the professionalism of participants and cognitive difference towards questions. This may cause insufficient objectivity and impact the data collection and precise analysis

References

[1] Armacost, R. L., Componation, P. J., Mullens, M. A. and Swart, W. W. (1994), "An AHP framework for prioritizing customer requirements in QFD: an industrialized housing application," *IIE Transactions*, 26(4), 72-79.

[2] Bossert, J. L. (1991), "Quality Function Deployment - A Practitioner's Approach," *ASQC Quality Press Inc*, New York.

[3] Chan, L. K. and Wu, M. L. (2005), "A systematic approach to quality function deployment with a full illustrative example," *Omega - The International Journal of management Science*, 33, 119-139.

[4] Chan, L. K., Kao, H. P., Ng, A. and Wu, M. L. (1999), "Rating the importance of customer needs in quality function deployment by fuzzy and entropy methods," *International Journal of Production Research*, 37(11), 2499-2518.

[5] Chen, L. H. and Weng, M. C. (2006), "An evaluation approach to engineering design in QFD processes using fuzzy goal programming models," *European Journal of Operational Research*, 172(1), 230-248.

[6] Chen, Y., Fung, R. Y. K. and Tang, J. (2006), "Rating technical attributes in Fuzzy QFD by integrating fuzzy weighted average method and fuzzy expected value operator," *European Journal of Operational Research*, 174(3), 1553-1566.

[7] Chiou, Hua-Kai and Tzeng, Gwo-Hshiung (2002), "Fuzzy Multiple-Criteria Decision-Making Approach for Industrial Green Engineering", *Environmental Management*, Vol. 30, No. 6, 816-830.

[8] Dalkey, N. C. and Helmer, O. (1963), "An experimental application of the Delphi method to the use of experts," *Management Science*, 9(3), 458-467.

[9] Desmet, P. M. A. (2002), *Designing Emotions*. Doctoral thesis, Delft University of Technology.

[10] Fung, R. Y. K., Chen, Y. and Tang, J. (2006), "Estimating the functional relationships for quality function deployment under uncertainties," *Fuzzy Sets and Systems*, 157(1), 98-120.

[11] Hauser, J.R. and Clausing, D. (1988), "The House of Quality," H*arvard Business Review*, 66(3), 63-73.

[12] Isen, A. M. (1993), "Positive Affect and

Decision Making," *Handbook of emotions*, M. Lewis and J. M. Haviland, New York, Guilford: 261-277.

[13] Ishikawa, A., Amagasa, T., Tamizawa, G., Totsuta, R. and Mieno, H. (1993), "The Max-Min Delphi Method and Fuzzy Delphi Method via Fuzzy Integration," *Fuzzy Sets and Systems*, 55, 241-253.

[14] Kahraman, C., Ertay, T. and Buyukozkan, G. (2006), "A fuzzy optimization model for QFD planning process using analytic network approach," *European Journal of Operational Research*, 171(2), 390-411.

[15] Karsak, E. E. (2004), "Fuzzy multiple objective programming framework to prioritize design requirements in quality function deployment," *Computers and Industrial Engineering*, 47(2-3), 149-163.

[16] Khoo, L. P. and Ho, N. C. (1996), "Framework of a fuzzy quality function deployment system," *International Journal of Production Research*, 34(2), 299-311.

[17] Kim, K. J., Moskowitz, H., Dhingra, A. and Evans, G. (2000), "Fuzzy multicriteria models for quality function deployment," *European Journal of Operational Research*, 121(3), 504-518.

[18] Laurel, B. (1990), "Interface Agents: Metaphors with Character," *The Art of Human-Computer Interface Design*, Addison-Wesley, New York, 355-365.

[19] Linstone (1978), H. A., *Handbook of Future Research*, London: Greenwood Press.

[20] Murray, T. J., Pipino, L. L. and Gigch, J. P. V. (1985), "A pilot study of fuzzy set modification of Delphi," *Human Systems Management*, 5(1), 76-80.

[21] Norman D. A., Ortony A. and Russell D. M (2003), "Affect and Machine Design: Lessons for the Development of Autonomous Machines," *IBM Systems Journal*, 42(1), 38-43.

[22] Norman, D. A. (2004), *Emotional Design: Why We Love (or Hate) Everyday Things*, New York: Basic Books.

[23] Overbeeke, K., Djadjadiningrat, T., Hummels, C. and Wensveen, S. (2002), "Beauty in usability: forget about ease of use," *Pleasure with Products: Beyond Usability*, Green, W. S. and Jordan, P. W. (eds) New York: Taylor and Francis, 9-17.

[24] Park, T. and Kim, K. J. (1998), "Determination of an optimal set of design requirements using house of quality," *Journal of Operations Management*, 16, 569-581.

[25] Picard, R.W. and Wexelblat, A. (2002), Future Interfaces: Social and Emotional. *Extended Abstracts of The CHI 2002 Conference on Human Factors in Computing Systems*, ACM Press, 698-699.

[26] Reeves, B. and Nass, C. (1996), *The media equation: how people treat computers, television, and new media like real people and places*. Stanford, CA; New York: CSLI Publications; Cambridge University Press.

[27] Shen, X. X., Tan, K. C. and Xie, M. (2001), "The implementation of quality function deployment based on linguistic data," *Journal of Intelligent Manufacturing*, 12(1), 65-75.

[28] Short, J., Williams, E. and Christie, B. (1976), *The social psychology of telecommunications*, John Willey and Sons Ltd, London.

[29] Sproull, L, Subramani, M., Kiesler, S., Walker J. H. and Waters K. (1996), "When the interface is a face," *Human-Computer Interaction*, Vol.11, 97-124.

[30] Sullivan, L. P. (1986), "Quality Function Deployment," *Quality Progress*, 19(6), 39-50.

[31] Tractinsky, N. (1997), "Aesthetics and apparent usability: Empirically assessing cultural and methodological issues." *Proceedings of the CHI 1997 Conference on Human Factors in Computing*, New York: ACM, 115-122.

[32] Vanegas, L. V. and Labib, A. W. (2001), "A fuzzy quality function deployment (FQFD) model for deriving optimum targets," *International Journal of Production Research*, 39(1), 99-120.

[33] Wang, J. (1999), "Fuzzy outranking approach to prioritize design requirements in quality function deployment," *International Journal of Production Research*, 37(4), 899-916.

[34] Wasserman, G. S. (1993), "On How to Prioritize Design Requirements During the QFD Planning Process," *IIE Transactions*, 25, 59-63.

[35] Wensveen, S.A.G., Overbeeke, C.J. and Djajadiningrat, J.P. (2000), "Touch me, hit me and I know how you feel. A design approach to emotionally rich interaction." *Proceedings of DIS 2000, Designing Interactive Systems*. ACM, New York, 48-53.

[36] Zadeh, L. A. (1975), "The Concept of a Linguistic Variable and Its Application to Approximate Reasoning, Parts 1, 2, and 3," *Information Science*, 8(2), 199-249, 8(3), 301-357; 9(1), 43-80.

[37] Zhou, M. (1998), "Fuzzy logic and optimization models for implementing QFD," *Computers and Industrial Engineering*, 35(1-4), 237-240.