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Analysis of Supplier Demand Factors Based on QFD in Mass Customization Environment

Yunlong Zhang[1*], Zengqiang Wang[2]

[1]People's Government of Ningnan County, Liangshan Prefecture 615400, Sichuan Province, China
[2]School of Management, Xihua University, Chengdu City 610000, Sichuan Province, China

Corresponding author: Yunlong Zhang, wzqlinger@163.com

Abstract: Supplier selection in a mass customization environment is a systematic engineering, and Quality Function Deployment (QFD) based on customer demand is a systematic product development method. This paper studies the adaptability of the QFD method and supplier selection process in a mass customization environment and puts forward a supplier selection framework based on the QFD idea. Furthermore, both the objective environment of demand factor analysis and the thinking of the customer representatives participating in the analysis have great uncertainty and fuzziness. Therefore, a demand factor analysis method for supplier selection in the mass customization environment based on language phrases of different granularity is proposed. The proposed method allows the customer representatives participating in the selection to use their preferred language phrase set to represent the importance of demand factors. Finally, the effectiveness and feasibility of the proposed method are verified by an example of a vehicle manufacturer.

Keywords: Mass customization; Supplier selection; Quality function deployment; Demand factors

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1. Introduction

Economic globalization intensifies the competition among enterprises, and customers begin to chase personalized and customized products. Under such circumstances, enterprises must quickly respond to various demands to obtain higher customer value and stronger economic benefits [1]. However, diversified product types bring opportunities to production enterprises, but also bring more challenges, the overall operation of the enterprise tends to be complex, and the design, production, sales, and distribution of all aspects of the overall coordination requirements are higher. Production enterprises need to introduce a new Mass Customization (MC) production mode, not only to improve the innovative research and development ability of products but also to choose more reliable suppliers to improve the overall performance of the supply chain.

In the past 30 years, the issue of supplier selection has received continuous attention, and the current research mainly focuses on the following three aspects. First, how to obtain the indicators of supplier selection, including

questionnaire survey, focus interview, field observation, and tree chart [2]. Second, the analysis of index weights. However, the existing literature mainly belongs to descriptive research, focusing on the determination of the index system, with little weight analysis of indicators. Third, some studies use the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Data Envelopment Analysis (DEA), fuzzy set ideas, and multi-objective linear programming to select and evaluate alternative suppliers [3]. It should be pointed out that the selection of suppliers in the MC environment is a system engineering, and the new MC model puts forward higher requirements for partners.

In the selection process, the driver factors, implementation process, and upstream and downstream relationship of suppliers should be comprehensively analyzed, and the current research results do not pay more attention to this. Quality Function Deployment (QFD), which originated in the 1960s, is a whole-process product development technology driven by customer demand and has been promoted in many industries and fields [4]. The core idea of QFD is to transform customer demand into information that designers and producers can understand, and it is reflected in the final products produced and provided by enterprises. This paper tries to apply the QFD idea in the process of supplier selection under the MC environment, puts forward some solutions for the implementation of MC mode for manufacturing enterprises, and applies these methods to the example of vehicle manufacturing enterprises.

2. Adaptability of supplier selection under QFD idea and MC environment

The basic characteristics of QFD can be summarized as follows.

(1) Through product planning, component planning, process planning, and production planning, a large number of unstructured and qualitative information can be converted into structured and quantitative information that can be measured and calculated.

(2) The whole process can be optimized through product planning quality house, parts planning quality house, process planning, and production planning quality house.

(3) QFD is a product development and design method based on customer needs, so it can effectively improve customer satisfaction.

(4) The application of the QFD method requires full cooperation between customers and product designers.

In the whole process of selecting the right supplier in the MC environment, the production enterprise is often decomposed through the whole process and then combined with the macro-environment of enterprise survival and the micro-environment of actual development [5]. From the perspective of the implementation mechanism of supplier selection, the basic characteristics of supplier selection in the MC environment can be summarized as follows.

(1) Through the analysis of demand factors and service characteristics, a large number of unstructured and qualitative information can be transformed into structured and quantitative information that can be measured and calculated by designing service schemes and other processes.

(2) The premise of supplier selection in the MC environment is to analyze the enterprise environment and development trend and determine the goals and requirements of supplier selection, that is, the selection process driven by external demand.

(3) The process of supplier selection in the MC environment needs to involve more activities, involving the cooperation and collaboration of various relevant departments of the enterprise.

Based on the above analysis, we can clearly see that the principle of the QFD method and the process of supplier selection in the MC environment are driven by external requirements and objectives, and the basic characteristics, specific implementation process, and logic relationship before and after the two are very similar. The principle of the QFD method has strong adaptability in the process of supplier selection in the MC environment.

3. The importance analysis method of supplier demand factors

In the process of supplier selection under the MC environment, the analysis of the importance of demand factors is a typical group decision problem, which requires the selection of multiple customer representatives to ensure a scientific and reasonable conclusion. However, the information environment in the process of supplier selection is more complex and uncertain. Therefore, this paper proposes a more targeted method of demand factor importance analysis.

(1) Step 1: Select customer representatives from production enterprises, distributors, and final customers to form an internal evaluation team of demand factors, and use pair-to-pair comparison method to determine the weight information of each customer. The project leader for the implementation of the MC model communicates to the members of the team about the requirements of the project and the tasks of the team. Through the detailed and comprehensive questionnaire survey, several key interviews, and the analysis of this information, the key demand factors of supplier selection in the MC environment are determined.

(2) Step 2: According to their familiarity with corporate culture and demand factors, customer representatives determine their favorite language phrase set, and then judge the importance of each key demand factor, and give the corresponding preference information, which can form a judgment matrix of the importance of demand factors. To facilitate elaboration and evaluation, the language phrase sets that can be selected in the process of demand factor importance analysis are listed as follows.

$$S^3 = \left\{S^3_{-2} = \text{very unimportant}, S^3_{-2/3} = \text{unimportant}, S^3_0 = \text{ordinary}, S^3_{2/3} = \text{important}, S^3_2 = \text{very important}\right\};$$

$$S^4 = \{S^4_{-3} = \text{very unimportant}, S^4_{-4/3} = \text{unimportant}, S^4_{-1/3} = \text{relativeyly unimportant}, S^4_0 = \text{ordinary}, S^4_{1/3} = \text{relativeyly important},$$

$$S^4_{4/3} = \text{important}, S^4_3 = \text{very important}\};$$

$$S^5 = \{S^5_{-4} = \text{extremely unimportant}, S^5_{-2} = \text{very unimportant}, S^5_{-1} = \text{unimportant}, S^5_{-0.4} = \text{relativeyly unimportant},$$

$$S^5_0 = \text{ordinary}, S^5_{0.4} = \text{relativeyly important}, S^5_1 = \text{important}, S^5_2 = \text{very important}, S^5_4 = \text{extremely important}\}.$$

(3) Step 3: The consistency processing function of different language phrases is used to transform these different language phrases into the same granularity of preference information, so that the judgment matrix of the same granularity is formed. According to the judgment matrix of the same granularity, the evaluation vector of the importance of each demand factor can be listed, and the positive and negative ideal points of the importance judgment vector of each demand factor can be determined using **Equation (1)**.

$$\begin{cases} x_i^+ = \max\limits_j \left\{\lambda_{ij}\right\} \\ y_i^- = \min\limits_j \left\{\lambda_{ij}\right\} \end{cases} \tag{1}$$

(4) Step 4: Calculate the deviation between the importance vector of each demand factor and the positive and negative ideal points respectively, and the calculation formulas are as follows.

$$d_j^+ = \theta_1 d\left(\lambda_{1j}, x_1^+\right) \oplus \theta_2 d\left(\lambda_{2j}, x_2^+\right) \oplus \ldots \oplus \theta_t d\left(\lambda_{tj}, x_t^+\right) \tag{2}$$

$$d_j^- = \theta_1 d\left(\lambda_{1j}, y_1^-\right) \oplus \theta_2 d\left(\lambda_{2j}, y_2^-\right) \oplus \ldots \oplus \theta_t d\left(\lambda_{tj}, y_t^-\right) \tag{3}$$

(5) Step 5: **Equation (4)** is used to calculate the estimated value between the importance vector of each demand factor and the positive and negative ideal points.

$$z_j^* = \frac{d_j^-}{d_j^+ + d_j^-} \tag{4}$$

The evaluation value of each demand factor is standardized and the importance of each demand factor is obtained. The calculation formula is as follows.

$$\rho_j = \frac{z_j^*}{\sum_{j=1}^{m} z_j^*} \tag{5}$$

4. Examples and analysis of results

This study takes the supplier selection of a vehicle manufacturer as an example to illustrate the feasibility of the proposed method in the process of demand factor importance analysis. Since the establishment of the enterprise, more focus on large-scale production and seize the market, and do not pay much attention to the diversified needs of customers for vehicles, which has a certain conflict with the current situation of strong personalized demand, resulting in a relatively serious excess production capacity of enterprises, investment output is relatively low. Nowadays, manufacturers try to introduce the MC mode driven by customer demand in the whole vehicle, and the selection range and standards of their suppliers have changed accordingly. The implementation team of MC mode requires the production enterprise to conduct a comprehensive analysis of the demand factors of the supplier, so as to provide some basis for the change of the production mode.

(1) Step 1: The project team responsible for the implementation of the MC mode of the vehicle enterprise invited the employee representatives of relevant departments within the enterprise, distributor representatives and end user representatives to form the decision-making team for supplier selection in the MC environment. The project leader stated the necessity and significance of the project to the decision-making team, and on this basis informed the team of the work and tasks that need to be completed. Through pairwise comparison, the decision-making team can determine the weight vector of each member as $\grave{e} = (0.286,\ 0.239,\ 0.265,\ 0.210)$. Then, the decision-making team conducts a comprehensive market research on the production status quo and supplier cooperation of the enterprise, fully understands the customer's demands for suppliers, and the decision-making team of demand factors conducts a comprehensive analysis of these materials, according to which the key demand factors for supplier selection in the MC environment are determined. Higher vehicle assembly quality, higher on-time delivery rate, faster response speed, better after-sales service, stronger quantitative flexibility, stronger targeted design, and stronger modular design.

(2) Step 2: Members of the decision-making team should conduct a scientific and reasonable analysis based

on their understanding of the production enterprise, suppliers and demand factors, and give corresponding preference information. This study suggests that decision-makers use their own preferred language phrase set, so as to give full play to the subjective initiative of members. According to the preference information of demand factors given by these decision makers, the judgment matrix of the importance of demand factors can be obtained.

(3) Step 3: The information matrix of the demand factors with the same granularity can be obtained by using the phrase conversion function to deal with the given preference information uniformly. Then, the importance vector of each demand factor can be listed as follows.

$$\ddot{\boldsymbol{e}}_1 = \left\{s_{4/3}^4, s_1^4, s_3^4, s_{4/3}^4\right\};\ \ddot{\boldsymbol{e}}_2 = \left\{s_{1/2}^4, s_0^4, s_{3/4}^4, s_{-4/3}^4\right\};\ \ddot{\boldsymbol{e}}_3 = \left\{s_{1/2}^4, s_1^4, s_{-0.3}^4, s_0^4\right\};\ \ddot{\boldsymbol{e}}_4 = \left\{s_0^4, s_0^4, s_{3/4}^4, s_0^4\right\}$$

$$\ddot{\boldsymbol{e}}_5 = \left\{s_{4/3}^4, s_3^4, s_{3/2}^4, s_3^4\right\};\ \ddot{\boldsymbol{e}}_6 = \left\{s_{1/2}^4, s_1^4, s_{3/4}^4, s_0^4\right\};\ \ddot{\boldsymbol{e}}_7 = \left\{s_{-1/2}^4, s_{-1}^4, s_{0.3}^4, s_{1/2}^4\right\}$$

Then, according to **Equation (1)**, the positive ideal points and negative ideal points of the importance vector of each demand factor are obtained respectively.

$$\boldsymbol{x}^+ = \left\{s_{4/3}^4, s_3^4, s_3^4, s_3^4\right\},\ \boldsymbol{y}^- = \left\{s_{-1/2}^4, s_{-1}^4, s_{-0.3}^4, s_{-4/3}^4\right\}.$$

(4) Step 4: Based on **Equation (2)** and **Equation (3)**, the deviation between the importance vector of each demand factor and the positive and negative ideal points can be obtained respectively.

$$d^+ = 0.104,\ d^+ = 0.308,\ d^+ = 0.278,\ d^+ = 0.291,\ d^+ = 0.050,\ d^+ = 0.243,\ d^+ = 0.360.$$

$$d^- = 0.305,\ d^- = 0.068,\ d^- = 0.165,\ d^- = 0.288,\ d^- = 0.117,\ d^- = 0.130,\ d^- = 0.100.$$

(5) Step 5: Based on **Equation (4)**, the estimated value of each demand factor can be obtained as

$$z = 0.746,\ z = 0.181,\ z = 0.372,\ z = 0.497,\ z = 0.701,\ z = 0.349,\ z = 0.217.$$

Using **Equation (5)** to standardize the above evaluation values, the importance of each demand factor can be determined.

$$\rho = 0.244,\ \rho = 0.059,\ \rho = 0.121,\ \rho = 0.162,\ \rho = 0.229,\ \rho = 0.114,\ \rho = 0.071.$$

It can be seen that the customer representative believes that the two demand factors of higher vehicle assembly quality and stronger quantitative flexibility are of high importance. The ranking result reflects the customer's requirements for suppliers in the MC environment, which should be fully considered in the subsequent redesign of supplier service schemes, and more resources should be put in.

5. Conclusion

MC mode is a new production strategy for production enterprises in the 21st century, which aims to provide personalized products and services for the final customers. In order to adapt to the new environment and take advantage in the competition, production enterprises need to determine more suitable suppliers based on limited information. This paper analyzes the selection process of suppliers in the MC environment by combining the QFD principle. The importance of supplier's demand factor is analyzed, and a method of demand factor importance

analysis based on different granularity language phrases is proposed.

(1) Based on the existing research, the principle of QFD and the basic characteristics of supplier selection process under MC environment are analyzed, and the results show that both are driven by external requirements and objectives, and there are great similarities in the specific implementation process and the logic relationship before and after. It is feasible to apply QFD principle to the process of supplier selection in MC environment.

(2) In order to effectively deal with the uncertainty of information in the process of supplier selection in the MC environment, this paper invites decision-makers to use preferred language phrases to represent their preference opinions. On the one hand, the method takes into account the different situations of each decision-maker in a more comprehensive way. The evaluator selects his or her preferred set of phrases based on his or her knowledge of the manufacturer, supplier and demand factors, as well as his or her own preferences, so as to take full advantage of the experience and knowledge of the decision maker. On the other hand, in the calculation process, the preference information given by the decision maker is calculated directly, which makes full use of the decision information.

Disclosure statement

The authors declare no conflict of interest.

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