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# Market demand estimation for new product development by using fuzzy modeling and discrete choice analysis

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ABSTRACT

Market demand estimation is an important process to assess the financial feasibility of new product development (NPD) projects. The development of models for market demand estimation involves market potential estimation and choice modeling. Previous studies commonly used conjoint analysis to develop utility functions which were then used in discrete choice models to generate market share models. The jury of executive opinion method is commonly used in industries wherein a number of experts and/or consultants are always involved in the market potential estimation. However, a high degree of fuzziness always exists in the data obtained from conjoint surveys and the market potential estimation because of the subjective judgments of respondents and experts. However, ignorance of the fuzziness would lead to the over-estimation of market demands. This research aims to tackle the fuzziness associated with market potential estimation and survey data in the development of market demand models. In this paper, a new methodology of developing fuzzy market demand models for NPD is proposed to address the fuzziness by which market demands can be estimated for the worst, normal, and best scenarios. The proposed methodology involves fuzzy choice modeling based on fuzzy regression and discrete choice analysis, and fuzzy estimate generation of market potential. To evaluate the effectiveness of the proposed methodology, a case study of market demand estimation of a new tablet PC is conducted based on the proposed methodology. The results of the implementation are compared with those based on a popular multinominal logit (MNL) based demand model. From the comparison, it can be noted that the estimated market demand based on the MNL model is very close to that for the normal scenario based on the proposed fuzzy demand model. However, the MNL model cannot provide estimates for other scenarios.



## 1. Introduction

Market demand estimation is widely used to assist companies in assessing the financial feasibility of new product development (NPD) projects. Market demand estimation commonly involves choice modeling and market potential estimation. Choice modeling [17] is a common method used in the decision-making process to understand customer buying behavior and preferences and measure tradeoffs among attributes in a given set of product alternatives. Early choice modeling applications have been used to solve problems in the travel, transportation, and tourism industries according to the principle of utility maximization of customers. In the last decades, choice modeling has been widely applied in marketing research [16]. In recent years, it has been used to associate consumer preferences with design attributes for NPD [26]. Choice modeling has a number of applications in the demand modeling of product design because of the necessity of integrating engineering design attributes with marketing desired attributes. Choice modeling can capture consumer preferences for a set of competitive products, thus making this approach suitable for integrating marketing and engineering approaches in product design [1]. Choice modeling outputs provide important information to decision makers in determining product features and variables to satisfy customer expectations. The latest research in choice modeling aims to understand heterogeneous consumer preferences, estimate market demand under competition and/or uncertainty, and study uncertainties associated with customer purchasing behavior in demand modeling [26].

Discrete choice analysis (DCA) is a disaggregate approach to choice modeling that is based on probabilistic distribution theory, which seeks the utility fraction of a given product among a set of competitive products. DCA aims to maximize the total utility of individual consumers who respond to experiments/surveys by capturing the tradeoffs among product attributes. DCA uses

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preference data to estimate the choice probabilities of competing alternatives for individual consumers. These individual estimations are then aggregated to predict the total choice share. Various DCA models, such as multinomial logit (MNL) [1,21], nested logit [8] and mixed logit (MXL) [4,26], have been applied in the demand modeling.

Conjoint analysis is a popular technique for capturing consumer preferences and measuring tradeoffs by estimating the consumer part-worth utilities for each attribute level of a product. Conjoint analysis can be used to generate the utility functions of products and determine the optimum setting of product attributes by using the collected data of conjoint surveys. Various types of conjoint analysis such as rankings, ratings, and choice-based alternatives exist [1]. Conjoint analysis and DCA have been successfully applied to develop market share models for new products [9,10]. Market potential estimations are combined with the generated market share models to develop market demand models. The jury of executive opinion method [2], wherein several experts are involved in the estimation, is commonly used in industries to estimate market potential for new products. However, marketing experts estimate market potential mainly based on their own subjective judgments and their estimates are always ambiguous such as 'somehow about 80 thousands', and 'close to 95 thousands'. As described by Kosko [7], fuzziness is "event ambiguity" which indicates the degree of occurring an event rather than randomness. Thus, estimates of market potential based on the jury of expert opinion can contain a high degree of fuzziness.

Studies have been conducted to consider the uncertainties in market demand estimation. Uncertainties such as subjective responses in surveys data, dynamic market conditions, and rapid technological development can significantly affect the predictive accuracy of developed market demand models. Therefore, the uncertainties should be considered in the development of market demand models. Turksen and Willson [27] developed a fuzzy set preference model to solve the problem of linguistic variable ambiguity in demand modeling in which fuzzy set was introduced to define subject ratings as linguistic ratings rather than numerical ratings, which is applied on conjoint analysis. Given the vagueness of consumer preferences, Lau et al. [11] extended the MNL model with switching regression techniques. Fuzzy part-worth utilities were proposed under different crisp and fuzzy scenarios to determine an optimal product line extension scheme, and estimate the market share by considering the uncertainty in consumer preferences [14]. Resende et al. [21] applied the Delta method to consider the uncertainty of choice model parameters in determining an optimal setting of product design attributes because of the vagueness in profit and market share estimations.

Demand uncertainty is caused by preference dynamics, demand model misspecification, choice context, and response variability. Xiong et al. [29] studied uncertainty in consumer demand by integrating fuzzy set theory into demand modeling to solve a dynamic pricing problem. Williams et al. [28] used multi-objective robust optimization approach to handle uncertainty issues in the market share estimation of bundled products. Razu and Takai [20] attempted to model uncertainty in market demand by estimating customer utility errors by applying bootstrap and Monte Carlo simulation on choice-based conjoint analysis. Lemos et al. [13] introduced the evolving fuzzy linear regression tree method to manage the risks and uncertainties associated with the sales forecasting of petroleum products. Lin et al. [14] studied the uncertainty of consumer preferences caused by poor awareness of new technologies, which can lead to the fuzziness of market potential estimation.

Consumer survey data contains high degrees of fuzziness because customer responses are subjective and imprecise. Although fuzziness in market share estimation was considered in previous studies, none of them addressed the fuzziness of survey data that was used to develop market demand models. On the other hand, the jury of executive opinion method is commonly used in industries to estimate market potential of new products. However, the fuzziness of the estimation was not addressed as well in previous studies. In this paper, a novel methodology of developing fuzzy market demand models is proposed to address the fuzziness. In the proposed method, fuzzy regression is introduced into DCA to address the fuzziness of the survey data, and the fuzzy estimates of market potential are generated based on the jury of executive opinion method to address the fuzziness of market potential estimation.

The rest of this paper is organized as follows. Section 2 describes the proposed methodology of generating fuzzy market demand models for new products. The proposed methodology involves conjoint survey design, fuzzy regression analysis, fuzzy market potential estimation, generation of fuzzy demand models, and defuzzification method. Section 3 presents a case study of generating a fuzzy demand model to estimate the market demand of a new tablet PC based on the proposed methodology. Finally, conclusion and future work are provided in Section 4.

## 2. Proposed methodology

To address the fuzziness of survey data, a fuzzy regression method is introduced into DCA to develop choice models. Fuzzy estimates of market potential, which are represented as triangular fuzzy numbers (TFNs), are generated by the jury of executive opinion method. Fig. 1 shows a flowchart of the proposed methodology for developing fuzzy market demand models for NPD. First, a conjoint survey is conducted to collect customer preferences on products. Survey respondents are classified into a number of segments by using a *K*-means clustering technique. Thereafter, fuzzy regression is used to generate the fuzzy utility functions of individual segments. Fuzzy choice (or market share) models are developed based on the developed fuzzy utility functions and MNL model of DCA. The fuzzy estimates of market potential are generated based on the jury of executive opinion method. Once the choice models are developed and the fuzzy estimates are obtained, fuzzy market demand models can be developed. Finally, a defuzzification method is introduced to estimate the market demand of new products.

### 2.1. Conjoint survey design

Rating- [6,15], ranking- [14], and choice-based [20] conjoint surveys are the three types of conjoint survey designs. The rating-based conjoint survey is adopted in this research; this type of survey is widely used in previous studies and requires a set of product profiles with respect to pre-defined attributes and attribute levels [6]. Rating-based conjoint surveys are commonly designed based on orthogonal arrays [16]. Consumers are then asked to rate the product profiles. Survey data is analyzed to generate the following utility functions:

$$U_{ij} = \sum_{k=1}^{m} \sum_{l=1}^{n_k} u_{ikl} x_{jkl}, \tag{1}$$

where $U_{ij}$ represents the utility of the $j$th product profile in the $i$th segment, and $u_{ikl}$ is the part-worth utility of the $l$th level of the $k$th attribute in the segment $i$. $m$ and $n_k$ denotes the number of attributes and number of attribute levels in the $k$th attribute, respectively. $x_{jkl}$ is defined as a dummy variable that is equal to one if the $l$th level of the $k$th attribute is chosen for the product profile $j$