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Research Paper

New product concept selection: an integrated approach using data envelopment analysis (DEA) and conjoint analysis (CA)

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Abstract

New product concept development is considered to be a critical step and the main determinant for the success or failure of new product development. This paper introduces a new methodology for the evaluation and selection of new product concepts using Data Envelopment Analysis (DEA) and Conjoint Analysis (CA). The proposed methodology integrates customer perceived value of the new product concepts through the use of CA and uses this perceived value as a measure for the new concepts' performance. In addition, the methodology takes into account the development burden that a company has to perform to bring the new concept into a state of market readiness. This development burden is estimated by determining two main factors, namely the burden to produce and the burden to sell the new product concept. The customer perceived value and the development burden are both used in DEA to evaluate the new product concepts resulting in the selection of the best product concept. The applicability of the proposed methodology is illustrated through a case study.

Keywords: *Product development, concept selection, data envelopment analysis, conjoint analysis.*

1. Introduction

New products can be developed as a response to pre-identified market opportunity, in which case marketing efforts have been exerted to explore potential consumer need which will be met through the design of product features. In addition, a new product could be created to deliver some benefit or meet a need that does not exist yet, in the sense that product developers believe that a need could be generated for this product and marketing efforts will be focused on convincing consumers with the merit of the benefits delivered by the product.

All products are thought to deliver benefits to consumers; these benefits could be tangible or intangible. The degree of success or failure of a specific product could be measured through the acceptance that this product will have. This acceptance stems from the perceived value that a potential customer associates with the benefits delivered by the product. One could say that a successful product is a product that has high value as perceived by the customer. But, a successful product from the point view of customers is not necessarily a successful one from the point of view of the company developing the product. That is, organizations develop new products for different reasons such as generating profits and increasing market share [1]; and not merely for the sake of delighting customers by delivering value products. It is accepted to assume that profitability and market share could be gained by ensuring customer delight. This valid assumption is the reason why product developers are seeking methods that could assess the benefits and value that a customer assigns to a product. Conjoint Analysis (CA) is a method that can be used to assess the value of products or new product concepts as perceived by customers [2]. Product developers use CA to measure the perceived value or utility that a customer associates with a new product concept, thus product developers would choose to develop product concepts that are perceived to have high value from the point of view of customers. This approach has only one potential flaw. This flaw being that a product concept with high perceived customer value may not be the best to develop if the company were to take into account the development effort needed to get this product concept to a state or market readiness. The development effort may render some products undesirable by the company despite their high value as perceived by the customer. In other words, the product concept may deliver value benefits to the customer but it may require high development effort from the company. In such cases, it may be more desirable for a company to develop a product concept that deliver value and does not require high development effort. This simply means that the evaluation process the company uses when selecting a new product concept should take into account the development effort needed for each product concept. Such a measure could be done by using Data Envelopment Analysis (DEA) which allows evaluating the efficiency of each product concept in achieving the output or the value as perceived by the customer, given the inputs or the development efforts needed to develop the product concept. This paper accomplishes this goal by proposing a new methodology that can be used to select new product concepts by making use of Conjoint Analysis to capture customer opinions about the new product concepts being considered, and DEA to evaluate the product concepts.

The rest of the paper is organized as follows: the problem of product concept selected is reviewed in the following section. Next, the new proposed methodology is explained. After that, the applicability of the methodology is illustrated though a case study to select a new smart phone.

2. Product concept selection

New product development can be triggered by the need to develop a product to meet a recognized market opportunity. Next, the development effort will be focused on generating several new product concepts to satisfy this market opportunity. The new product concepts are considered promising product ideas that the development team believes could produce and market to meet the market opportunity. The objective of the product concept generation is to generate as many product concepts as possible regardless of the concepts' technical and economic viability [3]. Next, the generated product concepts are screened by eliminating concepts that are deemed technically infeasible. In addition, the development team may choose to merge some product concepts and generate more concepts. This process of generating and screening concepts continue until the team manages to narrow down the number of viable product concepts. After that, a more detailed analysis of the concepts is launched. The concepts are evaluated using a set of criteria developed by the development team and the best new product concepts are selected. Concept selection is considered a crucial step in the product development process, since the development team will determine all the major product features and specification, and development efforts will be committed to develop the product as specified in this step. Any change in the product specifications or features beyond this step would incur unpredicted costs. It is well accepted in the literature that about 75 % of the product cost is committed during the concept selection phase [4].

The importance of the concept selection led product development practitioners to develop many techniques to aide in the selection process such as the concept selection matrix proposed by [5]. This technique was extended by [6] by taking into consideration the fact that new product development has to pass through different stages before deciding which alternative to choose. The process proposed includes two major steps, concept screening and concepts selection. [7] proposed a selection approach similar to the QFD matrix which allows determining the interaction between concepts. [4] developed a two-stage methodology to incorporate fuzzy logic into a pairwise comparison of Analytic Hierarchy Process (AHP) and simulation for final concept selection. Ayag and Özdemir [8] developed an approach using fuzzy Analytic Network Process (ANP) to evaluate a set of conceptual design alternatives. Geng et al. [9] proposed an integrated design concept evaluation approach based on vague sets.

It is noted from the literature that the product concept selection is mainly an activity conducted by the development team which is usually dominated by technical designers. This means that there will be limited interaction –if any- from the customers. Customer point of view is included through involving experts from marketing. This paper proposes a method for product concept evaluation and selection that incorporates the view point of customers measured through the perceived value that a target group of customers associates with a product concept while taking into account the development effort that a company has to exert to develop the product concept and bring it to a state of market readiness. The proposed method uses Conjoint Analysis (CA) to assess the perceived customer value, and Data Envelopment Analysis (DEA) to measure the efficiency of each product concept in utilizing the development effort relative to the perceived value gained from that product concept. The next sections of the paper will address how to use the CA to assess the perceived customer value and how to use DEA in concept selection.

3. Methodology

Product development includes a wide set of tasks and activities [10] that can be characterized at a macro level to encompass three main phases: Opportunity identification, Concept development, and Concept implementation. The first phase includes all the activities needed to reach a decision to launch a new product development effort. The second phase includes all the activities needed to decide what the product will be in terms of shape, form, and specification. The third phase includes all the activities needed to make the product function as intended. After the final phase the product is considered ready to be manufactured and lunched to the market. It should be mentioned here that the three phases are complex and overlapping. Nevertheless this characterization provides a satisfactory picture that illustrates where the focus of the methodology proposed in this paper research is located. The methodology proposed in this paper addresses the problem of selecting a product concept during the concept development phase. That is, the methodology operates as a filtration mechanism that aims at choosing the most feasible product concept to undergo further development. The proposed methodology consists of four major steps as following:

Step I: Get product concepts

The new product concept selection process starts after the generation of several concepts. That is, the development team usually develops several product concepts that are thought to meet customer needs. These concepts are considered the starting point for this methodology. It is essential that the development team analyze all product concepts and fully understand how each concept function. This will enable the development team to evaluate each concept when needed.

Step II: Estimate the development burden

The development burden is defined as the amount of effort needed by a certain company to fully develop a product concept into a marketable product. That is; the development burden entails an assessment of all the activities and resources needed to design, produce, and market a product. The estimation of the development burden involves estimating two major costs: the cost to produce a certain concept, and the cost to market the concept. Niazi et. al. [11] presented an extensive review of the different methods and techniques used for product cost estimation. The development team may choose any method to assess the development burden as long as the team maintains consistency during the assessment process. This paper will not propose nor recommend a specific cost estimation method since this would be beyond the scope of the paper.

Step III: Determine the perceived value of the new product concepts

The main objective of this step is to define and estimate the product concepts' expected performance. There are different measures which can assess the performance of product concepts such as the expected revenue, the market share, the generated sales, and the company's reputation. These methods are valuable and can provide great insights to organizations, but they tend to be "after-the-fact" measures. In the sense that an organization has to wait for the product success or failure to occur before an estimate about product value can be found. This means that these measures cannot be used during the early stages of product development since they cannot predict the value of new product concepts. On the other hand, estimating customer preference towards new product concepts could be done by using Conjoint Analysis (CA), a multivariate technique used mainly in marketing research to predict consumer behavior for certain deign attributes [12]. Conjoint analysis is used to measure, analyze, and predict customers' responses to new products and to new features of existing products [13]. Conjoint analysis enables companies to decompose customers' preferences for products and services into "part-worths" (or utilities) associated with each level of each attribute of the product. Part-worths can be recombined to predict customers' preferences for any possible combination of attribute levels. Conjoint analysis has been also used to determine the optimal product concept and to identify market segments that value a particular product concept. Conjoint Analysis enjoys several advantages that make it a useful tool in the product development process such as:

1) It focuses on the measurement of consumer preferences for a set of design attributes of a particular product [14].

2) It gives the ability to predict and simulate how customers may react to a product modifications or a new product launched to the market [15].

Conjoint analysis assumes that a product could be described by a set of attributes, and each attribute can be decomposed into a number of levels. That is, each product or new product is described by a combination of product attributes and the associated levels. Once products are defined using the attributes, conjoint analysis proceeds to survey customers regarding these products. Customers are asked to either rank-order or rate the products based on their own preferences. Next, the data collected will be analyzed to determine the part-worth function which will be used to determine the value or utility of each product. The procedure used to determine the perceived value of new product concepts is as follows:

a) Describe new product concepts using design attributes:

Product design attributes are product characteristics that are easily recognized by customers and are thought to influence customer preferences. For each design attribute, a set of alternatives within an attribute referred to as the attribute levels should be also defined. For example, if size is defined as a design attribute, then its associated levels could be: large, medium and small. These attributes and their associated levels are used to create a description for the new product concepts and utilize this description in the Conjoint Analysis. That is, each new product concept will be represented by a function that contains these design attributes. For example, assuming that k design attributes have been defined and each attribute has m levels, then the new product concepts could be described as in equation (1).

$$P_j = \sum_{k=1}^{K} \sum_{m=1}^{M_k} X_{km} \quad (1)$$

Where,

Pj = New product concept (j = 1 … J)

K = Number of attributes

Mk = Number of levels in attribute k.

$$X_{km} = \begin{cases} 1, & if\ m^{th}\ level\ of\ the\ k^{th}\ attribute\ is\ prsent\ in\ the\ new\ product\ concept. \\ 0, & otherwise \end{cases}$$

b) Get customer responses

Customers are asked in this step to rank the new product concepts according to their preferences from the most to the least preferred ones.

c) Develop new product concepts utility function

The gathered customer data will be analyzed in this step to provide utility value for each new product concept. This will be performed by determining the part-worth for each attribute level. The part-worth is a quantitative measure of customers' preferences for each design attribute level. The higher the part-worth value of the attribute level, the more preferred the attribute level for the customer. The analysis of the data provides a measure of the relative importance for each design attribute known as the importance score, which reflects the importance of each design, attribute to the overall preferences. The conjoint analysis approach used in this paper will use dummy variable regression with rank-order data as shown in equation (2):

$$R_{ij} = \sum_{k=1}^{K}\sum_{m=1}^{M_k} a_{ikm}X_{jkm} + \varepsilon_{ij} \quad (2)$$

Where,

j = a particular product or concept included in the study;

R_{ij} = the ranking provided by the customers (ranking reversed so that higher numbers represents stronger preference)

a_{ikm} = part-worth associated with m^{th} level ($m = 1, 2,..., M_k$) of the k^{th} attribute;

M_k = number of levels of attribute k;

K = number of attributes

X_{jkm} = dummy variable that takes on the value of 1 if the m^{th} level of the k^{th} attribute is present in product j and the value 0 otherwise;

ε_{ij} = error term,

Once the part-worths are found, the utility (U) of the new product concepts can be found using equation (2):

$$U_{ij} = \sum_{k=1}^{K}\sum_{m=1}^{M_k} \tilde{a}_{ikm}X_{jkm} \quad (3)$$

The utility function represents the preference (or perceived value) a certain customer or group of customers associate with a product concept. The higher the utility, the higher the value perceived by a customer in a product. It is always desirable to increase customer perceived value since it will increase the probability of the customer purchasing the product. But this does not necessarily mean that the product concept with highest perceived customer value should be selected for further development, these concepts may require high development burden which could affect the profitability of these concepts. Thus, the selection should not be made solely on the perceived value and should include other factors like the development burden which will be addressed in the next step.

Step IV: Evaluate the efficiency of product concepts using DEA

Data envelopment analysis (DEA) is a linear programming and a non-parametric method introduced by [16] for evaluating the performance of a set of peer entities called Decision Making Units (DMUs). The DMUs are a set of entities responsible for converting inputs into outputs and whose performances are to be evaluated [17] such as companies, organizations, brands or - as in the case of this paper - the product concepts. The DEA technique evaluates the performance of the DMUs by computing their relative efficiency which is defined as the weighted sum of outputs over the weighted sum of inputs. The computed efficiency values will be used to classify the DMUs as efficient or inefficient units. The efficient units are the best practice units relative to other units defined in the sample in terms of generating the highest outputs using the minimum amount of inputs. These units are located on the efficient frontier which consists of all the best practice DMUs that have an efficiency score of 100% while the inefficient DMUs are located below the efficient frontier. The definition of the efficient frontier depends on the scale to be used in defining the DEA model. This could be either constant returns-to-scale (CRS) or variable returns-to-scale (VRS).The CRS means that increasing all the inputs used by a certain percentage results in a proportionate increase in the amounts of the outputs while the VRS means that a change in the amounts of inputs will not necessarily lead to the same change in the amounts of outputs, the output might change to either more or less proportionate than inputs [18].

Charnes, et.al [16] extended Farrell's work in the measurement of technical efficiency and introduced the term data envelopment analysis, known as the CCR model. In this model, the efficiency evaluation of the DMUs is estimated using CRS assumption. Banker et al. [19] extended the CCR model. They analyzed the primary influencing factors of measured technical efficiency of DMU under the condition of different scales, and in doing so they eliminated influences caused by different scales. Both of the CCR and the BCC models produce efficiency scores and a set of optimization weights that give the DMU as high an efficiency score as possible, subject to the constraint that weighted outputs to weighted inputs must be equal to or less than one. However, using the BCC approach under the assumption of the variable returns to scale, will give the opportunity to find a larger number of solutions, as a result, the total number of 100% efficient units has a higher probability of increasing in number.

Tone [20] developed a DEA model, that deals with input and output slacks directly, called the Slack Based Model (SBM).This model differs from CCR and BCC models in measuring the efficiency of the DMU by considering the existence of both input excess and output shortfalls represented by the slacks values. While the CCR and the BCC models evaluate the efficiency of the DMU by considering the inputs reduction or outputs expansion without paying any consideration to the existence of slacks in inputs or outputs.

The CCR, BCC, and SBM models divide the DMUs into inefficient and efficient ones. However, as all efficient DMUs receive the same efficiency score of 1, it is not possible to distinguish between the efficient DMUs leading to difficulty in ranking. To overcome this problem; Andersen and Petersen [21] proposed a super efficiency model to improve the traditional DEA model and to allow ranking for the efficient DMUs. This model was found to suffer from infeasibility and instability under the condition of variable returns to scale. To overcome this deficiency, Tone [22] developed the Super-SBM model based on slack variables to solve this particular problem.

Another important aspect of the DEA model is the orientation measures used in developing the DEA model. The orientation of the model can be classified into input-oriented measures, output-oriented measure, and non-oriented measures. Input-oriented measures quantify the input reduction necessary for a DMU to become efficient while holding the output constant. Output-oriented measures quantify the necessary output expansion while holding the input constant. Non-oriented measures quantify the improvements when both inputs and outputs can be modified simultaneously.

The proposed method uses Data envelopment analysis (DEA) to compare and select the best new product concept. DEA will identify the most efficient new product concept by comparing the perceived value of the new product concepts relative to the development burden for each product concept. That is, DEA will be used to compute a relative efficiency score for each new product concept. The approach proposes computing the standard relative efficiency as a first step to identify efficient concepts that could progress to the next phase of product development process. The super efficiency model could also be used to further discriminate between the product concepts if needed. The evaluation procedure will be performed as following:

a) Prepare the data for DEA analysis

Using the DEA to evaluate the new product concepts requires the definition of a set of inputs, outputs, and decision making units (DMUs) which will be defined as following:

- DMUs: The DMUs are defined as a set of homogenous entities whose performance is measured with respect to a set of defined inputs and outputs [23]. The DMUs will be considered the proposed new product concepts which are thought to be capable of meeting customer needs.
- Inputs: The inputs will be considered to be the development burden undertaken by the company to develop and market a given product concept. This will be estimated using two measures: the cost to produce the product concept, and the cost to market the product concept.
- Output: The outputs are considered to be the perceived value of the new product concept as measured by conjoint analysis.

The number of new product concepts or DMUs that could be compared relative to the set of inputs and output should adhere to the relationship defined by [17] as shown in equation (4). Failing to satisfy this relationship will lead to the result that more DMUs having an efficiency score of one and thus, it will be difficult to discriminate between these DMUs.

$$N \geq \text{Max}(M * S, 3 * (M + S)) \tag{4}$$

Where,

N : is the number of DMUs

M : is the number of inputs

S : is the number of outputs

b) Compute the standard efficiency scores of the new product concepts

The Slack Based Method (SBM) is used in this paper for the evaluation of the new product concepts because it deals directly with input and output slacks. The input/output slacks represent the input excess and the output shortfalls for a given product concept. Thus, it gives the opportunity to identify the amount of inefficiencies for each new product concept represented as input/output slacks. The linear programming model for the SBM is shown in equation (5).

$$\text{Minimize } \rho = \frac{1 - \frac{1}{m} \frac{\sum_{i=1}^{m} s_i^-}{x_{io}}}{1 + \frac{1}{s} \frac{\sum_{i=1}^{s} s_i^+}{y_{io}}} \tag{5}$$

Subject to

$$x_0 = X\lambda + s^- \tag{6}$$

$$y_0 = Y\lambda - s^+ \tag{7}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{8}$$

$$\lambda \geq 0, s^- \geq 0, s^+ \geq 0 \tag{9}$$

Where:

ρ : The efficiency value for the DMU

λ : is the weight given for the DMU

X : The amount of input for the DMUs

Y : The amount of output for the DMUs

x_0: The amount of input for DMUs

y_0 : The amount of output for DMUs

s^- : The inputs slacks which represent the input excess

s^+ : The outputs slacks which represent the output shortfalls

Using DEA requires the specification of the type of return to scale and the orientation measure for the selected model. The return to scale concerns what happens to the DMUs' output when the amount of inputs are changed. There are two types of return to scale (RTS): constant return to scale (CRS) and variable (VRS). In this paper, the VRS is selected since it is a more general assumption that includes increasing, constant and variable return to scale. While the CRS is a restrictive assumption that implies that the outputs will change in the same proportion as inputs and that does not apply to all situations. As for the type of orientation; there are three types of orientation depending on the situation being analyzed: input oriented, output oriented and non-oriented measure. In this paper, the non-oriented measure is selected which quantifies the improvements when both inputs and outputs are modified simultaneously because it will be assumed that the producing companies are willing to maximize the customer preferences and minimize the amount of efforts in producing the product simultaneously.

The relative efficiency scores will be calculated for each new product concept by solving the LP model shown in equation (5) for each product concept. Then the new product concepts will be classified into efficient or inefficient concepts:

- The efficient concepts are the DMUs that have an efficiency score of unity and zero slack values in its inputs/outputs. These concepts are the best practice units relative to the other concepts with respect to the defined inputs/outputs.
- The inefficient concepts have efficiency scores of less than unity and non-zero slacks values in either its inputs/outputs. These concepts require more inputs however, they do not provide the desired level of output when compared to other concepts.

The standard efficiency calculated using the SBM model may leave some of the product concepts characterized as efficient undistinguishable. This is due to the fact that, it leaves all the efficient concepts having the same efficiency score of one. That is, several new product concepts will be found to be efficient and could undergo further development. An enterprise may choose to take all the efficient new product concepts to the next stage of development or may wish to further discriminate among those efficient new product concepts such that only one concept will be identified as the best new product concept. This could be done by using the super efficiency model as will be shown next.

c) Calculate the super efficiency of the efficient concepts

The super efficiency will be calculated for the efficient concepts based on Super efficiency SBM model using the formula shown in equation (10).

$$\text{Minimize} \quad \delta = \frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\bar{x}_i}{x_{io}}}{\frac{1}{s}\sum_{r=1}^{s}\frac{\bar{y}_r}{y_{ro}}} \tag{10}$$

Subject to

$$\bar{x} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j \tag{11}$$

$$\bar{y} \leq \sum_{j=1,\neq 0}^{k} \lambda_j y_j \tag{12}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{13}$$

$j \neq 0$

$$\bar{y} \geq 0, \quad \lambda \geq 0 \tag{14}$$

$$\lambda_j \geq 0, \quad j \neq 0 \tag{15}$$

Where:

δ : The super efficiency scores for the DMU,

λ_j : is the weight given for the DMU j,

x_j : The input for a DMUo under evaluation,

$\bar{y}$: The output for a DMUo under evaluation,

x_j : The amount of input j produced by the DMUi,

y_j : The amount of output j utilized by the DMUi,

The super efficiency model is used because it gives the possibility to further discriminate between the efficient concepts that have an efficiency index =1 under the standard DEA model. The super-efficiency model excludes the concept under evaluation from the reference set which allows the product concept to be located above the efficient frontier, i.e. to be super-efficient and take any value greater than or equal one. In this way, a better ranking of the efficient concept (i.e., the higher the value the higher the rank) is obtained, while the scores for inefficient concepts remain the same as in the standard DEA model. This is because under the super efficiency model; the efficiency of a single product concept is calculated by comparing the performance of the concept with the reference set on the efficient frontier and thus. The deletion of any concept that is not in the reference set will not affect the efficiency score of the inefficient concept. The super efficiency scores of the product concepts will be used to recommend the best product concept to further develop.

4. Case study: new smart phone design

4.1. Overview

The applicability of the proposed methodology will be illustrated using a case that was implemented to design a new smart phone that corresponds to the needs of a certain group of customers. It was determined that the main interests of this group of customers when purchasing a smart phone are weight, talk time, screen size, and price. These factors were determined based on the consensus of the design team relying mainly on the market analysis that was conducted to address this issue. These factors were deemed as the factors that are easily distinguishable by customers and can be the focus of the design effort. It should be mentioned here; that these factors constitute the customizable options that customers could have in addition to all the basic or standard features that must exist in the phone.

Step I: Get product concepts

The concept selection process starts once a group of product concepts are proposed to meet customer needs. These concepts are developed as a result of the market analysis that was performed by the product development team. Each product concept represents one idea for the product under development that possesses certain design characteristics and performs certain functions. The team is considering twelve different smart phone design concepts which share many features such as 8 megapixel rear camera, at least 16 Giga byte of internal memory storage, Wi-Fi, touch screen and differ in some features as illustrated in Table (1).

Table 1: New product concepts description

Product Concept Number	Weight (Grams)	Talk time (Hours)	Screen Size (Hours)	Price (USD)
1	133	22	4.8	549
2	119	7.0	4.3	589
3	130	10	4.7	599
4	135	8.0	4.65	349
5	112	8.0	4.0	649
6	126	20	4.3	649
7	127	12	4.3	549
8	170	6.0	4.3	499
9	130	7.0	4.5	599
10	145	21	4.3	649
11	116	9.0	4.3	600
12	179	7.0	4.0	549

Step II: Estimate the development burden

The development burden is defined as the amount of efforts and expenditure needed to produce and sell and a product concept. The development burden is estimated in this paper by estimating two measures, namely; the “burden to produce” and the “burden to sell”. The burden to produce is defined as the estimated cost for manufacturing a product concept, while the burden to sell is defined as the cost or effort needed to market and sell a product concept such as promotion cost.

The development team at this stage may not be at a position to make definite estimates due the ambiguity inherited in the design concepts. Nevertheless, the development team is capable of making educated estimates relying on their experience and using analogy to other products within the company. Thus the development team agreed to a five-point Likert scale system to estimate the burden to produce the and the burden to sell as depicted in Table (2).

Table 2: Five-point scale for estimating the development burden

Burden to Sell Scale		Burden to Produce Scale	
5	Very high burden to sell	5	Very high burden to produce
4	High burden to sell	4	High burden to produce
3	Moderate burden to sell	3	Moderate burden to produce
2	Low burden to sell	2	Low burden to produce
1	Very low burden to sell	1	Very low burden to produce

Using the five-point Likert scale was thought to be more appropriate for the estimating the development burden since the development team did not have any formal method to estimate the cost of selling and the cost of producing the product concepts at this time. The burden to produce and the burden to sell each product concept were estimated to be as in Table (3).

Table 3: New product concepts development burden

Product Concept	Burden to produce	Burden to sell
1	3	3
2	4	5
3	4	4
4	1	3
5	5	4
6	5	3
7	3	5
8	1	2
9	4	5
10	5	4
11	4	3
12	3	1

Step III: Determine the perceived value of the new product concepts

Customer perceived value of the new product concepts was assessed using Conjoint Analysis (CA) as following:

a) Describe new product concepts using design attributes:

Performing conjoint analysis requires presenting the data in terms of product concepts' attributes and their corresponding levels. The product concepts under study had four attributes that were used as differentiating factors. These attributes and their corresponding levels are shown in Table (4). The product concepts were also described in terms of these attributes as illustrated in Table (5).

Table 4: New Product Concepts Attributes

Attributes	Attributes levels
Weight	≤ 130 Grams > 130 Grams
Price	≤ 550 USD > 550 USD
Screen Size	≤ 4.3 inch > 4.3 inch
Talk Time	< 10 hours 10 – 15 hours > 15 hours

b) Get customer responses

The new product concepts were presented to a group of customers consisting of 45 individuals who represent the target users. The customers were asked to rank order the new product concepts in terms of preference. A partial listing of customer responses is shown in Table (6) where the cells show the preferences for each product concept. For example, customer number 1 ranked product concept number 3 as the most preferred, product concept 8 as the second most preferred, and product concept 10 as the least preferred.

Table 5: New Product Concepts Attributes

Product Concept	Screen size	Weight	Price	Talk time
1	> 4.3 inch	> 130 grams	≤ 550 USD	> 15 hours
2	≤ 4.3 inch	≤ 130 grams	> 550 USD	< 10 hours
3	> 4.3 inch	≤ 130 grams	> 550 USD	10 – 15 hours
4	> 4.3 inch	> 130 grams	≤ 550 USD	< 10 hours
5	≤ 4.3 inch	≤ 130 grams	> 550 USD	< 10 hours
6	≤ 4.3 inch	≤ 130 grams	> 550 USD	> 15 hours
7	≤ 4.3 inch	≤ 130 grams	≤ 550 USD	10 – 15 hours
8	≤ 4.3 inch	> 130 grams	≤ 550 USD	< 10 hours
9	> 4.3 inch	≤ 130 grams	> 550 USD	< 10 hours
10	≤ 4.3 inch	> 130 grams	> 550 USD	> 15 hours
11	≤ 4.3 inch	≤ 130 grams	> 550 USD	< 10 hours
12	≤ 4.3 inch	> 130 grams	≤ 550 USD	< 10 hours

Table 6: Customer preferences ranking – Partial List

	Customer Preference Order											
	Most preferred									Least preferred		
Customer No	1	2	3	4	5	6	7	8	9	10	11	12
1	3	8	5	12	2	11	9	7	6	1	4	10
2	2	9	7	11	12	10	4	3	6	5	1	8
3	11	2	10	7	6	9	5	1	4	8	3	12
4	1	2	3	4	5	6	7	8	9	10	11	12
5	12	4	11	7	10	6	9	8	2	1	3	5
6	3	5	12	4	11	7	10	6	9	8	2	1
7	9	11	7	2	6	10	5	3	4	12	1	8
8	3	12	1	8	4	5	2	11	7	6	10	9
9	3	2	1	5	4	6	7	8	9	10	11	12
10	2	1	3	4	6	5	7	8	9	12	11	10

c) Develop new product concepts utility function

Customer preferences were analyzed using the Conjoint Function in SPSS® to find the part-worths (or utilities) of the product concepts' attributes. The results are shown in Table (7). These results are used to construct the utility equation for the new product concept.

Table 7: The utility scores for the attribute levels.

	Design Attributes	Utility Estimate	Std. Error
Screen size	< 4.3 inch	-.317	.117
	> 4.3 inch	.317	.117
Weight	< 130 grams	-.667	.235
	> 130 grams	-1.333	.469
Price	< 550 USD	-1.278	.235
	> 550 USD	-2.556	.469
Talk time	< 10 hours	-.279	.142
	10 – 15 hours	-.558	.283
	> 15 hours	-.836	.425
(Constant)		7.905	0.568

Furthermore the importance score for each design attribute was found to be as shown in Table (8). The results show that the screen size has the highest importance score which indicates that this design attribute has the most influence on the overall customers' preferences. The results also show that the smart phone price played the least important role in determining the overall preference. The talk time and the weight played a significant role but not as significant as the screen size.

Table 8: The importance value for the design attributes.

Design Attributes	Importance values
Talk Time	20.2 %
Weight	21.3 %
Screen Size	40.7 %
Price	17.8 %

Equation (2) was used to compute the customer perceived value, and the result was found to be as illustrated in Table (9).

Customer perceived value is a good measure of the level of acceptance that product developers could expect for a certain product concept. This value could by itself be sufficient for the selection of which product concept to develop, which in this case would result in selecting product concept number 4 and possibly product concept number 7, since these two have the highest customer perceived value. The problem with this selection is that it ignores the point of view the company that will be developing and selling the product. That is, it only takes into account the customer perspective. Accounting for the company's capabilities requires incorporating the development burden in the assessment process before deciding on a specific product concept. This was done in the following step using the data envelopment analysis (DEA).

Step IV: Evaluate the efficiency of product concepts using DEA

The product development team compared the new product concepts relative to each other using data envelopment analysis and the best concept(s) was selected to undergo further development. The comparison took into account the development burden measured in terms of the burden to produce and the burden to sell, and the customer perceived value for each product concept. The team followed the steps proposed in the methodology and the results were as following.

a) Prepare the data for DEA analysis:

The input and output data needed for the data envelopment analysis (DEA) evaluation include the estimates for the development burden and the customer perceived value as shown Table (10).

Table 9: The utility scores for the proposed product concepts.

Product concepts	Customer Perceived Value
1	4.775
2	4.086
3	4.441
4	5.332
5	4.086
6	3.529
7	5.085
8	4.698
9	4.720
10	2.863
11	4.086
12	4.698

Table 10: Input and Output Data for the DEA Analysis

Product Concept No	Burden to Produce	Burden to Sell	Customer Perceived Value
1	3	3	4.775
2	4	5	4.085
3	4	4	4.441
4	1	3	5.332
5	5	4	4.086
6	5	3	3.529
7	3	5	5.085
8	1	2	4.698
9	4	5	4.720
10	5	4	2.863
11	4	3	4.086
12	3	1	4.698

b) Compute the standard efficiency scores of the product concepts

The Slack Based Model (SBM) was used to evaluate the product concepts. The SBM is considered a measure that makes its efficiency evaluation invariant to the units of measure used for the different inputs and outputs. That is, the SBM has the following important two properties:

- Unit Invariant: the measure is invariant with respect to the unit of measurement of each input and output item.
- Monotone: the measure is monotone decreasing in each input and output slack.

The efficiency scores were calculated for the product concepts using the DEA Solver Software® and were found to be as shown in Table (11):

It is clear from table (11) that product concepts 4, 8, and 12 are the best among all product concepts, since these product concepts were found to have the highest efficiency score of 1. Thus the development team could choose to consider these product concepts for further development. Nevertheless, the development team may desire to use super-efficiency model to further discriminate between these concepts.

c) Calculate the super efficiency of the efficient concepts

The super efficiency scores were calculated for the product concepts based on the super efficiency SBM model. The obtained results are shown in Table (12):

Table 11: The efficiency scores for the product concepts.

DMU	Score	Rank
4	1	1
8	1	1
12	1	1
1	0.520	4
7	0.427	5
11	0.398	6
3	0.354	7
9	0.328	8
6	0.325	9
5	0.304	10
2	0.282	11
10	0.213	12

Table 12: The super efficiency scores for the product concepts.

DMU	Score	Rank
12	1.500	1
8	1.249	2
4	1.134	3
1	0.520	4
7	0.427	5
11	0.398	6
3	0.354	7
9	0.328	8
6	0.325	9
5	0.304	10
2	0.282	11
10	0.213	12

The super efficiency results shows that product concepts number 12, 8, and 4 were classified as super-efficient concepts while the remaining concepts were classified as inefficient concepts. Among the super-efficient product concepts, concept number 12 got the highest the highest super efficiency value. Accordingly; this concept will be selected as the best concept that will undergo for further development.

It is worth mentioning here that product concept 12 did not receive the highest perceived value from the point of view of the customer when it was estimated using conjoint analysis. Nevertheless, it is the most efficient because of the amount of effort the company has to invest in its development as estimated by the development burden. This clearly shows the most efficient product concept may not be best one as perceived by the customers.

5. Conclusion

This paper presented a methodology for the selection of new product concepts taking into account customer perceived value of new product concepts and the development burden that a company must perform to develop the product concept. The developed methodology balance the need to create products that are valued by customers, and the need to for the company to be efficient in terms of utilizing its resources to create products that could generate profits.

The method uses Data Envelopment Analysis (DEA) to measure the relative efficiency of the new product concepts. The efficiency is defined in terms of how well the product concepts can create value to the customer with respect the amount of effort needed by the company to produce and sell these product concepts.

The method can be started once a set of product concepts that are thought to be able to meet customer needs are generated. The method then proceeds to estimate the development burden required to produce and sell these product concepts. After that, customer perceived value for each concept is estimated using Conjoint Analysis (CA). Finally, the relative efficiency of each concept is determined using DEA, where the output is defined as the amount of the customer perceived value for each concept as measured through CA, and the input is the development burden measured using the burden to sell and the burden to produce.

The methodology was tested using a case study to select a product concept for further development. The case clearly illustrates the usability of the methodology and provides evidence to the ability of the methodology to aide product development teams in selecting an appropriate product concept to develop. The case shows that a product concept that has a high perceived value from the point of view of customer many not be necessarily the best product concept to develop once the development burden is taken into account.

The developed methodology provides product developers with a systematic approach to evaluate and select product concepts. Although the methodology does not eliminate the subjectivity impeded in the new product concept evaluation and selection is does reduce the amount of subjectivity.

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