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Using integrated quality function deployment and theory of innovation problem solving approach for ergonomic product design

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ABSTRACT

A multidisciplinary approach integrating method of identification of customer satisfaction needs (CSNs), the House of Quality (HoQ) chart of quality function deployment (QFD), theory of innovation problem solving (TRIZ) and fuzzy group decision-making theory for ergonomic product innovative design and evaluation in the early design stages was proposed. An integrated model and the approach procedures consists of four steps. In step 1, identification of CSNs is based on a data source triangulation approach, questionnaire survey, 5-point liner numeric rating scale, factor analysis, and Cronbach's coefficient alpha statistic are utilized to guarantee that the CSNs are complete and reliable. In step 2, a correlation matrix is built to identify the critical ergonomic design areas and the key problems are established by analysis of the negative relationships obtained from interrelationship half-matrix at the roof of the HoQ. In step 3, to solve the problems, TRIZ main tools and contradiction analysis are utilized. Several innovative alternatives are generated by combining appropriate Inventive Principles of TRIZ, the critical ergonomic design areas and the ergonomic design principles. In step 4, a general and easy fuzzy group decision-making method for evaluating of the best design alternatives is presented. A case study of the integrated kitchen stove innovative design and evaluation is conducted to demonstrate the applicability of the proposed approach.

1. Introduction

Product design is a critical factor during the early phase of new product development (Crawford, 1997, Chapter 4). Enhancing customer satisfaction and providing innovative products become crucial strategies for success. Product designers normally focus on functionality, quality and cost, which have long been the most important factor in product design. However, in recent years, research in ergonomics and design aesthetics has illuminated that product functionality, quality and cost may not be the main determinant of customer satisfaction but that other design elements such as safety, comfort (Vink, Overbeeke, & Desmet, 2005, Chapter 4), usability and pleasurable appeal (Jordan, 1998, Chapter 3, 2000), emotion (Nagamachi, 2002), attractiveness and individuation (Liu, 2003) also play an important role. The focus of ergonomics is to study the role of humans in the safe and efficient operation of complex industrial systems and the application of ergonomic principles and anthropometric data to the design of products. An ergonomic product may be expressed through the elements of safety, comfort, easiness, size, etc. With regard to design aesthetics, it may refer to the objective features of a stimulus such as shape, color, tone and texture (Postrel, 2003, Chapter 5; Schifferstein & Hekkert, 2007, Chapter 2) or to the subjective reaction like attractiveness to the specific product features.

Customers have been pursuing ergonomically well-designed and aesthetic product. The reason for customers shifts is that ergonomic product design based on anthropometric dimensions and ergonomic principles may prevent the risk of occupational injuries (Sperling et al., 1993) and ergonomically well-designed product also offer comfortable use and high pleasure to the customers (Motamedzade, Choobineh, Mououdi, & Arghamj, 2007). Through experiments, Sonderegger and Sauer (2010), reported that perceived usability was positively influenced by the design aesthetics of the product. Design aesthetics is an important tool to attracts customers and gain their attentions. Product designers should thus provide ergonomic and aesthetic expertise to ergonomic product design problem through innovative methods and tools.

With regard to the design mehods for new product development, quality function deployment (QFD) is an important methodological approach to increase customer satisfaction and reduce the

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product costs and development cycle time. Proposed by Akao (1997, Chapter 1), QFD was originally developed at Mitsubishi's Kobe shipyards in 1972. According to House of Quality (HoQ) chart, the most recognized and widely used form of QFD, voice of customer can be availably and entirely translated into engineering characteristics. QFD has been successfully applied by industries around the world (Bergman, 1994, Chapter 3; Geuma, Kwak, & Yongtae Park, 2012; Vezzetti, Moos, & Kretli, 2011).

In addition, originally proposed by Altshuller, the theory of innovation problem solving (TRIZ) solves technical problems and provides innovative product structures by employing a knowledge base built from the analyses of approximately 2.5 million invention patents. The TRIZ approach has applied to numerous design problem-solving such as therapy bike design proposal for cerebral palsy children (Lin & Luh, 2009), vacuum cleaner design (Russo, Regazzoni, & Montecchi, 2011), five cooling device concept solutions to overcome the interface conflicts (Wessel, Tom, & Vaneker, 2011), and Technology Forecasting of washing machine (Solomani, Hua, Shi, & Wang, 2004). In each of these cases TRIZ is used as problem solving tool in order to provide solutions for innovative product design. Besides, designers provided eco-friendly solutions to product design problem through TRIZ methods to help implement eco-friendly designs. Fresner et al. (2010), used TRIZ in cleaner production to minimize industrial waste and emissions by increasing the efficiency of the use of materials and energy. Pelt and Hey (2011), compared the BetaMax by Sony Corporation with the Video Home System (VHS) by Japan Victory Corporation to exemplify technologically superior products failing to become a success. Several TRIZ specialists, as a result, have made efforts to integrate TRIZ with other design methods and tools. Alan Van Pelt addressed the application of TRIZ together with Human-Centered Design (HCD). Others have proposed integration with the Neuro Linguistic Programming to understand customers (Mann, 2002, Chapter 5) or the Kano model (Hashim & Dawal, 2012). Hipple (2006) interprets many consumer products from the perspective of the TRIZ methodology and Mann (2002, Chapter 2) provides an extension of the classical 9-Windows tool to include consideration of behavior, capability, and beliefs, values, and identity. Known as an innovative idea generation tool, TRIZ was prevailed and accepted in worldwide corporations such as Philips, Samsung, Siemens and Motorola.

Moreover, several alternatives of ergonomic product innovative design are generated in the early design stages. The method for evaluating of the best design alternatives is critical to success in new product development. Recently, Multi-Criteria Group Decision-Making (MCGDM) method is used in many real-world decision-making situations in various kinds of engineering and management fields (Hatami-Marbini & Tavana, 2011; Mojtahedi, Mousavi, & Makui, 2010; Vahdani, Meysam Mousavi, Tavakkoli-Moghaddam, & Hashemi, 2013). Selecting of design alternatives is a MCGDM problem which involves many factors of both customer needs and business constraints. In the early design stages, evaluation of design alternatives is difficult to precisely express by crisp data because the information available is usually subjective or imprecise. So, it is more appropriate to present the data by fuzzy numbers instead of crisp numbers (Buyuközkan, Arsenyan, & Ruan, 2012; Geng, Chu, & Zhang, 2010).

Despite of many success stories on both QFD and TRIZ applications, all of them implementation are not without problems. QFD is effective to indicate what problems to solve in order to satisfy customer needs, but does not necessarily offer a guide on how to generate solutions for the problem identified. With regard to overcome this challenge, TRIZ is one of the effective tool, However, TRIZ specialists are in doubt whether the problem or contradiction to be solved is the right one. Accordingly, a method of integrated QFD and TRIZ at product design stage for generating innovative alternatives is proposed. Besides, evaluating of ergonomic design alternatives is formulated as MCGDM problem and the evaluation criteria of alternatives have subjective perceptions. Therefore, fuzzy group decision-making method is proposed for the ergonomic design alternatives evaluation to ensure a more efficient and rational decision process. In this paper, we put forward a multidisciplinary approach integrating identification of customer satisfaction needs (CSNs), HoQ chart of QFD, TRIZ and fuzzy group decision-making theory for ergonomic product innovative design and evaluation in the early design stages.

2. Theoretical background

2.1. Quality function deployment (QFD)

2.1.1. The House of Quality (HoQ) chart of QFD

Quality function deployment (QFD) is a method for developing a design quality aimed at satisfying the customer and then translating the consumer needs into design targets and major quality assurance points to be used throughout the production stage.

The primary chart used in QFD is the House of Quality (HoQ). According to the HoQ, customer needs are translated into engineering characteristics, and subsequently into part or component characteristics, the process operations, and production requirements associated with the manufacturing process. Therefore, accuracy of customer needs input is critical for applying the HoQ with success. Toyota halved their design costs and reduced development time by a third after use QFD (Hauser and Clausing, 1988, Chapter 4). Marsot (2005) used the HoQ to design a boning knife. Haapalainen (1999/2000) evaluated pruning shears using the HoQ. Kuijt-evers, Morel, Eikelenberg, and Vink (2009), applied QFD as a design approach to ensure comfort in screwdriver design. Lo, Tseng, and Chu (2010), advanced One-step QFD for concept generation of computer mice design. The SOFRAGRAF Company has used QFD for the design of hand tools, staplers, nailing machines, etc. with success. In each of these cases QFD is successfully used as the tool that illustrates the translation of customer needs into product design characteristics in order to increase customer satisfaction (Lai, Xie, Tan, & Yang, 2008; Raharjo, Brombacher, & Xie, 2008).

The procedures of the traditional HoQ chart of QFD are divided into the following six steps (Fig. 1).

Step 1: Identifying the customers.
Step 2: Determining customer needs.

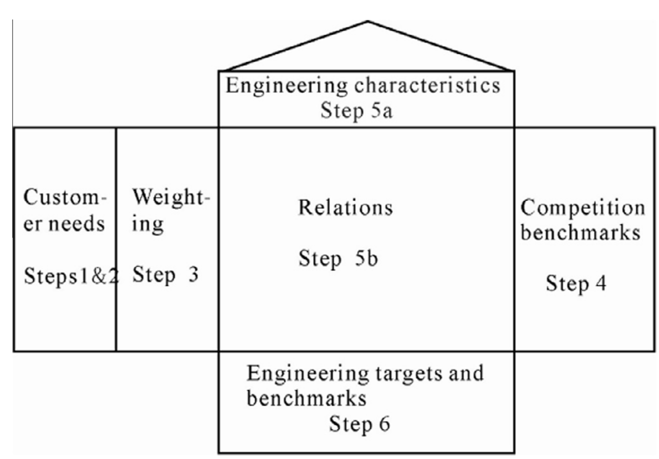

Fig. 1. QFD procedures model.