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A game theory-based model for product portfolio management in a competitive market

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ABSTRACT

In today's competitive markets, effective product portfolio is critical for manufacturers that offer several products. From manufacturers' perspective, the diversity must be maintained in a level in which the engineering costs do not exceed the acquired advantages of increased market share. On the other hand, product portfolio diversity is prominent for customers. In addition, manufacturers should always be careful about competitors activity. Therefore, we consider the problem of product portfolio management (PPM) in a competitive environment. This paper constructs a game theory-based mathematical model to deal with this new PPM problem. In this presented mathematical model, the PPM problem is formulated as a 2-person non-cooperative game with complete information. Each player has a set of strategies which correspond to the feasible product portfolios. Every payoff is determined by the procedure that considers the customer–engineering interaction in product portfolio planning, which aims to optimize product portfolio for a target market segment, and proposed a maximizing surplus share model for it. Therefore, obtaining the optimal product portfolio is determined by the Nash equilibrium point of this game. Finally, a numerical example is presented to demonstrate the feasibility of the approach.

1. Introduction

Consumers, industrial managers, and sales and marketing people, all demand products that improve their lifestyles or to gain an edge over the competition. So, the products that presented by manufacturers in their product portfolios (or sets) are interesting for many people. But unlimited product variety is not a way to be successful; there has to be an optimum (Forza & Salvador, 2008; Kumar, Chen, & Simpson, 2009). It is true for most companies that the Pareto rule applies: 80% of the sales and/or profits come from 20% of the products (Gorchels, 2000). It is evident that a single product cannot fulfill the manufacturer needs and on the other hand, for diversity there exists limitation (Song & Kusiak, 2009).

In today's highly competitive environment, determining an optimal product portfolio is very important for the survival of a firm. Optimal product portfolio has received considerable attention, because the rates of failure of new product portfolio and their associated losses are very high (Business Week, 1993). The whole product portfolio decision is very crucial for the progress of a firm, because it is very costly and difficult to change (Kotler, 1997; Lilien, Kotler, & Moorthy, 1992; Urban & Hauser, 1993). The key questions are, what the best product portfolio is, and how manufacturer can find it.

This type of decisions adheres to the general wisdom as suggested in the Boston Consulting Group's notion of product portfolio strategy (Henderson, 1970). The concept of product portfolio provides a useful synthesis of the analyses and judgments during the preliminary steps of the planning process, and is a provocative source of strategy alternatives (Day & George, 1977).

Product portfolio management (PPM) is a general business concept that analyze the production ability and market potential, simultaneously, and then determine the best set of products to offer, with the aim of manufacturer profit maximization (Dacko, 2008; McNally, Durmusoglu, Calantone, & Harmancioglu, 2009). PPM is developed to direct a product and its diversity including not only attributes, levels, and price's, but also analysis results, environmental component information, engineering requirements, manufacturing procedures, product performance information, and etc. (Cooper, Edgett, & Kleinschmidt, 1999). Therefore PPM has been classified as a combinatorial optimization problem. Each company strives for the optimality of its product offerings through various combinations of products (Kaul & Rao, 1995).

The PPM problem may develop from two perspectives: (I) For attract the opinion of customers in target markets. (II) For reduce the manufacture engineering costs. First is the problem of marketing managers, and second is the problem of producer. When both

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of them compose with each other as reflect to utility of costumers and engineering costs, contemporaneously, this problem becomes to miss link between sale and production chain. Jiao and Zhang (2005) consider the customer–engineering interaction in product portfolio planning, which aims to create product family specifications for a target market segment, and proposed a maximizing surplus share model for this problem.

In addition, the PPM can be considered in competitive environment. It means that we determine our product portfolio with regard to products that offer by competitors, while the competitors manage their product portfolios in regard to our products. Game theory can be used to model this problem.

Present paper extends previous works in PPM with regard to customer–engineering concerns and competitive environment. The objective of this research is to develop a game theory-based model as a procedure of finding optimal product portfolio. The proposed model constructs product portfolio based on customer–engineering interaction model in product portfolio planning which is developed by Jiao and Zhang (2005). The proposed model is not for any specific product, and it can be applied to a diversity of products or services.

This paper is organized in this way. In Section 2, there is the review of literature. In Section 3, brief description of the PPM problem is given. In Section 4, the mathematical formulation of the PPM is presented. In Section 5, an application of the proposed model to simple PPM problem is reported. In Section 6, finally, the conclusions of this paper and directions for future work are summarized.

2. Literature review

A PPM is defined as a decision making that optimizes some criteria, such as maximizing share-of-choices, or, in other words, market share. The main contribution of the most researches in PPM is summarized in following issues:

(1) Generating design alternatives via multi-objective optimization.
(2) Accounting for uncertainty and competition when estimating the achievement of business goals.
(3) Applying meta-heuristic algorithms to solve a combinatorial problem during the product line design.

Kohli and Krishnamurti (1987) developed a dynamic-programming-like heuristic to find a solution to the problem of identifying a new, multi-attribute product profile associated with the highest share of choices in a competitive market. This heuristic was then extended to cover product line design (Kohli & Sukumar, 1990). Nair, Thakur, and Wen (1995) developed an improved heuristic using beam-search methods to solve this problem efficiently. Balakrishnan and Jacob (1996) used genetic algorithms, which are based on population genetics, with conjoint data to generate product designs that are near-optimal. Heuristic approaches are justified because the product design problem has been shown to be too difficult (NP-hard) to optimally being solved in a reasonable period of time (Kohli & Krishnamurti, 1989). Li and Azarm (2002) presented the paper that extends the previous work in product line positioning by including all of the considering issues, i.e., large variety of customers' preferences, market competitions, multiple business goals, uncertainties in several factors that are used for evaluating the design alternatives, and commonality among the alternatives in a product line. Because of the combinatorial nature of this problem, they developed a genetic algorithm to solve it.

Thereafter, Jiao and Zhang (2005) examined the benefits of integrating customer concerns over product offerings with more engineering implications. To leverage both the customer and engineering concerns, a maximizing shared-surplus model that considers customer preferences, choice probabilities and platform based product costing, is proposed to address the product portfolio planning problem. Also, a genetic algorithm procedure is applied to solve the mixed-integer combinatorial optimization problem involved in product portfolio planning (Jiao, Zhang, & Wang, 2007).

Recently, Aiyoshi and Maki (2009) proposed a game problem under the constraints of allocation of product and market share simultaneously. Their research is considered several manufacturers in oligopoly market. This proposed model, on the one hand had the competitive circumstance, but on the other hand, did not has details discussed above, such as large variety of customers' preferences, customer–engineering concerns, etc. Next, we describe our method in integrate these details and competitive circumstance.

3. Description of the PPM problem

Considering the firm capabilities to produce several products, a set of product portfolios have been identified. Each product has certain desirability between customers. We propound the product portfolio planning problem with the goal of maximizing an expected surplus from both the customer and engineering perspectives. More specifically, we consider a scenario in which a set of products, have been identified, given that the manufacturer (m) has the capabilities (both design and production) to produce all these products, $P^m = \{p_1^m, \ldots, p_n^m, \ldots, p_{N_m}^m\}$. A product portfolio, z_j^m, is a set consisting of some selected product. Combined with the products, a set of product portfolios are created, $Z^m = \{z_1^m, \ldots, z_j^m, \ldots, z_{J_m}^m\}$. For example, if manufacturer m can produce 3 product, $P^m = \{p_1^m, p_2^m, p_3^m\}$, 7 product portfolio are available:

$$Z^m = \{z_1^m, \ldots, z_7^m\} \\ = \{\{p_1^m\}, \{p_2^m\}, \{p_3^m\}, \{p_1^m, p_2^m\}, \{p_1^m, p_3^m\}, \{p_2^m, p_3^m\}, \{p_1^m, p_2^m, p_3^m\}\}.$$

Every product, p_n^m, is associated with certain engineering costs, denoted as C_n^m. There are multiple market segments, $S = \{s_1, \ldots, s_g, \ldots, s_G\}$, each containing homogeneous customers, with a definite size, Q_g. The customer–engineering interaction is embodied in the decisions associated with customers' choices of different products. Various customer preferences on diverse products are represented by respective utilities, U_{gn}^m (utility of the gth segment for the nth product of mth manufacturer). Product demands or market shares, D_{gn}^m (market share of the gth segment for the nth product of mth manufacturer), are described by the probabilities of customers' choosing products. Customers choose a product based on the surplus buyer rule (Kaul & Rao, 1995). They have the option of not buying any products (if none of them produces a positive surplus) or buying competitors' products.

We assume that competitors respond to the manufacturer's moves, meaning that, the competition react by introducing new products. Competitive reactions appear implicitly in the customer utilities, which are influenced by the attributes of competing products (Yano & Dobson, 1998). This causes the problem based on game theory to model.

4. Problem formulation

The present paper considers a market with G segments, $S = \{s_1, \ldots, s_g, \ldots, s_G\}$, and 2 manufacturers that each of them can offer N_m products, $P^m = \{p_1^m, \ldots, p_n^m, \ldots, p_{N_m}^m\}$, and J_m product portfolios, $Z^m = \{z_1^m, \ldots, z_j^m, \ldots, z_{J_m}^m\}$. This gives the bimatrix-game problem with 2 players and J_m strategy for each, (m = 1 or 2).