Computers & Industrial Engineering 56 (2009) 368–379

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

# A hybrid approach to concept selection through fuzzy analytic network process

Z. Ayağ [a,*], R.G. Özdemir [b]

[a] Kadir Has University, Faculty of Engineering, Department of Industrial Engineering, Kadir Has Campus, 34083 Cibali, Istanbul, Turkey

[b] Istanbul Kültür University, Faculty of Engineering and Architecture, Department of Industrial Engineering, Atakoy Campus, D-100 Yanyol, 34156 Bakirkoy, Istanbul, Turkey

A R T I C L E   I N F O

*Article history:*
Received 4 September 2007
Received in revised form 11 June 2008
Accepted 13 June 2008
Available online 20 June 2008

*Keywords:*
New product development (NPD)
Concept selection
Multiple-criteria decision-making (MCDM)
Fuzzy logic
Analytic network process (ANP)

A B S T R A C T

Evaluating conceptual design alternatives in a new product development (NPD) environment has been one of the most critical issues for many companies which try to survive in the fast-growing world markets. Therefore, most companies have used various methods to successfully carry out this difficult and time-consuming evaluation process. Of these methods, analytic hierarchy process (AHP) has been widely used in multiple-criteria decision-making (MCDM) problems. But, in this study, we used analytical network process (ANP), a more general form of AHP, instead of AHP due to the fact that AHP cannot accommodate the variety of interactions, dependencies and feedback between higher and lower level elements. Furthermore, in some cases, due to the vagueness and uncertainty on the judgments of a decision-maker, the crisp pairwise comparison in the conventional ANP is insufficient and imprecise to capture the right judgments of the decision-maker. Therefore, a fuzzy logic is introduced in the pairwise comparison of ANP to make up for this deficiency in the conventional ANP, and is called as fuzzy ANP. In short, in this paper, a fuzzy ANP-based approach is proposed to evaluate a set of conceptual design alternatives developed in a NPD environment in order to reach to the best one satisfying both the needs and expectations of customers, and the engineering specifications of company. In addition, a numerical example is presented to illustrate the proposed approach.



## 1. Introduction

Today's world is characterized by major changes in market and economic conditions, coupled with rapid advances in technologies. As the natural result of this, companies have been forced to develop new products for current markets, most of all technology-driven or high-tech markets. The changing economic conditions and technologies combined with increased domestic and global competition, changing customer needs, rapid product obsolescence and the emergence of new markets, require very fast innovation process. The innovation process can be divided into three main areas such as fuzzy front-end (FFE) or project planning, new product development (NPD) process, and commercialization.

A NPD process is the sequence of steps or activities which an enterprise employs to conceive, design and commercialize a product. This development process typically includes the following activities: (i) identifying customer needs, (ii) establishing target specifications, (iii) concept generation, (iv) concept selection, (v) concept testing, (vi) setting final specifications, (vii) project planning, (viii) economic analysis, (ix) benchmarking of competitive products, (x) modeling and (xi) prototyping. In the NPD process, in item (v), a set of concepts are introduced and needs to be evaluated in terms of the criteria (i.e. highest performance and lowest cost) to reach to ultimate one. This process is called concept selection (Ayag, 2005b).

Concept selection is often the Rubicon in the design process. It is vital that the best concept is selected, as it determines the direction of the design embodiment stage. It is often said in the literature that nearly 60–80% of the cost is committed at this stage (Duffy, Andreasen, Maccallum, & Reijers, 1993). After this stage has been passed, the design process will diverge towards a detailed solution. Concept selection is therefore a vital part in the design process. It is recognized that the ability to rapidly evaluate design ideas, throughout their development within the design process, is an essential element in the goal to increase design productivity. Given the need for companies to produce more and more innovative products in an increasingly competitive market place, it follows that designers have to consider an increased number of design options. The activity of judging between and selecting from a range of competing design options is referred to as evaluation. As the number of options to evaluate increases and the time available decreases, it is evident that human evaluators will require increasing assistance in selecting the most satisfying design alternative. Due to the fact that the evaluation process of conceptual design alternatives is a multiple-criteria decision-making (MCDM) problem in the presence of many criteria and alternatives, a decision-maker(s) needs to use one of current MCDM methods. In this

* Corresponding author. Tel.: +90 212 533 6532x1409; fax: +90 212 533 5753.
*E-mail address:* zekia@khas.edu.tr (Z. Ayağ).

0360-8352/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cie.2008.06.011

paper, we utilized analytic network process (ANP) as presented next.

As one of the most commonly used techniques for solving MCDM problems, analytic hierarchy process (AHP) was first introduced by Saaty (1981). In the AHP, a hierarchy considers the distribution of a goal amongst the elements being compared, and judges which element has a greater influence on that goal. In reality, a holistic approach like ANP is needed if all attributes and alternatives involved are connected in a network system that accepts various dependencies. Several decision problems cannot be hierarchically structured because they involve the interactions and dependencies in higher or lower level elements. Not only does the importance of the attributes determine the importance of the alternatives as in the AHP, but the importance of alternatives themselves also influences the importance of the attributes.

Furthermore, in the conventional ANP method as in the AHP, the pairwise comparisons for each level with respect to the goal of the best alternative selection are conducted using a nine-point scale of Saaty. If this nine-point scale is used to make all pairwise comparions in the ANP, some shortcomings are observed similar to the AHP as follows: (i) it is mainly used in nearly crisp decision applications, (ii) it creates and deals with a very unbalanced scale of judgment, (iii) it does not take into account the uncertainty associated with the mapping of one's judgment to a number, (iv) its ranking is rather imprecise and (v) the subjective judgment, selection and preference of decision-makers have great influence on its results. Due to the vagueness and uncertainty on judgments of the decision-maker(s), the crisp pairwise comparison in the conventional ANP seems to be insufficient and imprecise to capture the right judgments of decision-maker(s). Therefore, in this study, a fuzzy logic is introduced in the pairwise comparison of ANP to make up for this deficiency in the conventional ANP, called as fuzzy ANP.

The objective of this paper is to present a fuzzy ANP-based approach to the concept selection problem using triangular fuzzy numbers in order to reach to the ultimate one satisfying both the expectations of customers, and the engineering specifications of company. Furthermore, a numerical example is presented to illustrate the proposed approach.

## 2. Related research

A NPD environment is a strategic business activity by intent or by default (Whitney, 1988). It is not only the critical linkage between a business organization and its market, but it is also fundamental to business success. Business organizations need to manage their product development activities strategically to gain competitive advantage in the market place. Firms that fail to manage their product development activities strategically are not only running their business from a position of disadvantage but also risking their future (Fitzsimmons, Kouvelis, & Mallick, 1991). The critical role of NPD in the survival and success of business organizations and the need for managing it strategically is being recognized increasingly in both the academic (Brown & Eisenhardt, 1995; Finger & Dixon, 1989a, 1989b; Griffin & Hauser, 1996; Krishnan & Ulrich, 2001) and practitioner literature (Chesbrough & Teece, 2002; Gates, 1999; Welch & Kerwin, 2003).

In a NPD process, concept selection is an important activity because it strongly influences its upstream and downstream activities in a NPD environment. As the result of this, many methods have been introduced to concept selection. In the literature, five main types of concept selection methods (CSMs) are defined by King and Sivaloganathan (1999) as follows: utility CSMs, AHP CSMs, graphical CSMs, QFD matrices, and fuzzy logic CSMs.

The evaluation of each CSM method is shortly summarized as follows: (i) *Utility theory:* Utility theory has formed the basis for the majority of CSMs in the literature. The method was first developed for economic decision-making and has since been incorporated into a number of systematic design models. The core principle in the theory is a mapping of how criteria will vary across the range of each criterion. This relationship is governed by a utility function. (ii) *AHP:* AHP was first developed by Saaty (1981) for decision-making, and Marsh, Moran, Nakui, and Hoffherr (1991) have developed a more specific method directly for design decision-making. The Marsh AHP has three steps ordering the factors (i.e. attributes) of a decision such that the most important ones receive greatest weight. (iii) *Graphical:* Pugh (1991) gives a simple graphical technique that centers on a matrix with columns (showing concepts), and rows (giving decision criteria). Pugh's evaluation matrix is very simple and fast. However, no measure is given of the importance of each of the criteria and it does not allow for coupled decisions. Therefore, there is a danger that the final concept can be distorted. The simplicity of Pugh's evaluation matrix makes the method a good screening process against highly unfeasible concepts and can allow the designer to focus on the best concepts using a different CSM. (iv) *Quality function deployment* (*QFD*) *matrices:* QFD is a graphical adaptation of utility theory with several additions to assist decision-making building block of the method is a matrix chart known as a ''House of Quality (HoQ)'' and columns follow the method of utility as given earlier in this paper. While the matrix follows utility theory in many ways, the interaction chart gives a measure of coupled decisions. However, no numerical method is given to this measure into the QFD calculation. Without a numerical method, this become complex for most design situations where many concepts are visual comparison would be almost impossible. (v) *Fuzzy logic:* Fuzzy logic is a concept used when a decision needs to be made near the boundary of two outcomes. Thurston and Carnahan (1992) proposed the application of fuzzy set theory to multiple-criteria engineering design evaluation process. They do not use normalized weights in order that the extended division will not be needed in the calculation. They developed a fuzzy logic CSM.

Comparing the methods above is given as follows: At a conceptual design phase, if information quality may be low and so systematic methods which are the easiest to use, such as those of Pahl and Beitz (1984) Pugh charts (Pugh, 1991) are appropriate. Most methods reviewed allow for multiple attributes to a decision, although the QFD matrix method represents this facility with greatest clarity because of its graphical template. The QFD method provides a qualitative interaction table, but this is used for ''optimal conflict information'' and does not provide a quantitative analysis of how one decision affects another. A choice to use one technology or component will significantly affect the rest of the design. The fuzzy logic method does require a rather lengthy methodology and is by no means easy to use. It is still necessary to determine the mathematical equation in order to establish a solution. In the field of design decision-making, many decisions are not based upon known (or definable) mathematical equations. The methodology therefore has a very limited advantage when considered as a general methodology for a CSM. In addition, none of the utility methods given in the literature accommodate coupled decisions within the calculation, although they are a reality in most design situations.

As one of the above-mentioned CSMs, the AHP has been widely used for MCDM selection problems in the literature (i.e. Ayag, 2002, 2005a; Scott, 2002; Zahedi, 1986). But, in this study, we used ANP, a more general form of AHP due to the fact that the AHP cannot accommodate the variety of interactions, dependencies and feedback between higher and lower level elements. The ANP approach may be considered as a second generation AHP, which