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Research paper



A systematic new product development methodology for creating affective products

Sa'Ed M. Salhieh Ph. D. *

Department of Industrial Engineering, School of Engineering, The University of Jordan, Amman, 11942, Jordan
**Corresponding author E-mail: salhieh@ju.edu.jo*

Abstract

The success of new product development (NPD) relies on the effective integration of marketing and engineering especially when the development is targeted at creating new products capable of satisfying customer needs generated by feelings, attitudes, and emotions. Such products can be called affective products. This paper introduces a systematic new product development methodology that integrates the processes needed to elicit both tangible/objective and intangible/affective customer needs and translates those needs into product parameters to be used in the development of new products that meet both the customer functional and affective needs. The methodology begins by identifying customer tangible and intangibles needs, then translates those needs into metrics. Next, perceptual mapping is used to determine initial specification and select a new position for the new product. After that, new product concepts are generated and tested. The methodology is illustrated using a case-study application of new pen development.

Keywords: *Affective Design; Kansei Engineering; Marketing; New Product Development; Perceptual Mapping.*

1. Introduction

The liberalization and globalization of markets created an intensified competition where product developers produce functionally equivalent products making it significantly difficult for customers to compare, evaluate, and choose a product merely based on functional performance. Consumer choice could be treated as being part of a broader customer ownership experience that contains both tangible and intangible components that begins with the recognition of the need for buying a product and ends with the disposal of it. The mental process used by consumers to choose a product involves the evaluation of multiple product parameters in conjunction with the preconceptions towards the product formed through previous experience, word of mouth, and/or the form by which the product was instantiated. The change of the way that customers deal with the choice and evaluation of products resulted in a considerable change in the methods used to develop new products. Therefore, product development practitioners began developing approaches that rely on using customer research instruments for the integration of intangible needs or affective values in the design of new products. These methods are based on the concept of Kansei engineering or Affective design which can be defined as an ergonomic consumer-oriented product development methodology for acquiring and transforming customer affections into design attribute settings using quantitative methods [1]. The methods developed based on Kansei engineering to integrate consumer emotions with product design adopt many different procedures, but they all address the problem of how to identify emotional requirements of a product, then how to establish the relationship between these emotional requirements and product design, and finally propose ways to improve product design to fulfill the consumer emotional requirements of Kansei needs. For example, Petiota and Yannou suggested a general approach to assess product semantics based on usability tests and several classical methods in marketing and decision-making theory [2]. Park and Han developed fuzzy rule-based models for explaining the relationship between affective user satisfaction and product design attributes [3]. Schütte proposed an overall framework of Kansei engineering to address the correlations between the Kansei domain and the product domain using various statistical methods [4]. Lai, Lin, and Yeh used artificial neural network to determine the best design combination of product form elements for matching a given product image represented by a word pair [5]. Hsiao and Tsai employed genetic algorithms to search for a near optimal design which would satisfy the required product image using a trained neural network as a fitness function [6]. Lau et al. used a fuzzy logic approach for the prediction of fabric specimens in fashion product development [7]. Jiao, Zhang, and Helander developed a Kansei mining system for generating Kansei mapping patterns using associated rule mining [8]. Barone, Lombardo, and Tarantino proposed a methodology using ordinal logistic regression for conducting a Kansei engineering project in the early phases of product development [9]. Chang used quantification theory I to examine visual comfort from the standpoint of a consumer's sense of looking or feeling at ease with a product [10]. Yan et al. suggested a target-oriented decision analysis method to quantify how well a product meets consumer's Kansei preferences using three types of fuzzy targets [11]. Hong, Han, and Kim proposed a variant of multiple response surfaces methodology for optimally balancing affective dimensions [12]. A setting of design attributes which optimally balance the luxuriousness, attractiveness and overall satisfaction was obtained. Orsborn, Cagan, and Boatwright quantified aesthetic form preference using utility functions [13]. Zhai, Khoo, and Zhong proposed a rough set-based decision support approach to study the interactions between customer affective needs and product attributes [14]. Aktar Demirtas, Anagun, and Koksal adopted an ordinal logistical regression to determine an optimal design attribute settings by maximizing the overall preference scores [15]. Yang and Shieh developed a model that predicts consumers' affective

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responses for product form design by using a genetic programming-based support vector regression model [16]. Chan, Kwong, et al. developed a method based on genetic programming (GP) to generate models for relating customer satisfaction to design attributes [17]. Fung et al. employed a multi-objective genetic algorithm approach to generate approximate rules used to determine the lower and upper limits of the affective effect of design patterns [18].
These methods focused on discovering the interaction between customer affections and design attributes and attempted to determine the optimal setting of the design attributes for affective characteristics of products to achieve the highest level of customer satisfaction. The underlying theme governing these studies was the belief that product designers' experience can discover these relations through the usage of quantification methods. Thus, the emphasis was on the quantification methods, and less emphasis was given to the linkage between marketing and engineering. However, it is also well recognized that the success of product design requires an efficient and effective integration of engineering and marketing especially in the early stages of product development which is usually called the fuzzy front-end of product design. The product development process is broken into a set of stages addressed separately. For instance, the marketing stage is concerned with understanding customer needs and identifying market opportunity while design engineers are concerned with specifying the functional parameters of products needed to meet a set of desired target performance. This means that the two main communities (marketing and engineering design) have different languages and notions of success drivers, optimization variables and the nature of constraints that govern product development. This led to the development of several formal methodologies to link marketing and engineering. For example, Luo et al. introduced a methodology that integrates design robustness with customer preference robustness to evolve new product design alternatives using multi-objective genetic algorithms [19]. Michalek et al. adopted an analytical target cascading (ATC) method to explore the interrelationships between consumer preferences and engineering capabilities and to formalize the process of coordinating marketing and engineering design to yield a joint optimal solution [20]. Besharati et al. developed an integrated design and marketing approach to facilitate the generation of an optimal robust set of product design alternatives to carry forward to the prototyping stage [21]. Jiao and Zhang were able to solve the product portfolio planning, while taking into account both the customer and engineering concerns, by formulating the product portfolio planning problem using conjoint analysis and multi-nominal logit choice models linking the marketing concerns with the product specifications and manufacturing cost, then solved the problem by proposing a genetic algorithm (GA) [22]. Kumar et al. relied on using market segmentation and nested logit to develop a methodology for integrating marketing with engineering concerns for product family design [23].
Although, several attempts were made to integrate marketing with engineering for the design of a single product or a product family. There is still a need for developing methodologies that incorporate affective design during the early stages of product design especially during the conceptual phase before any design strategy commitment is made. This research proposes a systematic new product development methodology capable of integrating the processes needed to elicit intangible customer needs that correspond to customer feelings, attitudes, and emotions and translates those needs into quantifiable and controllable product parameters that could be used in the development of new products to meet both customers' functional and affective needs.

2. The proposed methodology

In this paper, a methodology for developing new products is proposed. The methodology integrates both customers' tangible and intangible/affective needs into the development process and facilitates developing new product concepts that account for both types of needs. The methodology tries to embed customer needs into the process of determining the initial product design specification. The proposed methodology consists of five phases as shown in Fig. 1.

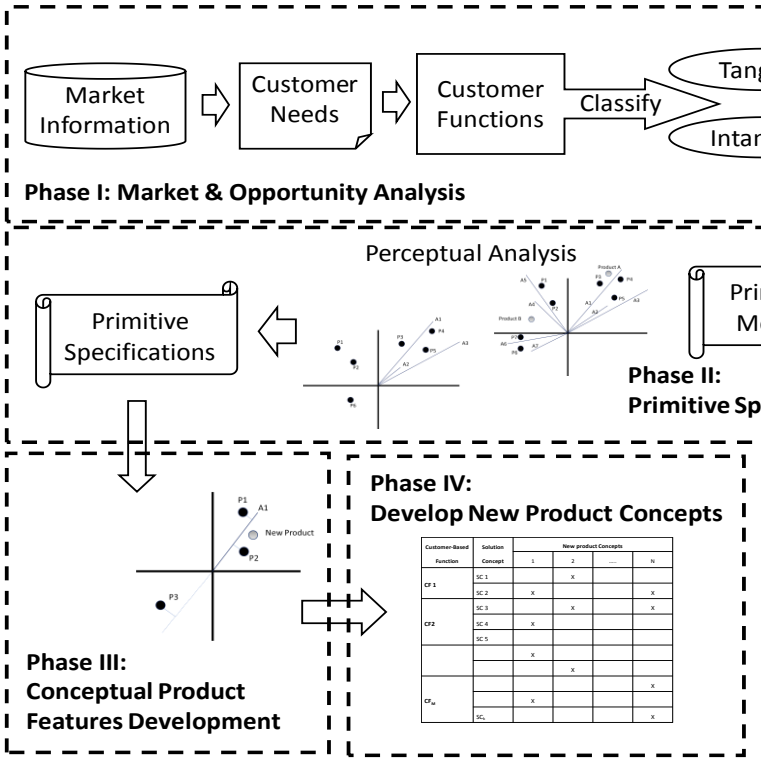


Fig. 1: The Proposed Methodology.

Phase I: Market & Opportunity Analysis.
Markets are composed of diverse customers who differ in their demographics, usage patterns, buying behaviors, and quality perceptions. Market analysis investigates these differences to identify a market opportunity that can be fulfilled by an engineering effort. This investigation includes identifying niche segments that could be served by customized products. Understanding customers' needs require understanding product quality from the perspective of customers since customer acceptance of products is motivated by the assessment that customers associate with the functions performed by the product and the way these functions were instantiated in form. Product quality features can be categorized into [24]:

a) Tangible Quality Features: these features are characterized by being predominantly measurable performance-based attributes of the product and could be related to customer requirements using Kano Model [25] which provides three categories of customer requirements related to product quality features that affect customer satisfaction. These categories are:

i) The must-be or basic quality: Here, customers become dissatisfied when the performance of this product criterion is low or the product attribute is absent. However, customer satisfaction does not rise above neutral with a high-performance product criterion.

ii) One-dimensional or performance quality: Here, customer satisfaction is a linear function of a product criterion performance. High attribute performance leads to high customer satisfaction and vice versa.

iii) The attractive or excitement quality: Here, customer satisfaction increases super-linearly with increasing attribute performance. There is not, however, a corresponding decrease in customer satisfaction with a decrease in criterion performance.

b) Intangible Quality Features: these are affective features which are mostly subjective and are related to perceptions. They are usually the result of an image the customer formed over time that may have been affected by a wider perception affected by marketing effort. These features include feelings, emotions, and aesthetics. It is important to note that the

customer cannot directly state the intangible quality features, and it is hard to directly correlate them to product features. This means that indirect or sensory measures are needed to assess and correlate these features.

Design effort is usually targeted at fulfilling product quality features by selecting a combination of product features capable of delivering the required performance to meet or exceed customer quality expectations. The design effort may include developing product features by specifying component details to deliver tangible quality features. In addition, the design effort may include specifying the requirements for a marketing campaign to alter customer perceptions about product intangible quality features. The focus of the market analysis phase to identify customer needs and represent these needs in term of functions that could be eventually delivered by a set of components. This analysis could be performed using the following procedure:

Step I: Elicit Customer Information

Customer information can be gathered by studying the current literature, product catalogs, magazines, manuals, and by interviewing representatives of potential and experienced end-users. The methods used include –but are not limited to- [26, 27]:

- Interviews: One or more design team members discuss the needs with a single customer. Interviews are usually held in the customer environment. One possible format of the interview is to watch customers use a product and then ask the customer to describe what they liked or disliked about the product.
- Focus Groups: A moderator facilitates a session with a group of customers where exploratory questions are asked by the moderator to uncover the customer needs.
- Questionnaire: The design team develops a list of criteria relevant to the customer and then the customers are asked to rank the product based on the developed criteria.
- Observe the product in use: the design team watches customers use an existing product or perform a task for which a new product is intended.

Step II: Translate Customer Statements into Customer Needs

Customer information gathered in step 1 is analyzed and expressed in terms of written needs by translating what the customer stated about the product understudy into what the design team believes the customer wanted/demanded through these statements. This process is highly dependent on the skill and experience of the design team, and there is a good chance that needs may be missed or be mistranslated. Nevertheless, some guidelines with respect to how the needs should be written can be followed to ensure that the translation process is effective [26, 27]. These guidelines are:

- Express the needs in terms of what the product does, not how it does it, nor what it does not do.
- Express the need as an attribute of the product.
- Avoid using any wording that implies importance such as must or should.

Step III: Express Needs as Functions

A product function describes what a product does to satisfy the customer. A function can be defined as a required performance action described by two words, a verb (active) and a noun (measurable), without identifying a specific method of performing that action. Expressing needs as functions requires that each customer need to be translated into a function that could be performed by the product. The mindset here is investigating what the product should do to satisfy the customer need, not how the product does it. This focus on functions enables the designers to focus on the required performance rather than on components. It should be noted here that there are needs that are served not by what the product does, but rather how the product is instantiated in form. The functions identified in this step will be called Customer-Based Functions (CF).

Step IV: Classify Customer-Based Functions

Once customer needs and their respective customer-based functions are identified, the next step would be to classify those functions into tangible and intangible/affective functions. Tangible functions refer to all functions that can be objectively measured with relative ease and are usually the result of direct engineering design effort where the features responsible for achieving such functions can either exist or not in the product under investigation. As for the intangible functions; they are usually subjective and are hard to measure or are non-measurable. Intangible functions are achieved through customer perceptions and affections towards the product and could be affected by the way the product was instantiated in form.

Step V: Prioritize Customer-Based Functions

Customer-based functions are the means by which the development team intends to achieve customer needs. Thus, it is well accepted that all functions should be considered important to some customers. On the other hand, it is more beneficial to know the importance of each function to all the population of customers, or the importance of each function to some customer segment. This allows the development team to focus their efforts on functions that matter more to customers and leads to developing more competitive products. It should be emphasized here that basic functions, which constitute the basic reason why a customer uses a product, should always exist in the product under development. There are many methods that can be used to determine the importance of customer functions. One common method is to simply rely on the consensus of the design team based on their experience with customers. Other methods include surveying customers using questionnaires and using various statistical tools to analyze and determine the needs' importance. The Analytical Hierarchy Process (AHP) is widely used in prioritization and will be used in this paper to prioritize the customer-based functions.

Phase II: Primitive Specification Development

Specification development is a process that entails interpreting customer needs represented by their respective customer-based functions into technical terms capable of describing the desired functional characteristics of the product under study. Customer-based functions tell what the product should do in general terms, while design specifications tell what the product should do in exact terms. Design specifications consist of a metric and a value. For example, a customer need for a product could be "the product is easy to assemble" and the respective customer-based function could be interpreted as "ease assembly", the corresponding specification might be "the average assembly time is less than 120 seconds". Developing specifications usually include developing a list of metrics that reflect the degree to which the product meets the predefined needs. Then competitive benchmarking can be used to determine the relationship of the new product to the competitive products. After that target values are assigned to the selected metrics and the specifications are refined. The process of establishing design specifications in this research is illustrated in the following steps:

Step I: Prepare a List of Primitive-Metrics

Customer-based functions identified in the previous steps are translated into measurable characteristics or metrics that reflect the degree to which the product satisfies the needs. In an ideal situation, the translation from customer-based functions to metrics is possible and each function can be represented by one (and only one) metric; thus, meeting the metrics will lead to customer satisfaction. This assumption is considered valid theoretically, but there are functions that cannot be measured or that are difficult to represent by a single metric. That is, some objective or tangible functions may require the use of more than one metric to achieve. As for intangible or affective functions, it may be hard to measure or even assign a specific metric to measure. This means that the development team will have to relate these intangible functions to some characteristic of the product under study. This includes the form by which the product was instantiated by investigating the perceptions customers have about products when compared to each other. This process is usually time-consuming and require a significant amount of effort to identify an appropriate set of metrics. The effort needed can be reduced by developing a set of "primitive-metrics" used primarily for comparing existing products or concepts. The main purpose of these primitive-metrics is to allow the relative comparison of products by customers which will eventually facilitate the process of discovering product characteristics that influence customer judgments. Each customer-based function will be represented by one primitive-metric that can assume a value on a scale ranging from

lowest performance to highest performance. For example, the customer-based function of "ease assembly" could be represented by the primitive-metric "easiness of assembly" and customers could be asked to rate several product concepts using a Likert-type scale where 1 represent the hardest to assemble and 5 represent the easiest to assemble. The use of such an approach allows the development team to incorporate the vagueness in the development at this conceptual stage and defers dealing with the particulars of engineering design to later stages. This will keep the analysis at a macro-level allowing the development team to explore more solution venues.

Step II: Analyze Customer Perceptions

Customer perceptions will be analyzed using perceptual mapping. A perceptual map is a graphical representation in which competing alternatives are plotted in a Euclidean space [28]. Perceptual maps are designed to show how the average target market consumer understands the positioning of the competing products in the marketplace. It is a tool that attempts to map the consumer's perceptions and understandings in a diagram. Perceptual maps measure the way products are positioned in the minds of consumers and show these perceptions on a graph whose axes are formed by product attributes [29]. A perceptual map represents customer perceptions and preferences spatially by means of a visual display. Perceptual maps can be constructed in three methods: (1) determinant perceptual mapping, (2) attribute rating (AR) perceptual mapping, and (3) overall similarities perceptual mapping [30]. Attribute rating (AR) perceptual mapping have been adopted in this research to derive perceptual maps from customer evaluations of competing products along pre-specified attributes. The attributes of interest will be the primitive-metrics that were determined based on the customer-based functions. The process of analyzing customer perceptions using perceptual maps involves the following steps:

a) Identify products for evaluation

This step involves surveying the market and identifying several existing variants of the product. This allows the design team to investigate a wide range of products that share similar features and vary in other features. The analysis will result in identifying the methods or components used in products to deliver customer needs.

b) Obtain perception data from questionnaires given to target segments

Customer perception data about product performance with respect to the primitive-metrics is gathered in this step. Customers are asked to rate either all products for one primitive-metric at a time or one product at a time for all primitive-metrics. Customer ratings range from 1 (worst) to 5 (best) for each primitive-metric. This data is averaged across customers within a certain target segment to represent the perception of this segment. The underlying assumption of the averaging is that customers within a specific segment share similar perceptions about competing products. In cases where this assumption is believed to be false, then the development team need to use a segmentation approach to identify customer sub-segments that share similar perceptions.

c) Plot the perceptual map

Plotting a perceptual map involves using statistical techniques such as factor analysis and multiple discriminant analysis. The specific mechanics of using such statistical techniques is beyond the scope of this paper and can be found in many references such as (Hair et. al and Malhorta) [31], [32]. The resulting map will include the products and the primitive-metrics as illustrated in Fig. 2.

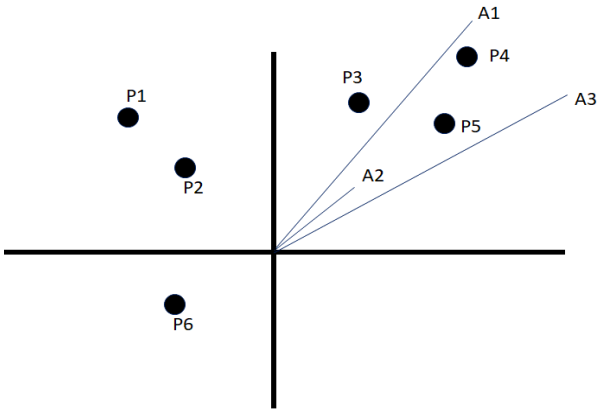


Fig. 2: Product and Attribute-Based Perceptual Maps.

The interpretation of the maps is as follows:

- The distances between products indicate similarities in the minds of customers, such that the shorter the distance, the more similar the products are perceived by consumers.
- Lines on the map indicates both the magnitude and direction of the primitive-metrics (attributes).
- The length of the line reflects the fraction of the variance in that primitive-metric (attribute) that the map is able to represent.
- Correlated primitive-metrics can be determined using Fig. 3.

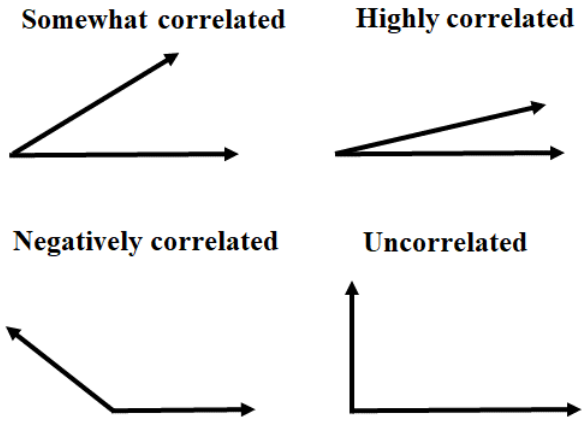


Fig. 3: Correlated Attributes.

Step III: Set New Target Position on the Perceptual Map

A target product position on the perceptual map represents how the development team would like the product to be perceived by the target customer segment. This can be done by selecting a position on the map close to some products that the development team believes that they can compete with. This location represents the market image the development team would like to construct for their product. For example, Product A on the map in Figure 4 represents a location for a product that is intended to compete with products P3 and P4. This new product will need to be perceived by customers as being similar to products P3 and P4 mainly with respect to attributes (primitive-metrics) A1 and A2 since these are the main metrics that affected the perception of the customers. On the other hand; the development team may instead select a position on the map that they believe represent a gap that can be filled by designing new products possessing similarities with different product groups. Product B on the map in Fig. 4 represents such a new product that will combine some similarities from Products P1, P2, P6, and P7 and serves a market segment that values the attributes dominant in these products, namely attribute A4, A5, A6 and A7.

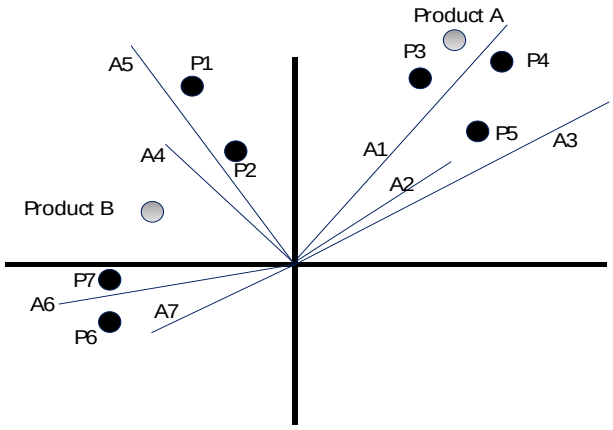


Fig. 4: Locating A Target Position for A New Product on A Perceptual Map.

The new target position may represent the design of a new product or a redesign of an existing product. In the case of new product design, the development team objective will be to develop a product that serves a specific market and thus it should be perceived as being similar and competitive with certain products. While the second case which includes the modification of an existing design, the objective will be to change the way a product is perceived by customers by determining which features should be modified to gain the required image or perception by customers. It should be mentioned here that sometimes, the development team may conclude that the existing design does not need any engineering modifications in terms of features and performance, and the problem would be a marketing issue mainly about communicating these features to customers which will require extensive marketing efforts to change the perception. This paper will not address how to design marketing campaigns to alter perceptions and will only focus on the steps needed to design new products.

Step IV: Value Assignment to Primitive-Metrics

The location of the new product on the perceptual map determined in the previous step is used to set the values to the primitive-metrics identified earlier. The values are assigned in a way to incorporate the relative position of the new product with respect to other products on the map. That is, the value assigned to each primitive-metric should include enough vagueness to allow the design team to explore more options and solutions while providing guidelines as to which products should be analyzed to uncover the deriving features that lead to the acceptable level of customer perceptions. This means that the primitive-metric will assume values like: similar to the performance of product X, not worse than product Y, better than Product Z, … etc. For example, the value assigned to the primitive-metric A1 of product A in Figure 4 will be better than the performance of product P3.

Phase III: Conceptual Product Features Development

This phase is intended to identify the product concept features that can deliver the required customer-based functions and perceptions as identified in earlier phases. The main idea here is to identify product features that affect both tangible and intangible functions, in addition to setting the required level of performance for each of those features such that the required perceptual image of the product could be gained. This approach allows the development team to enter a state of guided search where the focus will be on one primitive-metric at a time coupled with the analysis of the set of products that possess the desired performance on that specific metric, and the products that possess the undesirable performance.

The analysis in this phase involves conducting engineering analysis of the product(s) to identify sub-systems and/or components that influence the primitive-metrics. This will result in identifying several solutions or designs used by other products (competitors) to meet the desired customer-based function represented by the primitive-metric with various levels of success as depicted by the perceptual map. For example, Fig. 5 shows a subset of a perceptual map that shows one primitive-metric (attributes) called A1, and three products (P1, P2, P3) with different performances with respect to A1. Drawing a perpendicular line from each product to the attribute line will show the order of perceived performance of each product. In this case, P1 had the best performance followed by P2. As for P3, it falls on the negative side of the attribute line (the dotted line), which indicates a negative performance. According to this map, the new product should have a performance on attribute A1 that is between the performance of P1 and P2 which could be achieved by adopting design solutions (product features) similar to those used in P1 and P2 to accomplish the required performance. On the other hand, the design solution used in P3 should be avoided since it leads to negative perception with respect to attribute A1.

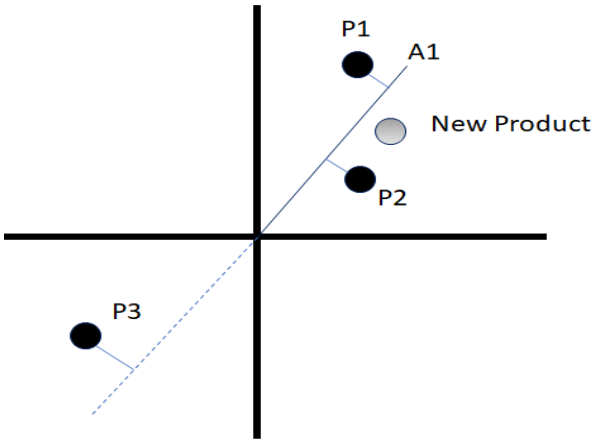


Fig. 5: Partial Perceptual Map Showing One Primitive Metric.

The general procedure followed in this phase for each primitive-metric will be as following:

- Select the product(s) that have the best performance with respect to the metric understudy, i.e. products that received high ratings on that metric.
- Decompose the product and determine the solution concept (product sub-system or features) that affects the metric.
- Set product specification with respect to the metric.

The result of this phase will be the identification of solution concepts along with product sub-systems responsible for delivering the function measured by the primitive metric.

Phase IV: Develop New Product Concepts:

A product concept is an approximate description of how a product will satisfy the customer needs. It consists of a description of how the product solution concepts identified earlier will be integrated to form a complete product or a set of variant products. The development team would need to decide which market segment the new product will serve and choose product solution capable of delivering the product functions that can serve the needs within this market segment. The process used in this phase starts by selecting a product solution concept for the most important customer-based function identified earlier. Then solution concepts for the next important function are selected and so on. This process considers any conflicts or restrictions that may exist between different concepts. For example, selecting a certain product concept may eliminate the possibility of using another concept. This process is facilitated by using a matrix as shown in Table 1, where the product functions and the solution concepts for each function are listed in the first two columns. The next column would represent product concepts. An "X" within the cells means that the concept solution is included in the product concept, and a blank cell means it is not.

Table 1: New Concept and Customer-Based Function Mapping Matrix

Customer-Based Function	Solution Concept	New product Concepts 1	2	….	N
CF 1	SC 1		X		
	SC 2	X			X
	SC 3		X		X
CF2	SC 4	X			
	SC 5				
		X			
			X		

		X
CF_M	X	
	SC_k	X

Phase V: Test and Validate New Concepts

This phase includes testing the new product concepts developed in the previous phase by showing it to target customers and recording their feedback. The process used here relies on developing a new perceptual map using the same approach used to assess the existing products in phase II. The goal here is to check if the new product concepts were able to achieve the required perception or not. If the concepts were successful, then the new product concept can undergo further development in the detail design phase. On the other hand, if the product concept failed to get the required perception, then the concept is abandoned.

Illustrative Example:

A case study of pen design was conducted based on the proposed methodology to illustrate its usage and evaluate its applicability.

Phase I: Market Analysis & Opportunity Analysis

Step I: Elicit Customer Information

Customer information was gathered by interviewing several customers. The interviews took place in a shop right after pen purchase took place. Where customers were asked about why did they buy the pen and what they liked and disliked about it, in addition to some demographic questions to gain a better understanding about the customers and their typical uses and needs. A sample of the form used for the interview is shown in table 2.

Table 2: Sample of Customer Statements

Age:	19 years
Profession:	College student
Typical uses:	Taking notes in a class
Price Paid:	$1.5
Number of pens purchased in the last three months:	2
Likes	It is easy to write with this pen, it is so smooth. The cost is so low that I don't care if I lose it. The pen writes so many pages. The pen writes firmly and precisely.
Dislikes	The pen sometimes smudges. The pen skips (the ink flow is not steady all the time). The cap gets lost easily.

Step II: Translate Customer Statements into Customer Needs

The customer statements gathered in the first step are now translated into needs that follow the guidelines presented previously in the paper.

Customer Needs

- The pen writes smoothly.
- The pen writes on paper.
- The pen is comfortable to use.
- The pen is attractive.
- The pen price is low (affordable).
- The pen indicates the amount of ink left.
- The pen shows the color of the ink.
- The pen looks elegant.
- The pen can project a luxurious image.
- The pen can fit in hand.
- The pen can fit in pocket.
- The pen preserves the ink (does not spill).
- The pen can last for a long time (writes a lot).

Step III: Express Needs as Functions

This step includes expressing customer needs as functions that can be performed by the product. It should be noted here that a customer need should be satisfied by at least one product function, and a product function can be used to meet one or more customer need. The functions identified will be called Customer-Based Function (CF) and are listed in Table 3.

Table 3: Customer-Based Functions (CF) for the Pen

Customer Need	Customer-Based Function
The pen writes smoothly	Provide smoothness
The pen writes on paper	Make marks
The pen is comfortable	Provide comfort
The pen is attractive	Attract customer
The pen price is low (affordable)	Minimize cost
The pen indicates the amount of ink left.	Indicate amount of ink
The pen shows the color of the ink.	Show color of ink
The pen looks elegant	Show elegance
The pen can project a luxurious image.	Project luxury
The pen can fit in hand	Fit hand Be compact
The pen can fit in pocket	Fit pocket Be compact
The pen preserves the ink (does not spill)	Maintain cleanness
The pen can last for a long time (writes a lot)	Maintain operation

Step IV: Classify Customer-Based Functions

The customer-based function identified are classified in this step into Tangible and Intangible functions. The classification was based on whether the function is objective in the sense that it can be associated with a measurable product feature, or the function is subjective and is the result of customer perceptions about the product. The classification of the functions for the pen is presented in Table 4.

Table 4: Customer Needs Classification

Customer-Based Function	Type	Justification
Provide smoothness	Tangible	Objective, can be related to some performance measures such as the follow of material
Make marks	Tangible	Objective, can be measured directly.
Provide comfort	Tangible	Objective, can be related to some performance measures such as the amount of pressure exerted by the customer to write.
Attract customer	Intangible	Subjective, cannot be measured directly.
Minimize cost	Tangible	Objective, although may vary considerably between different customer segments.
Indicate amount of ink	Tangible	Objective, can be related to a specific product feature.
Show color of ink	Tangible	Objective, can be related to a specific product feature.
Show elegance	Intangible	Subjective, cannot be measured directly, and cannot be related to a specific product feature.
Project luxury	Intangible	Subjective, cannot be measured directly, and cannot be related to a specific product feature.
Fit hand Be compact	Tangible	Objective, can be related to specific product features.
Fit pocket Be compact	Tangible	Objective, can be related to specific product features.
Maintain cleanness	Tangible	Objective, can be related to specific product features.
Maintain operation	Tangible	Objective, can be related to specific product features.

Step V: Prioritize Customer-based

The AHP was used to prioritize customer-based functions except for the basic function "Make Marks" since this function must exist in any new concept otherwise the pen will be rendered useless. The

results of the prioritization were found to be as shown in Table 5. The Consistency Ratio for the AHP was found to be 0.026 which indicates that the rating done by the customers were consistent.

Table 5: Function Importance Rating using AHP

Function	Importance Rating
Minimize Cost	5.3%
Be Compact	3.5%
Indicate Amount of Ink	4.0%
Show color of Ink	3.8%
Maintain Cleanness	9.5%
Provide Smoothness	12.2%
Provide Comfort	12.7%
Attract Customers	16.6%
Show Elegance	14.2%
Project Luxury	18.4%

The results of prioritization show that the most important functions from the perspective of customers are:

- Maintain Cleanness
- Provide Smoothness
- Provide Comfort
- Attract Customers
- Show Elegance
- Project Luxury

These functions will constitute the basis for further investigation and will be used in determining the specification for the pen understudy. The development team may eventually add features that correspond to less important functions if possible. But at this stage, the team was asked to concentrate on the most important functions in the subsequent phases.

Phase II: Primitive Specification Development

Step I: Prepare a list of Primitive-Metrics

A list of primitive-metrics corresponding to the customer-based function was developed as shown in Table 6.

Table 6: List of Primitive-Metrics

Customer-based function	Primitive-Metric
Maintain Cleanness	Cleanness
Provide Smoothness	Smoothness
Provide Comfort	Comfortability
Attract customer	Attractiveness
Show elegance	Elegance
Project luxury	Luxuriousness

Step II: Analyze Customer Perceptions

a) Identify products for evaluation

A group of nine pens was used in the analysis. These pens are shown in Fig. 6.

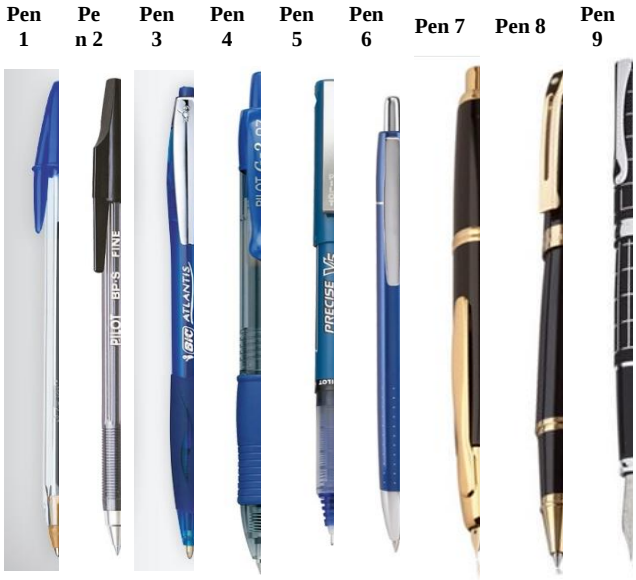


Fig. 6: Pens Used in the Analysis.

b) Obtain perception data from questionnaires given to target segment

The pens selected in the previous step were evaluated based on the primitive-metrics identified in the previous phase. The evaluation was conducted by showing the pens to customers and asking them to rate each pen with respect to the primitive-metrics. This was performed with the aid of the questionnaire shown in Fig. 7. The sample contained 45 respondents. Each respondent was asked to test and evaluate three pens to reduce fatigue. This resulted in 15 ratings per pen attribute.

How clean is the pen writing?

Least Clean				Most Clean
1	2	3	4	5

How smooth is the pen writing?

Least smooth				Very Smooth
1	2	3	4	5

How comfortable is the pen?

Least comfortable				Most Comfortable
1	2	3	4	5

How attractive is the pen?

Least attractive				Most attractive
1	2	3	4	5

How elegant is the pen?

Least elegant				Most elegant
1	2	3	4	5

How luxurious is the pen?

Least luxurious				Most luxurious
1	2	3	4	5

Fig. 7: Questionnaire Used to Gather Customers' Perception Data.

c) Plot the perceptual map

The resulting perceptual map was found to be as shown in Fig. 8.

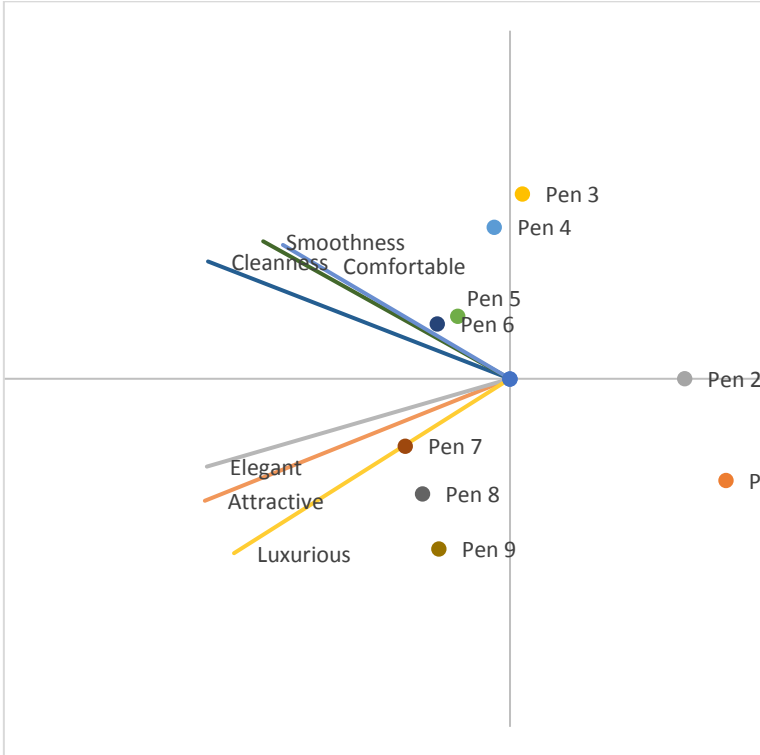


Fig. 8: Pens Perceptual Map.

Examining the map reveals the following:

- The primitive metrics smoothness and Comfortable are highly correlated, and both are somewhat correlated with cleanness. This means that these metrics could be caused by some interrelated features of the product.

- Elegance, attractive, and luxurious are somewhat correlated, which could also mean that perception of these metrics is influenced by similar product features.
- Pens 1 and 2 are perceived to be different than all other pens and they are perceived as having negative performance on all metrics (attributes)

Step III: Set New Target Position on the Perceptual Map
In this case, it is assumed that the development team wishes to develop a new pen that caters to customers who desire elegant, attractive and luxurious pens while maintaining a high level of cleanness, smoothness, and comfort. This new pen concept can be located on the perceptual map in area A as shown in Fig. 9.

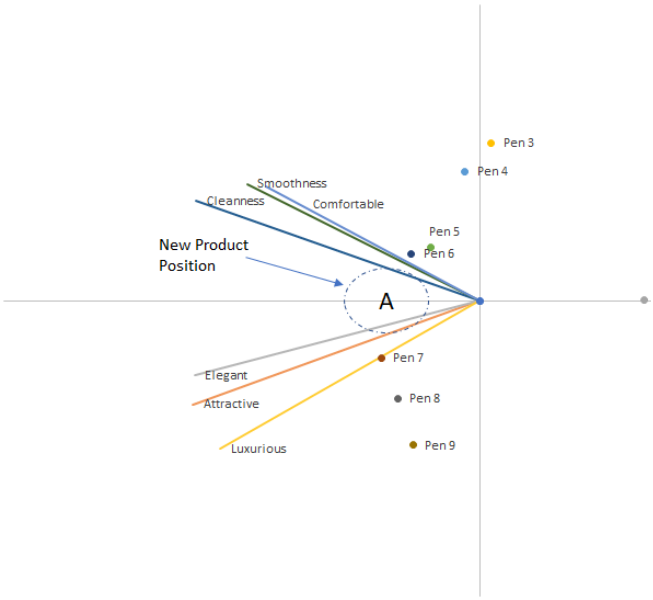


Fig. 9: New Product Target Position.

Step IV: Value Assignment to Primitive-Metrics:
Using the location of the new proposed pen position on the perceptual map, the following relative specifications could be specified as shown in Table 7.

Table 7: Relative Specifications

Feature	Relative Specification
Cleanness	
Comfort	Similar to Pens 6 and 5
Smoothness	
Attractive	
Elegant	Similar to Pens 7 and 8
Luxurious	

Phase III: Conceptual Product Features Development
The product features or design-concept solutions affecting the primitive-metric were identified in this phase and were found to be as following:
Primitive-metric: Smoothness
Using the partial perceptual mapping showing only the primitive-metric "smoothness" shown in Figure 10, the products perceptual ranking were as following:

- Best performance: Pen 3.
- Moderate performance: Pen 6, Pen 7.
- Low performance: Pen 1.

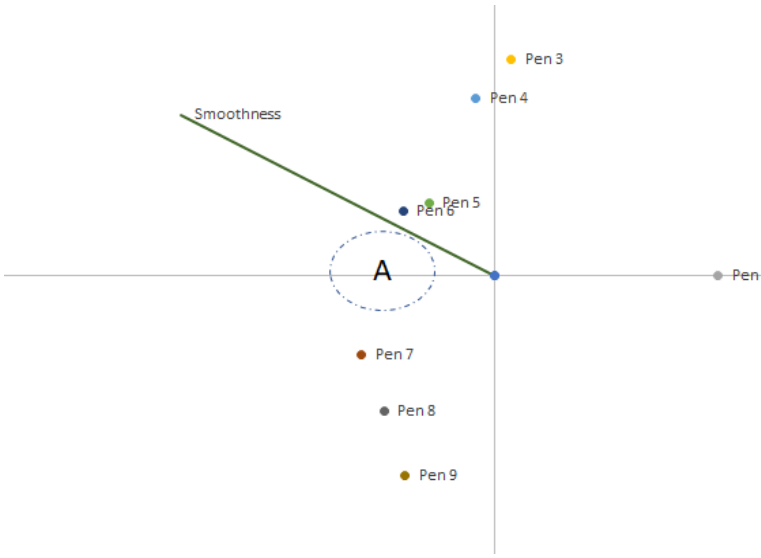


Fig. 10: Partial Perceptual Mapping Showing the Primitive-Metric "Smoothness".

Further investigation and decomposition of the products (Pen 1, 3, 6, and 7) revealed that pen smoothness could be related to the continuity of the pen writing caused by the fluidity of the ink when it passes through the ballpoint in the pen tip. This is also affected by the type and quality of ink used within the pen. The specification for this need could be measured by the consistency of the line thickness, and the existence of impurities within the ink. This need is mainly related to the Ink Delivery System and it was found that there are three general types of ink delivery systems in the pens; namely Ballpoint, Rollerball, and Fountain ink delivery system. Each system had a different level of ink fluidity and line consistency as shown in Table 8.

Table 8: Pen Ink Delivery Systems

Pen No.	Ink Delivery System Type	Ink Consistency Level
1	Ballpoint	Low
3	Rollerball	High
6	Ballpoint	Moderate
7	Fountain System	Moderate

The target conceptual specification of the new proposed product will be to use rollerball or fountain ink delivery system and avoid using a ballpoint ink delivery system.
Primitive-metric: Cleanness:
The products perceptual ranking with respect to "Cleanness" were as following,

- Best performance: Pen 3.
- Moderate performance: Pen 6.
- Low performance: Pen 1.

The perceptual map also showed that Pens 1, 2, 7, 8, and 9 are all on the negative side of the attribute. Pen cleanness is a function of the amount of ink smears that occurs when wet ink is smudged by hand. The more the smears the less the cleanness. This metric could be related to the type of ink and its drying time as shown in Table 9.

Table 9: Relation Between Ink Type and Amount Smearing

Pen No.	Ink Type	Amount of Smearing
1	Oil-based Ink	Moderate
3	Gel-based Ink	Low
6	Gel-based Ink	Low

A third type of ink also exits in fountain-type is water-based ink, and this type caused a high amount of smearing. The target conceptual specification of the new proposed product will be to use a gel-based type of ink and avoid using water or oil based type of ink.
Primitive-metric: Comfortability:
The products perceptual ranking with respect to "Comfortability" were as following,

- Best performance: Pen 3.
- Moderate performance: Pen 6.
- Low performance: Pens 1.

Comfort is related to the force felt by the user when holding the pen firmly to write. The pen body reacts to this force and causes discomfort to the user. The amount of this discomfort is a function of the pen-grip elasticity as shown in Table 10. The more elastic the material the more comfort it delivers.

Table 10: Relation Between Comfort and Pen-Grip Elasticity

Pen No.	Pen – Grip System	Elasticity
1	Pen Outer Tube (plastic)	Low
3	Special Rubber Grip	High
6	Pen Outer Tube (metal)	Low

The target specification for the new concept will be to use a special grip made of rubber to provide high elasticity and avoid using pens with plastic grips.

Primitive-metric: Elegance, Attractive, and Luxurious

These metrics represent intangible/affective needs, and the map shows that they are correlated. So they will be addressed as one metric for the sake of simplicity at this stage of the analysis. These metrics could be related to the pen material and the color of the material. As it can be shown in Figure 9 the pens that were perceived as being more elegant, attractive, and luxurious were made of colored metal with some parts being gold plated. While the least attractive, least elegant, and least luxurious were made of transparent plastic.

Table 11 shows a summary of the findings of this phase that lists all the primitive-metrics along with the suggested concept solutions based on the analysis of the existing products.

Table 11: List of Primitive-Metrics and Associated Solution Concepts

Primitive-Metric	Product Sub-System	Solutions Best	Moderate	Worse
Smoothness	Ink-Delivery System	Roller-ball	Fountain	Ballpoint
Cleanness	Type of Ink	Gel	Water-based	Oil-based
Comfort	Pen Grip	Rubber	Metal grip	Plastic Grip
Elegance	Aesthetics	Color: Black or dark colors		
Attractive	Aesthetics	Material: Metal with gold plating		
Luxurious	Aesthetics			

This phase allows the development team to focus their efforts on developing a product that can meet the desired tangible and intangible needs of customers and it also provides the team with the initial solution concepts that they may investigate to produce the required product. This also means that the development team is supported with a clear systematic method of exploring customer needs and generating solutions to meet these needs.

Phase IV: Develop New Product Concepts

The product solution concepts identified in the previous phase were integrated into new product concepts as shown in Table 12.

Table 12: New Product Concepts

Customer-Based Function	Solution	Concept 1	Concept 2
Project Luxury	Gold Plated	X	
	No Plating		X
Attract Customers	Black Color	X	
	Blue Color		X
	Transparent		
Show Elegance	Metal Outer body	X	X
	Plastic – High Grade		
	Plastic – Low grade		
Provide Comfort	Rubber Grip	X	X
	No Grip		
Provide Smoothness	Rollerball	X	X
	Fountain		
	Ballpoint		
Maintain Cleanness	Gel-based ink	X	X
	Water-based Ink		
	Oil-based ink		

Phase V: Test and Validate New Concepts

The two proposed product concepts were shown to customers along with the product (Pens: 5, 6, 7, 8) and the customers were asked to rate all products with respect to the attributes. Next, a new perceptual map was plotted. The existing pens were included in the analysis since the new product concepts are intended to include features and functions that resemble those pens and cover this area on the perceptual map as outlined earlier. The resulting perceptual map was found to be as depicted in Fig. 11.

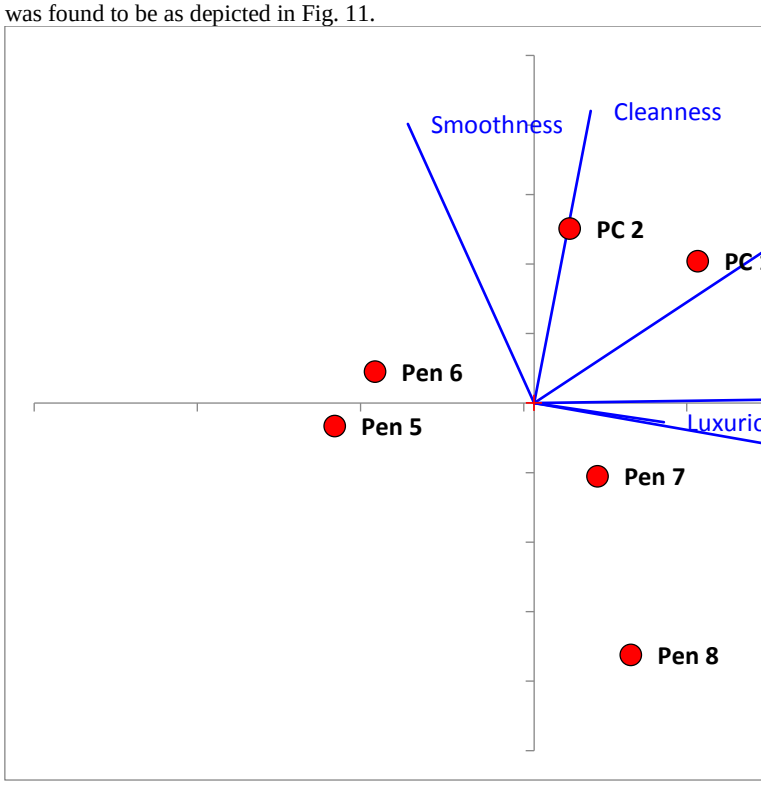


Fig. 11: Perceptual Map Showing New Product Concepts.

The perceptual map shown in Figure 11 clearly shows that the new product concepts PC1 and PC2 were perceived by customers as the development team intended. This means that the product concepts can enter the detail design phase and undergo further development.

3. Conclusion

A methodology that incorporates affective design during the early stages of product development is developed in this paper. The methodology consists of five stages that start by identifying customer tangible and intangible needs and translates those needs into metrics capable of measuring these needs. Then, initial specifications are determined in phase two with the help of perceptual mapping, and new target specification for the new product is determined after selecting a target position for the new product on the perceptual map in phase three. Next, new product concepts are generated in phase four. Finally, the new concepts are tested and validated in phase five. The use of the methodology was illustrated using a case of new pen development.

The developed methodology provides product development teams with a systematic procedure that builds on best practices used by product developers to elicit intangible customer needs that corresponds to customer feelings, attitudes, and emotions and translates those needs into product parameters that could be used in the development of new products that meet both the customer functional and affective needs. The developed methodology recognizes that product developers need to maintain a level of vagueness during the

early stages of product development so as to allow for creativity during the conceptual phase, and as a result, the methodology defers dealing with the specifics of design to later stages, namely during the detail design phase.

Future work could extend the proposed methodology to link it to the detailed engineering design phase. This may include developing procedures to assess product parameters based on their effect with respect to tangible and intangible needs, followed by an optimization methodology to select the best parameters to achieve the required level of product performance.

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