Expert Systems with Applications 37 (2010) 6775–6786

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A fuzzy-AHP approach to prioritization of CS attributes in target planning for automotive product development

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ARTICLE INFO

Keywords:
Fuzzy theory
Customer satisfaction attributes
AHP
Target planning
Automotive

ABSTRACT

Understanding customer requirements and incorporating them into the conceptual vehicle design is the first step of automotive product development (PD). However, lack of quantitative data and undefined relationships between the attributes makes it difficult to develop a quantitative model for analyzing subjective customer satisfaction (CS) attributes. While researchers and practitioners have accomplished a significant success in terms of developing tool such as quality function deployment (QFD) to capture the voice of customers, and mathematical models for selecting engineering design alternatives, there is limited precedence in terms of prior works on customer satisfaction driven quality improvement target planning and prioritization of customer satisfaction attributes for target planning. This paper presents a fuzzy set theory based analytic hierarchy process (fuzzy-AHP) framework for prioritizing CS attributes in target planning. Furthermore, unlike prior QFD papers, we consider a broad range of strategic and tactical factors for determining the weights. These weights are then incorporated into target planning by identifying the gap in the current CS level. A case example from automotive industry is presented to demonstrate efficacy of the proposed methodology. The framework has been implemented on MS Excel® so that the industry can easily adopt it with limited amount of training and at no additional software cost.

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1. Introduction

The automotive industry is striving hard to continuously develop higher quality products and improve business effectiveness. The industry uses various customer satisfaction attributes to improve the design of a vehicle. J.D. Power and Associates index is perhaps the most popular customer satisfaction survey used in automotive world (Power & Associates, 2007). They consider 77 vehicle attributes to measure customer satisfaction (CS). Both industry and customers consider these vehicle attributes as critical vehicle performance indicators and therefore important purchasing decision factors. Therefore, the auto industry uses them as one of the quantifiable measures to assess the vehicle performance, to identify potential improvement areas in CS and set future targets for further improvement. Generally, the customer satisfaction targets for vehicle attributes are set at the corporate level based on business and market consideration.

Realistically, it is not feasible to address all the potential attributes at once due to such practical constraints as the availability of budget and time, corporate strategic planning, product differentiation strategy, competitive product features, to name a few. Moreover, not all auto companies give equal importance to each attribute because every individual company tries to compete on different product features and attributes. This necessitates the prioritization of potential improvement opportunities (or vehicle attributes) while taking into consideration the existing gap and other practical consideration as mentioned above. However, the challenge is that most of these practical considerations are imprecise (or fuzzy), lacking quantitative measures, and often conflicting in nature. The top management always deliberates these issues in target planning process; however, there is no structured methodology available in public domain that provides a mechanism to capture these considerations in attribute prioritization and CS target setting.

The determination of correct relative importance of CS (vehicle) attributes is extremely important in order to achieve total alignment of continuous improvement efforts with corporate (business) strategy. Kano model (Kano, Seraku, Takahashi, & Tsuji, 1984) has been widely used by the design community to identify and prioritize those few attributes that have more potential to achieve higher CS (CQM, 1993; Yadav & Goel, 2008). Although various methods have been proposed to assign weights to the identified customer requirements, not much has been reported on the prioritization

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0957-4174/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.eswa.2010.03.048

of vehicle attributes. Ho, Lai, and Chang (1999) propose a group decision-making technique for obtaining the importance weights for the customer requirements. Analytic hierarchy process (AHP) developed by Saaty (1980) has been widely used in weighting customer requirements. Gustafsson and Gustafsson (1994) use a conjoint analysis method to determine the relative importance of the customer requirements. All these methods employ pair-wise comparisons of customer requirements to determine their relative importance.

Interestingly, the pair-wise comparison methods are based on crisp real number. However, in reality the expert's assessment in pair-wise comparison is always subjective and imprecise (Chan, Kao, Ng, & Wu, 1999). In order to deal with this deficiency, Kwong and Bai (2002, 2003) propose a fuzzy-AHP with an extent analysis approach to determine the importance weights for the customer requirements in quality function deployment (QFD). Another recent application of the integrated fuzzy-AHP model is proposed by Sun, Ma, Fan, and Wang (2008) in the selection of experts for evaluating R&D projects. However, the prioritization of CS vehicle attributes for target planning presents different and rather unique challenge of ensuring complete alignment of CS driven quality improvement efforts with corporate business strategy. The failure to do so will result in mismatch between corporate level business strategy and product development initiatives. Therefore, our intent in this research is to address the need for a comprehensive methodology for prioritization of CS attributes by dealing with subjective and imprecise assessments and ensuring proper alignment between corporate strategy and quality improvement initiatives in PD process.

The objective of this paper is to present a fuzzy-AHP framework for determining the relative importance of customer satisfaction attributes in target planning decisions to improve the functionality and performance of a product. With the AHP component, we determine the relative importance of product CS attributes more rationally by synthesizing all available information about the decision in a system-wide and systematic manner. The model further helps us to rank order the attributes by considering multiple factors according to the preference of decision makers. However, AHP's pair-wise comparison process involves semantic judgment and linguistic comparisons and uses ratings scale like "highly important than", "moderately important than" etc. which are "fuzzy" in nature. This is especially the case when the CS attributes are set at the corporate level. In order to analyze this subjective information, we propose a fuzzy logic based approach and perform sensitivity analysis of designer's confidence level on human judgment versus CS attributes prioritization decisions. Unlike Kwong and Bai (2002) application of fuzzy-AHP in QFD, our framework incorporates broader strategic factors (than just engineering) such as marketing, and long term strategic related criteria in target planning. Thereby, our framework integrates the corporate level business strategy with the product development initiatives. Another advantage of our approach is that the whole framework is implemented on MS Excel® which facilitates the adoption process in industry without incurring any additional cost for the software. While this paper discusses automotive case example to demonstrate the methodology, the proposed framework can be applied to any prioritization decision making setting involving multiple factors with limited information and dealing with semantic comparisons.

Section 2 describes the fuzzy-AHP methodology for prioritization of customer satisfaction attributes for target planning; Section 3 presents a case example from automotive application; in Section 4, we discuss results, sensitivity analysis and its utility in target planning; and finally Section 5 summarizes the contribution of the paper with some concluding remarks and a direction for future work.

2. Suitability of fuzzy-AHP for CS attributes prioritization problem in target planning

The traditional form of AHP has been widely used across the industry in many applications such as for project selection (Mustafa & Al-Bahar, 1991), setting priorities, allocating resources (Barbarosoglu & Pihas, 1995), measuring performances (Lee, Kwak, & Han, 1995), resolving conflict, and dealing with quality management, and strategic planning and policy making (Hongre, 2006). Cimren, Catay, and Budak (2007) have developed a decision support system for tool selection while Liu and Wu (2005) used AHP for supplier selection problem. Sharma and Gandhi (2006) have used it for determining remaining useful life of lube oil. The AHP treats the decision as a system and provides a structured approach to solving complex problems. In early stages of product development, the decision makers have limited or no clue about the relationship between different CS attributes or factors and how they can possibly be mapped with vehicle attributes. Decision makers struggle with many important but ill-defined attributes in terms of prioritizing and pursuing them for further actions to improve the functionality and performance of the product. Bounded rationality and limited cognitive processes make it nearly impossible for the decision maker to adequately consider all of the factors in a complex screening decision. Without a structured approach, the design engineers and PD managers are likely to base their decisions on only a subset of important criteria without understanding their relative importance and interactions. The AHP provides a framework for solving different types of complex and multi-criteria decision making problems based on the relative importance assigned to each criterion's contribution in accomplishing the stated goal or objective (Handfield, Walton, Sroufe, & Monczka, 2002). It employs a system-wide solution approach in systematic manner by synthesizing all available information that otherwise might not be possible (Handfield et al., 2002).

In this research, we use a fuzzy-AHP approach for determining the weights for CS attributes, because, early in the PD process the weight determination problem primarily depends on subjective judgment (or preference) of the design team. In such a situation, it is difficult to incorporate preference scales (such as "less likely", "more likely" etc.) in the analytical models. In fact, the meaning of "preference" is already embedded in fuzziness and human semantics. Therefore, using a crisp value for pairwise comparison is not suitable because it does not accurately represent the individual semantic cognition state of the decision makers. Fuzzy logic (Zadeh, 1965) is a proven scientific technique that allows us to convert linguistic measures into crisp measure using membership functions. Membership functions define the fuzzy boundary between two measurements scales such as 'less likely' and 'likely".

2.1. The proposed fuzzy-AHP model

Except for the fuzzy representation of pairwise comparison, the other steps in the proposed fuzzy-AHP model are same as those in the traditional AHP. The basis of AHP method is the hierarchical representation that helps to solve a complex problem through successive simple processes (Hongre, 2006). It requires a problem to be decomposed into levels, each of which is comprised of elements or factors. The elements of the hierarchy in a given level are mutually independent, but comparable to the elements of the same level. Each element must connect to at least one element of the next higher level, which is considered as a criterion according to which we compare the elements of the next level below. Typically, the following steps are required in an AHP model (Udo, 2000).