Qual Quant (2008) 42:563–578
DOI 10.1007/s11135-006-9058-y

ORIGINAL PAPER

A case study on the application of Fuzzy QFD in TRIZ for service quality improvement

Chao-Ton Su · Chin-Sen Lin

Accepted: 15 July 2006 / Published online: 4 January 2007

Abstract The improvement of service quality so as to enhance customer satisfaction has been widely mentioned over the past few decades. However, a creative and systematic way of achieving higher customer satisfaction in terms of service quality is rarely discussed. Recently, TRIZ, a Russian acronym which means "Theory of Inventive Problem Solving," has been proven to be a well-structured and innovative way to solve problems in both technical and non-technical areas. In this study, a systematic model based on the TRIZ methodology is proposed to generate creative solutions for service quality improvement. This is done by examining first the determinants of service quality based on a comprehensive qualitative study in the electronic commerce sector. Then the correlation between the imprecise requirements from customers and the determinants of service quality is analyzed with Fuzzy Quality Function Deployment (QFD) in order to identify the critical determinants relating to customer satisfaction. After which, the corresponding TRIZ engineering parameters can be effectively applied in the TRIZ contradiction matrix to identify the inventive principles. A case study is illustrated to demonstrate the effectiveness of our approach in an e-commerce company, and its results are presented to show the applicability of the TRIZ methodology in the e-service sector.

Keywords Fuzzy QFD · TRIZ · Contradiction Matrix · E-Commerce

C.-T. Su (✉)
Department of Industrial Engineering and Engineering Management, National Tsing Hua University, 101, Kuang Fu Road, Sec. 2, Hsinchu 300, Taiwan, R.O.C.
e-mail: ctsu@mx.nthu.edu.tw

C.-S. Lin
Department of Industrial Engineering and Management, National Chiao Tung University, 1001, Ta Hsueh Road, Hsinchu 300, Taiwan, R.O.C.
e-mail: jasoncslin@yahoo.com

1 Introduction

Service-oriented industries have experienced a significant growth over the past several decades, and service quality has become a frequently studied area in the service marketing literature. In the last three decades, this topic has been undertaken by researchers to understand and identify what service quality is (Kang and James 2004). Parasuraman et al. (2005) found from early researches that service quality stems from the comparison of what customers expect a company should offer with the company's actual service performance. Even though an increasing number of companies are realizing the importance of service quality and customer satisfaction, however, how to achieve these goals is not always clear for these companies. In this respect, a valid methodology for companies to achieve improvement in their services is recognized as the pivotal recipe. In response to this concern, TRIZ researchers have provided a number of successful models to validate TRIZ's effectiveness in creating and improving new services (Retseptor 2003; Zhang et al. 2003).

The strength of TRIZ as a method for developing creative solutions to problems lies in its removal of contradictions rather than the use of the conventional approach by means of compromise or tradeoffs. At this point, there are a number of ways forward, but within the TRIZ tool set, contradiction analysis is the most frequently and widely used method to resolve problems pertaining to the elimination of the problem's contradictions. The contradiction analysis process requires a matrix which is formed by 39 parameters of the technological systems and 40 types of inventive principles. When a problem solver faces a conflict, he/she first searches for the appropriate parameters by matching the meaning of each contradiction from the 39 engineering parameters that have been defined in the TRIZ. Then through the contradiction matrix, the user can indicate the suitable inventive principles and can suggest ways to generate the ideal solutions.

Generally, the TRIZ process starts with stripping away the side issues and preconceptions in order to define the core problem. This involves breaking the problem down into its most elementary components, understanding each component, expressing the components in the most elementary or fundamental way, and then finally freeing oneself from the constraints of the language in which the problem is expressed (Webb 2002). At this point, the TRIZ process relies on the problem solvers to actually look at the essentials of the problem and conceptualize the critical characteristics of the problem. In the beginning, the problem solvers need to clearly discuss and analyze the contradictory relationship within the specified problem. In practice, when the problem solvers focus on the process of formulating the problems, the uncertain and ambiguous expression of their opinions usually impedes the consensus of the discussion. This will consequently affect the level of inventive solutions. Therefore, with the noticeable results of applying TRIZ in the technological field, this study attempts to present a systematic process based on the TRIZ methodology with the contradiction matrix to resolve the problems in the specified industry and develop a systematic procedure to overcome the discrepancies in the problem-formulating process by using Fuzzy Quality Function Deployment (QFD); this will help analyze the imprecise and subjective problem information. Meanwhile, a case study on the e-service sector is demonstrated to show the practicability of our proposed approach. Besides, in our case study, the determinants of e-service quality are extracted and used to translate the essentials of the problem into their principal characteristics, and consequently,

the relevant TRIZ engineering parameters and inventive principles can be effectively identified.

2 TRIZ

The TRIZ methodology offers a well-structured and high-power inventive problem-solving process. The application of TRIZ thinking tools in diverse industries has successfully replaced the unsystematic trial-and-error method in the search for solutions in the daily life of engineers and developers. Altshuller, the proponent of the TRIZ method, analyzed thousands of worldwide patents from leading engineering fields, and categorized these patents in a novel way by removing the subject matter to identify the problem-solving process rather than by classifying the patents by industry. From this, he found that the same problems were often solved over and over again using one of only 40 fundamental inventive principles.

In this respect, Mann (2002) indicated that TRIZ researchers have encapsulated the principles of good inventive practice, and then set them into a general problem-solving structure. Loebmann (2002) explained the general process by which the TRIZ method overcomes the psychological inertia barrier, and this is through the generalization of the specific problem to an analogous TRIZ generic problem. Then through the comparison of this generic TRIZ problem with the analogous generic TRIZ solution in the knowledge database obtained from scientific effects and patents research, one can generate the solutions for the specific problem. Some classical methods used to resolve the specific problem by directly jumping into a specific solution are frequently done by luck or by intuitively finding out the solution. Collectively, TRIZ has become a process that is reliable when it comes to achieving systematic innovation, and it helps avoid an inefficient route for problem solving by providing a systematic and efficient way to solve the problem.

In the application of the TRIZ methodology, one of the recent trends is to integrate TRIZ with other methods in order to strengthen its strong points. Yanashina et al. (2002) described a new method to systematically integrate QFD with TRIZ, and in the process, enabled the effective and systematic creation of new products. In the current study, we attempt to apply the Fuzzy QFD matrix to analyze imprecise and subjective problem information in order to clarify the essentials of the problem under a fuzzy environment.

3 Fuzzy QFD

Quality Function Deployment is often used to understand the voice of customers regarding products, and relate them with product design specifications or technical characteristics to be subsequently translated into production requirements. However, when capturing customer requirements from qualitative or linguistic data, for example, human perception, judgment, and evaluation on the importance of customer requirement or relationship strength which are often vague and imprecise in nature, these are difficult to estimate exactly such as numerical data. Thereby, the linguistic data that the conventional QFD process uses can be treated to approximate exactness with the help of the fuzzy set theory.

The fuzzy set theory, introduced by Zadeh, is widely applied to resolve problems that are subjective, uncertain, and imprecise in nature. It provides a strict mathematical framework in which vague conceptual phenomena can be precisely and rigorously studied. The methodologies using Fuzzy QFD to convert qualitative information into quantitative parameters have been explored in various applications. Temponi et al. (1999) illustrated their approach, which is a fuzzy logic-based extension to House of Quality (HOQ) for capturing imprecise requirements to facilitate communication of team members and the formal representation of requirements, using a textile mill supply business application. Meanwhile, Sohn and Choi (2001) constructed a Fuzzy QFD model in order to convey the fuzzy relationship between customer needs and design specification for reliability in the context of Supply Chain Management (SCM).

4 Proposed approach

Based on the literature review in the context of TRIZ and Fuzzy QFD, and with our main focus on service quality improvement, we come up with a systematic framework in the problem-solving process for a specified sector. Figure 1 depicts the process flow of our proposed approach that comprises of five main stages.

Stage 1 Define the scope of the problem, and identify the sector under which it is classified. For example, depending on the service that an Application Software Provider (ASP) company provides, the problems arising from this company can be classified under the sector of electronic commerce (e-commerce).

Stage 2 The determinants which affect the quality of service and customer satisfaction can be extracted from the review of various perspectives regarding the specified sector. When we focus on service quality improvement especially, the reference materials relating to this sector should be extensively analyzed to find out the dominant characteristics affecting the service quality in this sector.

Stage 3 Apply the TRIZ contradiction matrix to resolve the problem step-by-step according to the general TRIZ problem-solving process.

Step 3.1 Describe the specified problem with all the customers' needs and expected requirements.

Step 3.2 Define the ideal situation to be achieved without using extra resources when the contradictions within the problem are resolved.

Step 3.3 With the items of determinants developed from stage 2, apply Fuzzy QFD to indicate the critical determinants relevant to the customers' requirements specified in step 3.1. The computational procedures for the fuzzy numbers in the Fuzzy QFD system are shown in the following:

Step 3.3.1 Identification of linguistic terms: In order to identify the correlative relationships between the customer requirements and the service quality determinants of the sector, we describe the importance of the relationship through linguistic terms with five distinct levels, which are extremely important (EI), very important (VI), important (I), a little important (LI), and not important (NI).

Step 3.3.2 Fuzzification of input data: The triangular fuzzy number which is shown in Fig. 2 is used in this study and all membership functions for the linguistic input data which is shown in Fig. 3 are standardized in the interval [0,1].

Step 3.3.3 Applying fuzzy arithmetic: The fuzzy arithmetic is applied to the calculation of the priorities of relevant service quality determinants, and the addition and multiplication of fuzzy numbers will be performed for the calculation. Suppose

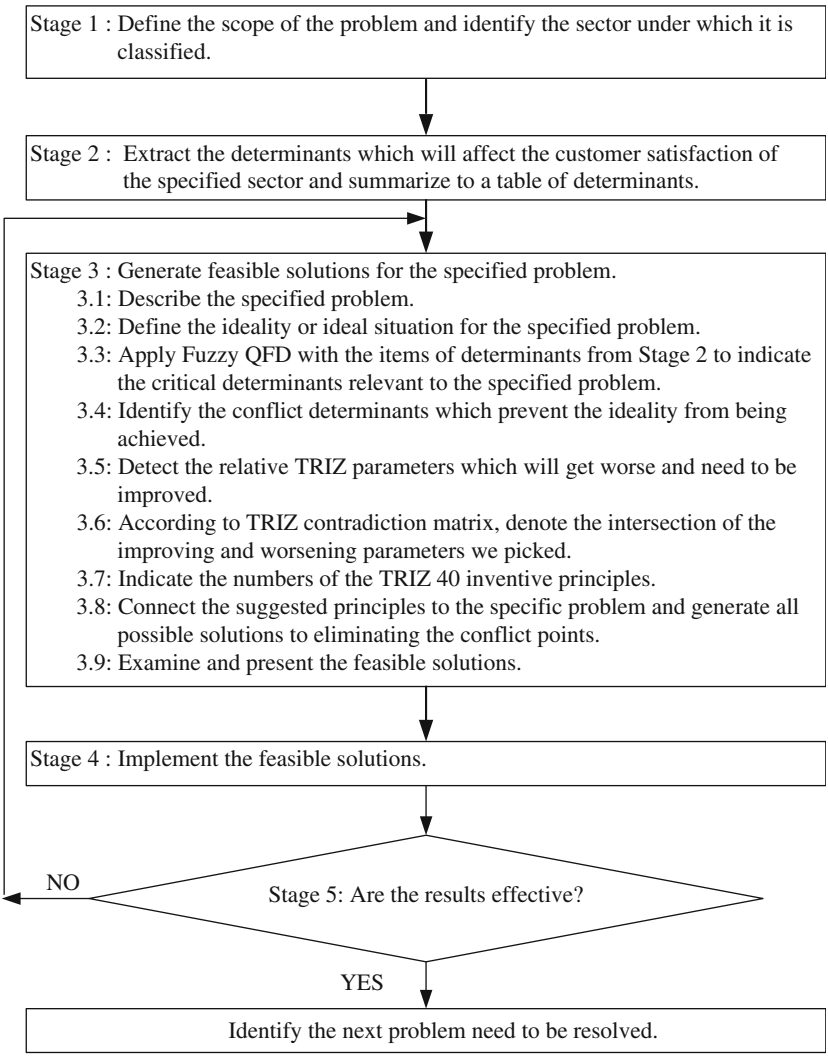

Fig. 1 The systematic problem-solving process for the specified sector

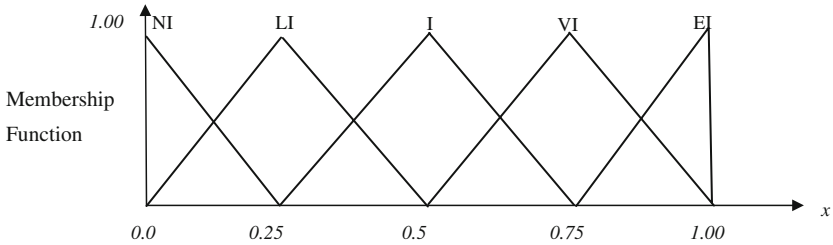

Fig. 2 The figure of the triangular fuzzy numbers in the interval [0,1]

Fig. 3 The membership functions of the triangular fuzzy number

$$\mu_{EI}(x) = \begin{cases} 4x-3, & 0.75 < x < 1 \\ 1, & x = 1 \\ 0, & \text{others} \end{cases}$$

$$\mu_{VI}(x) = \begin{cases} 4x-2, & 0.5 < x < 0.75 \\ 1, & x = 0.75 \\ -4x+4, & 0.75 < x < 1 \\ 0, & \text{others} \end{cases}$$

$$\mu_{I}(x) = \begin{cases} 4x-1, & 0.25 < x < 0.5 \\ 1, & x = 0.5 \\ -4x+3, & 0.5 < x < 0.75 \\ 0, & \text{others} \end{cases}$$

$$\mu_{LI}(x) = \begin{cases} 4x, & 0 < x < 0.25 \\ 1, & x = 0.25 \\ -4x+2, & 0.25 < x < 0.5 \\ 0, & \text{others} \end{cases}$$

$$\mu_{NI}(x) = \begin{cases} 1, & x = 0 \\ -4x+1, & 0 < x < 0.25 \\ 0, & \text{others} \end{cases}$$

$S_{itj} = (q_{itj}, o_{itj}, p_{itj})$ is the triangular fuzzy number of the jth team member assessing the correlative importance between the tth customer requirement and the ith category of service quality determinants. Then S_{it} is defined as the average fuzzy number of the ith category of the service quality determinant for the tth customer requirement, where n is the number of the team members.

$$S_{it} = \frac{1}{n} \sum_{j=1}^{n} S_{itj}. \tag{1}$$

We have $S_{it} = (q_{it}, o_{it}, p_{it})$ calculated by the following equations:

$$q_{it} = \frac{1}{n} \sum_{j=1}^{n} q_{itj}, \tag{2}$$

$$o_{it} = \frac{1}{n} \sum_{j=1}^{n} o_{itj}, \tag{3}$$

$$p_{it} = \frac{1}{n} \sum_{j=1}^{n} p_{itj}. \tag{4}$$

Suppose there is no weighting difference considered among the determinants of service quality, and the integrated fuzzy number of each service quality determinant (Q_i, O_i, P_i) can be calculated by the following equations:

$$Q_i = \frac{1}{k}\sum_{t=1}^{k} q_{it}, \tag{5}$$

$$O_i = \frac{1}{k}\sum_{t=1}^{k} o_{it}, \tag{6}$$

$$P_i = \frac{1}{k}\sum_{t=1}^{k} p_{it}. \tag{7}$$

Step 3.3.4 Defuzzification of output data: It is suggested that the output results be presented in crisp data as they are easier to interpret, and the defuzzification method used in Chen's research (1996) is applied in the current study. Let X denote the defuzzified value of the integrated fuzzy number for each service quality determinant (Q_i, O_i, P_i), and the defuzzified values can be calculated with the following equation:

$$X = \frac{Q_i + O_i + O_i + P_i}{4}. \tag{8}$$

Step 3.3.5 Ranking the defuzzified values of service quality determinants.

Step 3.4 From the most important determinants selected from the rankings, we discuss to identify the conflicting determinants which will enhance and prevent the ideal solution to be acquired.

Step 3.5 Detect the corresponding TRIZ engineering parameters which become worse and need to be improved from the contradiction matrix based on the determinants which were identified from step 3.4.

Step 3.6 According to the TRIZ contradiction matrix, the denoted numbers of the 40 TRIZ inventive principles can be gathered from the intersection of the improving and worsening TRIZ parameters.

Step 3.7 When we indicate the 40 TRIZ inventive principles based on the content of the specified problem, we suggest that the appropriate re-explanations and examples of the 40 TRIZ inventive principles developed in distinct areas be examined and benchmarked. For instance, the studies of Mann and Domb (1999), Rea (2001), Retseptor (2003, 2005), and Zhang et al. (2003) are relevant to service quality in the non-technical field.

Step 3.8 Following the indicated principles and suggested ways, all possible solutions may be generated through various discussing meetings.

Step 3.9 Examine to obtain the feasible solutions with concerned criteria such as cost, time, available human resources, technological level, etc.

Stages 4 and 5 After the feasible solutions have been examined and presented, the confirmed feasible solutions can be implemented in the fourth stage. After a period of implementation, the results can be evaluated with various specified performance criteria in the fifth stage. If the results indicate that the conflicts of the problem were not effectively resolved, the third stage is repeated to examine which step involved the problem.

5 Case study

The studied company, EC.COM, specializes in the development of online database application and has achieved the largest market share in Taiwan, as well as the largest market share in online database software in Asia. The products of EC.COM are designed to help enterprises solve data management problems. With absolute competitive advantages, EC.COM's products have obtained a number of worldwide patents and won appraisal from customers.

The case study focused on providing a systematic way of idea generation to solve EC.COM's problems in service operations and to create valuable services in order to enhance the satisfaction of customers. However, since the delivery of new information technology services and business solutions to their clients, many of the client companies adopting their services experienced various problems in the areas of software availability, online security, maintenance of cost, and technical support. Hence, the company hoped that the true nature of the problems could be studied in depth, and they endeavored to generate solutions that will provide customers with overall value-added services.

We started by organizing a problem-solving team in EC.COM in the first step. Investigations were done on the business map, and interviews with relevant individuals in certain divisions of the company were likewise conducted. Finally, we found that there were various service contradictions contained within the services provided by the company, for instance, the contradiction of "Functionality versus Ease of use" remained unresolved among the division of software design for such a long time, and it might be possible to use TRIZ to resolve the service problems which have embedded contradictions. Therefore, we recognized that our proposed approach is suitable to resolve the problems, and we attempted to follow the steps in Fig. 1 to generate the inventive solutions to resolve the company's problems.

Stage 1 In our studied case, the company delivers and manages computer applications and services from remote data centers to multiple users. Thus, depending on the type of services this company provides, the problem of this company can be classified under the scope of the e-commerce sector.

Stage 2 Service quality is indicated as one of the best performance-based measured factors of success. Hence, in this stage, we studied various perspectives from the existing literature in order to extract the major determinants of service quality in e-commerce. Through the categorization of the related academic papers within the scope of the case problem, we concluded how customer satisfaction is influenced through the identification of the dominant characteristics of e-commerce: determinants of e-business operation, the measurement of the determinants of e-service quality, and the determinants of e-service satisfaction.

After extensively discussing the papers relating to the determinants which affect service quality and customer satisfaction in e-commerce, the items perceived to be similar in explanatory meanings were gathered in the same category and redefined after comparing the definitions of similar determinants. To compute for the total, 29 categories were classified as the dominant characteristics of e-service quality. We summarized and described all these categories of determinants in Table 1.

Stage 3 The feasible solutions were generated through the following steps:

Step 3.1 Software availability, online security, maintenance of cost, and technical support were the four main customer requirements specified in this problem.

Table 1 The Summary of the e-service quality determinants

Category	Determinants	Interpretations	Referenced papers	Name of the referenced papers
1	Active feedback	The activity to find out the best solution for the customer, notification about delays, feedback about procedures and decisions.	[1], [2], [6], [7]	[1] Parasuraman et al. (2005) [2] Stauss (2002)
2	Adequacy	The adequacy of the problem's solution, fairness of the compensation, and fit-to-task information offered.	[2]	[3] Madu and Madu (2002)
3	Aesthetics Appearance Visual appeal Aesthetic design	The appearance of the website including the clarity and readability of texts, and site creativity.	[2], [11]	[4] Szymanski and Hise (2000) [5] Ribbink et al. (2004)
4	Assurance	The ability to convey trust and confidence in the organization with respect to security and privacy.	[3], [6], [8], [11], [15]	[6] Cox and Dale (2001)
5	Communication External communication Internal communication Ease of understanding Friendliness Integration of traditional and Web-based communication	The integration of internal and external communication systems, and the ability of the website to tailor its products and services to meet customers' expectations.	[3], [5], [9], [14]	[7] Surjadjaja, Ghosh and Antony (2003) [8] Santos (2003) [9] Iwaarden et al. (2003) [10] Rea (2001)
6	Compensation Return process Service recovery	The degree to which the website compensates customers for problems.	[2], [6–8], [11], [14]	[11] Loebmann (2002) [12] Wolfinbarger and Gilly (2003)
7	Contact	The availability of assistance through telephone or online representatives.	[1], [7], [13]	[13] Zeithaml et al. (2002)

Table 1 continued

Category	Determinants	Interpretations	Referenced papers	Name of the referenced papers
8	Content Quality of information Up to date information	The presentation and layout of factual information and functions on the website	[8], [13]	[14] Li et al. (2003)
9	Convenience	The trading hours, absence of queues, availability of more alternatives, and faster transactions.	[7], [8], [14]	[15] Yoo and Donthu (2001)
10	Customer service	Responsive and helpful service that responds to customer inquiries quickly.	[7]	[16] Yang and Jun (2002)
11	Customization Personalization Product or service differentiation and customization	The degree of change according to customers' requirements and the ability to learn their needs in order to anticipate.	[1–3], [6–8],	
		their future preferences	[9], [12–14], [16]	
12	Ease of use Intuitive operation	Concise, orderly, easy-to-understand, and easy-to-navigate website contents.	[12]	
13	Effort	The visible effort to resolve customers' problem.	[3], [7], [16]	
14	Empathy Understanding Flow or emotional appeal	The willingness to take customers' perspective.	[5], [8], [11], [15], [16]	
15	Incentives Relative advantage Better than alternative channels	The encouragement given by the website to consumers in consideration of the alternatives already available	[1], [3], [4], [7], [8], [11], [13]	
16	Interactivity Real time assistance by a CSR Support	The services provided to enable interaction between a customer and a company representative or another customer of the website.	[2]	

Table 1 continued

Category	Determinants	Interpretations	Referenced papers	Name of the referenced papers
17	Perceived risk	The level of perceived risk with the activities provided by online service providers.	[2], [3], [6], [9], [11], [14]	
18	Performance Efficiency Navigability Online convenience Linkage Online completeness Storage capability	The ability of the website to access the information needed and make it easily available to its customers when needed	[3–5], [7–9], [11], [12], [14]	
19	Price	The cost which customers are willing to spend in engaging in online activities.	[1], [3], [4], [7], [8], [12], [13], [15]	
20	Credibility Reliability Fulfillment	The ability to perform the promised service effectively, dependability, and consistency in performance.	[8], [10], [11]	
21	Reputation Organizational reputation Consistent image	The perception which is affected by past experience, the site's performance, and other unexplainable intangibles that the customer may perceive.	[2], [3]	
22	Responsiveness Response time Speed of response Processing speed	The processing speed of a company to provide accurate and consistent response, promptness of response to customers' complaints, and speed of online processing.	[7], [8], [11]	

Table 1 continued

Category	Determinants	Interpretations	Referenced papers	Name of the referenced papers
23	Privacy Security and system integrity Security of personal and financial information	The degree to which the site is considered safe and protects customer information, including assurance of shopping behavior data and credit card information.	[3], [10], [11]	
24	Serviceability Individual handling	The quality of provision of various services, and the resolution of conflicts and complaints from customers.	[10]	
25	Features Site design Site effectiveness and functionality Structure and layout Tangibles Innovativeness	How information is effectively presented including all elements affecting consumers' experience in the website.	[7]	
26	Availability System availability Accessibility Access	Easy and convenient access to various sources in the website	[1–3], [7], [11], [13–15]	
27	Systems integration	Internal integration of the company's system or external integration with its business partners.	[3], [7], [9], [11]	
28	Responsibility Trusted service Trust	Exact delivery of promised services and the willingness to help customers in providing prompt service.	[7]	
29	Web store policies	Customer-oriented policies like the provision of effective warranty programs available in online purchases and the assurance of convenience for customers.	[3]	

Step 3.2 Following the principle of ideality in the TRIZ definition, we defined the ideal situation as the "provision of an easily operated environment for users without any effort".

Step 3.3 The Fuzzy QFD process was proceeded to indicate the critical service quality determinants. First, the correlative importance between the specified customer requirements of the problem in step 3.1 and the determinants of service quality in Table 1 was collected in linguistic terms from the opinions of three managers in EC.COM. Then the linguistic variables were translated into triangular fuzzy numbers from Fig. 2. Computing from Eqs. 1 to 4, the average fuzzy numbers of the translating results for the determinants of service quality were obtained. The integrated triangular fuzzy numbers for the determinants of service quality were computed by Eqs. 5–7, and the defuzzied values of integrated fuzzy numbers for each service quality determinant were calculated by Eq. 8. Consequently, the prioritized importance of each determinant was ranked by the defuzzied values.

We identified the first five ranked categories of determinants as the major characteristics which influenced the client's inconvenience when it comes to manipulation and application of the software. The primary determinants selected from each category were the following: Aesthetic design, Ease of use, Interactivity, Reliability, and System availability.

Step 3.4 In order to achieve the ideal situation, with the exclusion of the five important determinants identified in step 3.3 to achieve the ideality, there were relatively two main issues which called our attention:

(1) The design complexity in software and application environment will be increased.
(2) The training cost that EC.COM provides to clients will be increased.

Refer to Table 1 with their intent, and these two conflict points were made to correspond to the determinants of "site effectiveness and functionality" and "price" in e-service quality, respectively.

Step 3.5 Compare the major enhancing properties pointed out in step 3.3 with the 39 TRIZ engineering parameters, and the corresponding TRIZ parameters to be improved were the following: No. 12 Shape (referred from "aesthetic design"), No. 27 Reliability (referred from "reliability"), No. 32 Ease of manufacture (referred from "system availability"), No. 33 Ease of operation (referred from "ease of use"), No. 35 Adaptability or versatility (referred from "interactivity").

Similarly, the corresponding TRIZ parameters which became worse were the following: No. 11 Stress or pressure (referred from "site effectiveness and functionality"), No. 26 Amount of substance (referred from "price").

Step 3.6 According to the TRIZ contradiction matrix, we denoted the numbers of TRIZ inventive principles in the intersection of the improving and worsening TRIZ parameters which were identified in step 3.5.

Step 3.7 We ranked the orders of the denoted numbers of inventive principles by their frequencies: No. 35 occurred six times; No. 1, No. 3, No. 10, No. 12, No. 15, No. 19, and No. 24 occurred two times; and the rest occurred only once. We suggested using those inventive principles occurring at least twice as our targeted reference principles to start with.

Step 3.8 We iteratively analyzed each of the inventive principles and examples from the related researches, and conducted discussions with the managers of the

business development and customer service divisions to generate the following ideas for solutions:

Idea 1 Referring to the subprinciple "change an object's physical state" of the inventive principle No. 35, there was an example which suggested "virtual shopping" in the study of Mann and Domb (1999), and this idea gave us a hint to provide an "online training program" to a client company instead of sending people to train on-site. This suggestion reduced the cost of EC.COM in sending engineers to train the client on how to use the software. The proposed online training service could also be accessed easily at any time and place for the client's convenience.

Idea 2 As to the subprinciple "dividing an object into independent parts" of the inventive principle No. 1, there was an example from the work of Rea (2001) which stated the "division of a system into autonomous components." The customer service division of EC.COM proposed an idea called "Web 080," and this aimed to provide clients with direct online communication through a virtual service representative rather than communicating with the service provider on the telephone only. With a live representative to talk to online, the interface between the service representatives and clients become friendlier.

Idea 3 Referring to the example of the subprinciple "make each part of an object or system fulfill a different and useful function" of the inventive principle No. 3 from Zhang et al.'s work (2003), it is stated that "in most service industries, service package is a mix of tangible and intangible goods." From this example, we appended one more suggestion to idea 1. Besides the "online training program" provided on the website which targets primary or specific customers, it was also helpful to provide an on-site training program to client companies in order to extend relations with them.

Idea 4 From the subprinciple "perform, before it is needed, the required change of an object or system (either fully or partially)" of the inventive principle No. 10, we suggested that EC.COM provide an online chatting session on its website for customers. The new policies or products of EC.COM can be published in advance, though not formally, enabling the company to get opinions from chatting with clients. Through this, the company can realize the needs of customers, and the customers' response can in turn provide valuable information to amend policies or products.

Idea 5 From the example of the subprinciple "allow the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition" of the inventive principle No. 15 from the study of Mann and Domb (1999), it is suggested that a "customer response team" be organized. Likewise, we suggested that EC.COM organize this team which should consist of members from various divisions, including all the divisions relating to customer services.

Idea 6 The example of the subprinciple "if an action is already periodic, change the periodic magnitude or frequency" of the inventive principle No. 19 from Retseptor's study (2003) stated that "monthly and weekly feedback reporting should be done instead of annual reviews." We suggested that the managers of each division in EC.COM should shorten the customer response time period, and focus on the direct customer service divisions from 1 day to 4 h. It was really challenging for these divisions to do so because this practice differed from their current one, but for the sake of obtaining a competitive advantage in this market, it was worthwhile for EC.COM to work out this policy.

Step 3.9 After the solutions were generated, we attempted to prioritize them in the grading based on the following scale and its corresponding values: not feasible (0), weak (1–3), intermediate (4–7), and strong (8–10). We proposed the generated

solutions to the president of the company, who in turn opined that there are three criteria which should be addressed in making the final decision: cost, time, and manpower support. The five proposed ideas were evaluated through the grading done by three managers, and, according to priority, ideas 4, 2, 1, 6, and 5 were arranged, respectively.

Following stage 4 of the problem-solving process in Fig. 1, these solutions were suggested to the company for implementation. Stage 5 is the process to be iterated for the evaluation of the results and for the resolution of new problems which are not further demonstrated in this case study.

6 Discussion and conclusion

As compared to other problem-solving methodologies, TRIZ provides a powerful knowledge-based and systematic procedure to generate quality and innovative solutions without compromise. Specifically, when some aspects of the TRIZ methodology have been successfully applied to challenge the human psychological inertia that aims to break the conventional mindset, the emergence of the TRIZ methodology has therefore been an attempt to stimulate a creative way of thinking and to develop various new solutions.

In this study, in order to capture the characteristics of the e-commerce sector, an extensive literature analysis in the e-commerce sector was used to extract 29 significant categories of the determinants of e-service quality which are closely related to customer satisfaction. We tried to narrow down to a specific scope of work in e-service quality in order to identify the specific vital elements which are valued by e-service providers. Thus, it may be necessary to further discuss the various facts and characteristics of the e-commerce sector and then precisely define the determinants which can be completely acquired.

The other main point emphasized in this study is that when applying the TRIZ method in practice, especially in the primary stage of formulating a problem, the subjective and ambiguous expression of opinions among the problem solvers frequently impedes consensus in the achievement of results. However, the influence of this circumstance is rarely discussed by TRIZ practitioners. As a matter of fact, thereafter, the level of inventive solutions generated from the TRIZ process will be affected by the vague and inappropriate identification of TRIZ engineering parameters. In this regard, the application of the TRIZ method in our study is focused on applying the Fuzzy QFD method to analyze the correlation between the imprecise requirements from customers and the determinants of service quality in order to identify the critical determinants which pertain to customer satisfaction. Consequently, the corresponding TRIZ engineering parameters from the specified problem can be efficiently and precisely extracted.

Following the case example demonstrated in EC.COM, the proposed approach is illustrated to help companies get rid of previous non-systematic practices in developing new services, and as was shown, it is obvious that this methodology is feasible and can be efficiently implemented. From this research, we can foresee the applicability of extensively applying the TRIZ model to a broader arena in the near future.

References

Chen, S.M.: Evaluating weapon systems using fuzzy arithmetic operations. Fuzzy Sets Syst. **77**, 265–276 (1996)

Cox, F., Dale, B.G.: Service quality and e-commerce: an exploratory analysis. Manag. Serv. Qual. **11**(2), 121 (2001)

Iwaarden, J., Wiele, T., Ball, L., Millen, R.: Applying SERVQUAL to Web sites: an exploratory study. Int. J. Qual. Rel. Manage. **20**(8), 919–935 (2003)

Kang, G.D., James, J.: Service quality dimensions: an examination of Grönroos's service quality model. Manag. Serv. Qual. **14**(4), 266–277 (2004)

Li, Y.N., Tan, K.C., Xie, M.: Factor analysis of service quality dimension shifts in the information age. Manage. Auditing J. **18**(4), 297–302 (2003)

Loebmann, A.: The TRIZ methodology- an always ongoing innovative cycle, TRIZ J. March Issue (2002)

Loiacono, E., Watson, R.T., Goodhue, D.: WEBQUAL: a measure of website quality. In: Evans, K., Scheer, L. (eds.) Marketing Educators' Conference: Marketing Theory and Applications, vol. 13, pp. 432–437 (2002)

Madu, C.N., Madu, A.A.: Dimensions of e-quality. Int. J. Quality Reliability Management **19**(3), 246–258 (2002)

Mann, D. Hands-on Systematic Innovation. CREAX Press, Belgium (2002)

Mann, D., Domb, E.: 40 inventive (Business) principles with examples. TRIZ J. September Issue (1999)

Parasuraman, A., Zeithaml, V.A., Malhotra, A.: E-S-QUAL A Multiple-item Scale for assessing electronic service quality. J. Serv. Res. **7**(3), 213–233 (2005)

Rea, K.C.: TRIZ and software- 40 principle analogies, part 1. TRIZ J. September Issue (2001)

Retseptor, G.: 40 inventive principles in marketing, sales and advertising. TRIZ J. April Issue (2005)

Retseptor, G.: 40 inventive principles in quality management. TRIZ J. March Issue (2003)

Ribbink, D., Riel, A.C.R., Liljander, V., Streukens, S.: Comfort your online customer: quality, trust and loyalty on the internet. Manag. Serv. Qual. **14**(6), 446–456 (2004)

Ruyter, K., Wetzels, M., Kleijnen, M.: Customer adoption of e-service: an experimental study. Int. J. Serv. Ind. Manage. **12**(2), 184 (2001)

Santos, J.: E-service quality: a model of virtual service quality dimensions. Manag. Serv. Qual. **13**(3), 233–246 (2003)

Sohn, S.Y., Choi, I.S.: Fuzzy QFD for supply chain management with reliability consideration. Rel. Eng. Syst. Safety **72**, 327–334 (2001)

Stauss, B.: The dimension of complaint satisfaction: process and outcome complaint satisfaction versus cold fact and warm act complaint satisfaction. Manag. Serv. Qual. **12**(3), 173–183 (2002)

Surjadjaja, H., Ghosh, S., Antony, J.: Determining and assessing the determinants of e-service operations. Manag. Serv. Qual. **13**(1), 39–53 (2003)

Szymanski, D.M., Hise, R.T.: E-satisfaction: an initial examination. J. Retailing **76**(3), 309–322 (2000)

Temponi, C., Yen, J., Tiao, W.A.: House of quality: a fuzzy logic-based requirements analysis. Eur. J. Oper. Res. **117**, 340–354 (1999)

Webb, A.: TRIZ: an inventive approach to invention. Eng. Manage. J. **June**, 117–124 (2002)

Wolfinbarger, M., Gilly, M.C.: eTailQ: dimensionalizing, measuring and predicting etail quality. J. Retailing **79**, 183–198 (2003)

Yanashina, H., Ito, T., Kawada, H.: Innovative product development process by integrating QFD and TRIZ. Int. J. Prod. Res. **40**(5), 1031–1050 (2002)

Yang, Z., Jun, M.: Consumer perception of e-service quality: from internet purchaser and non-purchaser perspectives. J. Bus. Strateg. **19**(1), 19–41 (2002)

Yoo, B., Donthu, N.: Developing a scale to measure the perceived quality of an Internet shopping site (SITEQUAL). Q. J. Electron. Commer. **2**(1), 31–46 (2001)

Zhang, J., Chai, K.H., Tan, K.C.: 40 inventive principles with applications in service operations management. TRIZ J. December Issue (2003)

Zeithaml, V.A., Parasuraman, A., Malhotra, A.: Service quality delivery through web sites: a critical review of extant knowledge. J. Acad. Mark. Sci. **30**(4), 362–375 (2002)