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A novel approach to incorporate customer preference and perception into product configuration: A case study on smart pads

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ABSTRACT

This paper proposes a hybrid framework combining AHP (analytical hierarchy process), KM (Kano model), with DEMATEL (decision making trial and evaluation laboratory) to incorporate customer preference and perception into the process of product development. Initially, AHP is applied to respondents to form a basis of market segmentation. Thereafter, with respect to identified segments, AHP and KM are employed to extract customer preference for design attributes (DAs) and customer perception of marketing requirements (MRs), respectively. Finally, by means of DEMATEL, the causal relationships between MRs and DAs are systematically recognized to uncover new ideas of next-generation products.

1. Introduction

In a traditional "*supply-push*" driven era, manufacturing companies merely considered offering products with high quality, low cost, functioning performance and courteous after-sales service to satisfy market majorities [12]. Nowadays, owing to the concept of mass customization, customer satisfaction has become a growing concern to dominate the competing paradigm [2,6]. In order to survive in today's "*demand-pull*" environments, modern companies need to conceive attractive products/services to acquire different market segments and even for "customized" individuals [18]. Nevertheless, customers are too diverse, too heterogeneous, and too widely scattered in their preferences, perceptions, shopping behaviors, lifestyles, and their psychological demographics [27]. Thus, irrespective of the fact that high product variety does significantly stimulate product sales, most manufacturing companies are inevitably facing the trade-offs between increasing product variety and controlling manufacturing complexity [14,29]. In practice, to respond to dynamically changing customer desire, awareness of customer preference/perception is becoming much more imperative than ever before during the process of product development [21].

To tackle the aforementioned issues, one of the most famous schemes originated from the discipline of strategic marketing is a so-called "STP" approach (segmentation-targeting-positioning), which has been widely adopted among academic researchers and industrial practitioners [16]. Specifically, the step of "segmentation" allows marketers to divide the entire market into ad-hoc segments in which customers demonstrate similar patterns within a group but behave heterogeneously between groups. Secondly, the step of "targeting" helps a firm assess each segment's attractiveness, profitability, and then be able to select one or more segments to run their business. Finally, the step of "positioning" emphasizes differentiating a firm from competitors through offering attractive alternatives.

Apparently, market segmentation is the most critical step to achieve the success of the entire process of STP. According to Wang [28], there are several commonly used variables for market segmentation, including demographic variables (i.e. age, gender, race, and salary), psychographic variables (i.e. social class, lifestyle and personality) and behavioral variables (i.e. user preference, usage pattern, and loyalty status). Theoretically, market segmentation assumes that groups of customers with similar profiles or patterns are likely to demonstrate a homogeneous response to specific product promotion and marketing programs [9]. In this study, the purpose of market segmentation is to form a launch pad for generating and assessing potential product alternatives, particularly with respect to those identified niche segments. To effectively divide the whole market, customers' perceived importance degrees of design attributes are treated as input variables to carry out market segmentation.

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Furthermore, to help an enterprise better understand and capture dynamically changing customer desire, this paper attempts to incorporate customer preference as well as customer perception into the process of product development, especially to diminish the gap between customers' requirements and manufacturers' alternatives. Consequently, a market-oriented framework which integrates AHP, KM with DEMATEL is proposed and several key issues are addressed below:

- Learning which design attributes (DAs) are more representative to segment the entire market,
- Examining customer preference for multi-leveled DAs for generating concepts and assessing product alternatives in a customer-driven manner,
- Eliciting customer perception of marketing requirements (MRs) to form a launch pad for discovering new ideas of the next-generation products,
- Identifying the complicated interrelationships between DAs and MRs to help product managers better understand their inherent dynamics.

The rest of this paper is structured as follows. Section 2 briefly overviews classical techniques for eliciting customer preference and Section 3 introduces the proposed framework. An industrial example regarding configuring product varieties of smart pads is illustrated in Section 4. Finally, conclusions and future studies are drawn in Section 5.

2. Review of classical techniques to elicit customer preference

In an era of mass customization, companies need to deliberately understand what customers want and need in order to avoid fatal mistakes before implementing their product strategies [9,12]. New product development (NPD), defined as a process of transforming an identified market opportunity into profitable product(s) for sale, usually consists of a sequence of steps in which an enterprise employs to conceive, design, and commercialize product alternatives [3]. As a matter of fact, NPD is an interdisciplinary activity involving marketing, operation, manufacturing, and requires sustainable commitment from the top level of management. Therefore, various disciplines including marketing research, consumer behavior, and concurrent engineering, attempt to contribute to different stages of NPD [18]. Currently, recent publications have witnessed emerging growth of the front-end issues such as customer relationship management and customer requirement management [14].

In fact, the capability of concept generation and concept evaluation for different segments has been recognized as one of the key determinants for many firms to survive in an extremely uncertain business environment [3,4,9,19]. Nevertheless, without incorporating customer preference or customer perception into the process of concept generation/evaluation, the objective of customer satisfaction is difficult to be fulfilled [2,6,21]. To the best of our knowledge, several techniques which are widely applied to various industries like quality function deployment (QFD), conjoint analysis (CA), and Kano model (KM), are shortly overviewed later.

2.1. Quality function deployment (QFD)

Quality function deployment [1] is a well-known scheme that provides a structural framework to translate customers' voices into tangible product design. Typically, the conventional QFD consists of the following four phases: phase one translates marketing requirements into design attributes; phase two translates design attributes into part characteristics; phase three translates part characteristics into manufacturing operation, and phase four translates manufacturing operation into production requirements [17]. By considering the interdependences between MRs and DAs and the correlations among themselves, QFD is capable to derive the priorities of DAs in terms of the weights of MRs [29,30]:

$$R_{ij}{}' = \frac{\sum_{k=1}^{n} R_{ik} \times \gamma_{kj}}{\sum_{k=1}^{n}\sum_{k=1}^{n} R_{ik} \times \gamma_{kj}}, \tag{1}$$

$$Wt_{DAj} = \sum_{i=1}^{m} Wt_{MRi} \times R_{ij}{}', \tag{2}$$

where Wt_{MRi} and Wt_{DAj} represent the weight of MR_i and DA_j, respectively. Here, m marketing requirements and n design attributes are assumed to characterize the QFD, R_{ij}' is the normalized dependence between MR_i and DA_j, and λ_{ik} and γ_{kj} denote the correlations among MRs and DAs, respectively.

Nevertheless, QFD has been criticized by insufficient customer involvement (i.e. customer preference and customer satisfaction) when generating the weights of MRs or DAs. In addition, QFD is deficient in generating/assessing product concepts, especially when a product is functionally decomposed into various design attributes associated with multi-levels. To enhance its applicability, several researchers suggest to combine the QFD with conjoint analysis (CA) or Kano model (KM) [8,21,24,26].

2.2. Conjoint analysis (CA)

Conjoint analysis [20] is one of the most popular techniques to measure diverse customer preference among multi-attributed products or services. When a product is decomposed into independent attributes associated with their corresponding levels, a respondent's overall utility could be decomposed into his/her part-worth values [8,25]. For reference, a general mathematical form of CA can be modeled as follows [13]:

$$U_k = \beta_0 + \sum_{i=1}^{m}\sum_{j=1}^{n} u_{ijk}, \tag{3}$$

where U_k means alternative k's overall utility, β_0 denotes a regularized constant, u_{ijk} represents alternative k's part-worth utility corresponding to attribute i associated with level j, m is the number of attributes and n is the number of associated levels for attribute i. To derive the importance degree of various attributes, it is widely accepted that an attribute having a wider range of part-worth values should have greater impact on the overall utility of a product.

For convenience, let's illustrate a simple example. Suppose that a smart pad is characterized by six attributes (A1–A6) associated with multi-levels (e.g. A1(3), A2(2), A3(3), A4(2), A5(2), and A6(2)), intuitively, a maximal number of 144 ($3^{2*}2^4$) combinations might be possibly generated. To derive their part-worth utilities of six attributes, it is impossible to ask an evaluator to prioritize 144 alternatives at a time. Hopefully, by means of fractional factorial design, the entire process could be significantly simplified and reduced to rank only 16 orthogonal alternatives. Obviously, CA treats a multi-attributed product on a single layer and thus it cannot process a functional hierarchy structure.

2.3. Kano model (KM)

The basic idea of KM [15] is using a nonlinear way to measure customers' asymmetric perceptions of two sides: positive delight when an attribute is present and negative disgust when an attribute is

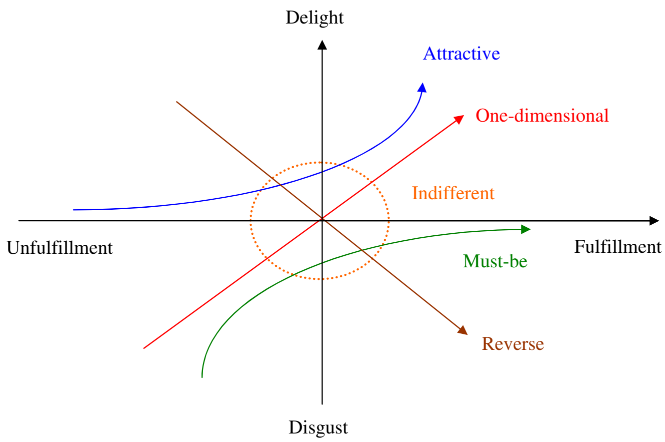

Fig. 1. Kano model for displaying customer perception.

absent, respectively. Referring to Fig. 1, various Kano categories are briefly explained as follows [21,24]:

- *Must-be* (M): the attribute which belongs to this category consists of the basic criteria of a product since customers are extremely dissatisfied if it is not fulfilled. However, its fulfillment cannot significantly increase satisfaction level since customers take them for granted,
- *One-dimensional* (O): the presence of an attribute will increase customer satisfaction level while its absence will proportionally decrease satisfaction level. This category enhances customer loyalty for companies,
- *Attractive* (A): an attribute classified in this category usually acts as a weapon to differentiate companies from their competitors since its fulfillment generates absolutely positive satisfaction while customers are not dissatisfied at all when it is unfulfilled,
- *Reverse* (R): an attribute falling into this category should be removed from a product since its presence is harmful to customer satisfaction while its absence is beneficial,
- *Indifferent* (I): an attributes falling into this category do not contribute much to customer satisfaction regardless whether they are present or absent in a product,
- *Questionable* (Q): this outcome indicates that either the questionnaire was incorrectly described or an illogical response was sent by an evaluator.

Traditionally, the Kano categories are prioritized in an order of $M \succ O \succ A$, indicating that the "*must-be*" category should be configured first, followed by the "*one-dimensional*" category, and then the "*attractive*" category. Apparently, both indifferent and reverse categories should be excluded because they cannot enhance satisfaction level at all but also incur extra manufacturing cost. To track the research trend of Kano model, interested readers could refer to a state-of-art review [22].

Although numerous studies [8,19,21,24,26] have fused various techniques to tackle different problems, most of them cannot efficiently decompose a functional product hierarchy as well as effectively facilitate customer involvement into the process of product development. After carefully review several classical techniques, an overall comparison among them is shown in Table 1 to demonstrate their relative strengths and weaknesses. Despite CA is capable to generate design concepts, it is not considered in our paper because of its deficiency of identifying the interdependences between MRs and DAs. In addition, it is found that respondents are often impatient to complete the CA questionnaires when requiring them to balance the trade-offs among design attributes. To concurrently address the aforementioned issues, the AHP is incorporated into our hybrid framework.

Table 1
An overall comparison between QFD, CA, and KM.

	QFD	CA	KM
Identifying relationships between MRs and DAs	Yes	No	No
Handling multi-leveled product attributes	No	Yes	No
Extracting subjective customer preference	Limited	Yes	Limited
Eliciting vague customer perception	No	No	Yes
Performing concept generation/evaluation	Limited	Yes	Limited
Practical feasibility	High	Low	High

3. The proposed hybrid framework

As indicated by Fig. 2, a hybrid framework which combines AHP, KM, with DEMATEL is presented and its details are operated as follows:

- Representative MRs and DAs for characterizing a smart pad are listed after surveying product specifications and consulting focus groups,
- AHP is initially utilized to extract customers' perceived importance degrees of DAs to carry out market segmentation through the *K*-means clustering,
- With respect to those identified segments, AHP and KM are employed to extract customer preference for DAs and customer perception of MRs, respectively,
- Based on the results obtained in the previous steps, competitive product alternatives are generated and evaluated in a market-oriented manner,
- By virtue of DEMATEL, the causal relationships between MRs and DAs are systematically identified to uncover new ideas of the next-generation products.

3.1. Use of AHP to extract customers' preferences for DAs

AHP (analytic hierarchy process) was originally proposed by Saaty [23] to tackle the problem of scarce resource allocation for the military. It is a simple, intuitive, yet powerful methodology to determine the importance degrees of the evaluation criteria and the priorities of competitive alternatives [3,4]. Today, AHP has been successfully applied to various domain problems [11,19]. Generally, the AHP comprises the following steps:

- Constructing a hierarchy of the decision problem: followed by a top-down approach, the hierarchy is usually decomposed into multi-levels which consist of main criteria, associated sub-criteria and competing alternatives.

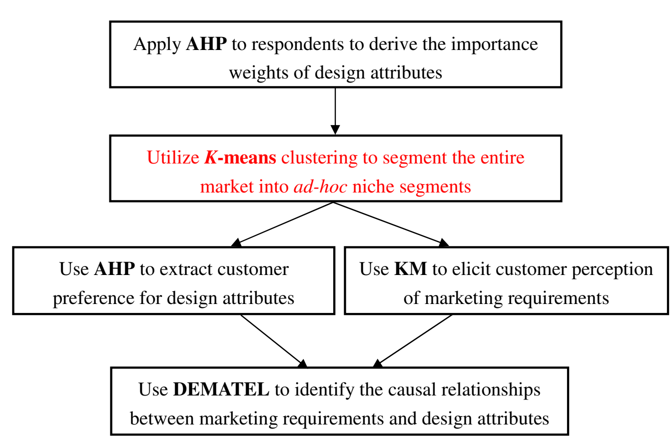

Fig. 2. Proposed techniques for market segmentation and concept evaluation.

- Employing pairwise comparisons between evaluation criteria (alternatives): Saaty [20] recommended using a 9-point rating scale to express human preference among criteria, like equally, weakly, moderately, strongly, and extremely preferred with scales of 1, 3, 5, 7, and 9, respectively. Values of 2, 4, 6, and 8 are the intermediate values for the preference scales (see Table 2).
- Computing the maximal eigenvalue (see Eq. (4)) and its associated eigenvector (see Eq. (5)) to derive their relative weights of n evaluation criteria:

$$|A - \lambda I| = 0, \tag{4}$$

$$(A - \lambda I)X = 0, \tag{5}$$

where I denotes an identity matrix, A means a $n \times n$ pairwise comparison matrix generated by n main criteria and its element a_{ij} represents the preference degree of criterion i over criterion j. In particular, when the maximal eigenvalue of matrix A (λ_{max}) is extracted, the weights of n criteria (W) could be obtained via finding its corresponding eigenvector ($AW = \lambda_{max}W$).
- Checking the decision quality of using the AHP: it is related to examine whether respondents demonstrated consistency during the process of pairwise comparisons. For example, the property of transitivity implies that "*if A is preferred to B, and B is preferred to C, then A should be preferred to C*". Hence, the consistency index (CI) and consistency ratio (CR) defined as:

$$CI = \frac{\lambda_{max} - n}{n - 1}, \tag{6}$$

$$CR = \frac{CI}{RI}, \tag{7}$$

where CI that is more closer to zero indicates its greater consistency, and RI is a random index (see Table 3) suggested by Saaty [23]. When the value of CR is less than the threshold of 0.1, the decision process might be considered to be highly consistent.

In this study, the relative weights of DAs of respondents are used to form a basis to carry out preference-based market segmentation. Meanwhile, AHP is also applied to the identified segments to extract their aggregated preference for the associated multi-levels of DAs.

3.2. Use Kano model (KM) to elicit customer perception of marketing requirements

The Kano questionnaire [15], as shown in Table 4, provides a quantitative approach to investigate asymmetric customers' perceptions: positive delight for functional fulfillment and negative disgust for dysfunctional unfulfillment (see Fig. 1. again). Initially, a respondent needs to select one of the following five linguistic terms, such as "*like*", "*must-be*", "*neutral*", "*live-with*", and "*dislike*", to reflect his/her perception of the above-mentioned two scenarios. As indicated by Table 5, 25 possible combinations of assessments are classified into one out of the six Kano categories, namely, "*attractive*" (A), "*one-dimensional*" (O), "*must-be*" (M), "*indifferent*" (I), "*reverse*" (R), and "*questionable*" (Q).

Table 2
A nine-point rating scale used in AHP and DEMATEL.

Scale	Preference measure	Influence measure
1	*Equally* preferred	*Slightly* influenced
3	*Weakly* preferred	*Weakly* influenced
5	*Moderately* preferred	*Moderately* influenced
7	*Strongly* preferred	*Strongly* influenced
9	*Extremely* preferred	*Extremely* influenced
2, 4, 6, 8	Intermediate scale between two adjacent degrees	

Table 3
Random index (RI) used by the AHP.

	Order of matrix (number of criteria)						
n	2	3	4	5	6	7	8
RI	0	0.58	0.90	1.12	1.24	1.32	1.41

In additional to obtaining Kano categories for product attributes, it is difficult to be equipped with quantitative assessments in practical implementations [22]. Based on [5,24], positive delight (d_i^+), negative disgust (d_i^-) and the importance weight of attribute i are slightly modified as follows:

$$d_i^+ = \frac{A_i + O_i - R_i}{A_i + O_i + M_i + R_i + I_i}, \tag{8}$$

$$d_i^- = -\frac{O_i + M_i - R_i}{A_i + O_i + M_i + R_i + I_i}, \tag{9}$$

$$w_i = \frac{G_i}{\sum_i G_i}, G_i = d_i^+ - d_i^-, \tag{10}$$

where A_i, O_i, M_i, R_i, and I_i represent corresponding percentages of responses among various Kano categories and the relative weight (w_i) of attribute i can be obtained through normalizing its range (G_i) defined by positive delight less negative disgust. Here, the KM is used to elicit customer perception of MRs and to derive their relative priorities for different segments. Thus, in conjunction with previously extracted customer preference for DAs, design concepts of smart pads could be systematically generated and assessed to suit customers' needs.

3.3. Use DEMATEL to identify the causal relationships between MRs and DAs

DEMATEL (decision making trial and evaluation laboratory), developed by the science and human affairs program of the Battelle Memorial Institute of Geneva Research Centre [10], is able to visualize the complex relationship among the interdependent factors. Through converting the causal relationship of the whole system into a structure model, the DEMATEL could distinguish all factors into two distinct groups: the dispatcher group and the receiver group. Its details are described as follows [29]:

- Generating the direct-relation matrix: based on a nine-point rating scale (see Table 2 again), domain experts are invited to complete influence measures between factors. Suppose there are n factors and then, a $n \times n$ influence matrix A in which its element a_{ij} denotes the impact of factor i on factor j, displays the mutual influences between these two factors.
- Normalizing the direct-relation matrix: the normalized matrix B can be obtained through Eqs. (11)–(12), in which the diagonal elements of matrix B are set zeros.

$$B = k \times A \tag{11}$$

Table 4
A sample of Kano questionnaires.

How do you feel about this attribute?		I *like* it that way	It *must be* that way	I am *neutral*	I can *live with* it	I *dislike* it that way
Attribute 1	Functional	√				
	Dysfunctional				√	
	Functional					
	Dysfunctional					
Attribute n	Functional		√			
	Dysfunctional					√

Table 5
Evaluation summary for Kano classification.

Functional presence	Dysfunctional absence				
	Like (L)	Must-be (M)	Neutral (N)	Live-with (W)	Dislike (D)
Like (L)	*Q*	*A*	*A*	*A*	*O*
Must-be (M)	*R*	*I*	*I*	*I*	*M*
Neutral (N)	*R*	*I*	*I*	*I*	*M*
Live-with (W)	*R*	*I*	*I*	*I*	*M*
Dislike (D)	*R*	*R*	*R*	*R*	*Q*

*A = attractive, I = indifferent, M = must-be, O = one-dimensional, R = reverse, and Q = questionable.

$$k = \mathrm{Min}\left(\frac{1}{\max\limits_{1\le i\le n}\sum_{j=1}^{n} a_{ij}}, \frac{1}{\max\limits_{1\le j\le n}\sum_{i=1}^{n} a_{ij}}\right). \tag{12}$$

- Generating the total-relation matrix: the total-relation matrix M can be derived via Eq. (13), where I denotes an identity matrix.

$$M = B + B^2 + B^3 + \cdots = B(I-B)^{-1}. \tag{13}$$

- Computing a causal diagram through distinguishing the transmitter group from the receiver group: Here, notice that T_i means factor i's total dispatched influence (e.g. the sum of rows in the total-relation matrix) while R_j means factor j's total received impacts (the sum of columns in the total-relation matrix).

$$T_i = \sum_{j=1}^{n} M_{ij}, \tag{14}$$

$$R_j = \sum_{i=1}^{n} M_{ij}. \tag{15}$$

By portraying the dataset comprising $(T+R, T-R)$, a causal diagram is visualized, where the horizontal axis represents "$T+R$" and the vertical axis denotes "$T-R$". Specifically, the "$T+R$" named "*prominence*" reveals how significant the factor is. On the other hand, the "$T-R$" named "*influence*" separates a factor into either the cause group or the effect group. In simple words, a factor fallen in the cause group is acting as a "*dispatcher*" since it tends to impact on other factors. By contrast, a factor fallen in the effect group is acting as a "*receiver*" because it is affected by other factors.

Table 6
Symbols of MAs and DAs for characterizing a smart pad.

MR (marketing requirements)		DA (design attributes)		Associated levels
R1	User interface	A1	CPU (type)	a11 — Atom a12 — Dual a13 — Quad
R2	System performance	A2	ROM capacity (GB)	a21 — 8 GB a22 — 4 GB
R3	Response speed (boot/networking)	A3	Operating system	a31 — Apple iOS a32 — Google android a33 — MS window
R4	Multi-media performance	A4	Screen size (inch)	a41 — 9–10 in. a42 — 7–8 in.
R5	Durability	A5	Front/back camera (mega pixels)	a51 — 200 M/500 M a52 — 130 M/300 M
R6	Portability	A6	Battery capacity (mAH)	a61 — 6000mAH a62 — 35000mAH

Table 7
Illustration of simplified questionnaires.

Schemes	Corresponding questions	Scales	Respondents
AHP	● How much degree is DA_i preferred to DA_j? ● How much degree is level i preferred to level j for a design attribute?	Numeric (9-point)	Customers
KM	● How do you feel about MR_j if it is fulfilled? ● How do you feel about MR_j if it is unfulfilled?	Linguistic (5-point)	Customers
DEMATEL	● How much influence does DA_i exert on MR_j?	Numeric (9-point)	Experts

4. Empirical results and discussion

In this section, an industrial example was realized in a middle scale Taiwanese company which manufactures various types of consumer electronics, such as mobile phones, LCD monitors, and notebooks. Recently, in order to extend its product lines, this company planned to design varieties of smart pads to meet diverse customers' needs. According to its marketing survey, the boundary between smart pads, smart phones, and smart cameras is now becoming more and more blurred and this implies that these products might be functionally replaceable to some extent [7]. To diminish the gap between customer expectation and customer perception, the company's top management decides to carry out a cross-functional project to incorporate customer involvement into the process of product development. Prior to describing its details of the whole project, six representative MRs and DAs associated with multi-levels are highlighted by domain experts and listed in Table 6. For reference, a simplified questionnaire is abbreviated and illustrated in Table 7.

4.1. Segmenting the entire market based on customers' perceived importance degrees

Initially, 120 customers are examined to investigate their perceived importance degrees of DAs by using the AHP questionnaire (also see Table 7). After completing the process of customer survey, their results are processed by the AHP and then passed to the K-means clustering for the purpose of market segmentation. However, the number of segments, or equivalently the value of K needs to be specified in advance. To determine an optimal number of segments, a metrics called F score is adopted in this study. In simple words, F score is defined by the ratio of "*mean square error between groups*" divided by "*mean square error within groups*". To seek an optimal number of segments, F ratio needs to pass a significance test among all segmentation variables (like DAs in our example). Through a try-and-error process, $K = 3$ is optimally determined since all DAs have passed a

Table 8
Average importance weights of DAs for different segments.

	S1 (*home*)	S2 (*business*)	S3 (*entertainment*)
A1	0.217	0.377	0.241
A2	0.058	0.146	0.065
A3	0.325	0.279	0.059
A4	0.253	0.084	0.332
A5	0.049	0.038	0.117
A6	0.098	0.075	0.186
Count	45	36	39

Table 9
Extracted customer preference of DAs for different segments.

Attributes	Specifications	S1	S2	S3
A1 CPU	a11 — Quad	0.108	0.226	0.108
	a12 — Dual	0.065	0.113	0.084
	a13 — Atom	0.043	0.038	0.048
A2 ROM capacity	a21 — 8 GB	0.038	0.103	0.037
	a22 — 4 GB	0.020	0.044	0.027
A3 operating system	a31 — Android	0.137	0.117	0.031
	a32 — iOS	0.130	0.139	0.023
	a33 — Window	0.059	0.022	0.006
A4 screen size	a41 — 9–10 in.	0.129	0.039	0.196
	a42 — 7–8 in.	0.124	0.046	0.136
A5 front/back camera	a51 — 200 M/500 M	0.032	0.023	0.082
	a52 — 130 M/300 M	0.017	0.015	0.035
A6 battery capacity	a61 — above 5000 mAH	0.059	0.049	0.126
	a62 — below 5000 mAH	0.039	0.026	0.060

Table 10
The top three priorities of smart-pad alternatives.

	S1 (home)			S2 (business)			S3 (entertainment)		
	#1	#2	#3	#1	#2	#3	#1	#2	#3
A1	a11	a11	a11	a11	a11	a11	a11	a11	a11
A2	a21	a21	a21	a21	a21	a21	a21	a21	a22
A3	a31	a31	a32	a32	a32	a32	a31	a32	a31
A4	a41	a42	a41	a42	a41	a42	a41	a41	a41
A5	a51	a51	a51	a51	a51	a52	a51	a51	a51
A6	a61	a61	a61	a61	a61	a61	a61	a61	a61

statistical testing. As indicated by Table 8, three distinct segments are named as S1 (home), S2 (business), and S3 (entertainment), respectively. And their top three significant DAs are particularly marked to display their differences between segments.

Specifically, the home segment (S1) presents an order of $A3 \succ A4 \succ A1$ while the patterns of $A1 \succ A3 \succ A2$ and $A4 \succ A1 \succ A6$ are demonstrated by the business segment (S2) and the entertainment segment (S3), respectively. Not surprisingly, attribute A1 (CPU) is concurrently critical to three segments. By contrast, attribute A3 (operating system) is significant to both segments of S1 and S2 whereas attribute A4 (screen size) is important to both segments of S1 and S3. Apparently, customers in the business segment concern much more about DAs which might impact on "system performance" and similar explanations could be generalized to other segments.

4.2. Extracting customer preference and customer perception for identified segments

Based on three identified segments, AHP and KM are utilized to extract customer preference for associated levels of DAs and customer perception of MRs, respectively. After looking into the details of Table 9, it is observed that two DAs involving A3 (operating system) and A4 (screen size) are diversely scattered among segments. To conclude, Android OS (a31) is favored by both home (S1) and entertainment (S3) segments while the business segment (S2) prefers iOS (a32). Similarly, both S1 and S3 desire large screen size (a41), but small screen size (a42) is favored by S2 for the consideration of portability. Again, with the consideration of six DAs associated with their multi-levels, there might possibly generate up to 144 ($3^2 \times 2^4$) concepts of smart pads. Consecutively, to perform concept evaluation in a market-oriented manner, customer preference needs to be coupled into the entire process and the results are depicted in Table 10. Here, for simplification, only the top three priorities among 144 alternatives are demonstrated and their transitions arisen from balancing the trade-offs between DAs are also indicated.

Meanwhile, with the aid of KM, customers' perceptions of MRs are elicited with respect to two scenarios: positive delight for functional fulfillment and negative disgust for dysfunctional unfulfillment (see Eqs. (8)–(9)). Similar to the concept of conjoint analysis, the range which is defined by "*delight less disgust*" is used to derive the priorities of MRs for three segments (see Eq. (10)). As shown in Table 11, the pattern of $R6 \succ R2 \succ R3$ consists of the top three MRs for S1 while $R2 \succ R3 \succ R5$ and $R4 \succ R3 \succ R1$ are presented by S2 and S3, respectively. Obviously, these findings imply that Kano model is effective to reveal customers' vague perceptions of MRs and also present the relative priorities for different segments. Hence, it might be suitable for gathering and tracking new ideas of the next-generation products.

4.3. Identifying the causal relationships between MRs and DAs

Referring to Table 7 again, several cross-functional managers are invited to fill out their assessments on the interdependences between MRs and DAs (also see Fig. 3). After consulting all experts, their evaluation results are aggregated as a 12×12 direct-relation matrix. Then, by virtue of DEMATEL, four main scores of all factors could be calculated and shown in Table 12 (also see Eqs. (11)–(15)). In brief, the "*active*" score of a factor denotes the sum of its dispatched impact on other factors and the "*passive*" score represents the sum of its received influence sent from other factors. Intuitively, the "*prominence*" score defined by adding the "active" score to the "passive" score

Table 11
Elicited customer perception of MRs for different segments.

		A	M	O	R	I	Q	Delight	Disgust	Range	Rank
S1 home	R1	20%	47%	33%				0.530	−0.800	1.330	3
	R2	45%	20%	35%				0.800	−0.550	1.350	2
	R3	36%	18%	38%		8%		0.740	−0.560	1.300	6
	R4	30%	26%	38%		6%		0.680	−0.640	1.320	4
	R5	28%	35%	37%				0.650	−0.720	1.370	1
	R6	28%	40%	32%				0.600	−0.720	1.320	4
S2 business segment	R1	15%	55%	30%				0.450	−0.850	1.300	5
	R2	13%	42%	45%				0.580	−0.870	1.450	1
	R3	18%	40%	42%				0.600	−0.820	1.420	2
	R4	36%	23%	32%		9%		0.680	−0.550	1.230	6
	R5	14%	46%	40%				0.540	−0.860	1.400	3
	R6	27%	25%	42%		6%		0.690	−0.670	1.360	4
S3 entertainment segment	R1	18%	48%	34%				0.520	−0.820	1.340	3
	R2	34%	23%	38%		5%		0.720	−0.610	1.330	5
	R3	25%	35%	40%				0.650	−0.750	1.400	2
	R4	8%	51%	41%				0.490	−0.920	1.410	1
	R5	15%	41%	39%		5%		0.540	−0.800	1.340	3
	R6	31%	30%	32%		7%		0.630	−0.620	1.250	6

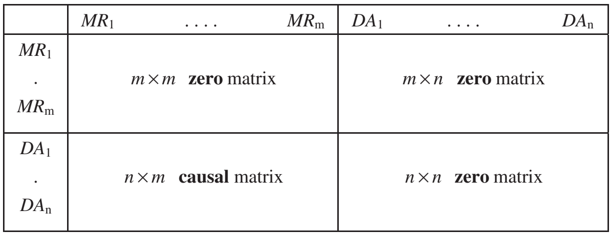

Fig. 3. A schematic representation for the input matrix of the DEMATEL.

reflects the importance degree of a factor. By contrast, the "*influence*" score defined by subtracting the "active" score from the "passive" score indicates the causality of a factor.

Furthermore, based on Table 12, the complicated interrelationships among all factors (e.g. MRs and DAs) could be visualized and portrayed in Fig. 4. Recall that the coordinates consist of ($T+R$, $T-R$), where "$T+R$" represents the horizontal axis and "$T-R$" denotes the vertical axis. Apparently, all DAs (denoted by the red "squares") are categorized into the "cause" (dispatcher) group because of having "positive" influence. Conversely, all MRs (denoted by the blue "diamonds") are classified into the "effect" (receiver) group due to having "negative" influence. More importantly, this structural diagram successfully assists product managers in separating MRs and DAs into two distinct groups and hence product engineers could find clues for enhancing specific MRs through improving corresponding DAs.

5. Conclusion and future research

For eventual survival and continuous growing of an enterprise, product planners or project managers spend most of their time to make crucial decisions under uncertain business environments. In a globally customized economy, meeting customers' requirements and going beyond their expectations still capture the focal point to achieve successful new product development. For instance, a firm might want to know who are its potential customers and which characteristics do they own? Meanwhile, a firm might be also interested in understanding what are its target segments and which product varieties should be offered to fit these segments? In practice, identifying profitable niche segments and configuring potential product alternatives with respect to these segments are vitally important to fulfill the aforementioned goals. In this paper, a hybrid framework combining AHP, KM, with DEMATEL is proposed to incorporate customer preference and customer perception into the decision-making process of concept generation and product evaluation.

To validate the applicability of our proposed approach, an industrial example regarding configuring and prioritizing smart pads is demonstrated for distinct segments. Based on our experimental results, this paper contributes to this domain by demonstrating the following: (1) learning which design attributes are crucial to segment the entire market, (2) generating and evaluating competitive product alternatives in a market-oriented manner, (3) understanding customer perception of marketing requirements to uncover new ideas of the next-generation products, and (4) recognizing the complicated interrelationships between marketing requirements and design attributes to offer managerial insights for industrial practitioners. To further provide decision supports on managing various product lines, we might integrate the current framework with other data mining techniques to explore how customer preference and/or customer perception impacts on customers' eventual selection of substitute products (i.e. ultrabooks or tablets) in future studies.

Table 12
Visualizing a causal diagram between MRs and DAs via the DEMATEL.

	Active score T_i	Passive score R_j	Prominence score T_i+R_j	Influence score T_i-R_j
R1	0	0.533	0.533	−0.533
R2	0	0.733	0.733	−0.733
R3	0	0.600	0.600	−0.600
R4	0	0.800	0.800	−0.800
R5	0	0.333	0.333	−0.333
R6	0	0.667	0.667	−0.667
A1	0.867	0	0.867	0.867
A2	0.667	0	0.667	0.667
A3	1.000	0	1.000	1.000
A4	0.600	0	0.600	0.600
A5	0.200	0	0.200	0.200
A6	0.333	0	0.333	0.333

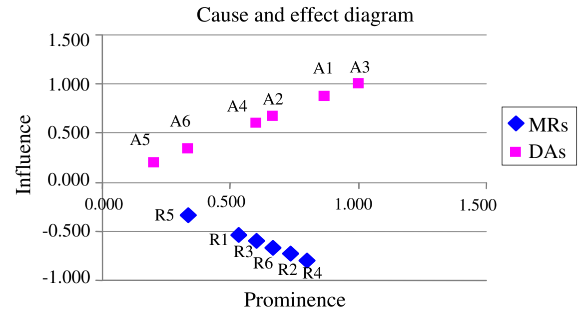

Fig. 4. The causal diagram between MRs and DAs.

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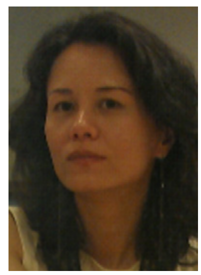

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