

2005

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Erman Coskun

LeMoyne College, ermanc@sakarya.edu.tr

Mevlut Baydar

Gebze Yuksek Teknoloji Institute, baydam@hotmail.com

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Recommended Citation

Coskun, Erman and Baydar, Mevlut, "Selections of Software Quality Attributes: Joint Optimization Model for Customer Needs and Producers' Software Quality Expenditures" (2005). *AMCIS 2005 Proceedings*. 385.

<http://aisel.aisnet.org/amcis2005/385>

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Selections of Software Quality Attributes: A Joint Optimization Model for Customer Needs and Producers' Software Quality Expenditures

Erman Coskun

Sakarya University Business Department
Sakarya, Turkey

&

LeMoyne College Information Systems Dept.
Syracuse, NY USA
ermanc@sakarya.edu.tr

Mevlut Baydar

Gebze Yuksek Teknoloji Institute
Management Department
Gebze, Turkey
baydam@hotmail.com

ABSTRACT

This paper analyzes to find a general model of the decision to add a quality attribute to a software product with the objective of maximizing consumers' welfare (utility) while maximizing producer's and marketers' profit at the same time. The optimal strategy, optimal combination of software quality attributes, is found in two steps. First we derive from the firm optimization problem the optimal price as a function of software quality attributes. Second we solve the consumer problem from substituting price by this optimal price. Although this paper's focus is on software products, this model can be generalized to pricing decisions for any kind of high-tech product with many attributes.

Keywords (Required)

Joint Optimization, Software Design, Software Quality Attributes, Software Pricing.

INTRODUCTION

Quality has been discussed for a long time and has been mentioned as a significant competitive tool for both manufacturing and service industries. Competition made firms pay special attention to the product and service quality. In order to survive, to keep the market share, to meet the consumer expectations, even to expand the market share, companies have been raising their quality standards. Companies such as Motorola and GE have been spending millions of dollars to apply six-sigma concept in their businesses so that they would have approximately 3.4 defective products in per million products produced (<http://www.ge.com/sixsigma/sixsigstrategy.html> and <http://www.qualitydigest.com/dec97/html/motsix.html>). Software design and development is one of the areas where the importance of quality has been proliferating especially with new application areas such as command and control systems and some business systems.

Quality concerns both consumers and marketers. Consumers pay for quality, and producers invest money to improve the quality. Consumers want to maximize their utility function and producers want to maximize their profits. The American National Standards Institute and the American Society for Quality Control define quality as "*the total of attributes and characteristics of a product or service that bears on its ability to satisfy given needs.*" (ANSI/ASQC 1978). Therefore adding to the level of the quality is meaningless if consumers are unwilling to buy it. The concept of quality is not just for the sake of having high quality, but for providing the consumers with what they need and what they want.

MacMillan & McGrath (1996) claim that companies are building profitable product strategies around giving consumers the exact mix attributes. If the companies underinvest in those attributes valued by consumers, then they lose consumers. On the other hand, if the companies overinvest in attributes not valued by consumers, then they lose money. Consequently consumers who buy from those overinvesting companies are also losing money because they are paying for unutilized attributes.

Reichheld and Sasser (1990) claim that if companies knew how much it really cost to lose a consumer, they would be able to make accurate evaluations of investments designed to retain consumers. They also claim that if consumers are served

correctly, they generate more and more profits every year as long as they stay with the company. It is difficult to keep consumers with inadequate quality level in today's market place.

In this study we try to maximize both consumers and marketers' objectives by finding an optimum quality level corresponding to utility maximizing consumers, and wealthy producers. We first develop a mathematical model for one product and one consumer segment, then we continue with one product and multiple segments.

Products in software markets are highly sophisticated. Often times consumers do not utilize many of their attributes, although they must pay for them. On the other hand producers spend resources to develop those unutilized attributes, which contribute to higher cost for the end users. Hence consumers and firms spend resources in attributes of the software product that consumers would never use, and this cause waste of time and money for both consumers and producers.

LITERATURE REVIEW

The concept of quality is used commonly in our daily life. It is a subjective concept as it depends on an individual's needs, which changes from person to person. One must thus specify what criteria contribute to quality.

Evans and Lindsay (1996) propose several criteria to describe the concept of quality. These criteria are judgmental, product-based, user-based, value-based, and manufacturing based. In addition to these criteria, Garvin (1984) talks about eight quality dimensions. These are "*performance* primary operating characteristics of a product, *attributes* the bells and whistles of a product, *reliability* the probability of a product's surviving over a specified period of time under stated conditions of use, *conformance* the degree to which physical and performance characteristics of a product match pre-established standards, *durability* the amount of use one gets from a product before it physically deteriorates or until replacement is preferable, *serviceability* the speed, courtesy, and competence of repair, *aesthetics* how a product looks, feels, sounds, tastes, or smells, *perceived quality* subjective assessment of quality resulting from imagine, advertising, or brand names."

We are going to investigate deeply one dimension, attributes because we believe that software producers invest in attributes to make their software preferable over competitors' software. By investing in attributes they try to make their products at least as appealing as those of competitors' products. Also attributes account for more of the New Product Development (NPD), and Research & Development (R&D) cost for the software companies. Thus this extra cost reflects to the price of the product and consumers are asked to pay for this.

We know that considerable research has been applied to understand how consumers prefer, and how consumers combine perceptions of product attributes to their preferences (Hauser, and Urban, 1979). In addition in econometrics, stochastic modeling used to estimate the importance of product attributes (McFadden, 1970). MacMillan and McGrath (1996) classify product attributes into three categories, namely basic, discriminator, and energizer attributes. Basic attributes are those expected from all competitors by the target consumer group. Discriminator attributes are the ones distinguishing a product from competitors'. Energizer attributes are those not only distinguishing the product from others, but also become basis on which a purchase decision is made. In this classification consumers' feelings toward attributes are very important. MacMillan and McGrath further explain the relationship between product attribute and consumer's feeling toward the product by their ACE (Attribute Categorization and Evaluation) Matrix. According to the ACE Matrix, consumers have positive, negative, or neutral feelings for a product attribute. If consumers have a positive feeling for an attribute, then a producer gains from providing it, as it can compete against other producers. Similarly if the consumers have negative feeling, then producers should work on that attribute to make consumers feel positive for that attribute. If the consumers have neutral feelings for an attribute, then this attribute contributes to costs but not to sales because this attribute doesn't make consumer buy the product.

In software and high tech markets, most consumers do not have enough information about product attributes, and often do not know how to utilize those attributes. A word processing program or spreadsheet program has many attributes and is thus a good example. An average consumer may not have enough knowledge to use every attribute or may not need to utilize all of them. Many extra attributes are beyond consumers' expectations. Offering more for less is not the key. The key is offering the right product attributes. By doing so companies enable themselves to charge a premium for their products or services (Power 1991). Parasuraman, Zeithaml, and Berry (1988) define the concept of perceived quality and relate it with the concept of perception and expectations. "Perceived quality is viewed as the degree and direction of discrepancy between consumers' perceptions and expectations." Rust, Inman, Jia, and Zahorik (1999) claim that some of the most common beliefs about consumer-perceived quality are wrong, and that it is not necessary to exceed consumer expectations to increase preference. Likewise MacMillan and McGrath (1996) explain the common belief that adding or enhancing a product's

attributes increases consumer satisfaction is not necessarily true. They also say that commonly producers do not recover what they have spent on adding or enhancing product attributes.

Olshavsky and Miller (1972) predicted that if consumer expectations are high (due to advertising, word of mouth, etc...) but the product performance is lower than expected, then consumers with high expectation rate product quality higher than consumers with low expectations. Likewise, if a consumer has low expectations but the product performance is higher than expected, then those who have low expectations will rate the product quality lower than those who have high expectations. It is thus important to characterize how consumers perceive the brand in the given market, regardless of the actual product quality. If adding new attributes improves product quality, then quality improvement is beneficial to organizations up to a point. This point corresponds to the quality level after which any expenditure in quality improvement will not contribute to profitability. Hence expenditures on quality can result in decreased profit (Aaker and Jacobson, 1994).

According to Roland, Zahorik, and Keiningham (1995), "since we are in cost cutting era, quality expenditures must be made financially accountable." Financially accountable means that all of the money and time invested in quality improvement must be profitable. These authors also develop a mathematical model where; quality is an investment, quality efforts must be financially accountable, it is possible to spend too much on quality, and not all quality expenditures are equally valid. They have such an analytical setting, which allows management to evaluate profitability from quality improvement efforts. According to the ROQ approach, a producer can measure his efforts' return, and evaluate his decision based on ROQ ratio. Then, comparisons can be made with alternative investment options.

According to many management experts before addressing ROQ, companies must re-evaluate their basic operations. Not only do companies spot the opportunity and get sense of job well done, but they can also get solid monetary results with well-implemented ROQ (Greising 1994). ROQ emphasizes the existing consumer retention, which consumers tend to purchase more than new consumers (Rose 1990).

In software engineering literature, quality has been defined with two main approaches. The first one is minimizing undesired features such as likelihood of bugs or design errors (Hopkins, 1994; Takahashi 1996) and the second one is increased level of correctness, reliability, usability, and maintainability (Lauesen and Younessi 1998). Software Attributes (<http://www.ataccess.org/resources/atabook/s02/s02-02.html>) suggest that the following attributes should be considered explore and compare different software. Easy-to-Read Screens, Consistency, Intuitive Characteristics, Logical Labels, Instructional Choices, Graphics, Friendly Documentation, On-Screen Instructions, Auditory Cues, Visual Cues, Built-in Access Methods, Built-in Utilities, Alternatives to a Mouse, Optional Cursors, Creation of Custom Programs.

Since there are different types of software used for different needs, some of these quality attributes will have more importance comparing to others in different areas or industries. For safety-critical systems, number of bugs and usability might be very important while for business systems they have moderate importance. Thus, in this study we will consider mix of attributes important for any kind of software. After all these literature review, we classify software quality attributes as shown in Table 1.

ASSUMPTIONS AND MODEL DESCRIPTION

Rational choice theory argues that "consumer decisions has been to assume a rational decision-maker with well-defined preferences that do not depend on particular descriptions of the options or on the specific methods used to elicit those preferences. Each option in a choice set is assumed to have a utility, or subjective value, that depends only on the option. It is assumed that the consumer has ability or skill in computation that enables the calculation of which option will maximize his or her received value and selects accordingly." (Bettman, Luce, Payne, 1998).

"Consumer knowledge foresees utilization of extrinsic product attributes and willingness to pay for a product. Compared to measures of familiarity and subjective expertise, objective expertise is found to be a more efficient predictor of product evaluation and to be more consistent in valuing extrinsic attributes in accordance with their diagnostic utility." (Codell, 1997). From these statements we have our first assumption:

Assumption 1- Consumers have to make a decision based on the information available to them.

SOFTWARE QUALITY ATTRIBUTES	
Performance	Speed, resource usage
Functionality	Answering users' different needs
Usability	Ease and efficacy of use
Screen Design	
Easy-to-Read Screens	
Consistency	
Intuitive Characteristics	
Logical Labels	
Instructional Choices	
Graphics	
Friendly Documentation	
On-Screen Instructions	
Auditory Cues	
Visual Cues	
Built-in Access Methods	
Built-in Utilities	
Alternatives to a Mouse	
Reliability	Probability of failure, number of bugs, design errors
Conformance	Meeting with software requirements
Durability	Product life
Scalability	Possibility of expansion
Perceived quality	Brand name or popularity of the software
Security	Security of data and information, access restrictions
Correctness	Processing correctly and producing correct results
Maintainability, Serviceability and Supportability	Support for problems or user needs

Table 1. Software Quality Attributes in Literature

Lancaster (1966) theory assumes that consumers maximize a utility function. Also, when George Stigler (1987) proposes the characteristics of a consumer he claims that consumers maximizes their utilities while making decisions. This statement supports our second assumption which is:

Assumption 2- Consumers are maximizing their utility. This means that consumers are trying to maximize their utility from the particular product by looking at its attributes.

The utility function is a numerical representation of a preference ordering (Phlips, 1974) and one of the most popular assumption about preferences is additive separability. Therefore the utility function is made up of subutilities and they are combined additively. Although this assumption is considered very strong in the case of multiple products, preferences are said to be additive or wants are independent where there is only one product (Deaton, Muellbauer, 1981). Similarly Edwards and Newman (1983) propose additive utility function form where one product and multiple attributes are the case. Gensch and Recker (1979) also use linear additive form of utility function where multiattributes are the case as consistent with Turban and Metersky (1971). In addition, Ratchford (1979) states that utility function is linear when multiple attributes are the case. Since we are maximizing the utility from just one single product in this study we can state our third assumption as:

Assumption 3- We assume that the consumer utility function is linear additive.

Srinivasan, Lovejoy, and Beach (1997) argue that cost is a function of the product attributes. Hence if a firm chooses to increase the number of product attributes, it must spend more money to offer that product. Therefore the cost of the product increases as the number of attributes increases.

Waltstrom, Hardgrave, and Wilson (1995) state that expert consumers invest their time and money economically by consuming the best material possible. As a consumer's expertise increases, the need for more attributes increases with an increasing rate. If the consumer has enough knowledge to utilize all of the product attributes, it is likely that he will use those attributes. The expert consumer will need more product attributes. On the other hand if the consumer is not familiar with the product attributes, then these attributes will be unutilized. Pekelman and Sen (1979) show that satisfaction increases as the level of attribute increases up to a certain point (threshold), and after that point the level of satisfaction decreases even

though the level of attribute increases. Therefore we can say that the level of satisfaction increases as the number of attributes increases but once the number of attributes reaches to a certain threshold the level of satisfaction begins to decline as the number of attributes increases.

Adding a new attribute to an existing product is equivalent to innovating (Hamel and Prahalad, 1991) but this will affect cost, price, and demand (Leech, 1982). We know that demand is a function of price as the number of goods sold increases with reduced price. The higher the cost, the higher the price, which cost is driven by the number of product attributes. Also, the number of attributes determines quality.

Basic Model: One Product and One Segment

First we consider one product and one consumer segment which is the only segment consuming the product. This one segment wants to maximize its utility by having the right product attribute combination whereas the marketer is trying to maximize its profit by selling the product at highest price possible. Clearly we want to find such a product attribute combination that is maximizing consumers' utility function while maximizing marketers' profit from that product. In order to find such a product attribute combination, we first model consumer problem, then the marketer problem, and finally find a solution which maximizes both consumers' utility function and marketers' profit.

The Consumer Problem

A consumer's objective is to maximize utility, which utility is the sum of utilities from individual software product used by that consumer (Ferber 1974, Simon 1966). In turn the utility from each product used is a function of that product's attributes (Lancaster, 1991; Cropper, Deck, Kishor, and McConnell, 1993). In the basic model we assume only one product. An overall set of n possible attributes for the product is considered, and the consumer chooses the sub-set of attributes that maximizes his/her utility, U .

Let $a_i = 1$ whenever the product possesses the i -th attribute and 0 otherwise, $i = 1, 2, \dots, n$. Let u_i be attribute i 's contribution to consumer utility. Let P be the price of the product and u_p (>0) the consumer disutility per dollar spent. The consumer optimization problem can be thus formulated as

$$\begin{aligned} \text{Max}_{a_i, i=1, 2, \dots, n} U &= \text{Max}_{a_i, i=1, 2, \dots, n} \left\{ \sum_{i=1}^n u_i a_i - u_p P \right\} \\ \text{subject to} \quad a_i &\in \{0, 1\}, \quad i = 1, 2, \dots, n. \end{aligned} \quad (1)$$

The vector (u_1, u_2, \dots, u_n) characterizes the consumer segment. Consumers' preferences for attribute i vary, and are utilized to allocate a sign to u_i (MacMillan and McGrath, 1996). A consumer may like attribute i , in which case $u_i > 0$. The consumer may be neutral for attribute i , $u_i = 0$, or dislike it, $u_i < 0$.

The Firm Problem

A firm's objective is to select a price for the product so as to maximize profits from sales (Ferber, 1974). Let d represent the product demand as a linear function of consumer utility, that is

$$d(U) = \varphi \times U = \varphi \times \left[\sum_{i=1}^n u_i a_i - u_p P \right], \quad (2)$$

where φ is a scaling parameter.

The firm's total profit, denoted by z , is the product of demand and per unit profit. Let c_i represent the cost of attribute i , $i = 1, 2, \dots, n$. The firm optimization problem can be thus formulated as

$$\begin{aligned} \text{Max}_P z &= \text{Max}_P \left\{ \left[\varphi \times \left(\sum_{i=1}^n u_i a_i - u_p P \right) \right] \times \left[P - \sum_{i=1}^n c_i a_i \right] \right\} \\ \text{subject to} \quad a_i &\in \{0, 1\}, \quad i = 1, 2, \dots, n. \end{aligned} \quad (3)$$

Without loss of generality we can select $\varphi = 1$, and rewrite (3) as

$$\begin{aligned} \text{Max}_P \left\{ P \sum_{i=1}^n u_i a_i - \left(\sum_{i=1}^n u_i a_i \right) \times \left(\sum_{i=1}^n c_i a_i \right) - u_p P^2 + u_p P \sum_{i=1}^n c_i a_i \right\} \\ \text{subject to} \quad a_i &\in \{0, 1\}, \quad i = 1, 2, \dots, n. \end{aligned} \quad (4)$$

The Optimal Combination of Product Attributes

The optimal strategy, i.e. optimal combination of product attributes, is found in two steps. First we derive from the firm optimization problem the optimal price, denoted by P^* , as a function of product attributes. Second we solve the consumer problem from substituting P by this optimal price.

From applying the first order derivative condition for optimality to (4) we obtain

$$\frac{\partial z}{\partial P} = \sum_{i=1}^n u_i a_i - 2u_p P + u_p \sum_{i=1}^n c_i a_i = 0 \text{ yielding } P^* = \frac{\sum_{i=1}^n u_i a_i}{2u_p} + \frac{\sum_{i=1}^n c_i a_i}{2}. \quad (5)$$

The second order derivative condition for maximization is satisfied since $\partial^2 z / \partial P^2 = -2u_p < 0$ for any P .

Next we substitute P in (1) with P^* in (5) to obtain

$$\text{Max}_{a_i, i=1, \dots, n} \left\{ \sum_{i=1}^n u_i a_i - u_p \left(\frac{\sum_{i=1}^n u_i a_i}{2u_p} + \frac{\sum_{i=1}^n c_i a_i}{2} \right) \right\} = \frac{1}{2} \text{Max}_{a_i, i=1, \dots, n} \left\{ \sum_{i=1}^n (u_i - u_p c_i) a_i \right\}. \quad (6)$$

Since (6) is a linear combination of the a_i 's, it follows that

$$a_i = 1 \text{ if } \frac{u_i}{c_i} > u_p \text{ and } a_i = 0 \text{ otherwise.} \quad (7)$$

Therefore the product should possess attribute i whenever the ratio of consumer utility to firm's cost from adding that attribute exceeds consumer disutility per dollar to be spent (u_p).

A Model for Two Segments

We extend the basic model by including an additional consumer segment. A similar analysis follows where the product price that maximizes firm's profit is first derived and then substituted into the consumers' objective function to determine the optimal combination of attributes for the product.

We have an additional consumer segment to our basic model, and this additional segment and existing segments are considered to be independent of each other. Thus one segment's decision does not affect the other segment's decision. Besides we consider there is no overlap and cannibalization between these two consumer segments. Hence if one consumer fits in one segment, he/she will not be counted in another segment. Namely, there is no consumer fits in both segments.

Assumption 4- The two segments are independent of each other, and there is no cannibalization and overlap between these two segments.

The Consumer Problem

Consumer segments are differentiated by their combination of product attribute utilities (u_1, u_2, \dots, u_n). Hence, consumer utilities (say U_1 and U_2) from two different segments are expected to be different (for the same product, i.e. the same combination of attributes). The consumer objective function thus becomes the maximization of total consumer welfare, W . From the welfare economic literature (e.g. Johansson, 1992), consumer welfare is a linear combination of consumer utilities where $W = w_1 U_1 + w_2 U_2$, with w_1 and w_2 being the welfare weights.

Assumption 5- According to utilitarian thought, welfare function expresses a view on the distribution of welfare in society (Johansson, 1992). Consequently if we increase the size of population in welfare function, we will have higher welfare level. Therefore we assume w_1 and w_2 are the relative size of consumer segments in our modeling.

The welfare weight associated with segment i is thus the relative size of that segment, i.e. $w_i = S_i / (S_i + S_j)$ for segment i , $i \in \{1, 2\}$, $j \in \{1, 2\}$, $j \neq i$, where S_i is the size of segment i . The consumer optimization problem is thus expressed by

$$\text{Max}_{a_i, i=1, \dots, n} W = \text{Max}_{a_i, i=1, \dots, n} \left\{ w_1 \times \left(\sum_{i=1}^n u_{1,i} a_i - P u_{1,p} \right) + w_2 \times \left(\sum_{i=1}^n u_{2,i} a_i - P u_{2,p} \right) \right\}, \quad (8)$$

where $u_{1,i}$, $u_{2,i}$ are the utilities from attribute i and $u_{1,p}$, $u_{2,p}$ the disutilities per dollar to be spent, respectively for segment 1 and 2.

The Firm Problem

The firm still selects a price for the product so as to maximize profits. The demand function, d , becomes a linear function of consumer welfare, that is

$$d(W) = \varphi \times W = \varphi \times \left[\left(w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i \right) - (w_1 P u_{1,p} + w_2 P u_{2,p}) \right], \quad (9)$$

where φ is a scaling parameter.

The firm’s total profit, z , is still the product of demand and per unit profit, and so the firm optimization problem is

$$\text{Max}_P z = \text{Max}_P \left\{ \varphi \times \left[\left(w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i \right) - (w_1 P u_{1,p} + w_2 P u_{2,p}) \right] \times \left[P - \sum_{i=1}^n c_i a_i \right] \right\} \quad (10)$$

subject to $a_i \in \{0,1\}$, $i = 1,2, \dots, n$.

Without loss of generality we can select $\varphi = 1$, and rewrite (10) as

$$\text{Max}_P \left\{ \begin{aligned} & P w_1 \sum_{i=1}^n u_{1,i} a_i + P w_2 \sum_{i=1}^n u_{2,i} a_i - P^2 w_1 u_{1,p} - P^2 w_2 u_{2,p} \\ & - (w_1 \sum_{i=1}^n c_i a_i) \times \left(\sum_{i=1}^n u_{1,i} a_i \right) - (w_2 \sum_{i=1}^n c_i a_i) \times \left(\sum_{i=1}^n u_{2,i} a_i \right) + w_1 P u_{1,p} \sum_{i=1}^n c_i a_i + w_2 P u_{2,p} \sum_{i=1}^n c_i a_i \end{aligned} \right\} \quad (11)$$

subject to $a_i \in \{0,1\}$, $i = 1,2, \dots, n$.

The Optimal Combination of Product Attributes

The optimal combination of product attributes is again found in two steps. We begin by deriving from the firm optimization problem the optimal price, P^* , and then we solve the consumer problem from substituting P by P^* .

From applying the first order derivative condition for optimality to (11) we find

$$\begin{aligned} \frac{\partial z}{\partial P} &= w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i - 2P w_1 u_{1,p} - 2P w_2 u_{2,p} + w_1 u_{1,p} \sum_{i=1}^n c_i a_i + w_2 u_{2,p} \sum_{i=1}^n c_i a_i = 0 \\ \text{yielding } P^* &= \frac{w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i + (w_1 u_{1,p} + w_2 u_{2,p}) \sum_{i=1}^n c_i a_i}{2(w_1 u_{1,p} + w_2 u_{2,p})}. \end{aligned} \quad (12)$$

The second order derivative condition for maximization is satisfied since $\partial^2 z / \partial P^2 = -2(W_1 u_{1,p} + W_2 u_{2,p}) < 0$ for any P .

Next we substitute P in (8) with P^* in (12) to obtain

$$\begin{aligned}
 & \left. \begin{aligned} & \left(w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i \right) \\ & - \left[\left(\frac{w_1 \sum_{i=1}^n u_{1,i} a_i + w_2 \sum_{i=1}^n u_{2,i} a_i + (w_1 u_{1,p} + w_2 u_{2,p}) \sum_{i=1}^n c_i a_i}{2(w_1 u_{1,p} + w_2 u_{2,p})} \right) (w_1 u_{1,p} + w_2 u_{2,p}) \right] \end{aligned} \right\} \\
 & = \frac{1}{2} \text{Max}_{a_i, i=1, \dots, n} \left\{ \sum_{i=1}^n (w_1 u_{1,i} + w_2 u_{2,i} - c_i [w_1 u_{1,p} + w_2 u_{2,p}]) a_i \right\} \tag{13}
 \end{aligned}$$

Since (13) is a linear combination of the a_i 's, it follows that

$$a_i = 1 \text{ if } \frac{w_1 u_{1,i} + w_2 u_{2,i}}{c_i} > w_1 u_{1,p} + w_2 u_{2,p} \text{ and } a_i = 0 \text{ otherwise.} \tag{14}$$

Therefore the product should possess attribute i whenever the ratio of consumer welfare to firm's cost from adding that attribute exceeds the loss in consumer welfare per dollar to be spent (u_p).

The General Model

We know that in real life one product is consumed by more than two segments many times. Therefore we need a generalized model including multiple segments. In order to achieve a general model for one product and multiple segments, we follow the same procedure as we did in one segment, and two segments. Let assume j is the number of segments and $j=1, \dots, m$. Thus the decision criteria to add an attribute to the product for m segments will be

$$a_i = 1 \text{ if } \frac{\sum_{j=1}^m w_j u_{j,i}}{c_i} > \sum_{j=1}^m w_j u_{j,p}, \text{ and } a_i = 0 \text{ otherwise}$$

Hence the attribute i should be added to the product when the ratio of consumer welfare to firm's cost is higher than the loss in consumer welfare per dollar to be spent.

IMPLICATIONS FROM THESE MODELS

These models developed in the paper provides an important implication regarding the threshold for a marketer's decision to add an attribute to a product. The threshold in all of the models is the disutility (the loss in consumer welfare per dollar to be spent) and this threshold is fixed for all attributes. In the basic model (one product one consumer segment case), marketers should add those attributes whose ratio of consumer utility to firm's cost is higher than the threshold, and should not add otherwise. Similarly, in two segments model, product should possess those attributes as long as their ratio of consumer welfare to firm's cost is higher than threshold. Finally in the generalized model (one product multiple segments case), the product should have those attributes providing higher value in ratio of combined consumer welfare to firm's cost than threshold which is also combination of disutilities.

As a result, we can say that the model is very easy to apply once we have the disutility numbers and consumer welfare to firm's cost ratios for every attribute. Those attributes, whose consumer welfare to firm's cost ratio is higher than disutility should be in the product, and if the same ratio doesn't provide a higher number than disutility should not be added to the product.

DISCUSSIONS AND CONCLUSIONS

In this research, we have developed a general model of the decision to add an attribute to a product with the objective of maximizing consumers' utility function while maximizing marketers' profit simultaneously in three steps. First we developed

a model for one product one segment, then we developed a model for one product and two segments, and finally we developed generalized model for one product multiple segments.

In this joint optimization model, we located a threshold line, which determines whether an attribute should be in the product or not. This threshold is the loss in consumer welfare (utility in one segment case) per dollar to be spent and is called disutility in the paper. An attribute should be in the product if its ratio of consumer welfare to firm's cost exceeds the threshold. On the other hand, if this ratio doesn't provide a higher value compare to threshold, that attribute should not be in the product.

Our solution is valid as long as the separability assumption for product attributes holds. We know that in practice, marketers bundle attributes, and try to sell them as a bundle. However this maximizes only marketers' profit, but not consumers' welfare. Therefore our model provides both maximized welfare for consumers and maximized profit for marketers.

We considered that the demand is a linear function of consumers' utility, thus this research would be extended by considering different demand function. We also assumed that consumers behave rationally in marketplace, but we know that consumers do not act rationally at all the time. Another extension to this research could be relaxing rationality assumption by putting into consideration of different factors affecting consumers' buying decision such as advertising, consumer loyalty.

We believe that once the model is completely tested, it would be used for pricing decisions of any kind of high-tech product with multiple attributes.

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