Customer satisfaction evaluation method for customized product development using Entropy weight and Analytic Hierarchy Process

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\textbf{A B S T R A C T}

Providing customized products with high customer satisfaction (CS) has become an inevitable trend for modern customized companies to remain competitive. This study proposes a CS evaluation method for customized product development using Entropy weight and Analytic Hierarchy Process (AHP). Firstly, customer requirements are identified based on Voice-of-Customer (VoC), and classified into four categories (positive, negative, must-be and fuzzy attributes) according to the characteristics of CS criteria. Then, CS evaluation model and its solution method are introduced in detail. This study especially focuses on the quantitative methods for each category of the evaluation criteria through formulating several mathematical models, and criteria weights are obtained through integrating Entropy weight and AHP method. Finally, a case study of applying the proposed methodology to customized portrait-based product industry demonstrates the functionality of the proposed methodology.

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\section{1. Introduction}

In order to gain a competitive advantage in the buyer's market, the product production mode is shifting from production-centralized to customer-driven (Kwong, Wong, & Chan, 2009). The change in production mode induces a shift from mass production to mass or small-batch personalized customization (Pine, 1993). With the rapid development of the internet and other information technologies, customer's participation in a personalized product is no longer subjected to geographical restrictions. Therefore, a significant increase is seen in customer participation of personalized products. Manufacturing production companies can out-compete its peers if they provide high quality products and service with high customer satisfaction (CS) for customers and provide flexible response to market demand. Meanwhile, it becomes more acceptable that customers are willing to pay more for products that cater to their individual preferences, styles, needs, or expressions (Du, Jiao, & Tseng, 2006).

Customer satisfaction level is one of the most important factors in the evaluation of the quality and service during development of a new product, especially for customized product development. That's because customized products generally belong to small batch production. Once a customer places an order to customize a personalized product, the company will place expenses for the customer due to service for him. Therefore, most companies tend to take measures to prevent customers from canceling the order during product development phase. One such measure requires the customer to pay a certain percentage of deposit depending on a fixed schedule after an order has been placed. If the customer is dissatisfied with the final product then the company will experience a loss of sale. When this occurs, not only the customer will lose his deposit to the company, the company will have also wasted the material allocated for the manufacturing of the product. Thus, such a loss will greatly affect the company's future production of the product.

Therefore, the reduction of transaction risks associated with customer dissatisfaction and the maintenance of mutual interest of both parties are crucial issues facing personalized product customization companies. Implementing CS evaluation to the customized product is the best solution to this problem. CS evaluation offers immediate and objective feedback about customer's preferences and expectations (Li, Liu, Peng, & Gao, 2013). This way, company's performance could be evaluated using multiple criteria which will indicate the strength and weakness of the company. Meanwhile, implementing CS evaluation can also help decision-makers and designers of companies to make the right decisions, and help them to identify which products are competitive for
future production. However, there is still no study on the suitable evaluation model, reasonable criteria and quantitative methods for customized product development. This paper attempts to fill this gap in the literature through proposing a methodology of CS evaluation for customized product development, which focuses on the quantitative methods for each category of the evaluation criteria through formulating several mathematical models, and criteria weights are obtained through integrating Entropy weight and Analytic Hierarchy Process (AHP) method. Our approach for calculating the CS value and criteria weights has considered both the subjective and objective attributes when customers perform CS evaluation. Through the case study, the proposed methodology is appropriate for applications in the customized portrait-based product industry. This methodology can reduce the risk of economic loss for customers and companies.

The remainder of the paper is organized as follows: Section 2 briefly discusses the existing relevant literature. Section 3 introduces the proposed methodology. Section 4 describes a case study: application to customized portrait-based product industry. Conclusions are given in Section 5.

2. Literature review

Since the late 1980s, a number of countries have established the national customer satisfaction index (CSI) model. The establishment of a national CSI typically requires 4–5 years (Preliminary survey conduction, evaluation of results and correlation with general financial indices, development of database, etc.). Johnson, Gustafsson, Andreassen, et al. (2001) and Kenett and Salini (2011) presented the latest surveys. The first model was the Swedish Customer Satisfaction Barometer (SCSB) built by Swedish researchers in 1989 (Fornell & Johnson, 1992). A derivative model of the SCSB was the American Customer Satisfaction Index (ACSI) which was developed with complete data in 1994 and reported results for approximately 200 companies from 34 industries (Fornell, Johnson, Anderson, et al., 1996). The ACSI defined the satisfaction as a weighted average of three survey ratings: perceived quality, perceived value, and customer expectations. ACSI has been used to measure CS for manufacturing, transportation, communications industry and other areas such as utilities, finance, insurance, retail, services, public administration, and government. Another well-known CSI model was the European Customer Satisfaction Index (ECSI) across 4 industries and 11 countries in the European Union in 1999 (e.g. Martensen, Kristensen, & Gronholt, 2000; Westlund & Eklof, 2002). Although these models and their derivatives (Hsu, 2008) are an accepted satisfaction evaluation methodology, they are not suitable for the customized product industry, and the ACSI model criteria cannot be used for this kind of industries.

In recent years, the theoretical models of CS and CSI have found numerous applications in various industries. Yadav and Goel (2008) proposed a comprehensive framework of target planning for CS driven quality improvement efforts in the automotive product development process. The proposed framework facilitated a link between corporate and engineering decision making process, and the potential vehicles for the facilitation were classified and prioritized for further improvement using Kano model and Quality Function Development (QFD). The mathematical models were formulated as optimization problems in order to cascade down top-level targets to lower-level elements within given constraints. Chen and Aritejo (2008) and Kuo, Wu, and Deng (2009) successively focused on the CS and service quality measurements in Mobile industry. Deng, Lu, Wei, and Zhang (2010) presented the determinants of CS and loyalty to mobile instant message (MIM) services in China. Their findings confirmed that trust, perceived service quality, perceived customer value (including functional value and emotional value), contributed to generating CS with MIM, and the results showed that trust, CS and switching cost directly related to customer loyalty. Additionally, they found age, gender, and usage time had indirect effects. Yang and Peng (2008) developed a novel CS evaluation model for construction project management using a questionnaire-based survey and statistical analysis, which included two stages. One stage was In-service, which included cost, quality, time, communication and technique/tool, and another stage was Post-service, which included cost, quality, time and scope. They used descriptive statistical method to analyze important characteristics and summarized survey results. Yang and Zhu (2006) developed a housing satisfaction index (HIS) model based on the ACSI model, which was a set of causal equations that linked customer expectations, perceived quality, and perceived value to customer satisfaction. In turn, customer satisfaction was linked to consequences as defined by complaints and customer loyalty. In additional, CS evaluation or measurement models were proposed for various other service industries, such as e-commerce (Liu, Zeng, Xu, & Koehl, 2008) and e-service (e.g. Udo, Bagchi, & Kirs, 2010; Liu, Zhou, & Chen, 2010; Finn, 2011), financial service (e.g. Arbore & Busacca, 2009; Pyon, Woo, & Park, 2011), EMS (Liu, Li, & Ge, 2006), and hotel (e.g. Gu & Ryan, 2008; Wu & Liang, 2009; Han, Kim, & Hyun 2010; Hsieh & Lin, 2010), and Tourism (Pyon, Lee, & Park, 2009).

These CS models may be suitable for their specific areas of industries, but are generally not suitable for customized product development due to the characteristics of the products and services. Du et al. (2006) analyzed diverse elements of product quality in relation to customization and introduced utility functions to quantify the customer-perceived value in terms of the quality utility per unit cost and the ratio of marginal utility to marginal cost. However, there is still no study on the suitable evaluation model, reasonable criteria and quantitative methods for customized product development. This study attempts to fill this gap in the literature through proposing a methodology of CS evaluation for customized product development, including identifying customer requirements, classifying CS criteria, establishing CS model, as well as the quantitative methods for each category of the criteria and their weights.

3. The proposed methodology

The aim of this study is to propose a CS evaluation model for customized product development in the buyer’s perspective. The major steps of the proposed methodology involve (a) identifying and classifying customer requirements based on Voice-of-Customer (VoC), (b) modeling, (c) model solution, including quantitative method for each criterion, and the corresponding weights by integration of Entropy weight and Analytic Hierarchy Process (AHP). Details of each step are presented in the following subsections.

3.1. Identifying and classifying customer requirements based on VoC

It is important to identify the most vital and representative criteria to evaluate the CS value for new product development. Note that there are various tools and techniques available to capture customer requirements and preferences. These are customer questionnaire, individual inquiring, intensive expert interviews or surveys via internet, paper and pencil, etc (e.g. Du et al., 2006; Martensen et al., 2006). Regardless of which approach, our aim here is to highlight that identification of the CS criteria should be based on VoC. This process can be achieved by thorough discussions between the analyst and the decision maker of the company.
with customer involvement. In any case, the reliability of the set of criteria has to be tested in a representative set of customers. The CS evaluation criteria can be established according to the characteristics of each product and the survey data about customer’s considerations before and after purchase.

Kano, Seraku, Takashi, and Tsuji (1984) develop a two-dimensional model widely used to characterize attributes of a product or service based on how well these attributes satisfy customer requirements. The Kano model classifies product criteria into attractive, one-dimensional, must-be attribute. Some researchers showed the advantages of using the Kano model (e.g. Chen & Chuang, 2008; Yu & Yu, 2009) or an integrative approach involving the Kano model and quality function deployment (QFD) (Yadav & Goel, 2008), or Kano model and Fuzzy method (Florez-Lopez & Ramon-Jeronimo, 2012) to classify customer requirements. However, it is sometimes difficult to identify a criterion that belongs to the attractive attribute or one-dimensional attribute, and it is difficult to give an explicit formulation to quantify these two categories. Therefore, we use Positive related attribute to describe this kind of criteria. Additionally, after a large number of survey and analysis of customer requirements, there is a kind of criteria which is contrary with Positive related attribute, we called Negative related attribute in this study. Here, we retain Must-be attribute according to Kano model. However, there are some criteria that belong to subjective preferences, which are difficult to quantify. In this paper, we use Fuzzy attribute to describe this kind of criteria. Therefore, in order to reasonably quantify all of the criteria, we classify the CS criteria into the following four categories according to the characteristics of each criterion:

- **Positive related attribute** (‘P’ for short) is an attribute that has the property that the higher the value of the attribute, the higher of the CS.
- **Negative related attribute** (‘N’ for short) is an attribute that has the property that the lower criteria value leads to higher CS evaluation value.
- **Must-be attribute** (‘M’ for short) is a basic attribute which customers believe that it is a necessity, such as the material, color, etc. If these attributes are not fulfilled, the customer will be extremely dissatisfied.
- **Fuzzy attribute** (‘F’ for short) is an attribute which is used to indicate customer’s subjective preferences or perceives of the customized products.

### 3.2. Modeling

Before introducing the model, Table 1 summarizes the key notations used during modeling.

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_i$</td>
<td>The $i$th evaluation criterion of the $j$th customized product</td>
</tr>
<tr>
<td>$CS(X_j)$</td>
<td>The customer’s evaluation value of the $i$th criterion for the $j$th customized product</td>
</tr>
<tr>
<td>$m$</td>
<td>The number of criteria</td>
</tr>
<tr>
<td>$n$</td>
<td>The number of customized products</td>
</tr>
<tr>
<td>$CS^M(X_j)$</td>
<td>The customer’s evaluation value of the must-be attribute for criterion $X_j$</td>
</tr>
<tr>
<td>$p_i'$</td>
<td>The profit margin of the $j$th customized product</td>
</tr>
<tr>
<td>$p_0'$</td>
<td>The minimum profit margin required by the company</td>
</tr>
<tr>
<td>$p_l$</td>
<td>The price of the $j$th customized product</td>
</tr>
<tr>
<td>$c_i$</td>
<td>The cost of the $j$th customized product</td>
</tr>
<tr>
<td>$T_{min}$</td>
<td>The shortest production and delivery time for the $j$th customized product of the company</td>
</tr>
<tr>
<td>$T_{L}$</td>
<td>The longest customized time of the $j$th customized product required by customers</td>
</tr>
<tr>
<td>$PC$</td>
<td>The production capability for producing customized products, such as the design capacity, processing capacity, and assembly capacity, etc</td>
</tr>
<tr>
<td>$PC_0$</td>
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The essential problem of product customization is how to produce a customized product within the company’s capabilities while maximizing customer satisfaction. Therefore, CS evaluation model for customized product development can be stated as

**Objective**: \[ \text{Max} \sum_{j=1}^{n} w_j \sum_{i=1}^{m} w_i CS(X_j) \quad (1 \leq i \leq m, 1 \leq j \leq n) \]

subject to

\[
\begin{align*}
CS^M(X_j) &\geq CS^M(X_j) \left( \frac{p_i}{c_i} - 1 \right) \cdot 100\% \geq p_0' \\
T_{min} &< T_{L} \\
PC &\leq PC_0
\end{align*}
\]

From the model above, we can see that in order to solve the model, it is necessary that the company accurately grasp the individual preferences of customers, and meet their preferences as much as possible within the constraint of existing resources and current production capability. Therefore, the key in solving Eq. (1) is how to calculate customer’s evaluation value $CS(X_j)$ and the corresponding weights $w_i$ under constraints, which will be introduced in detail in the following sub-sections.

### 3.3. Model solution

#### 3.3.1. Quantitative method for $CS(X_j)$

In order to correctly and objectively calculate the customer’s evaluation value $CS(X_j)$ for different criterion of the $j$th customized product, we have presented four different calculation methods according to the characteristics of the four categories of the customer requirements. Details will be introduced as follows.

**3.3.1.1. Formulation of ‘P’ attributes.** One group of the survey data of ‘P’ attribute is shown in Table 2, which is obtained by a customer who customizes a portrait-based product. In Table 2, Similarity is the measure data, $CS$ is the customer satisfaction value by the customer. After the analysis of a large number of research data collation and curve fitting using Matlab, the relation between the value of the ‘P’ attribute and the corresponding CS value is an exponential relationship instead of a linear relationship as commonly thought. The fitting curve is shown in the middle part of Fig. 1.

Given $x_i$ is the expectative value of customers, $x_i'$ is the least tolerate threshold value of customers, and $x_i$ is the evaluation value of the criterion $X_i$. Then, we can define the following formulation to calculate the CS evaluation value for ‘P’ attributes.

\[
CS^P(X_j) = \begin{cases} 
1 & x_i' \geq x_i \\
\frac{x_i - x_i'}{e^{x_i - x_i'}} & x_i' < x_i < x_i'' \\
0 & x_i \leq x_i'' 
\end{cases}
\]  

#### Table 1

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CS graph of ‘P’ attributes is shown by the solid curve in Fig. 1. We can see that when \( x_0 \) is closer to \( x_{ij} \), CS of ‘P’ attribute will increase faster, the graph becomes steeper. While \( x_0 \) is closer to \( x_{ij} \), the change in the value of CS is smaller, and the curve has a small slope. This is consistent with the actual situation.

3.3.1.2. Formulation of ‘N’ attributes. ‘N’ attributes have the property that the lower criteria value implies higher CS evaluation value. The formulation of ‘N’ attributes is given by

\[
CS_N(X_{ij}) = \begin{cases} 
1 & x_0 < x_{ij} \\
\frac{e^{-x_{ij}/x_0}}{1 - e^{-x_{ij}/x_0}} & x_0 < x_{ij} < x_0 \\
0 & x_0 \geq x_{ij}
\end{cases}
\]

CS graph of ‘N’ attributes is shown by the dotted curve in Fig. 1. Similar to the graph of ‘P’ attributes, when \( x_0 \) is closer to \( x_{ij} \), the CS of ‘N’ attribute will increase faster, the curve becomes steeper. When \( x_0 \) is closer to \( x_{ij} \), the slope of the graph becomes smaller.

3.3.1.3. Formulation of ‘M’ attributes. ‘M’ attributes indicate insufficiency of a ‘M’ attribute results in dissatisfaction, but basic product performance is sufficient for satisfying the customer requirements. Customers believe that such an attribute is a necessity, but high attribute performance does not generate correspondingly high CS. Therefore, the formulation of ‘M’ attributes can be stated as

\[
CS_M(X_{ij}) = \begin{cases} 
1 & x_0 \leq x_{ij} \\
0 & x_0 > x_{ij}
\end{cases}
\]

3.3.1.4. Quantitative method for ‘F’ attributes. For the criteria, quantitative methods should be used to the greatest extent of their application, however, there are some criteria that belong to subjective preferences, which are difficult to quantify. To take subject preferences, such as the Individuation attribute, into consideration, the qualitative method must be selected together. In the actual evaluation process, the qualitative indexes should be reasonably quantified through appropriate methods to make all evaluation criteria comparable. There are various viable quantitative methods. One of the best solutions is the fuzzy logic approach (Liu et al., 2008) and its extensions, such as Neuro-fuzzy (e.g., Kwong et al., 2009; Lin, 2007) and Fuzzy-QFD (Jia & Bai, 2010). In this study, we also adopt the fuzzy logic to measure the subjective criteria. The linguistic variables and scoring rules are shown in Table 3.

3.3.2. Determining criteria weights using Entropy weight and AHP

Criteria weights are usually assigned according to expert opinions, and this may cause a subjective bias. In this study, we present a method of integrating Entropy weight method (Zeleny, 1982) and conventional AHP method (Rezaei & Ortt, 2013). The key metrics of our method is that adopting AHP method can comprehensively take the subjective attributes into consideration, and adopting Entropy weight method can objectively determine the weights of the criteria which rest on the basis of the criteria evaluating only. The criteria weight processing steps are summarized as follows:

Step 1: Construct sample evaluation matrix \( R = (r_{ij})_{m \times n} \), where \( r_{ij} \) is the evaluation value of the jth criteria for the ith experiment products, \( i = 1, 2, \ldots, m \) and \( j = 1, 2, \ldots, n \);

Step 2: Normalize the evaluation value;

Step 3: Get the normal evaluation matrix \( R = (r_{ij})_{m \times n} \);

Step 4: Assume that \( h_i \) is the converted value via \( r_{ij} \), which can be defined as \( h_i = r_{ij}/\sum_{j=1}^{n} r_{ij} \);

Step 5: Calculate the Entropy \( e_i \) of the jth criteria for the ith product using the following equation, where \( k = 1/\ln(m) \), and \( e_i > 0 \):

\[
e_i = -k \sum_{i=1}^{m} h_i \ln h_i
\]

Step 6: Calculate the objective Entropy weight \( B_{ij} \):

\[
B_{ij} = \frac{1 - e_i}{m - \sum_{i=1}^{m} e_i}
\]

Step 7: Calculate criteria weight \( A_{ij} \) using the method of AHP considering the subjective features of the criteria. Details of the calculation process of AHP method can be referred to the study of Rezaei and Ortt (2013);

Step 8: Calculate the final weight \( w_{ij} \) by integrating the weight of AHP \( A_{ij} \) and Entropy weight \( B_{ij} \):

\[
w_{ij} = \frac{A_{ij} B_{ij}}{\sum_{i=1}^{m} A_{ij} B_{ij}}
\]

4. Case study: application to portrait-based product industry

This section presents an application of the proposed methodology in the industry of the customized portrait-based product development. Portrait-based product manufacturing is a typical customized product industry which is designed according to customers’ photographs via online-shopping, which is going to become a potentially major manufacturing-based industry (Li et al., 2013). A salient characteristic of the portrait-based product is that the success of such product greatly depends on the CS level.
of the end result, since CS determines not only the market perspective of the product, but also the risks of economic loss for both companies and customers.

4.1. Identifying and classifying multiple criteria for portrait-based products

The following example demonstrates how CS evaluation method can be used in an instance of ordering of a product. A customer wants to customize an individual portrait-based product via online-shopping. After communicating with the customer, the company acquires the most important and representative eight criteria which affect on the CS evaluation value, the identified product attributes (CS criteria) and the categories are shown in Table 4.

The expectative values and the least tolerate values of the customer are shown in Table 5. According to the customer's requirements, the company can provide four schemes to the customer. Evaluation values $x_{ij}$ of the criterion $X_{ij}$ for four schemes are also shown in Table 5.

We can calculate $CS(X_{ij})$ using the proposed method in Section 3.3.1. For example, $CS(X_{ij})$ is calculated as

$$CS(X_{ij}) = e^{85/90} = 0.819$$

The final results of $CS(X_{ij})$ for the four schemes are shown in Table 6.

4.2. Calculation of CS evaluation value $CS(X_{ij})$ for each criterion

The expectative values and the least tolerate values of the customer are shown in Table 5. According to the customer's requirements, the company can provide four schemes to the customer. Evaluation values $x_{ij}$ of the criterion $X_{ij}$ for four schemes are also shown in Table 5.

We can calculate CS evaluation value $CS(X_{ij})$ using the proposed method in Section 3.3.1. For example, $CS(X_{ij})$ is calculated as

$$CS(X_{ij}) = e^{85/90} = 0.819$$

The final results of $CS(X_{ij})$ for the four schemes are shown in Table 6.
4.3. Calculation of the criteria weights using Entropy weight and AHP

We can calculate Entropy weights using the steps introduced in Subsection 3.3.2. Sample evaluation matrix \( R_0 = (r_{ij})_{n \times m} \) in Step 1 is the results of \( CS(X_{ij}) \), which is calculated according to 4.2, as shown in Table 6 in bold (where \( i = 4, j = 8 \)). Then, the final results of Entropy (Eq. (5)) and Entropy weights (Eq. (6)) for each criterion are obtained according to the steps introduced in Subsection 3.3.2, and the final integrated weights can be got by Eq. (7), all of the results are shown in Table 7.

From the results, we can see the Entropy weights of Material criterion equals 0, that is because the Entropy of Material equals 1. This result is consistent with the actual situation, since Material is identified as a must-be attribute according to the classification, which is regarded as a constraint in the customized model, as stated by Eq. (1). AHP weights are obtained through traditional methods which can be referred to the study of Rezaei and Ortt (2013). The results of AHP weights are also shown in Table 7. Then, we can obtain the final integrated weights using Eq. (7).

4.4. Obtaining customer satisfaction score

After obtaining customer satisfaction value \( CS(X_{ij}) \) and weights \( w_j \) for each criterion, we can get the overall CS score \( CS(X_j) = \sum_{i=1}^{m} w_i CS(X_{ij}) \) for the jth customized product using formulation (1). The results of the four schemes of customized portrait-based product are (0.77, 0.677, 0.642, and 0.478). Therefore, we can draw the conclusion that scheme 1 obtain the highest CS score. Thus scheme 1 is the best choice. The final product scheme is shown in Fig. 2.

Qualitative analysis results of CS criteria and weights are presented in Tables 6 and 7, respectively. We can see that:

![Fig. 2. The final scheme of the customized portrait-based product.](image)

<table>
<thead>
<tr>
<th>Table 8</th>
<th>CS evaluation results of personalized Barbie doll (N = 30).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation means for product 1</td>
<td>0.739 0.816 0.811 0.792 1 0.768 0.647 0.837</td>
</tr>
<tr>
<td>Evaluation means for product 2</td>
<td>0.803 0.823 0.827 0.801 1 0.547 0.705 0.859</td>
</tr>
<tr>
<td>Evaluation means for product 3</td>
<td>0.792 0.796 0.803 0.801 1 0.567 0.549 0.826</td>
</tr>
<tr>
<td>Evaluation means for product 4</td>
<td>0.820 0.806 0.831 0.799 1 0.549 0.585 0.819</td>
</tr>
</tbody>
</table>
(1) Similarity criterion possesses the highest relative importance weight among all the criteria. Therefore, we can draw a conclusion that the company should place an emphasis on improving/enhancing this criterion in the future design of the product.

(2) The value of the Price criterion is the smallest among the eight criteria. This is because the portrait-based product is an individual customized product, and it generally is small batch production, thus, the company will set the price higher than general product price. Therefore, from the customer's perspective, the price of this kind of product are higher than general products, which brings about lower customer satisfaction value.

4.5. Determining competitive products

The proposed methodology can provide an approach for companies to determine competitive products. We can also take the personalized Barbie doll (as shown above) for example. After a period of marketing, there are \( N \) customers who have customized such type of products, decision-makers and designers of the company analyze the results of CS scores evaluated by customers. As shown in Table 8 (\( N = 30 \)), there are 30 CS results in terms of eight criteria, we can calculate the average CS result for this type of customized products. From the average satisfaction value, decision-makers and designers can be aware of the market feedbacks of this product. Thus, the company can assess the market prospects for this type of products. Similarly, company can design and assess other types of customized products through the feedbacks. Therefore, products which have higher average CS scores can be regarded as the competitive products, and the company can allocate more human, financial and material resources to develop these products. Table 8 (shown in bold) shows four types of the competitive products which have gotten higher CS evaluation scores. Some products are shown in Table 9. Type 1 is the individual Barbie dolls, type 2 is the combinations of the head created through machining and clay body created manually, type 3 is the 2D embosses, and type 4 is the full machining 3D sculptures.

The test data can be further updated and refined through adding more customers’ feedbacks with the development of marketing, the test results will be more accurate. Competitive products of the company will be decided through the final CS scores. Meanwhile, through analyzing the evaluation value (as shown in Table 8), designers can identify and improve the weak criteria in the product design.

The proposed methodology can also be used to evaluate the customized digital product designed by engineers before it is manufactured. If the evaluation result does not meet the customer’s requirements, subsequent processes will not be implemented so to avoid greater economic losses. In this situation, designers of the company should check the relevant criteria before revising the digital model until the criteria finally meet customer’s requirements.

The analysis result of the final evaluation value can reflect the market feedbacks of the product, and offer an immediate, meaningful and objective feedback about customers’ preferences and expectations. Through gradually collecting large amounts of CS evaluation results, companies could find out its strength and weakness in marketing and product development, and gradually improve the weak criteria of a product. The proposed methodology is helpful to assess the product performance in the market and set future targets for further improvement, which would ensure sustained customer loyalty and help the company to remain competitive.

5. Conclusions

Providing customized products with high CS value has become an inevitable trend for modern manufacturing companies to remain competitive. CS evaluation plays an important role in identifying customer perceptions toward the customized products. The evaluation models can help company and organizations to better understand the relationships between product attributes and CS.

In this study, we proposed a methodology for evaluating CS for customized product development. Firstly, customer requirements are identified based on the VoC, and classified into four categories

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Table 9
Four types of the determined competitive products for the portrait-based product industry.

<table>
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<tr>
<th>Type 1</th>
<th>Type 2</th>
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<tbody>
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<td><img src="image1" alt="Type 1 Image" /></td>
<td><img src="image2" alt="Type 2 Image" /></td>
<td><img src="image3" alt="Type 3 Image" /></td>
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</table>
according to the criteria attributes. Then, the CS evaluation model, quantitative methods for each category of the evaluation criteria and weights are introduced in detail. The case study revealed that the proposed methodology can reflect the market feedback of the product. Our experience has shown that the proposed methodology is particularly appropriate for applications in the customized portrait-based product industry for effectively reducing the risk of economic loss for customers and companies.

In the actual application of this methodology, there are still some aspects need to be improved. The first problem is that the number of the experiment subjects is limited, therefore the methodology needs to be gradually perfected through daily trials. Another problem is that since it is difficult to collect all of the customers’ feedbacks for the evaluation, the selection of the evaluation criteria might not comprehensively reflect the feedbacks of all customers. These two aspects are the directions for further research.

Acknowledgments

This research was supported by National Natural Science Foundation of China (No. 51405396), Fundamental Research Funds for the Central Universities (No. XDJK2014B007 and No. SWU113086), China Postdoctoral Science Foundation (No. 2012M521671), and the Chongqing Postdoctoral Science Foundation (No. XM2012007). We would like to thank Bolin Gao for his helpful language revision.

We are grateful to other people in the team of “Computer-aided Design and Manufacturing for Customized Portrait based Product Development” for collaboration and discussion.

References


