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Research Article

A Decision Method to Maximize Service Quality under Budget Constraints: The Kano Study of a Chinese Machinery Manufacturer

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Manufacturers are increasingly facing keen competition and improving customers' position in the value chain. Many of them have made efforts to promote service quality and enhance customer satisfaction. Research is lacking in considering the trade-off between service costs and customer satisfaction when tackling service quality issues in the machinery industry. A decision method is proposed for maximizing service quality in machinery industry under budget constraints, from the perspective of enterprise capacity and customer satisfaction. Due to the strength of the Kano model in acknowledging the nonlinear impacts of quality elements on customer satisfaction, we formalize the relationship between customer satisfaction and sufficiency of service quality elements quantitatively. And then we develop a novel nonlinear programming model to maximize service quality under budget constraints. In particular, we implement our model at Xuzhou Construction Machinery Group Co., Ltd., one of the largest Chinese construction machinery companies, to validate the efficacy of the method.

1. Introduction

To meet complex customer requirements and respond quickly to increasing competition and technological developments, the machinery industry has recognized customer value as a source of competitive advantage [1]. The machinery industry produces and maintains machines for consumers, the industry, and other companies. Many machinery manufacturers transform themselves from being product-oriented companies to being service providers [2–4]. They believe effective service planning and high level of quality service delivery are necessary to improve operations efficiency and enhance competitive edge [5].

Indeed, the changing environment has led to a lot of machinery manufacturers to rethink their service strategies. The concept of service is not limited to after-sale service, it will be extended to cover the whole lifetime cycle. This includes the service components integrated into the process of delivery, consumption, and use. Researchers have used various expressions to refer to the escalation of services, for example, "servitisation" [6], "integrated solutions" [7], and product-service systems (PSS) [8–11]. Obviously, service is crucial for machine manufacturers to enhance customer value and gain additional business. To gain customer endorsement and loyalty, firms need to put efforts into service design to improve service quality [12].

Oliva and Kallenberg (2003) [2] highlighted the significance of service quality in satisfying and retaining customers in manufacturing industries, while Izogo and Ogba (2015) [12] believe customer's satisfaction of service quality is the determinant of customer loyalty. However, manufacturers offer services of varying scopes and degrees, and the service quality is significantly related to the specific service processes and service participants. To achieve high service quality, one needs to understand the relationships between various service quality elements and other related elements, for example, processes, personnel, and resources [13].

The literatures have mainly focused on categorizing customer service requirements, planning, and designing proper service products to assure customer satisfaction. There is a lack of a systematic and quantitative verification scheme for service quality improvement, especially in the machinery industry. In general, services influence costs, and high service quality often leads to high service costs. It is therefore vital to strike a good balance between customer satisfaction and service costs when improving service quality in machinery industries, while researchers have not yet addressed this important issue enough. To make contributions to the existing literatures, we try to find out a solution of service quality improvement in machinery industries to leverage customer satisfaction and budget constraints from bilateral perspectives (customer satisfaction and service provider's capacity). Thus, the relationships between customer satisfaction, service costs, and service quality elements will be identified, and then a novel quantitative decision method will be set up to determine the priorities of service quality elements in quality improvement.

In an effort to propose a decision method to maximize the overall customer satisfaction under budget constraints, we formulate two research issues:

(1) In the machinery industry there is a limit on resources allocation to services. Most resources are focused on tangible products. There is still a need for a continuous improvement process in regard to service quality. So based on a bilateral prospective, how can this help to develop a systemic and quantitative framework to identify key service quality elements, detect the relationship among quality elements, and determine the improvement priorities for service transformation in machinery industries?

(2) The level of customer satisfaction depends on adequate supply of the service components, which relies on large monetary investment. Then, how can this help to develop a mathematical model balancing customer satisfaction and service costs and validate the results empirically?

The paper proceeds as follows. Section 2 covers a review of the literatures. Section 3 proposes the research framework. We implement the proposed model and its solution methodology to Xuzhou Construction Machinery Group Co., Ltd. (XCMG), the largest construction machinery company in China, in Section 4 and prove its validity. Research conclusions and future research are discussed in Section 5.

2. Literature Review

2.1. Kano's Model. Kano et al. (1984) [14] proposed the Kano model adapting Herzberg's "motivation-hygiene theory" [15]. This model demonstrates the nonlinear relationship between customer satisfaction and the performance of quality elements. And it classifies quality elements into five dimensions: must-be, one-dimensional, attractive, indifferent, and reverse, as shown in Figure 1.

The Kano model has been widely used for customers' needs analysis, decision-making analysis, and other management practices [16–18]. However, it has some disadvantages; that is, it uses qualitative analysis techniques and does not define the classification criteria explicitly in quality elements' classification. It also fails to account for the provider's concerns in terms of the capacity to fulfill the customer requirements [17].

Many studies tried to improve Kano's model for supporting product and service design in different ways. Through the quantitative analysis of Kano's model, Berger et al. (1993) [19] used two indicators of customer satisfaction (CS) and customer dissatisfaction (DS) to indicate the average impact of customer requirements on customer satisfaction. This improves Kano's model in understanding the influence about different categories of customer requirements on CS [20]. Further, Wang and Ji (2010) [21] proposed a novel approach to identify the relationships between customer satisfaction and the fulfillment of customer requirements (S-CR) in Kano's model, and it provided an effective way to integrate Kano's model to other mathematical model in engineering design process.

In addition, the traditional Kano survey forces customers to choose one answer for a particular question. This ignores the fuzzy and uncertainty factors related to human thinking when the questionnaire is being designed. Thus, some scholars proposed the fuzzy Kano model using integrated fuzzy set theory [22–24].

To improve Kano's model for decision support, literatures discussed the issues of integrating Kano model with other techniques. These techniques include SERVQUAL [25, 26], QFD [27–29], Importance-Performance Analysis (IPA) [30], and Kaisei engineering [31, 32]. It is very beneficial for improving Kano methodology [33].

2.2. Kano's Model in Service Quality Management. Understanding each category of the quality elements will be helpful in service quality management. Thus, the Kano model has been applied in various industries to classify service quality elements and make decisions in improving service quality. An overview of the reviewed literature in this theme is given in Table 1, encompassing authors, research focus, industry, and model type (theory, quantitative method, or empirical).

Previous research in the area has shown focus on service quality elements identification, evaluation, and classification. There has not been an emphasis on the decision-making method of service quality improvement. The small amount of research in this area dealt with qualitative analysis, and there is a dearth of quantitative research. Table 1 shows that the Kano model has a wide application in improving service quality in many industries. However, most of these applications are in the service business, and little research is focused on service quality in machinery enterprises.

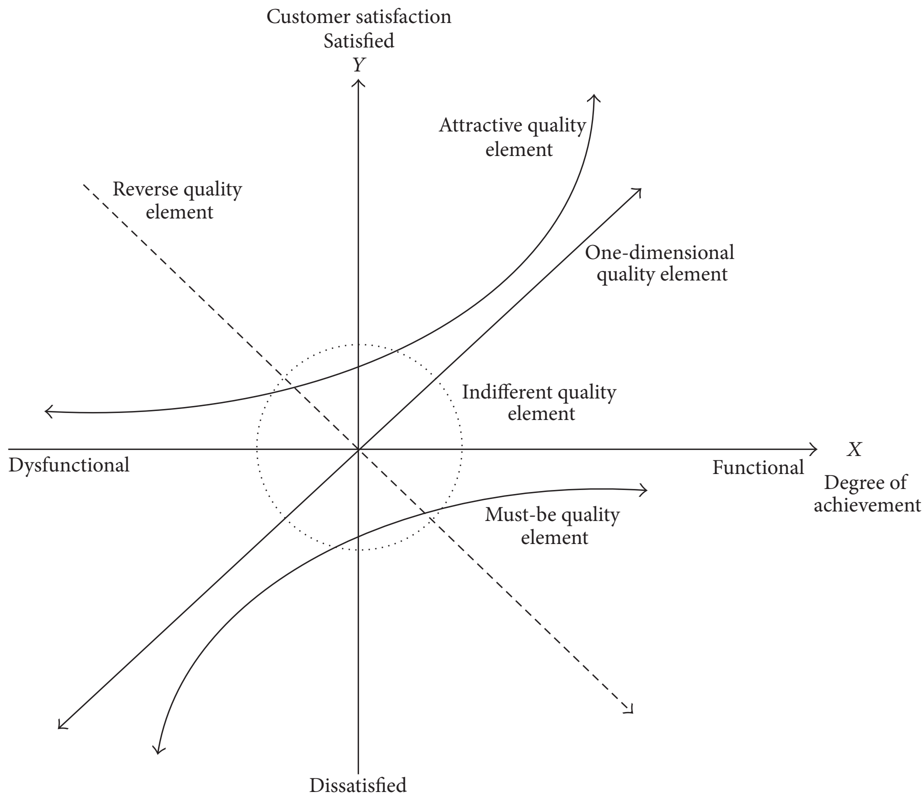

Figure 1: An overview of Kano model.

2.3. Conclusions on the Literatures. From the review of related literatures the following conclusions were drawn:

(1) The Kano model is an effective tool to identify and classify service quality elements whether in service product development or service quality improvement. But Kano model is still a qualitative method in nature, and setting up a quantitative Kano methodology would be beneficial to provide support for decisions more effectively.

(2) Service quality research has largely been focused on service business, leading to a dearth of research on service quality in machinery industries. Service quality is a critical element for machinery industries to gain and maintain competitive advantage, so it is meaningful to extend the application to machinery industries.

(3) Researchers stressed the importance of understanding service quality elements that have the greatest impact on customer satisfaction and promoting the priority of these quality elements. In the decision-making process for service quality improvement, the service provider's capacity needs to also be considered. Cost constraints are usually accommodated in the decision-making. The goal of the decision-making process is to seek a solution of service quality improvement that leverages customer satisfaction and the service provider's resource constraints.

3. Methodology

In this section, an integrated framework is proposed to maximize machinery industry service quality under budget constraints, by considering the trade-off between customer satisfaction and service costs. Figure 2 shows the proposed research framework with its subprocesses. These subprocesses include identification of service quality elements, division of market segmentation, Kano model survey, quantitative analysis of Kano model, and decision model formulation.

3.1. Identification of Service Quality Elements. Service quality elements extraction and identification are the foundation not only of the Kano model, but also of decision analysis in service quality improvement. Service qualities are different from general products with the distinctive features of intangibility, inseparability, heterogeneity, and perishability [53]. So it is very necessary to find an effective way to translate customer requirements into a set of service quality elements from the customer perspective. There are several methods that can be used to identify customer service quality elements, such as SERVQUAL model and QFD, which are currently thought of as useful methods to extract service quality elements by listening to the voice of customers [29].

3.2. Division of Market Segments. The division of market segments aims to find the appropriate target customers in the decision analysis process. As a rule, different customers have different utility expectations of service quality. At this point, the customer base is divided into several customer segments

Table 1: An overview of the reviewed literatures in this theme.

Authors	Research focus	Industry	Model type
Tan and Shen (2000) [27]	Integrating Kano model of QFD	Web page	Quantitative method
Erto and Vanacore (2002) [34]	Service quality measurement	Hotel service quality	Empirical
Ting and Chen (2002) [35]	Quality elements identification and classification	Hypermarket	Empirical
Kuo (2004) [30]	Classification of service quality attributes	Virtual community websites	Empirical
Yang (2005) [36]	Classification of service quality attributes	Technical products	Theory
Nilsson Witell and Fundin (2005) [37]	Dynamics of service attributes	E-service	Theory, empirical
Chang et al. (2006) [38]	Service quality improvement from customers' satisfaction perspective	Hospital services	Quantitative method
Chen et al. (2010) [39]	Service quality improvement by integrating Kano model of Six-Sigma	Stationary industry	Quantitative method
Chen and Lee (2009) [40]	Quality elements identification and classification	Chain convenient stores	Method, empirical
Kuo et al. (2009) [41]	Service quality measurement and classification	Mobile value-added services	Theory, empirical
Chen et al. (2009) [42]	Attractive quality elements discovering	Massively multiplayer online role-playing game	Method, empirical
Yang (2011) [43]	Quality elements identification	International certification service	Theory, empirical
Xie et al. (2010) [44]	Quality elements evaluation	NPO products	Empirical
Chen and Kuo (2011) [45]	Quality elements identification and classification	E-learning service	Empirical
Tsai et al. (2011) [46]	Potential service quality gaps discovery	Human resource service online agency	Method, empirical
Kuo et al. (2012) [47]	Service quality improvement decision using IPA-Kano model	Mobile service	Method, empirical
Florez-Lopez and Ramon-Jeronimo (2012) [48]	Quality elements identification and classification using fuzzy Kano model	Logistics service	Quantitative method
Tontini and Dagostin Picolo (2014) [49]	Quality elements interaction analysis based on psychological foundations	Pizzerias and video rental stores	Theory, empirical
F.-Y. Chen and S.-H. Chen (2014) [50]	Service quality improvement	Hot spring industry	Method, empirical
Bandyopadhyay et al. (2015) [51]	Classification of service quality attributes	Banking	Empirical
Esmaeili et al. (2015) [52]	A fuzzy method to assess and identify service quality attributes	Logistics service	Quantitative method
Meng et al. (2015) [24]	Decision method for service quality improvement	Logistics service	Method, empirical

according to their demographic information, psychographic data, and purchase behaviors. The different customer segments have distinguished characteristics about service quality perceptions. Effective marketing research and customer-tailored management actions are taken for each segment, guaranteeing an optimal level of customer satisfaction in different customer segments under budget constraints. Many methods and tools are available to assist the process including clustering, classification, self-organizing maps (SOM), evolutionary algorithms, interaction detection methods, and artificial neural networks [54].

3.3. Classification of Service Quality Elements Using the Fuzzy Kano Model. The Kano model provides a systematic way of service quality elements classification. It is based on three tools: the Kano questionnaire, the Kano evaluation table, and the Kano final results table [14]. The Kano questionnaire examines each service quality element with a pair of questions, functional and dysfunctional. There are five possible answers for each question, that is, “like,” “must-be,” “neutral,” “live-with,” and “dislike” [14]. According to the Kano evaluation table, for each respondent, the service quality element is classified as one of Kano categories. Generally, according to the Kano final results table, the most frequent observations of the sample set of responses are considered as the final category for the service quality element [14].

Generally, the traditional Kano model is lacking in processing the vagueness and uncertainties in human judgment and decision-making when surveying. Fuzzy set theory introduced by Zadeh (1965) has many advantages in analyzing

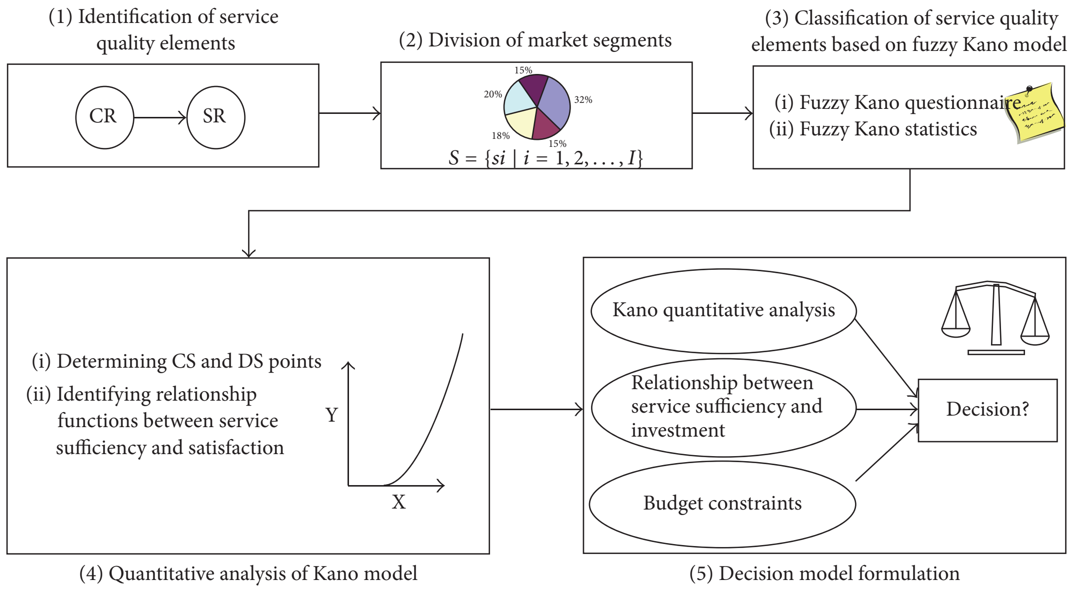

Figure 2: The proposed research framework.

fuzzy linguistics and fuzzy inference, and it is successfully used in fuzzy decision-making [55]. Thus, some scholars suggested incorporating the fuzzy set theory into Kano model to accommodate linguistic properties of subjective and vague human perception [22–24]. The fuzzy Kano model has been found capable of mimicking a realistic cognition process in practice. An evaluator's multiple feelings can be expressed by the possibility degrees in the fuzzy Kano model. In this study, we are inclined to use fuzzy Kano model to elicit customers' perception and gain classification results of service quality elements [55].

3.4. Quantitative Analysis of the Kano Model. After the classification results based on the fuzzy Kano model are obtained, the quantitative analysis is conducted as the literature of Wang and Ji (2010) [21].

Based on the findings of service quality elements classification, it is possible to calculate two values, namely, customer satisfaction (CS) and customer dissatisfaction (DS) [19]:

$$\mathrm{CS}_i = \frac{f_A + f_O}{f_A + f_O + f_M + f_I}, \quad \mathrm{DS}_i = \frac{f_O + f_M}{f_A + f_O + f_M + f_I}. \tag{1}$$

Let f_A denote the number of attractive quality elements, f_O the number of one-dimensional quality elements, f_M the number of must-be quality elements, and f_I the number of indifferent quality elements.

Consequently, the two points define the customer satisfaction if a quality element can be fully fulfilled or completely nonfulfilled. These points can be plotted as $(1, \mathrm{CS}_i)$ and $(0, -\mathrm{DS}_i)$ [21]. The relationship function between customer satisfaction and service quality element fulfillment can be identified given the category of the quality element. The relationship function can be expressed as $S = f(x, a, b)$, where S denotes the customer satisfaction, x denotes the fulfillment level, and a and b are adjustment parameters for the Kano categories of service quality elements. For one-dimensional quality elements, the function is $S = a_1 x + b_1$, and the shape of the linear curve must pass the CS and DS points. Then we can get $a_1 = \mathrm{CS}_i - \mathrm{DS}_i$ and $b_1 = \mathrm{DS}_i$. Therefore, the function for one-dimensional quality elements is

$$S_{oi} = (\mathrm{CS}_i - \mathrm{DS}_i)\, x_{oi} + \mathrm{DS}_i. \tag{2}$$

For attractive quality elements, the function can be seen to be exponential; $S = a_2 e^x + b_2$. Substituting $(1, \mathrm{CS}_i)$ and $(0, -\mathrm{DS}_i)$ into the equation, we can get $a_2 = (\mathrm{CS}_i - \mathrm{DS}_i)/(e-1)$ and $b_2 = -(\mathrm{CS}_i - e\mathrm{DS}_i)/(e-1)$. The function for attractive quality elements is therefore

$$S_{ai} = \frac{\mathrm{CS}_i - \mathrm{DS}_i}{e-1} e^{x_{ai}} - \frac{\mathrm{CS}_i - e\mathrm{DS}_i}{e-1}. \tag{3}$$

Using the similar approach, for must-be quality elements, the function is modified to be $S = -a_3 e^{-x} + b_3$, and we can acquire $a_3 = e(\mathrm{CS}_i - \mathrm{DS}_i)/(e-1)$ and $b_3 = (e\mathrm{CS}_i - \mathrm{DS}_i)/(e-1)$. Then the function for must-be quality elements is

$$S_{mi} = -\frac{e(\mathrm{CS}_i - \mathrm{DS}_i)}{e-1} e^{-x_{mi}} + \frac{e\mathrm{CS}_i - \mathrm{DS}_i}{e-1}. \tag{4}$$

3.5. Decision Model Formulation. In this stage, a decision model for maximizing service quality under budget constraints is developed based on the quantitative Kano model. Different service quality element categories have different influence on satisfaction. Fulfilling customer expectations of service quality to a great extent does not necessarily guarantee a higher customer satisfaction. Sufficient provision will lead to increased costs. It is a very important task to seek for an efficient way to leverage the customer satisfaction and

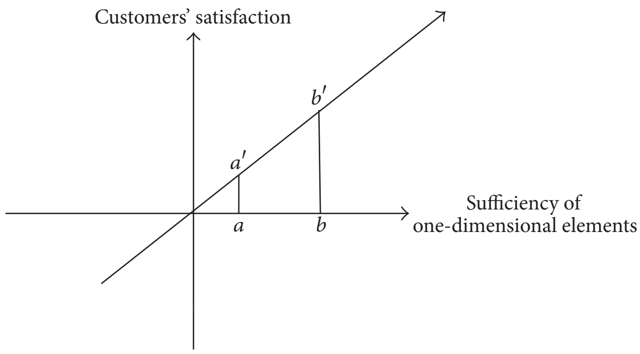

Figure 3: Sufficiency of one-dimensional elements and customers' satisfaction.

cost constraints. This will be done using a service quality maximization model, and its construction will be shown in the following section. Firstly, the relationships between sufficiencies of different service quality elements categories and customer satisfactions are discussed.

(i) One-Dimensional Quality Elements. Figure 3 shows the function for one-dimensional quality elements identified in Section 3.4. When the sufficiency is provided by x_{oi} from level a to b resulting from one unit of monetary investment, the increased satisfaction, A_o, is the area A_o surrounded by points a, b, a', and b', and it can be computed as

$$A_o = \int_a^b \left[\left(\mathrm{CS}_i - \mathrm{DS}_i\right) x_{oi} + \mathrm{DS}_i\right] dx_{oi}. \quad (5)$$

When an enterprise provides n one-dimensional service quality elements and if the sufficiency provided by each x_{oi} increases from a_i to b_i, then TA_o, the level of satisfaction increased by n one-dimensional elements, can be expressed as

$$TA_o = \sum_{i=1}^{n} A_{oi} = \sum_{i=1}^{n} \int_{a_i}^{b_i} \left[\left(\mathrm{CS}_i - \mathrm{DS}_i\right) x_{oi} + \mathrm{DS}_i\right] dx_{oi}, \quad i = 1, 2, \ldots, n. \quad (6)$$

For simplicity, assuming that $a_1 = a_2 = \cdots = a_n = a, b_1 = b_2 = \cdots = b_n = b$, the total increased customer satisfaction TA_o provided by n one-dimensional elements can be computed as

$$TA_o = \sum_{i=1}^{n} \int_a^b \left[\left(\mathrm{CS}_i - \mathrm{DS}_i\right) x_{oi} + \mathrm{DS}_i\right] dx_{oi}. \quad (7)$$

(ii) Attractive Quality Elements. Figure 4 shows the example of an attractive quality element. The relationship function is $S_{ai} = ((\mathrm{CS}_i - \mathrm{DS}_i)/(e - 1))e^{x_{ai}} - (\mathrm{CS}_i - e\mathrm{DS}_i)/(e - 1)$, and when the sufficiency is provided by x_{ai} from level c to d resulting from one unit of monetary investment, the increased satisfaction A_a surrounded by points c, d, c', and d' can be computed as

$$A_a = \int_c^d \left(\frac{\mathrm{CS}_i - \mathrm{DS}_i}{e - 1} e^{x_{ai}} - \frac{\mathrm{CS}_i - e\mathrm{DS}_i}{e - 1}\right) dx_{ai}. \quad (8)$$

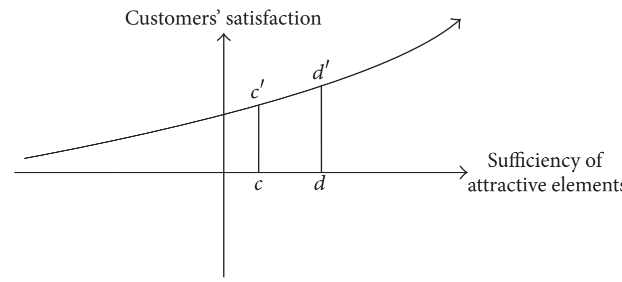

Figure 4: Sufficiency of attractive elements and customers' satisfaction.

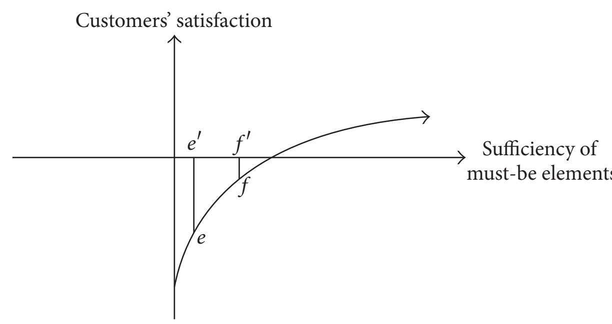

Figure 5: Sufficiency of must-be elements and customers' satisfaction.

If n attractive quality elements provided, with the sufficiency of each x_{ai}, increase from c_i to d_i, the increased satisfaction TA_a can be expressed as

$$TA_a = \sum_{i=1}^{n} A_a = \sum_{i=1}^{n} \int_{c_i}^{d_i} \left(\frac{\mathrm{CS}_i - \mathrm{DS}_i}{e - 1} e^{x_{ai}} - \frac{\mathrm{CS}_i - e\mathrm{DS}_i}{e - 1}\right) dx_{ai}, \quad i = 1, 2, \ldots, n. \quad (9)$$

For the ease of manifestation, assuming that $c_1 = c_2 = \cdots = c_n = c, d_1 = d_2 = \cdots = d_n = d$, the total increased satisfaction TA_a can be simplified as

$$TA_a = \sum_{i=1}^{n} \int_c^d \left(\frac{\mathrm{CS}_i - \mathrm{DS}_i}{e - 1} e^{x_{ai}} - \frac{\mathrm{CS}_i - e\mathrm{DS}_i}{e - 1}\right) dx_{ai}. \quad (10)$$

(iii) Must-Be Quality Elements. As Figure 5 shows, the relationship function for must-be quality element is $S_{mi} = -(e(\mathrm{CS}_i - \mathrm{DS}_i)/(e-1))e^{-x_{mi}} + (e\mathrm{CS}_i - \mathrm{DS}_i)/(e-1)$, and when the sufficiency is provided by x_{mi} from level e to f resulting from one unit of monetary investment, the decreased dissatisfaction A_m surrounded by points e, f, e', and f' is computed as

$$A_m = \int_e^f \left(-\frac{e\left(\mathrm{CS}_i - \mathrm{DS}_i\right)}{e - 1} e^{-x_{mi}} + \frac{e\mathrm{CS}_i - \mathrm{DS}_i}{e - 1}\right) dx_{mi}. \quad (11)$$

If n must-be quality elements provided, with the sufficiency provided by each x_{mi}, increase from e_i to f_i, then the decreased dissatisfaction TA_m can be expressed as

$$\begin{aligned} TA_m &= \sum_{i=1}^{n} A_m \\ &= \sum_{i=1}^{n} \int_{e_i}^{f_i} \left(-\frac{e\left(\mathrm{CS}_i - \mathrm{DS}_i\right)}{e-1} e^{-x_{mi}} + \frac{e\mathrm{CS}_i - \mathrm{DS}_i}{e-1} \right) dx_{mi}, \\ & \qquad i = 1, 2, \ldots, n. \end{aligned} \tag{12}$$

Assuming that $e_1 = e_2 = \cdots = e_n = e$, $f_1 = f_2 = \cdots = f_n = f$, the total decreased dissatisfaction TA_m is simplified as

$$\begin{aligned} &TA_m \\ &= \sum_{i=1}^{n} \int_{e}^{f} \left(-\frac{e\left(\mathrm{CS}_i - \mathrm{DS}_i\right)}{e-1} e^{-x_{mi}} + \frac{e\mathrm{CS}_i - \mathrm{DS}_i}{e-1} \right) dx_{mi}. \end{aligned} \tag{13}$$

The equations above now can be applied to improve the machinery service quality. There are many factors that can be related to the machinery service quality, and some fall into must-be elements, and others are one-dimensional or attractive quality elements. Moreover, the increased satisfaction resulting from investment on must-be, one-dimensional, and attractive quality elements is certainly different. Thus, the problem is how to properly allocate the budget to service quality elements in order to maximize the overall customer satisfaction. At this point the following model can be proposed:

$$\begin{aligned} M\colon \max \quad & C_o\left(TA_o\right) + C_a\left(TA_a\right) + C_m\left(TA_m\right) \\ \text{s.t.} \quad & C_o + C_a + C_m \le B \\ & 0 \le C_o \le B \\ & 0 \le C_a \le B \\ & 0 \le C_m \le B \\ & C_o = k_1\left(b - a\right) \\ & C_a = k_2\left(d - c\right) \\ & C_m = k_3\left(f - e\right) \\ & 0 \le a \le b \le D \le 1 \\ & 0 \le c \le d \le E \le 1 \\ & 0 \le e \le f \le F \le 1, \end{aligned} \tag{14}$$

where C_o, C_a, and C_m denote the individual budget allocated to one-dimensional, attractive, and must-be quality elements and these are the decision variables. B is the total budget to improve the overall service quality. When budgeted, C_o can be increased from a to b with D being the upper limit. With the same principles, C_a can be increased from c to d with E being the upper limit, and C_m can be increased from e to f with F being the upper limit. The coefficients of k_1, k_2, and k_3 stand for the relationship between budget allocated and the level of quality improvement. The nonlinear mathematical model can be solved by optimization software Lingo, and the details will be shown in the following illustrative example.

4. An Empirical Study

To demonstrate the performance of the proposed method, an empirical study in Xuzhou Construction Machinery Group Co., Ltd. (XCMG), is given in this section. XCMG is the largest construction machinery company in China. Its products cover road machineries, crane trucks, heavy-duty road rollers, and so on, which include 75 series and 330 varieties. The product sales network of XCMG covers more than 170 countries and regions, and the annual export value has exceeded $1.6 Billion USD. But in recent years with the scale enlargement of markets and the implementation of the "Going Global" strategy, XCMG is facing much greater variety and uncertainty in customer requirement. XCMG now needs to explore the appropriate strategy on the service quality management to gain competitive advantage. Since 2011, XCMG launched the project of "Hanfeng Program" to establish a control system for service quality improvement. And the decision method proposed in this paper is implied in the program.

4.1. Service Quality Elements Identification in XCMG. Based on the SERVQUAL model, several experts in XCMG and some users are investigated by the team members, and twelve service quality elements and benefits provided for customers in XCMG are extracted in Table 2.

4.2. Data Collection and Analysis. According to the twelve service quality elements, the fuzzy Kano questionnaire is designed, which is divided into two parts: in the first part, there is some demographic information of respondents such as organization characters (state-owned business, private business, foreign-funded enterprise, or joint venture enterprise) and types of customers (general customers, key accounts, or strategic customers). In the second part, the questionnaire focuses on a set of 12 items of service quality elements, and the form of each item is presented with both functional and dysfunctional forms, but, unlike traditional Kano model using binary data, the fuzzy Kano model questionnaire allows respondents to express their multiple feelings by the possibility degrees among multiple items. Additional information on the fuzzy Kano questionnaire can be found in the literature [55].

The fuzzy Kano questionnaire is distributed randomly face-to-face by the employees from marketing department and after-sale service support department and team members in the program. The first step is to provide respondents with a brief introduction of Kano model, and then customers are asked to give multiple answers of the pair questions about service quality elements. From September 15 to December 15, 2012, 250 copies of the questionnaire have been issued and 196 completed copies are retrieved. This is a reasonable response rate of 78.4%. The sample demographic characteristics are shown in Table 3.

Table 2: Service quality elements and benefits provided for customers in XCMG.

Service quality elements	Description and specification	Benefits provided
SQ_1	Fulfill service commitments, maintenance service in PLC	Reliability, safety
SQ_2	Quick response to requirements and complaints	Speediness
SQ_3	Consultation and solutions customization	Empathy, added value
SQ_4	Repair and maintenance service covers widely	Safety, assurance, and reliability
SQ_5	Machinery vehicles status monitoring and warning, long range information transmission, and diagnosis	Safety, convenience
SQ_6	Value-added service	Added value, empathy
SQ_7	Network and online service	Convenience, speediness
SQ_8	Used machinery vehicles business	Convenience, empathy
SQ_9	High quality service staffs' professional and technical abilities	Pleasure, assurance
SQ_{10}	Compensation for delaying	Reliability, safety
SQ_{11}	Proactive services provided regularly and periodically	Convenience, reliability
SQ_{12}	Customer participation in service process	Added value, empathy

Table 3: Demographic characteristics of respondents.

Demographic characteristics	Number	Percentage (%)
Organization characters		
State-owned business	54	27.55%
Private business	43	21.94%
Foreign-funded enterprise	47	23.98%
Joint venture enterprise	52	26.53%
Types of customers		
General customers	79	40.31%
Key accounts	65	33.16%
Strategic customers	52	26.53%

4.3. Service Quality Elements Classification. Based on fuzzy Kano survey and statistical analysis, the classification results of service quality elements in XCMG are given from the preliminary qualitative results by the author [55], as is shown in Table 4.

4.4. Decision Results. According to results of service quality elements classification, the service quality elements, SQ_{11} (proactive services provided regularly and periodically) and SQ_{12} (customer participation in service process), are classified as indifferent quality elements. They are not included in the further analysis due to the low impact on customer satisfaction. At this point the proposed quantitative analysis in Section 3 is applied. Firstly, the values of CS and DS are computed for each service quality element as shown in Table 5. Based on the classification results in Table 4, the values of a and b are calculated to determine the function for each service quality element. Accordingly, all the relationship functions of three category quality elements are estimated in Table 5.

Given the data of cost for each service quality element drawn from investigation in XCMG, as is shown in Table 6, the total budget for service quality improvement is ¥150,000.

Assuming $k_1 = 150$, $k_2 = 300$, $k_3 = 100$, $a = 0.55$, $c = 0.55$, $e = 0.55$, and $D = 0.9$, $E = 0.8$ and $F = 1$. Then the model becomes

$$\begin{aligned} M\colon \max \quad & C_o(TA_o) + C_a(TA_a) + C_m(TA_m) \\ \text{s.t.} \quad & C_o + C_a + C_m \le 150 \\ & 0 \le C_o \le 150 \\ & 0 \le C_a \le 150 \\ & 0 \le C_m \le 150 \\ & C_o = 150(b - 0.55) \\ & C_a = 300(d - 0.55) \\ & C_m = 100(f - 0.55) \\ & 0.55 \le b \le 0.9 \\ & 0.55 \le d \le 0.8 \\ & 0.55 \le f \le 1.0 \\ & TA_o = 2.015b^2 - 2.03b + 0.507 \\ & TA_a = 1.32e^d - 2.25d - 1.0504 \\ & TA_m = 8.88e^{-f} + 5.51f - 8.1538. \end{aligned} \tag{15}$$

The nonlinear programming model is solved by Lingo 11.0, and the results are obtained as $C_o = 52.5$, $C_a = 52.5$, and $C_m = 45$; $TA_o = 0.31$, $TA_a = 0.04$, and $TA_m = 0.62$; and the overall customer satisfaction is 46.72. It appears that XCMG should allocate ¥52,500 to improve the one-dimensional quality elements, with the level of service quality being improved from 0.55 to 0.9. ¥52,500 of the budget should be allocated for the attractive quality elements, with the level of service quality being improved from 0.55 to 0.725. And ¥45,000 should be allocated for the must-be quality elements, and it will improve the level of service quality from 0.55 to 1.

To examine the appropriateness of the results, three different parameter values of coefficients k_i are applied in the model for a sensitivity analysis. Due to the fact that the categories of service quality elements are the most effective factors on resource utilization, the sensitivity analysis focuses mainly on the coefficients k_i. Table 7 shows the results of the sensitivity analysis.

The results in Table 7 show that the coefficients k_i have some effect on the decision-making results. In the three

Table 4: Service quality elements classification results from Kano model.

Service quality elements (number)	Traditional Kano model					Fuzzy Kano model				
	M	A	I	O	Category	M	A	I	O	Category
SQ_1	88	32	25	51	M	106	38	18	44	M
SQ_2	78	45	23	50	M	98	42	20	51	M
SQ_3	45	38	20	93	O	51	43	25	99	O
SQ_4	89	51	11	45	M	95	56	15	37	M
SQ_5	40	82	24	50	A	46	88	27	53	A
SQ_6	45	90	16	45	A	49	92	18	48	A
SQ_7	84	39	26	47	M	95	52	24	38	M
SQ_8	37	90	21	48	A	39	48	19	92	O
SQ_9	49	90	19	38	A	54	46	24	95	O
SQ_{10}	51	80	15	50	A	84	56	13	47	M
SQ_{11}	38	59	80	19	I	43	64	86	25	I
SQ_{12}	55	47	73	21	I	56	48	78	22	I

Table 5: Quantitative results of service quality elements based on Kano model.

Number	CS	DS	CS point	DS point	a	b	$f(x)$	$S = af(x) + b$
SQ_1	0.40	−0.73	(1, 0.4)	(0, −0.73)	1.78	1.05	e^{-x}	$S = -1.78e^{-x} + 1.05$
SQ_2	0.44	−0.71	(1, 0.44)	(0, −0.71)	1.81	1.11	e^{-x}	$S = -1.81e^{-x} + 1.11$
SQ_3	0.65	−0.69	(1, 0.65)	(0, −0.69)	1.34	−0.69	x	$S = 1.34x - 0.69$
SQ_4	0.46	−0.65	(1, 0.46)	(0, −0.65)	1.75	1.10	e^{-x}	$S = -1.75e^{-x} + 1.10$
SQ_5	0.66	−0.46	(1, 0.66)	(0, −0.46)	0.65	−1.12	e^{x}	$S = 0.65e^{x} - 1.12$
SQ_6	0.68	−0.47	(1, 0.68)	(0, −0.47)	0.67	−1.13	e^{x}	$S = 0.67e^{x} - 1.13$
SQ_7	0.43	−0.64	(1, 0.43)	(0, −0.64)	1.69	1.05	e^{-x}	$S = -1.69e^{-x} + 1.05$
SQ_8	0.71	−0.66	(1, 0.71)	(0, −0.66)	1.37	−0.66	x	$S = 1.37x - 0.66$
SQ_9	0.64	−0.68	(1, 0.64)	(0, −0.68)	1.32	−0.68	x	$S = 1.32x - 0.68$
SQ_{10}	0.52	−0.66	(1, 0.52)	(0, −0.66)	1.85	1.20	e^{-x}	$S = -1.85e^{-x} + 1.2$

Table 6: Cost for each service quality element.

Service quality elements (number)	Description and specification	Costs (¥1000)
SQ_1	Fulfill service commitments, maintenance service in PLC	4800
SQ_2	Quick response to requirements and complaints	295
SQ_3	Consultation and solutions customization	400
SQ_4	Repair and maintenance service covers widely	4300
SQ_5	Machinery vehicles status monitoring and warning, long range information transmission, and diagnosis	360
SQ_6	Value-added service	200
SQ_7	Network and online service	170
SQ_8	Used machinery vehicles business	215
SQ_9	High quality service staffs' professional and technical abilities	310
SQ_{10}	Compensation for delaying	460

conditions, the must-be quality elements will first achieve their targets (always $f = 1$), and they must be allocated to the budget to be fully fulfilled, while the one-dimensional and attractive quality elements are quite different. The performance of must-be quality elements has the priority in service quality improvement. With a limited budget (¥150,000) it can only be guaranteed that the must-be and one-dimensional quality elements achieve their goals, while the attractive quality elements cannot be assured.

4.5. Suggestions. From the results, it appears that XCMG should firstly invest in must-be quality elements to assure an entirely fulfilled system with limited resources. Specifically, XCMG will establish a service standard system to fulfill service commitments, provide the maintenance service in a product's life cycle, and assure these quality elements to a high level. XCMG must guarantee a quick response to service requirements and complaints from customers, and this can be done through the use of both a Customer Relationship Management (CRM) system and Mobile Internet Technology (MIT). The service quality element "repair and maintenance service covers widely" will be improved in a large scale

Table 7: Solutions with different parameter values of k_i.

Number	k_1	k_2	k_3	C_o	C_a	C_m	TA_o	TA_a	TA_m	b	d	f	max CS
1	150	300	100	52.5	52.5	45	0.31	0.04	0.62	0.9	0.73	**1**	46.72
2	100	150	300	0	15	135	$3.75 * 10^{-5}$	0.02	0.62	0.55	0.65	**1**	**84.34**
3	300	100	150	102.73	0.02	47.25	0.30	0	0.62	0.89	0.55	**1**	60.28

with the business expansion. Meanwhile, "the network and online service" needs also to be investigated within the company, as poor service quality for this element leads to strong dissatisfaction. If the must-be quality elements are not fulfilled, it would be essential to provide compensation to customers that place complaints.

The one-dimensional elements of "consultation and solutions customization," "used machinery vehicles business," and "high quality service staffs' professional and technical abilities" should also be improved to a high level to maximize customer satisfaction for XCMG. Considering customers' heterogeneities, service customization and service specialization will be the general trend in the future. The service quality is significantly related with service staffs, and XCMG must make sure that there are a group of service employees with high levels of professional and technical abilities. In addition to the focus on must-be and one-dimensional elements, it is wise to seek for some effective ways to improve the attractive quality elements, if there is potential for additional monetary investment.

The decision method proposed is also practical and functional for other enterprises to improve service quality. Firstly, it is critical to better identify and understand service quality elements from customers' perspective. Secondly, it is necessary to account for the budget constraints in the decision-making of service quality improvement. Thirdly, with the limited budget, to maximize the overall customer satisfaction, the must-be quality elements must be allocated to the budget to be fully fulfilled and to achieve the targets.

5. Conclusions

Service quality has become one of the sources for competitive advantage, especially for some machinery industries transforming into product-service system providers. And more importantly, service quality is the crucial determinant of customer satisfaction and customer loyalty. This integrated framework, proposed for maximizing machinery industry service quality under budget constraints, involves service quality elements identification and classification, quantitative analysis of Kano model, and decision model formulation. It provides a guidance principle of "origin from customers, application for customers" for enterprises to manage service quality in the customers-dominated logic era. As Wang and Ji (2010) [21] stated before, it is important to provide a way for quantitative Kano model to be integrated with other mathematical models for optimizing customer-focused product or service design.

The contributions of this research can be summarized as follows. First, the decision method proposed provides a systematic and quantitative solution for improving service quality in machinery manufacturers to balance customer satisfaction and service costs. Second, the integrated framework gives a practical roadmap for enterprises to improve service quality with limited budgets, and it involves several key processes: service quality elements identification, classification, and service quality improvement decision-making. Finally, the results provide empirical evidence that must-be quality elements have higher priorities in budget allocation for quality improvement, compared with one-dimensional and attractive quality elements, under the limited budgets.

Yet, there are some limitations in this paper. Firstly, in the nonlinear programming model (14), the coefficients parameters which related the budgets to the level of quality improvement should be discussed further, using a large amount of historical data in the future. Secondly, in the empirical research, the perceptions varieties in classification of service quality elements from different customer segments are not considered. And it is significant for the enterprises to make decisions with different customer orientation. Finally, more empirical studies on the decision method should be conducted to test the applicability.

Competing Interests

The authors declare that there are no competing interests regarding the publication of this paper.

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