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Research Article

Multiobjective Optimization Model of Production Planning in Cloud Manufacturing Based on TOPSIS Method with Combined Weights

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Combined with the research of mass customization and cloud manufacturing mode, this paper discussed the production planning of mass customization enterprises in the context of cloud manufacturing in detail, analyzed the attribute index of manufacturing resource combination, and given a system considering the characteristics of batch production in mass customization and the decentralization of manufacturing resources in cloud manufacturing environment. Then, a multiobjective optimization model has been constructed according to the product delivery date, product cost, and product quality that customers care most about. The Pareto solution set of production plan has been obtained by using NSGA-II algorithm. This paper established a six-tier attribute index system evaluation model for the optimization of production planning scheme set of mass customization enterprises in cloud manufacturing environment. The weight coefficients of attribute indexes were calculated by combining subjective and objective weights with analytic hierarchy process (AHP) and entropy weight method. Finally, the combined weights calculated were applied to the improved TOPSIS method, and the optimal production planning scheme has been obtained by ranking. This paper validated the effectiveness and feasibility of the multiobjective model and NSGA-II algorithm by the example of company A. The Pareto effective solution has been obtained by solving the model. Then the production plan set has been sorted synthetically according to the comprehensive evaluation model, and the optimal production plan has been obtained.

1. Introduction

With the advent of the big data era and the introduction of the concept of cloud manufacturing, great changes have taken place in the production mode of the manufacturing industry. Cloud manufacturing mode can promote the value added of resources and services, promote the comprehensive sharing of resources, and improve the utilization of resources. Due to the increasing diversity of people's needs and the increasing functional requirements of products, services with a single function cannot meet the needs of customers, but services with multiple functions have diversity and quantity, which makes it possible to have a variety of possibilities and uncertainties to select cloud manufacturing resources. Because the problem of cloud manufacturing production scheme is a multiobjective optimization problem, in order to enable manufacturing enterprises to choose the optimal production plan, so as to carry out production in an organized manner, it is necessary to design and optimize the production planning.

The concept of cloud manufacturing is put forward by Lee et al. [1] in 2010; he thought the cloud manufacturing is an advanced network manufacturing mode to manage the manufacturing resources and provide the manufacturing services for enterprises through the cloud manufacturing service platform. In view of the cloud manufacturing architecture proposed by Lee, many scholars have carried out relevant theoretical research and proposed different cloud manufacturing architecture models applied in different fields. Du et al. [2] proposed a system architecture of the cloud manufacturing platform based on double-chain architecture to solve the problem of transaction security of the cloud manufacturing platform, aiming at the common problems of information islands and low trust in the cloud manufacturing platform. In the key technologies of cloud manufacturing, in cloud manufacturing system, it is necessary to virtualize and encapsulate manufacturing resources scattered in different places and connect them into the cloud manufacturing service platform [3]. In this process, the capability and function of manufacturing resources should be considered, so as to establish different granularity description models of manufacturing resources and capabilities. S. Huang and B. Huang [4] analyzed the security requirements of the cloud manufacturing platform in view of the proposed architecture and established a security requirement model of could manufacturing platform, which strengthened the security of the cloud manufacturing platform from three aspects: data security, access rights, and network transmission security. In terms of search matching of cloud manufacturing, Yang et al. [5] established an ontology-based cloud service discovery model to realize the search and intelligent matching capabilities of cloud manufacturing. In order to allocate cloud manufacturing resources to manufacturing tasks more effectively, Zhang et al. [6] proposed a dynamic parameter ant colony algorithm in cloud manufacturing combinatorial optimization, which was proved to be effective by an example.

The scholars at home and abroad have also studied mass customization. A domestic scholar named Zhou et al. [7] thinks that mass customization is a kind of mass production mode which meets the market environment and customers' individualized requirements; it can provide customers with products that can meet their individualized needs with mass production costs. Liu et al. [8] described the process of building a product family model based on product family deformation design in product design and combined with family table function in pro/pre to achieve rapid product deformation design. Cariagai et al. [9] analyzed customer needs and indexed customer demand information. On this basis, the change of customer needs was studied through encapsulation and analysis of data. Wu et al. [10] analyzed and demonstrated the mechanism of mass intelligent customization in view of the structure of the black box of personalized demand and the linking of supply and demand paths. It showed that with, the help of virtual market and data technology effect, enterprises can meet the personalized demand in the sense of scale. Katzy [11] constructed a conceptual model of agile manufacturing and illustrated the feasibility of the model through an application example of an enterprise.

In this paper, the production planning and optimization of mass customization manufacturing enterprises in the cloud environment are studied, in order to make mass manufacturing enterprises fully and reasonably meet customer requirements and obtain maximum benefits in the cloud manufacturing environment.

2. Formulation of Production Planning in Cloud Manufacturing Environment

Manufacturing enterprises in cloud manufacturing environment can share information at a high level through cloud manufacturing service platform, realize virtualization and integration of manufacturing resources and manufacturing capabilities, and realize the information exchange and sharing among enterprises.

2.1. Influencing Factors of Production Planning

2.1.1. Production Cost. The cost of production-related products mainly includes production cost, inventory cost, and shortage cost. In the cloud manufacturing environment, enterprises can obtain the services they need at any time through the cloud manufacturing service platform, so the inventory cost is neglected. However, the shortage of goods will affect customer satisfaction and will also lead to the loss of business opportunities and market share, which has a great impact on the competitiveness of enterprises. Therefore, the cost of shortage should be avoided as far as possible. Cost control is particularly important for choosing manufacturers.

2.1.2. Transportation Cost. The distance between each manufacturer and the customer is different, so the transportation cost is different, and the transportation cost accounts for a certain proportion of the total cost. In order to reduce the total product cost of manufacturing enterprises and improve manufacturing efficiency, transportation cost, as one of the product cost, is also a key factor to be considered.

2.1.3. Product Quality. Manufacturers registered and approved in cloud manufacturing service platform need to provide specific information about their manufacturing resources and manufacturing capabilities and provide the qualified rate of a certain product. When selecting manufacturing suppliers, the quality of the products they can supply shall be fully considered. The quality is an important factor in selecting the manufacturing suppliers to complete the manufacturing tasks.

2.1.4. Delivery Time. The delivery time refers to the time between receipt of orders and delivery, which is influenced by factors such as production time, transportation, and information transmission, and has certain uncertainty. Delivery time usually includes the production time of the product and the transportation time. Customers have strict requirements for delivery time, so delivery time has become an important factor affecting production planning and design in cloud manufacturing environment.

2.2. Model Construction

2.2.1. Problem Description. Combined with the actual characteristics of multitask and multimanufacturer selection in cloud manufacturing environment, considering the four factors of production cost, transportation cost, product quality, and delivery time as the key factors in the process of production planning design in cloud manufacturing environment, this paper chooses product cost (C), product quality (Q), and delivery time (T) as the objective of optimization, in which the product cost includes the sum of production cost and transportation cost. The lower the cost, the higher the profit the manufacturing enterprise can get. Product quality refers to the degree to which the product can meet the needs of customers, expressed by the qualified rate of the product. Delivery time includes the production time of the product and the haulage time of the product, and the delivery time needs to be completed within the customer's time limit. The shorter the delivery time is, the better it is.

To sum up, the problem can be described as follows: at a certain time, a manufacturing enterprise receives the demand of m kinds of products from customers. The enterprise makes production planning on the basis of combining its own manufacturing resources and manufacturing capacities. Through the intelligent search in the cloud manufacturing service platform, it can be seen that there are n manufacturing suppliers that meet the functional requirements of the products, and the index values of different manufacturing suppliers are different. The enterprise can assign some of the products to u manufacturing suppliers, so that the above index values can reach the optimal.

2.2.2. Model Assumptions

(1) Many kinds of products can be manufactured at each manufacturer, and the products are independent of each other

(2) Due to the limitation of manufacturing resources and manufacturing capacities of manufacturing enterprises, it is difficult to meet the needs of customers on their own, so it is necessary to find the products that can meet the needs of customers through the cloud manufacturing service platform, so as to allocate the manufacturing tasks

(3) Mass production and bulk delivery are carried out by each manufacturing supplier, that is, delivery is carried out for every batch of products completed

(4) There is no idle time between the batches produced by each manufacturer

(5) Transportation costs are borne by manufacturing enterprises

(6) Taking into account the volume discount, when the amount purchased meets the corresponding requirements, all purchased products are given the same discount

2.2.3. Symbol Meaning

i: the serial number of the manufacturing supplier that can provide the product ($i = 0, 1, 2, \ldots, n$) (if $i = 0$, the product is provided by the manufacturer who received the customers' order)

n: number of manufacturing suppliers to choose from

j: the serial numbers of different types of products ($j = 1, 2, \ldots, m$)

m: number of product categories in customer orders received by manufacturing enterprises

x_{ij}: quantity of products j produced by manufacturing supplier i (when $i = 0$, it is the cost of the product j produced by the manufacturing enterprise itself)

p_{ij}: undiscounted unit price of product j provided by manufacturing supplier i (when $i = 0$, it is the cost of manufacturing enterprises' own products j)

k: serial number of discount phase

r_{ijk}: the discount rate of the k stage given to the manufacturing supplier i when the product j reaches a certain quantity

$y_{ijk} = \{1,$ if the periodic discount k of product j can be obtained from manufacturing supplier i, 0, if not;

$\lambda_{ij} = \{1,$ if the manufacturing supplier i produces product j, 0, if not;

L_i: the transport batch from manufacturing supplier i to customers

b: the maximum number of products that can be transported per batch

c_i: transportation costs per batch between manufacturer i and customer

t_{ij}: unit production time for manufacturing supplier i to manufacture product j

h_i: transportation time from manufacturing supplier i to customers

q_{ij}: product percent of pass of product j provided by manufacturing supplier i

d_j: demand for product j

Q_j: acceptable minimum product percent of pass of product j

PR_{ij}: maximum production capacity of manufacturer-supplied product j, a constant (when $i = 0$, it is the maximum production capacity of manufacturing enterprises themselves)

2.2.4. Constraint Condition

(1) Supply and Demand Balance Constraints. Supply-demand balance means that the quantity of products supplied by manufacturing suppliers should be in line with the quantity of products required by customers. If the quantity of products supplied does not reach the quantity of products demanded by customers, it will affect customer satisfaction, thereby reducing the reputation and economic benefits of enterprises. If the quantity of products supplied exceeds the quantity of demand, waste will occur to a certain extent, so the supply-demand balance constraints are as follows:

$$\sum_{i=0}^{n} \lambda_{ij} x_{ij} = d_j, \quad j = 1, 2, \ldots, m. \tag{1}$$

(2) Production Capacity Constraints of Each Manufacturing Supplier. Due to the different production capacities and different constraints of each manufacturer, the maximum production capacity that supplier i can provide is PR_{ij}. Therefore, the output of products whether manufactured by the manufacturing enterprise itself or by manufacturing suppliers on the cloud manufacturing platform should not be greater than the manufacturer's maximum production capacity. That is to say:

$$\sum_{j=1}^{m} \lambda_{ij} x_{ij} \leq PR_{ij}, \quad i = 0, 1, 2, \ldots, m. \tag{2}$$

(3) Discount Constraints on Purchased Products. Because of the mass customization production model, when the quantity of manufactured products that manufacturers can provide is within a certain range, the discount constraint of manufactured products can be provided for manufacturers. The discount rate of product j purchased from manufacturer i should only fall within one range, that is, only one discount rate or no discount is used, that is,

$$\sum_{k=1}^{K} y_{ijk} \leq 1. \tag{3}$$

(4) Quality Constraints. With the gradual development of customization and individualization, the quality level is one of the most important factors for users. Good product quality can win customer satisfaction, thus gaining the competitiveness of the industry. Suppose Q_j is the minimum quality percent of pass acceptable to product j, q_{ij} is the percent of pass the product j provided by the manufacturing supplier i. The percent of pass of product j provided by all manufacturers should satisfy the following constraints:

$$\sum_{i=0}^{n} \sum_{j=1}^{m} \frac{\lambda_{ij} x_{ij} q_{ij}}{D_j} \geq Q_j d_j. \tag{4}$$

(5) Delivery Time Constraints. Customers' requirements for punctualization are gradually increasing, and punctual delivery of products can improve customer satisfaction and thus gain industry competitiveness. The time of delivery mainly includes production time and transportation time. The time for the enterprise to produce the product j in factory i is t_{ij}, the time of transportation from factory i to customers is H_i, and the time of delivery required by customers is T'. Then, the time of delivery should meet the following constraints:

$$\sum_{i=0}^{n} \sum_{j=1}^{m} \lambda_{ij} x_{ij} t_{ij} + \sum_{i=0}^{n} H_i \leq T'. \tag{5}$$

2.2.5. Objective Function

(1) Product Cost. Product cost is an important factor affecting customer satisfaction. Product cost is mainly composed of production cost and transportation cost. Considering that manufacturers in cloud manufacturing service platform can offer discounts, the objective function of product cost is as follows:

$$P_1 = \sum_{j=1}^{m} x_{0j} p_{0j} + \sum_{t=1}^{T} \sum_{i=1}^{n} \sum_{j=1}^{m} \lambda_{ij} x_{ij} p_{ij} r_{ijk} y_{ijk}. \tag{6}$$

Because the location of cloud manufacturing service providers is different from that of customers, the cost of products in the transportation process should also be considered. Because the manufacturing mode of products is mass customization, there are a large number of products. Assuming that the products are transported in batches, the transportation batches from manufacturing suppliers to customers are as follows:

$$L_i = \sum_{j=1}^{m} \frac{\lambda_{ij} x_{ij}}{b}. \tag{7}$$

The transportation cost of the manufacturing supplier i to the customer is given by

$$P_2 = \sum_{i=0}^{n} L_i c_i = \sum_{i=0}^{n} \sum_{j=1}^{m} \left(\frac{\lambda_{ij} x_{ij}}{b} \right) c_i. \tag{8}$$

From the above, it can be seen that the product cost is composed of production cost and transportation cost; the smaller the cost, the better the attribute. Then

$$\mathrm{Min}\ P = P_1 + P_2 = \sum_{j=1}^{m} x_{0j} p_{0j} + \sum_{t=1}^{T} \sum_{i=1}^{n} \sum_{j=1}^{m} \lambda_{ij} x_{ij} p_{ij} r_{ijk} y_{ijk} + \sum_{i=0}^{n} \sum_{j=1}^{m} \left(\frac{\lambda_{ij} x_{ij}}{b} \right) c_i. \tag{9}$$

(2) Product Delivery Time. The competition in the manufacturing industry is becoming more and more fierce. Enterprise users have more stringent requirements on delivery time. Manufacturing suppliers need to strictly control their delivery time, so as to improve customer satisfaction. In cloud manufacturing environment, due to the geographical location of each manufacturing supplier, transportation time is a factor that must be considered besides production time. On the premise of meeting customer needs, the shorter the delivery time is, the better the objective function of delivery time is as follows:

$$\mathrm{Min}\, T = \sum_{i=0}^{n} \sum_{j=1}^{m} \lambda_{ij} x_{ij} t_{ij} + \sum_{i=0}^{n} H_i. \tag{10}$$

(3) Product Quality. Manufacturing products are gradually developing towards individualization and diversification. Customers' requirements for product quality are getting higher and higher. The quality of products affects customer satisfaction. The higher the quality of the product is, the

better it is. Therefore, the objective function of product quality is as follows:

$$\max Q = \sum_{i=0}^{n}\sum_{j=1}^{m}\frac{\lambda_{ij}x_{ij}q_{ij}}{D_j}. \tag{11}$$

From the above description, it can be seen that the production planning problem of manufacturing enterprises in cloud manufacturing environment is a multiobjective optimization problem. The complete mathematical expression of this problem is as follows:

$$\begin{aligned}
&\min P = P_1 + P_2 = \sum_{j=1}^{m} x_{0j}p_{0j} + \sum_{t=1}^{T}\sum_{i=1}^{n}\sum_{j=1}^{m}\lambda_{ij}x_{ij}p_{ij}r_{ijk}y_{ijk} + \sum_{i=0}^{n}\sum_{j=1}^{m}\left(\frac{\lambda_{ij}x_{ij}}{b}\right)c_i,\\
&\min T = \sum_{i=0}^{n}\sum_{j=1}^{m}\lambda_{ij}x_{ij}t_{ij} + \sum_{i=0}^{n}H_i,\\
&\max Q = \sum_{i=0}^{n}\sum_{j=1}^{m}\frac{\lambda_{ij}x_{ij}q_{ij}}{D_j},\\
&\sum_{i=0}^{n}\lambda_{ij}x_{ij} = d_j,\\
&\sum_{j=1}^{m}\lambda_{ij}x_{ij} \le PR_{ij},\\
&\sum_{k=1}^{K} y_{ijk} \le 1,\\
&\sum_{i=0}^{n}\sum_{j=1}^{m}\lambda_{ij}x_{ij}q_{ij} \ge Q_j d_j,\\
&\sum_{i=0}^{n}\sum_{j=1}^{m}\lambda_{ij}x_{ij}t_{ij} + \sum_{i=0}^{n}H_i \le T',\\
&x_{ij} \ge 0, i = 0,1,2,\ldots,n, j = 1,2,\ldots,m.
\end{aligned} \tag{12}$$

2.3. Model Solution

2.3.1. Pareto Optimal Solution. For conventional multiobjective programming problems, if the minimum value is to be calculated, the concept of Pareto optimal solution corresponds to the following: when setting the interval of variables, for the variable group X^*, if there is no other design variable group X, conform to $f_i(X) \le f_i(X^*)$ without conflict with constraint conditions, then X^* is the Pareto optimal solution.

For multiobjective optimization problems, the solution is not a set of solutions, which constitutes the Pareto optimal solution set to a large extent. There are no more excellent solutions in the feasible solution set, and there are no advantages or disadvantages among the Pareto optimal solutions. Therefore, the decision makers can choose the most ideal solution according to the will and the importance of the goal.

2.3.2. Algorithmic Design. The main process of the elite strategy of NSGA-II is shown in Figure 1. According to the image, the steps taken are as follows:

(a) Combining P_t and Q_t, the corresponding population R_t is obtained, and its actual size is equal to $2N$.

(b) Complete the standardized nondominated sorting of R_t, calculate the crowding distance of all individuals, and define the individuals according to the level. When the total number of individuals reaches N, a new paternal population P_{t+1} is formed.

(c) On this condition, a new generation of variation is formed and the offspring population $Q_t + 1$ is formed.

According to the analysis above, the calculation flow of using NSGA-II to solve the production planning problem of manufacturing enterprises in cloud manufacturing environment is as follows:

Step 1: the initial population P_t with the total amount equal to N is not oriented in the solution space. After that, all target fitness values are analyzed, and then the hierarchical operation is implemented on it, and the

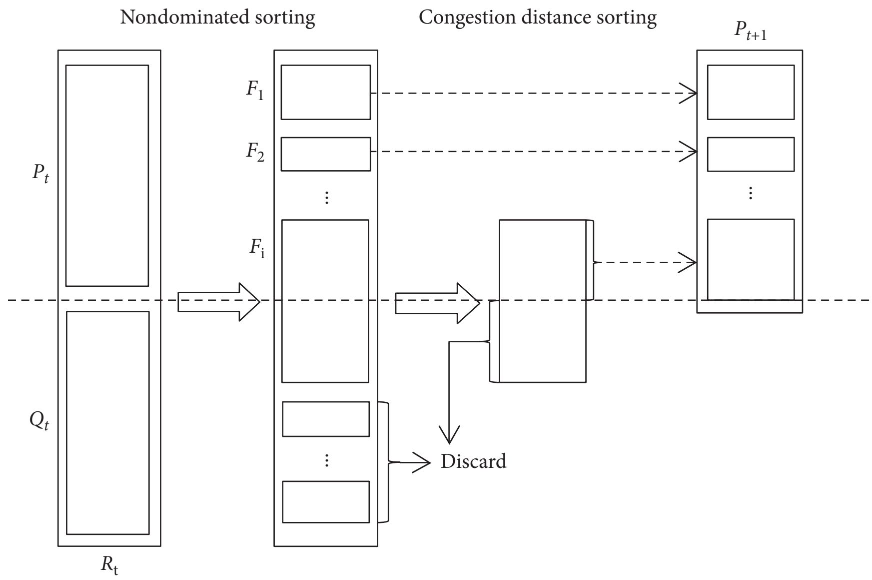

Figure 1: Process sketch of NSGA-II elite strategy.

crowding distance corresponding to individuals in various groups is calculated.

Step 2: the binary tournament mechanism is mainly used to make a reasonable selection of the individuals covered by population P_t, and then the genetic operation of variation is completed according to the specification, and then the progeny population Q_t with the total amount equal to N is obtained.

Step 3 (elite strategy): P_t and Q_t are merged effectively, and then population R_t is obtained. After nondominated sorting, the front segment of the nondominated solution can be obtained. Then, the crowding degree is calculated and N individuals in the front are selected to form P_{t+1}.

Step 4: let $t = t + 1$, steps 2-3 are completed several times in the set iteration interval to obtain the optimal solution set corresponding to the production planning.

3. Optimization of Production Planning in Cloud Manufacturing Environment

3.1. Problem Description. In order to optimize the existing production planning and select the optimal production planning, it is necessary to establish a set of perfect and reasonable optimization system. Effective evaluation methods are adopted to evaluate the production planning comprehensively. On the basis of a comprehensive evaluation, the optimal selection of production planning of mass customization enterprises in cloud manufacturing environment should be fully combined with the needs of customers and the distinction of importance should be made between competitive targets.

3.2. Construction of Evaluation and Optimization Model. Combining with the three important selected attribute indexes in this paper, this section gives a model of evaluation and optimization of production planning in cloud manufacturing environment as shown in Figure 2. The following is a detailed description of resource layer, scheme layer, criteria layer, weight layer, and target layer:

Resource layer: according to the request of manufacturing enterprises, the cloud manufacturing service platform searches for manufacturing suppliers who can complete various manufacturing tasks.

Scheme layer: the functional requirements and specific constraints of the manufacturing tasks proposed by the manufacturing enterprises can be met, and the set of manufacturing schemes is formed after being screened by the multiobjective optimization algorithm.

Criteria layer: criteria layer is the evaluation attribute indexes of candidate manufacturing scheme.

Weight layer: the weight layer mainly determines the weight coefficients of each attribute index, which is determined by the users' needs and the value of the attribute index itself.

Evaluation layer: evaluation layer uses a decision method to evaluate and rank all alternative manufacturing schemes comprehensively.

Target layer: target layer is the optimal production planning which is determined by comprehensive evaluation of each production planning through attribute index system. It is the best plan to fully meet needs of customers and management and development of enterprises. It is the ultimate goal to optimize the production planning of manufacturing enterprises in cloud manufacturing environment.

3.3. Model Solution

3.3.1. Pretreatment of Attribute Index Values for Scheme Optimization. According to the characteristics that the decision maker expects to show to the attribute value, the

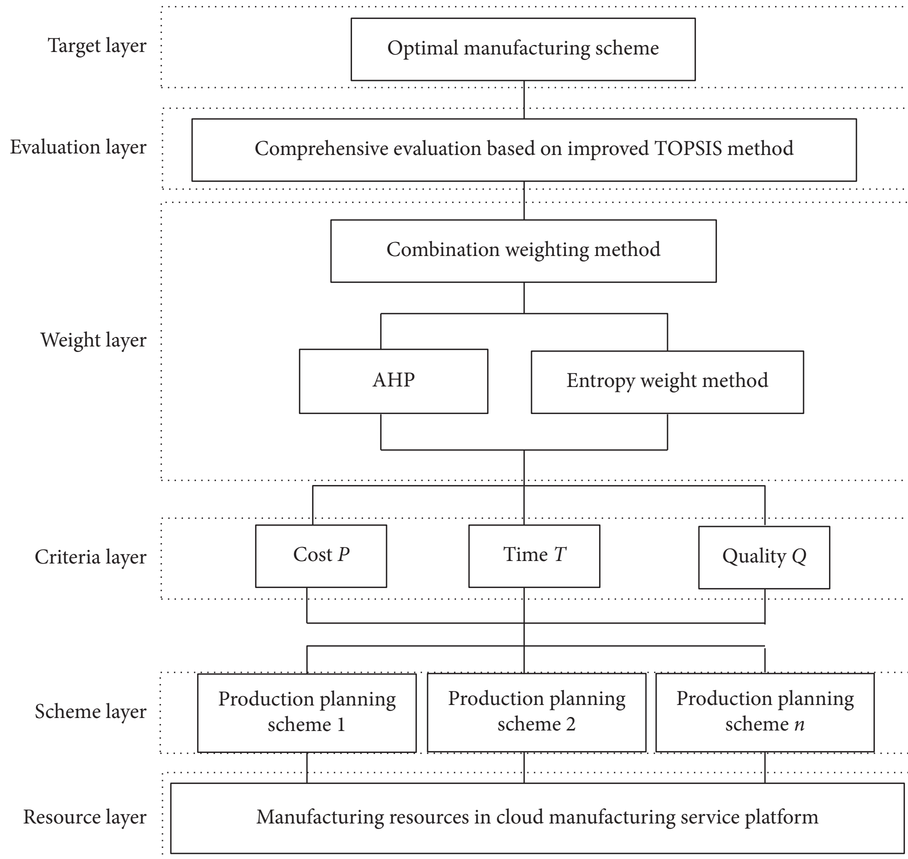

FIGURE 2: A model for evaluating and optimizing production schemes in cloud manufacturing environment.

types of attributes are usually divided into six categories, and their names and characteristics are referred to in Table 1.

In this study, combined with the impact of the attribute index value set by the scheme on the optimal selection, it can be classified as benefit index and cost index. For the traditional three attribute indicators, time and cost are very typical cost indicators, while quality is a representative benefit indicator.

Because there are some deviations in the way of describing the attributes of the production planning, there are great differences in the corresponding range and the unit of quantification is also inconsistent. In order to effectively reduce the negative impact of such factors on the optimization evaluation, so that the consistency check can be completed in the course of the assessment, it is necessary to carry out standardized pretreatment of the attribute index value of the production planning. The representative methods of data preprocessing include normative approach and range transformation.

In the application of the range transformation data preprocessing method, the attribute values measured by each attribute index are mainly changed in [0, 1], and it is convenient to carry out an objective evaluation of other schemes. Therefore, this study mainly chooses the method of range transformation.

Assuming that the total number of production schemes is m, covering n attribute indexes, the original data matrix of all attribute indexes is $X = (x_{ij})_{m\times n}$, and x_{ij} refers to the value of j attribute indexes at this time; the method of pretreatment that can be used at this time is as follows:

TABLE 1: Six common attribute types.

Attribute type	Characteristic
Benefit	The larger the attribute value, the better the attribute
Cost	The smaller the attribute value, the better the attribute
Fixed	The closer the attribute value is to a fixed value, the better it is
Interval	The closer the attribute value is or belongs to a fixed interval, the better it is
Deviation	The more the attribute value deviates from a fixed value, the better it is
Deviation interval	The more the attribute value deviates from a fixed interval, the better it is

(1) Benefit indexes can be calculated as follows:

$$R_{ij} = \begin{cases} \dfrac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}, & \max\limits_j x_{ij} - \min\limits_j x_{ij} \neq 0, \\ 1, & \max\limits_j x_{ij} - \min\limits_j x_{ij} = 0. \end{cases} \tag{13}$$

(2) Cost indexes can be calculated as follows:

$$R_{ij} = \begin{cases} \dfrac{\max_j x_{ij} - x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}, & \max\limits_j x_{ij} - \min\limits_j x_{ij} \neq 0, \\ 1, & \max\limits_j x_{ij} - \min\limits_j x_{ij} = 0. \end{cases} \quad (14)$$

At this time, $i = 1,2,\ldots,m$; $j = 1,2,\ldots,n$; x_{ij} mainly refers to the attribute index value corresponding to the scheme i; $\min_j x_{ij}$ refers to the minimum attribute index value corresponding to the group manufacturing resource service composition; $\max_j x_{ij}$ refers to the maximum attribute index value corresponding to the scheme m; and R_{ij} refers to the attribute index value obtained after normalization.

3.3.2. Combined Weight Method Based on AHP and Entropy Method

(1) AHP. Through AHP, the core processes corresponding to weight coefficients are defined:

(1) Constructing the hierarchy corresponding to the objective problem.

(2) Constructing decision judgment matrix. Representing specific attributes by a_i $(i = 1, 2, \ldots, n)$, a_{ij} refers to the importance of a_i over attributes a_j, which can be quantified with the values in Table 2. If a_{ij} is obtained by comparing attribute a_i with attribute a_j, the important level of comparison between a_j and a_i is $a_{ji} = 1/a_{ij}$. The decision judgment matrix B corresponding to the objective problem can be established by using the following formula:

$$B = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}. \quad (15)$$

(3) Consistency test:

In some cases, the constructed matrix will show obvious inconsistency. In order to prevent this situation from leading to the lack of scientific results after weight distribution, it must be tested and analyzed according to the following formula:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}. \quad (16)$$

In the above formula, CR mainly refers to the random consistency ratio corresponding to the decision judgment matrix; CI refers to the corresponding consistency index at this time, which can be calculated by using formula (17); and RI refers to the random consistency index corresponding to the matrix, and the RI value corresponding to the judgment matrix is shown in Table 3:

$$\mathrm{CI} = \frac{(\lambda_{\max} - n)}{(n-1)}. \quad (17)$$

If the consistency ratio of matrix B conforms to $\mathrm{CR} < 0.1$, or the maximum eigenvalue conforms to the standard of $\lambda_{\max} = n$, then the consistency of matrix B can be determined to be acceptable. If it does not meet the above criteria, it should be adjusted to reach the criteria of consistency testing.

(4) The maximum eigenvalues are calculated and the specific eigenvectors are clarified. Matrix B is calculated according to formula (18), so that its maximum eigenvalue is $\lambda_{\max}$ and corresponding eigenvector $X = (X_1, X_2, \ldots, X_n)$. At this time, all the components corresponding to X are positive components:

$$\mathrm{BX} = \lambda_{\max} X. \quad (18)$$

(5) The weight coefficients are calculated. Eigenvector of maximum eigenvalue $\lambda_{\max}$ is processed according to formula (19), so that the weight vector constructed by weight coefficient can be obtained:

$$t = \frac{X}{\sum_{i=1}^{n} X_i}. \quad (19)$$

(2) Entropy Weight Method. Assuming that there are m sets of data samples and n evaluation indexes, the initial data matrix is $X = (x_{ij})_{m\times n}$; x_{ij} mainly refers to the value of attribute j. The process of defining the weight coefficients is as follows:

(1) Data standardization: since the corresponding order of magnitudes of each evaluation index is not consistent, in order to effectively eliminate incomparability, the standardized processing of information should be carried out by the method of range normalization, which lays a good foundation for statistical analysis. Assuming that R refers to the matrix obtained after processing, then the operation steps of R_{ij} refer to as formula (13) and formula (14).

(2) The proportion of attribute index P_{ij} is calculated. At this time, the ratio corresponding to the evaluation value of the object i is as follows:

$$P_{ij} = \frac{R_{ij}}{\sum_{i=1}^{m} R_{ij}}, \quad \left(0 \le P_{ij} \le 1\right). \quad (20)$$

(3) The entropy value e_j of the attribute index is calculated, and then the entropy value corresponding to attribute index j is as follows:

$$e_j = \begin{cases} -\dfrac{1}{\ln(m)\sum_{i=1}^{m} P_{ij}\ln P_{ij}}, & P_{ij} \neq 0, \\ 0, & P_{ij} = 0. \end{cases} \quad (21)$$

At this time, $0 \leq e_j \leq 1$.

(4) The diversity factor h_i of attribute index is calculated, and the diversity factor is as follows:

$$h_j = 1 - e_j. \quad (22)$$

(5) The weight v_j corresponding to the attribute index is calculated, so the weight corresponding to the attribute index of item j is as follows:

$$v_j = \frac{h_j}{\sum_{j=1}^{n} h_j}. \quad (23)$$

(3) Combination Weighting Method. In this part, the subjective weight method and the objective weight method are effectively combined according to the objective needs. The operation method is as follows:

$$w_j = \frac{t_j v_j}{\sum_{j=1}^{n} t_j v_j}. \quad (24)$$

In the above formula, t_j and v_j refer to the weight coefficient corresponding to the j index obtained by the method of AHP and entropy, and w_j refers to the corresponding combination weight coefficients.

3.3.3. Multiattribute Decision Method Based on Improved TOPSIS. At present, assuming that the decision matrix formed by m scheme and n attributes is $X = (x_{ij})_{m\times n}$; at this time, x_{ij} mainly refers to the attribute value of item j, and the operating process of the TOPSIS method after adjustment is as follows:

Step 1: firstly, the decision matrix R is established according to the standard, and the operation method of R_{ij} is referred to as formulas (13) and (14) at this time.

Step 2: the weighted decision matrix V is established by the decision matrix R, and V_{ij} is given by

$$V_{ij} = w_j R_{ij}. \quad (25)$$

At this time, w_j mainly refers to the weight coefficients corresponding to the attribute j; $\sum_{j=} 1^n w_j = 1$, solved by formula (24).

Step 3: the ideal solution V^+ and the negative ideal solution V^- are clarified, which meet the following requirements:

$$V_j^+ = \begin{cases} \max\{V_{1j}, V_{2j}, \ldots, V_{mj}\}, \text{Item } j \text{ is a benefit attribute}, \\ \min\{V_{1j}, V_{2j}, \ldots, V_{mj}\}, \text{Item } j \text{ is a cost attribute}, \end{cases}$$
$$V_j^- = \begin{cases} \min\{V_{1j}, V_{2j}, \ldots, V_{mj}\}, \text{Item } j \text{ is a benefit attribute}, \\ \max\{V_{1j}, V_{2j}, \ldots, V_{mj}\}, \text{Item } j \text{ is a cost attribute}. \end{cases} \quad (26)$$

Step 4: the distance between the two points of all schemes are D^+, D^-; at that time, D^+ and $D^-$are given by

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^+\right)^2},$$
$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2}. \quad (27)$$

Step 5: the approximate horizontal C_i of each scheme i to the ideal solution is calculated using the following equation:

$$C_i = \frac{D_i^+}{D_i^+ + D_i^-}. \quad (28)$$

Step 6: according to the relative degree of approximation C_i in Step 5, all the schemes are ranked reasonably according to the method of descending order, so as to optimize the selection of the schemes and obtain the corresponding optimal production planning.

4. Case Analysis

4.1. Formulation of Production Planning of Company A in Cloud Manufacturing Environment. Company A receives an order for automobile production and processing. Because of the limitation of production capacity and the high cost of production, some production tasks need to be handed over to some manufacturers through the cloud manufacturing platform. The enterprise decomposes the automobile processing order according to the modularization theory and concludes that there are three kinds of specific modules that need to be produced and processed, which are recorded as Module 1, Module 2, and Module 3. After that, the enterprise submits specific module requirements to the cloud manufacturing platform. Due to the large difference in the type and functional requirements of the module, some candidate resources can be processed, some cannot be processed, and some candidate resources can be partially processed. Company A needs to work out a production planning for the order according to the specific needs of the customers, combined with the manufacturing resources and manufacturing capabilities of the enterprise and the manufacturers in the cloud manufacturing platform, and the production planning is optimized according to the preferences of the decision makers and the objective situation. The specific process is shown in Figure 3.

As company A still needs to assemble the parts after the processing module to form the product in the order for delivery, according to the requirements of quantity, delivery time, and quality of products required by the project order, company A adjusts the specific requirements of the order according to its own processing conditions as shown in Table 4.

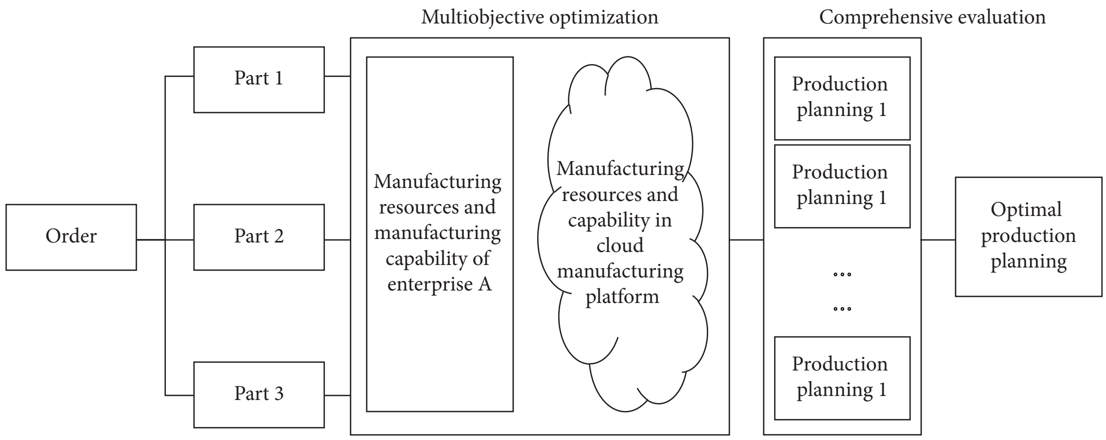

FIGURE 3: Production planning and optimizing process of enterprise A in cloud manufacturing environment.

According to the functional requirements of the parts, company A searches and matches the manufacturing resources using the cloud manufacturing platform and finds out five production suppliers that can meet the requirements of the module tasks. According to the situation of company A, the specific parameters of the manufacturer of its manufacturing module can be obtained from the enterprise and cloud manufacturing platform as shown in Table 5.

In addition, because these enterprises are mass customization production enterprises, when the number of production batches reaches a certain level, there is also a certain discount. The specific discount stage is as follows:

$$\begin{cases} k = 1, & 0 \le x_{ij} \le 500, \\ k = 2, & 501 \le x_{ij} \le 1000, \\ k = 3, & 1001 \le x_{ij} \le 1500, \\ k = 4, & x_{ij} \ge 1501. \end{cases} \quad (29)$$

The corresponding discount rate is given by

$$\begin{cases} r_{ij}1 = 0.90, & k = 1, \\ r_{ij}2 = 0.85, & k = 2, \\ r_{ij}3 = 0.80, & k = 3, \\ r_{ij}4 = 0.75, & k = 4. \end{cases} \quad (30)$$

According to the multiobjective optimization model proposed above, this paper uses the operation software of Matlab2017a and the NSGA-II algorithm to solve the model above. The RAM of CPU is 4G, 2.5 GHz. The initial population is $N = 100$, the maximum iteration number is maxgen = 200, the crossover probability is $P_c = 0.90$, and the mutation probability is $P_m = 0.05$. The ratio of the complete dominating set problem is shown in Figure 4, which shows that the proportion of complete nondominating set problem to population tends to be stable after 60 generations of program operation. The Pareto frontier map obtained by running the program based on three dimensions selected is shown in Figure 5, from which we can obtain the solution set of Pareto. The running time of the program is 33.56 s.

Table 6 is the production planning information set corresponding to all completely nondominating set problem obtained by the algorithm. The results of calculation include 20 groups of noninferior solutions, and each

TABLE 2: Scale value of decision judgment matrix.

Order of importance	Value of a_{ij}
Element a_i is as important as element a_j	1
Element a_i is slightly more important than element a_j	3
Element a_i is obviously more important than element a_j	5
Element a_i is mightily more important than element a_j	7
Element a_i is extremely more important than element a_j	9
The intermediate value of the adjacent judgment above	2, 4, 6, 8

TABLE 3: The value of the mean random consistency index RI of n-order decision judgment matrix.

n	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41

TABLE 4: The specific needs of the order.

Index	Module 1	Module 2	Module 3
Quantity demanded	3000	3500	4000
Maximum delivery cost		15000	
Latest delivery time		70000	
Minimum qualified rate		80%	

Table 5: A enterprise and manufacturers on cloud platform.

Manufacturer	Type of production module	Productive capacity	Production unit price	Production unit time	Product percent of pass (%)	Delivery time	Delivery cost per batch
Company A	Module 1	1000	10	5	92	—	—
	Module 2	—	—	—	—		
	Module 3	2000	14	10	95		
Cloud manufacturer1	Module 1	3000	13	4	90	3	23
	Module 2	2000	25	12	92		
	Module 3	1000	12	11	85		
Cloud manufacturer 2	Module 1	—	—	—	—	6	25
	Module 2	1000	20	6	85		
	Module 3	2000	14	8	92		
Cloud manufacturer 3	Module 1	3000	11	7	82	4	23
	Module 2	1500	22	5	90		
	Module 3	1500	13	8	85		
Cloud manufacturer 4	Module 1	1000	10	8	80	6	25
	Module 2	1500	21	6	88		
	Module 3	—	—	—	—		
Cloud manufacturer 5	Module 1	2000	12	2	82	3	23
	Module 2	1000	23	8	82		
	Module 3	1000	13	10	80		

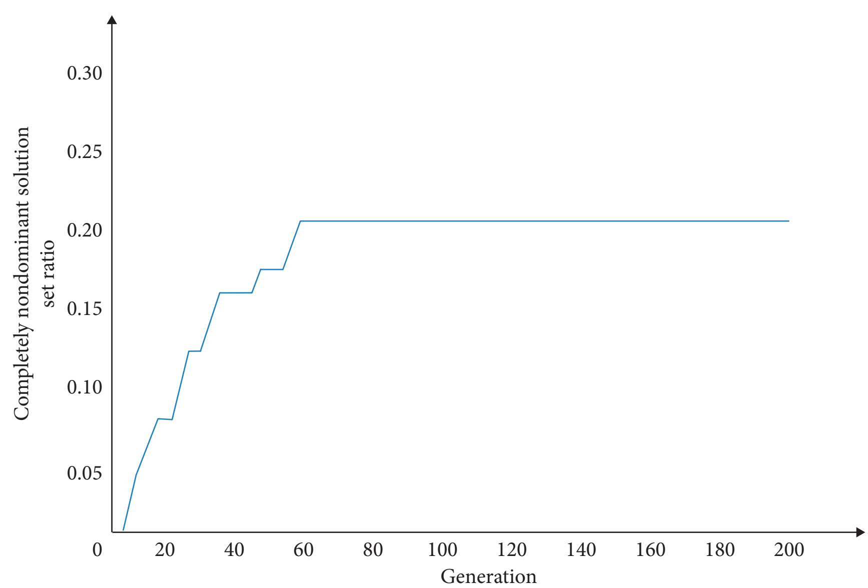

Figure 4: Proportion of completely nondominant solution sets.

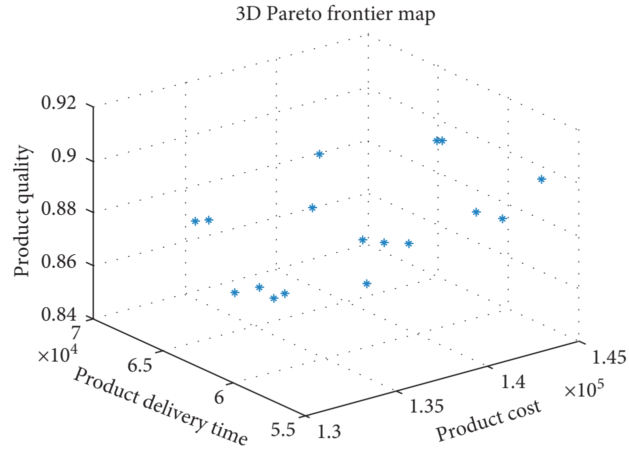

Figure 5: Solution set of Pareto.

Table 6: Production planning set corresponding to completely nondominating solutions obtained by NSGA-II.

Number	Type of modules	Company A	Cloud manufacturer 1	2	3	4	5	Cost	Delivery time	Product quality (%)
Scheme 1	Module 1	251	1570	—	715	256	208	13581	58053	87.14
	Module 2	—	17	926	1150	549	858			
	Module 3	285	908	1892	172	—	773			
Scheme 2	Module 1	254	1571	—	715	255	205	14155	55959	89.06
	Module 2	—	17	926	1453	169	935			
	Module 3	1908	16	1863	174	—	39			
Scheme 3	Module 1	254	21	—	715	2556	1754	13453	62239	85.98
	Module 2	—	17	926	1455	170	932			
	Module 3	285	907	1863	172	—	773			
Scheme 4	Module 1	254	1571	—	715	256	204	14265	61662	90.38
	Module 2	—	1852	258	1150	170	70			
	Module 3	1908	16	1863	175	—	38			
Scheme 5	Module 1	254	1570	—	715	256	205	13915	59417	87.71
	Module 2	—	773	328	1454	169	776			
	Module 3	285	907	1863	172	—	773			
Scheme 6	Module 1	19	21	—	715	735	1510	14038	67404	88.90
	Module 2	—	1852	328	1150	170	—			
	Module 3	1908	16	1863	172	—	41			
Scheme 7	Module 1	251	1570	0	716	256	207	13751	60622	87.88
	Module 2	—	773	928	1453	169	177			
	Module 3	285	907	1863	172	—	773			
Scheme 8	Module 1	19	21	0	715	255	1990	13523	68547	87.10
	Module 2	—	1852	328	1150	170	—			
	Module 3	285	907	1862	174	—	772			
Scheme 9	Module 1	254	1570	—	715	256	205	13846	60305	87.65
	Module 2	—	773	925	1150	169	483			
	Module 3	286	907	1863	173	—	771			
Scheme 10	Module 1	254	1571	—	716	256	203	14246	61801	90.41
	Module 2	—	1852	328	1150	170	—			
	Module 3	1909	18	1863	175	—	35			
Scheme 11	Module 1	254	1570	—	715	256	205	14155	55964	89.06
	Module 2	—	17	926	1453	170	934			
	Module 3	1909	15	1863	174	—	39			
Scheme 12	Module 1	19	21	—	715	735	1510	13312	63953	85.88
	Module 2	—	17	928	1455	549	551			
	Module 3	284	908	1862	172	—	774			
Scheme 13	Module 1	19	21	—	715	256	1989	13431	62712	85.76
	Module 2	—	17	928	1454	170	931			
	Module 3	285	907	1863	172	—	773			
Scheme 14	Module 1	19	21	—	715	735	151	13486	69030	87.01
	Module 2	—	1852	328	1150	170	—			
	Module 3	284	908	1862	172	—	774			
Scheme 15	Module 1	254	21	—	173	256	1753	13371	63004	86.20
	Module 2	—	18	928	1455	549	550			
	Module 3	285	907	1863	716	—	772			
Scheme 16	Module 1	254	1571	—	715	255	205	14494	57565	89.52
	Module 2	—	774	258	1368	169	931			
	Module 3	1909	16	1863	174	—	38			
Scheme 17	Module 1	254	1570	—	715	256	205	13695	63430	88.51
	Module 2	0	1852	328	1150	170	—			
	Module 3	284	907	1863	174	—	772			
Scheme 18	Module 1	253	1571	—	715	255	206	14074	56722	89.28
	Module 2	—	18	926	1453	548	555			
	Module 3	1909	16	1863	174	—	38			

Table 6: Continued.

Number	Type of modules	Company A	Cloud manufacturer					Cost	Delivery time	Product quality (%)
			1	2	3	4	5			
Scheme 19	Module 1	19	21	—	715	735	1510	14038	67404	88.91
	Module 2	—	1852	328	1150	170	—			
	Module 3	1908	16	1863	172	—	41			
Scheme 20	Module 1	20	21	—	715	735	1509	13313	63594	85.89
	Module 2	—	18	928	1455	549	550			
	Module 3	285	908	1862	172	—	773			

Table 7: Comprehensive ranked list of the production planning scheme.

Number	Product cost	Delivery time	Product quality (%)	Relative proximity	Rank
1	13581	58053	87.14	0.742858	6
2	14155	55959	89.06	0.454256	14
3	13453	62239	85.98	0.789696	1
4	14265	61662	90.38	0.240388	19
5	13915	59417	87.71	0.591227	8
6	14038	67404	88.90	0.303556	17
7	13751	60622	87.88	0.582332	9
8	13523	68547	87.10	0.569427	11
9	13846	60305	87.65	0.598745	7
10	14246	61801	90.41	0.238531	20
11	14155	55964	89.06	0.454184	15
12	13312	36953	85.88	0.759994	5
13	13431	32712	85.76	0.787249	2
14	13486	69030	87.01	0.573461	10
15	13371	63004	86.20	0.765317	4
16	14494	57565	89.52	0.356862	16
17	13695	63430	88.51	0.471384	12
18	14074	56722	89.28	0.434359	13
19	14038	67404	88.91	0.302320	18
20	13313	63594	85.89	0.768361	3

Table 8: Final optimum production planning scheme.

Type of production	Company A	Cloud manufacturer					Product cost	Delivery time	Product quality
		1	2	3	4	5			
Module 1	254	21	—	715	2556	1754	13453	62239	85.98
Module 2	—	17	926	1455	170	932			
Module 3	285	907	1863	172	—	773			

group of noninferior solutions corresponds to a production planning.

4.2. Optimization of Production Planning of Company A in Cloud Manufacturing Environment

4.2.1. Weight Determination. According to the comprehensive evaluation model, firstly, the comprehensive weight is determined from subjective and objective aspects by using the AHP and the entropy weight method. According to the preference degree of company A for product cost, product delivery time, and product quality, the decision judgment matrix is obtained as follows:

$$B = \begin{bmatrix} 1 & 3 & \frac{1}{2} \\ \frac{1}{3} & 1 & 2 \\ 2 & \frac{1}{2} & 1 \end{bmatrix}. \quad (31)$$

By the method of AHP, it can be considered that the weight vector of preference of company A for product cost, product delivery time, and product quality are $T = [0.369841, 0.297884, 0.332275]$.

Secondly, according to the method of entropy, each group of production planning schemes is weighted objectively. Because there are different quantitative levels and dimensions among different evaluation indicators, it is necessary to standardize the data of product cost, product delivery time, and product quality indicators to obtain the following data preprocessing matrix:

$$\begin{bmatrix} 0.77242 & 0.839798 & 0.296774 \\ 0.286802 & 1 & 0.709677 \\ 0.880711 & 0.519547 & 0.047312 \\ 0.193739 & 0.563691 & 0.993548 \\ 0.489848 & 0.735445 & 0.419355 \\ 0.385787 & 0.124398 & 0.675269 \\ 0.628596 & 0.643256 & 0.455914 \\ 0.821489 & 0.036952 & 0.288172 \\ 0.548223 & 0.667508 & 0.406452 \\ 0.209814 & 0.553056 & 1 \\ 0.286802 & 0.999617 & 0.709677 \\ 1 & 0.388417 & 0.025806 \\ 0.899323 & 0.48336 & 0 \\ 0.852792 & 0 & 0.268817 \\ 0.950085 & 0.461021 & 0.094624 \\ 0 & 0.877133 & 0.808602 \\ 0.675973 & 0.428429 & 0.591396 \\ 0.35533 & 0.941627 & 0.756989 \\ 0.385787 & 0.124398 & 0.677419 \\ 0.999154 & 0.415882 & 0.027957 \end{bmatrix}. \quad (32)$$

According to the calculation formula of the entropy weight method, the objective index weight vector $V = [0.246654, 0.303342, 0.450004]$ is obtained by calculating the three indexes of product cost, product delivery time, and product quality.

Then according to the formula of the combination weighting method established in Section 3.3.2, the subjective weight obtained by AHP and objective weight obtained by entropy weight method are synthesized, and the final combination weight vector is $W = [0.275508, 0.272903, 0.451589]$.

4.2.2. Optimal Selection of Production Planning Based on TOPSIS Method. According to the relevant steps of the TOPSIS method, the weight vector values calculated in the previous section are calculated into the model, and the weighted decision matrix V is obtained as follows:

$$\begin{bmatrix} 0.212808 & 0.229184 & 0.13402 \\ 0.079016 & 0.272903 & 0.320483 \\ 0.242643 & 0.141786 & 0.021366 \\ 0.053377 & 0.153833 & 0.448676 \\ 0.134957 & 0.200705 & 0.189376 \\ 0.106287 & 0.033948 & 0.304944 \\ 0.173183 & 0.175547 & 0.205886 \\ 0.226327 & 0.010084 & 0.130135 \\ 0.15104 & 0.182165 & 0.183549 \\ 0.057805 & 0.150931 & 0.451589 \\ 0.079016 & 0.272799 & 0.320483 \\ 0.275508 & 0.106 & 0.011654 \\ 0.247771 & 0.131911 & 0 \\ 0.234951 & 0 & 0.121395 \\ 0.261756 & 0.125814 & 0.042731 \\ 0 & 0.239372 & 0.365156 \\ 0.186236 & 0.11692 & 0.267069 \\ 0.097896 & 0.256973 & 0.341848 \\ 0.106287 & 0.033948 & 0.305915 \\ 0.275275 & 0.113496 & 0.012625 \end{bmatrix}. \quad (33)$$

The positive ideal solution V^+ and the negative ideal solution V^- are determined, and the distance from the point corresponding to each production planning scheme to the positive ideal solution and the negative ideal solution is calculated, respectively. Then the relative proximity of each scheme to the ideal solution is calculated, and then each production planning scheme is sorted according to the relative distance, and the comprehensive ranking table is shown in Table 7.

According to the comprehensive ranking calculated by the comprehensive ranking table of production planning schemes, company A can choose the highest comprehensive ranking, that is, production planning Scheme 3 (as shown in Table 8) to arrange production. If there is a change in the actual production, the decision makers can also use the scheme close to the optimal production scheme as the final implementation scheme, in order to improve the flexibility of the production plan.

5. Conclusion

(1) In this paper, the achievements of domestic and foreign scholars in cloud manufacturing, mass customization, multiobjective optimization, and so on are thoroughly studied and sorted out, the characteristics and attributes of cloud manufacturing system are summarized, and the operation process of cloud manufacturing service platform is systematically introduced.

(2) The current background is that the manufacturing resources and manufacturing capacity of cloud manufacturing are distributed in different geographical regions. Mass customization enterprises have large manufacturing batches and limited production capacity. Under the premise of meeting the needs of customers, in order to improve the profit of enterprises, the cost, time, and quality that customers are most concerned about are taken as the index, and a multiobjective mathematical model for the production planning of mass customization enterprises in cloud manufacturing environment with the lowest cost, the shortest time, and the highest quality is established. In view of the shortcomings of the traditional multiobjective optimization problem, the algorithm of NSGA-II is used to solve the above multiobjective optimization model.

(3) The index evaluation model of mass customization enterprise production planning optimization under cloud manufacturing environment is established, and the calculation method of weight coefficient in comprehensive evaluation is improved. The method of combining AHP with entropy weight is used to combine subjective and objective weighting, which is applied to the improved TOPSIS multiattribute decision method, and select the optimal production plan according to the final order.

(4) Company A is taken as an example to make a case study. According to the needs of customers, combined with the company's own production capacity constraints, the manufacturing resources and manufacturing capacities that meet the manufacturing conditions are searched from the cloud manufacturing platform. According to the multiobjective optimization model proposed above, a set of Pareto solutions satisfying the conditions are solved. According to the comprehensive evaluation model proposed above, the optimal production planning is selected according to the final ranking by using the combined weighting method and TOPSIS, which provides a reference for mass customization enterprises to formulate and optimize the production planning and then verifies the effectiveness of the production planning and optimization method for mass customization enterprises in cloud manufacturing environment.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] B. Li, L. Zhang, and S. Wang, "Cloud manufacturing: a new service-oriented networked manufacturing model," *Computer Integrated Manufacturing Systems*, vol. 16, no. 1, pp. 1–7, 2010.

[2] L. Du, L. Chen, L. Dai, L. Zhang, and Y. Shen, "Blockchain-based architecture model of cloud manufacturing platform system," *Information Technology and Network Security*, vol. 1, pp. 101–105, 2019.

[3] E. Qi, T. Li, L. Liang, and Y. Huang, "The review of manufacturing theory,technologies and application states," *Industrial Engineering and Management*, vol. 20, no. 1, pp. 8–14, 2015.

[4] S. Huang and B. Huang, "Security architecture for cloud manufacturing platform," *Computer Integrated and Manufacturing Systems*, vol. 24, no. 4, pp. 851–861, 2018.

[5] Y. Chen and W. Zhongjie, "Research on the cloud manufacturing service discovery for industry manufacturing system based on ontology," *Advanced Materials Research*, vol. 712–715, pp. 2639–2643, 2013.

[6] Y. Zhang, Q. Zhou, and L. Qiang, "Cloud manufacturing service composition based on dynamic parameters ant colony algorithm," *Computer Technology and Development*, vol. 28, no. 1, pp. 127–130, 2018.

[7] B. Zhou, H. Shi, and J. Cai, "Research on the conceptual model of mass customization production," *Journal of Shanghai University of Engineering Science*, vol. 4, pp. 278–284, 2000.

[8] L. Liu, D. Xu, and J. Du, "Techniques research for product family variant design under in mass customization," *Aviation Precision Manufacturing Technology*, vol. 51, no. 6, pp. 32–35, 2015.

[9] I. Cariaga, T. El-Diraby, and H. Osman, "Integrating value analysis and quality function deployment for evaluating design alternatives," *Journal of Construction Engineering and Management*, vol. 133, no. 10, pp. 761–770, 2007.

[10] Y. Wu, Y. Sheng, and N. Cai, "Mass intelligent customization based on Internet+: a case study of Qingdao red collar clothing and Foshan Weishang furniture," *Chinese Industrial Economy*, vol. 4, pp. 127–143, 2016.

[11] B. R. Katzy, "Design and implementation of virtual organizations," in *Proceedings of the Hawaii international Conference on System Sciences*, p. 142, IEEE Computer Society, Kohala Coast, HI, USA, January 1998.