Product Line Optimization as a Two Stage Problem

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Abstract. Optimizing product lines is the task of planning the joint offer of multiple substitutes concurrently. Actually, this resembles the design of a choice menu where consumers are supposed to choose at most one item from a set of alternatives.

In this paper we model the product line optimization problem by decomposing it into two stages. Product decision is done in the first stage by anticipating possible outcomes of the subsequent (price) stage. This so-called hierarchical decision situation is considered due to uncertainty about consumers' tastes. Results suggest that substantial increase of expected profit can be drawn from the hierarchical approach.

1 Basics in Product Line Optimization

1.1 Background

Making decisions in an uncertain environment can be managed by two basically different strategies depending on the decider's option for possibly postponing parts of the respective decision. The first strategy consists in just waiting and deciding after realizations of the decision environment become known, i.e., *wait-and-see*. The second one is characterized by the fact that there is no time left for delaying decision making, i.e. decisions have to be taken *here-and-now* (e.g. [9]). Usually, decisions have strategical relevance, constitute some kind of commitment and, thus, cannot be changed for the short term. However, minor adjustments - frequently referred to as recourse actions - may be allowed after realizations of the decision environment are revealed.

Situations, similar to the latter, are typically found in new product development (NPD) processes. Cooper and Kleinschmidt (e.g. [6]) identified that an early and sharp definition of product concepts is one of the most important success factors in the NPD process. An early definition disciplines the NPD process by fostering the timely start of subsequent phases in product development as well as by making the whole process more stable, i.e., insusceptible to changing input information [3]. However, it should be noticed that the design and selection of concepts constitutes a very critical part of NPD processes, since they are extremely vulnerable to any miss-specification in this early phase ([15], pp. 40). This implies that there might occur two

major difficulties that complicate the planning process. First, in dynamic markets consumer preference data used in the product definition and concept selection phase may become obsolete when market introduction follows with considerable delay of time ([5]). Second, consumers may find it difficult to state their preferences for widely unknown products ([16]). So, firms are expectetd to determine their spectrum of products to be offered by accepting shortcomings of information about consumer tastes and potential trends that may evolve within the time to market. Milliken [12] calls this "uncertainty concerning external factors". However, uncertainty about consumers' tastes diminishes while approaching the point where production starts. Since product policy cannot be changed in short-term due to commitments in early phases in the NPD process there just remains adaption by means of tactical marketing methods, such as, e.g., pricing. The structure of the described problem is thus similar to those of hierarchical decision situations ([10]) that may be found in various situations some of which are electrical power management (e.g., [8]), scheduling (e.g. [4]), (vehicle) routing ([11]), or revenue management ([2]).

1.2 Notation and Constraints

We first introduce some basic notation in product line optimization on which the hierarchical model in the next section is based. Suppose that there is a set of consumer segments $\mathcal{I}$ which are of size N_i ($i \in \mathcal{I}$) and which are interested in a firm's new product line described by a set of potential products $\mathcal{L}$. Usually, some kind of utility measure r_{il} is considered to quantify how some segment $i \in \mathcal{I}$ values some product $l \in \mathcal{L}$. We suppose that the outcomes of r_{il} are measured on a monetary scale. In accordance with literature, we refer to this measure as reservation price.

Furthermore, to state the product line optimization problem more formally the following binary decision variables are needed, where

$$\theta_{il} = \begin{cases} 1, & \text{if segment } i \text{ selects product } l, \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

and

$$y_l = \begin{cases} 1, & \text{if product concept } l \text{ is selected by the firm,} \\ 0, & \text{otherwise.} \end{cases} \tag{2}$$

Despite this, we explicitly allow the setting of prices p_l for the products. Additionally, potential fixed costs F_l, that may occur in connection with the development of new products $l \in \mathcal{L}$, are considered, and - of course - variable costs c_l arise if a product l has to be produced. Last of all, we have to specify consumer choice behavior that constitutes a crucial part in choice-based product line designs. A quite often used mechanism is the first-choice rule where a segment i chooses the product $l^*(i)$ in the line that consumers of the segment like best. If we follow the general modeling the most