Multi-Core and Cross-Chain Evaluation Method Based on Multi-Core Mesh Collaboration Relationship

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ABSTRACT With the increasing economic globalization and the cooperation system of division of labor in the automobile industry, the multi-core network complex cooperative relationship between upstream and downstream enterprises and automobile manufacturing enterprises is gradually formed. Therefore, the automobile manufacturing enterprises at the core of the industrial chain, how to effectively control the upstream and downstream cooperative enterprises in the wide area manufacturing environment, has gradually become a severe challenge to the competition of the industrial chain. In view of the above problems, this article abandoned the idea of traditional single industry chain evaluation, and innovatively put forward a multi-core and cross-chain cooperative evaluation scheme based on the cloud platform environment. First of all, a multi-core and cross-chain cooperative relationship model is constructed through using the industrial cooperative relationship between upstream and downstream enterprise clusters and core enterprises. Combined with this model, a multi-level framework supporting multi-core and cross-chain evaluation based on cloud platform is explored and constructed. Then, taking the evaluation of the downstream marketing chain as an example, the first-level and second-level correlation index system based on multi-core and cross-chain is constructed one by one. Combined with the internal relationship between the two levels of index elements, this article establishes a corresponding multi-core and cross-chain index weight system. In order to solve the problem of multi-core and cross-chain evaluation in cloud environment, this article constructs a multi-core and cross-chain evaluation model based on cloud platform cooperation relationship through the semantic research of cooperation relationship between upstream and downstream enterprises and core enterprises. Then the corresponding cross-chain cooperative evaluation algorithm is given to solve the model. Finally, the feasibility and effectiveness of the multi-core and cross-chain evaluation method are verified by example and simulation. The method studied in this article provides a scientific and feasible decision support scheme to solve the problem of large-scale business collaboration evaluation for across-industry chains in wide area cloud manufacturing environment.

INDEX TERMS Multi-core and cross-chain, cloud platform, index system, evaluation model, cooperative relationship.

I. INTRODUCTION
Automobile industry chain is a complex distributed giant system. With the increasing competition of automobile industry and the development of economic globalization, the competition of automobile industry is no longer a competition among traditional single enterprises, and has gradually evolved into the competition between upstream and downstream industrial chains. Therefore, the evaluation of manufacturing industry chain becomes an important way to enhance the competitiveness of industrial chain. For example, Chirra and Dinesh [1] uses the fuzzy DEMATEL method to
evaluate the flexibility of the supply chain in the automobile industry. Chen et al. [2] adopts the AHP based method to carry out the evaluation research around the intelligent association problem of automobile industry chain. In addition to the automobile industry, some scholars have also carried out the evaluation research of the integration and coordination model of the industrial chain network from the angle of iron and steel, chemical industry, construction and other industries [3]–[5].

The above research focuses on the evaluation from the perspective of the industrial chain, but neglects the role of the core enterprises in the industrial chain. An established fact is that an industrial chain must be formed by a core enterprise usually. For example, a certain automobile industry chain, which takes the automobile manufacturing enterprise as the core, uses the business cooperation relationship to integrate the upstream supplier enterprise and the downstream dealer enterprise to form a specific industrial chain. The cooperation quality, ability and level of upstream and downstream enterprises in industrial chain are the key to guarantee the quality of automobile products of core enterprises. Because there are many cooperative enterprises in the industrial chain and the good and bad are mixed, if the core enterprises do not take effective evaluation means to prevent and control, it is bound to directly affect the product quality of the core automobile enterprises, and will also bring potential risks to the development of the industrial chain of the core automobile enterprises.

The industrial chain of different manufacturing industries formed by the core enterprises, the risks faced are affected by many factors, mainly from endogenous risk and exogenous risk. Under the influence of various uncertain unexpected factors and irresistible events in the supply chain, the exogenous risk is often uncontrollable for the core enterprises of the industrial chain. The endogenous risk can be led and assessed by the core manufacturing enterprises, so as to restrain or reduce the potential hidden danger brought by the endogenous risk [6]. The endogenous risk assessment of industrial supply chain from different angles was, analyzed in literature [7], [8], which enhanced the sustainability of the healthy development of industrial chain.

Although the above research can effectively control the risk of industrial chain from the point of view of endogenous risk, while strengthening risk control, it ignores the effective utilization rate of industrial resources, which leads to the consumption of a large number of manufacturing resources. Aiming at this problem, the concept of green supply chain is widely adopted by many manufacturing enterprises, so as to restrain or reduce the potential hidden danger brought by the endogenous risk [6].

To exemplify the practical utility of the framework we introduce a multiple criteria evaluation of green supply programs using a novel multiple criteria approach that integrates rough set theory elements and fuzzy TOPSIS. In literature [13], the robust ranking technique with neutrosophic set is used to handle practices and performances in green supply chain management. However, the above research on green supply chain, mainly stay on the theoretical level, has not been carried out from the perspective of the new generation of information technology. Without the support of effective information technology means, the problem of waste of manufacturing resources can not be solved.

With the development of cloud computing, Internet of things and other new information technology, as well as the arrival of the industry 4.0 era, it has become a future research trend to combine the frontier information technology with the application of supply chain [14]. At the same time, more and more scholars have also carried out some column studies. For example, in literatures [15], [16], based on industry 4.0, a theoretical framework for supply chain networks and an evaluation index system for coordinating supply chains, are proposed respectively. In literatures [17], [18], a benefit distribution model and inventory control problem of industrial chain is explored based on cloud environment. In literatures [19], [20], a comprehensive utility models is proposed, which considers energy consumption, cost, and risk for the three sides (i.e. provider, consumer, and operator), and is established in the resource service scheduling process of industry chain in cloud manufacturing system. The research of industrial chain based on cloud environment can not only effectively improve the resource utilization rate of industrial chain through information technology, but also provide effective support for upstream and downstream industrial chain cluster collaboration in wide area environment.

With the further refinement of the cooperative division of labor in the automobile industry, there are more and more enterprises in the industrial chain. Many upstream and downstream enterprises usually have business collaboration relationship with multiple core enterprises, which leads to the increasing demand for business collaboration across-industry chain and system. In this way, a cross-chain cooperative relationship is formed between the core enterprises and the cooperative enterprises in many industrial chains, which is undoubtedly a frontier research topic. As far as the above literature is concerned, no research has been carried out from the perspective of cross-industry chain.

At the same time, the traditional single software system has been difficult to support the complex cooperation of large-scale upstream and downstream cross-chain business and the integration of multi-source information systems, which leads to the serious waste of upstream and downstream manufacturing resources of cross-industry chain cooperation. Undoubtedly, using cloud platform service mode will be an effective way to solve the centralized interaction of large-scale cluster resources across industrial chains. To this end, this article takes multi-core enterprises as the research
object, from the point of view of multi-core network cooperation relationship, and adopts the software service environment based on cloud platform to carry out the research of multi-core cross-industry chain assessment and evaluation system.

II. MULTI-CORE AND CROSS-CHAIN COOPERATIVE RELATIONSHIP MODEL

The cooperation of automobile industry chain will take automobile manufacturing enterprise as the core, involving upstream supplier enterprise clusters and downstream sales(or dealer) enterprise clusters. From the analysis of cooperative relationship, the upstream supply chain of automobile industry is formed between supplier enterprises and vehicle manufacturing enterprises. Meanwhile, the downstream sales chain of automobile industry is formed between sales enterprises and automobile manufacturing enterprises. Taking a single industry chain association as an example, it is not difficult to conclude the single industry chain cooperation relationship as shown in Fig. 1.

With the intensification of homogenization competition in automobile industry, the industrial chain gradually presents the characteristics of agglomeration and cluster. Different supplier enterprises and different vehicle manufacturing enterprises form a cooperative relationship. At the same time, different dealer enterprises and different vehicle manufacturing enterprises to form a cooperative relationship. Take three supplier enterprises, three dealer enterprises and three automobile manufacturing enterprises as examples, assuming that there is upstream and downstream business collaboration between them, and then a complex collaboration relationship with three automobile manufacturing enterprises as the core will be formed, as shown in Fig. 2.

From the actual cooperation relationship to analyze, a single core manufacturing enterprise usually works with multiple upstream supplier enterprise clusters and multiple downstream dealer enterprise clusters for industrial chain collaboration. For the industrial chain supplier cluster or dealer cluster which belongs to any core enterprises, there is usually a business cooperation relationship with the core enterprises of other industrial chains. Therefore, from the above cooperative relationship semantics, a multi-core network cooperative relationship model is formed between the upstream supply chain and the downstream distribution chain and the core enterprise, which is shown in Fig. 3.
III. MULTI-LEVEL SUPPORTING MULTI-CORE AND CROSS-CHAIN EVALUATION FRAMEWORK

In order to support the multi-core and cross-chain evaluation problem in cloud platform environment, it is necessary to hierarchicalize the complex cross-chain evaluation problem, that is, to construct a hierarchical structural framework model. For the complex problems involved in this model, it will be decomposed into multiple levels one by one, and each layer is independent of each other. By processing and solving each layer one by one to solve the whole problem, the coupling of the problem can be reduced better. At the same time, each level will contain the corresponding constituent elements to be solved, which may be dynamic logical processing elements or static attribute elements.

It can be seen that the hierarchy of the framework model is actually formed according to the attributes of elements and their relationship semantics. It is no doubt that dynamic processing elements and static attribute elements form an organic relationship of domination, invocation, inclusion or support. In terms of the hierarchical semantic relationship embodied by the elements, the upper level elements will dominate, call or contain the lower level elements, while the lower level elements may provide the data source support for the upper level elements.

Since the subject and object of multi-core and cross-chain evaluation are core enterprises and cooperative enterprises respectively, the evaluation indexes will implement the whole evaluation process. Therefore, in order to facilitate the following description, taking the marketing industry chain evaluation as an example, the following frequently used above various objects are given to the formal representation as shown in Table 1.

The above formalized representation of \( \alpha \) and \( X \) can represent any core enterprise and dealer collaborative enterprise, which is universal.

According to the above solutions, the overall solution of the multi-level framework model supporting multi-core and cross-chain evaluation is constructed as shown in Fig. 4. According to the attributes and relations of the elements involved in the framework, seven levels are designed.

| Core vehicle manufacturer \( \alpha \) | \( \Psi_\alpha \) |
|---------------------------------------|------------------|
| Industrial chain formed with \( \Psi_\alpha \) as the core | \( \Psi_\alpha^c \) |
| Dealer collaborative enterprise \( X \) | \( \Psi^X \) |
| \( \Psi_\alpha \)'s dealer collaboration enterprise \( X \) | \( \Psi_\alpha^x \) |
| The first-level index \( i \) of \( \Psi_\alpha \) evaluating \( \Psi_\alpha^X \) | \( Q_i(\Psi_\alpha^X) \) |
| The second-level index \( j \) contained in \( Q_i(\Psi_\alpha^X) \) | \( Q_j^2(\Psi_\alpha^X) \) |

Through further analysis of the attributes and relations between the layers, the whole hierarchy can be divided into three categories, as follows:

The first category involves the top two layers, corresponding to the subject object layer of multi-core and cross-chain evaluation, including the subject driving layer and object layer.

That is, multiple core vehicle enterprises as driving or triggering the subject of evaluation, dealer cooperation enterprises as the object of subject evaluation. How to support cross-chain evaluation between host and guest needs to use cloud platform environment as carrier to form cross-chain interactive support. It is no doubt that a cross-chain relationship management model of subject-object collaboration should be constructed through cloud platform, which is discussed in detail in the following cross-chain evaluation model.

The second category involves the middle three layers, corresponding to the multi-core and cross-chain evaluation index system layer, including the target layer, factor layer and index layer.

Among them, the target layer is the final goal or ideal result of the cross-chain evaluation requirements, which is reflected as the element value of the evaluation result of the specific subject to the specific object. The factor layer covers the four types of factors involved in evaluating dealers’ comprehensive sales capabilities, namely marketing risk, marketing trends, profitability and auxiliary marketing indexes. The index layer is the specific sales indexes included in the above...
four categories of factors. Specifically: judging the sales recovery rate, sales inventory turnover rate, asset-liability ratio, and vehicle return rate covered by the first-level indexes of marketing risk; Predict the growth rate of automobile booking amount and sales growth rate covered by the first-level indexes of marketing trends; Judge the profit rate, return on investment and profit growth rate of the first-level index factors of profitability. Auxiliary indexes of weak support for the quantity of vehicles ordered, amount of vehicles ordered, number of vehicles sold, amount of vehicles sold, and real-time inventory quantity will need to be further quantified in order to form directly usable index data.

The third type involves the bottom two layers, corresponding to the multi-core and cross-chain data processing layer, including the data quantification layer and the source data providing layer. Among them, the data quantification layer is mainly responsible for the relevant settings and measures selection of data quantification. Specifically, it includes the
setting of quantification threshold, the selection of quantification according to data range or data value, and the selection of relative quantification or absolute quantification to realize the data cleaning pre-processing before quantification, so as to provide directly usable data for the calculation of secondary index value. The data source layer mainly provides the most original data source support for cross-chain evaluation. These data sources are actually the objective business data generated by the sales business interaction between the core vehicle manufacturing enterprises and the dealer collaboration enterprises. Undoubtedly, these data will be stored in the cloud platform database cluster center.

IV. CONSTRUCTING INDEX SYSTEM BASED ON MULTI-CORE AND CROSS-CHAIN

A. MARKETING RISK INDEX SYSTEM

1) SALES PAYBACK RATE

Whether the dealer pays back in time or not, the proportion of its return will be an important means to measure the quality of the dealer’s return.

If during the \( t = t_\beta - t_a \) time period, the core enterprise \( \Psi_a \) in the cloud platform sells \( k \) different vehicle types to dealer \( \Psi_a^X \), involving \( CT_1, CT_2, \ldots, CT_k \). For the above vehicle types, \( \Psi_a^X \) sold \( CT_1^{x_1}, CT_2^{x_2}, \ldots, CT_k^{x_k} \) respectively. Within this time period, the amount of the above-mentioned vehicle types are \( CT_1^{x_1}, CT_2^{x_2}, \ldots, CT_k^{x_k} \) respectively, and the corresponding ex-factory prices are \( e_1, e_2, \ldots, e_k \) respectively. Then the sales payback rate can be expressed as:

\[
\gamma = \frac{\sum_{i=1}^{k} CT_i^{x_i} \times e_i}{\sum_{i=1}^{k} CT_i^{x_i} \times e_i} = \frac{\sum_{i=1}^{k} CT_i^{x_i} \times e_i}{\sum_{i=1}^{k} CT_i^{x_i} \times e_i}
\]

2) SALES INVENTORY TURNOVER

If during the \( t = t_\beta - t_a \) time period, without considering the new sales vehicle type, the inventory vehicle types of dealer enterprise \( \Psi_a^X \) involves \( CT_1, CT_2, \ldots, CT_k \), their corresponding ex-factory price is \( e_1, e_2, \ldots, e_k \), the sales price is \( e_1', e_2', \ldots, e_k' \), the sales vehicle quantity is respectively \( \bar{CT}_1, \bar{CT}_2, \ldots, \bar{CT}_k \), respectively.

For the above vehicle types \( CT_1, CT_2, \ldots, CT_k \), the inventory quantities at \( t_a \) time is \( CT_1^{\alpha_1}, CT_2^{\alpha_2}, \ldots, CT_k^{\alpha_k} \), and the inventory quantities at \( t_\beta \) time is \( CT_1^{\beta_1}, CT_2^{\beta_2}, \ldots, CT_k^{\beta_k} \), respectively. Then during the period, the sales inventory turnover of \( \Psi_a^X \) can be expressed in (2), as shown at the bottom of the page.

3) ASSET-LIABILITY RATIO

The ratio of assets and liabilities is an index to measure the ability of sales enterprises to use creditor funds to carry out business activities, and it is also an important index to measure the degree of financial risk of enterprises. Therefore, the ratio of assets and liabilities also should be included in the index assessment category of marketing ability.

In order to achieve the goal of using the asset-liability ratio for marketing capability evaluation, \( \Psi_a \) requires all dealers to regularly enter the current total assets and total liabilities through the cloud platform. Suppose that at \( t' (t' \in [t_a, t_\beta]) \), the total assets of \( \Psi_a^X \) is \( \psi \) and the total liabilities is \( \ell \). Then the corresponding asset-liability ratio indexes can be expressed as follows:

\[
\frac{\partial}{\psi} \times 100% \leq \ell_0;
\]

\[
\frac{\partial}{\psi} \times 100% > \ell_0.
\]

When \( \alpha > \psi \), it indicates that the auto dealer \( \Psi_a^X \) has the risk of insolvency. In order to prevent real-time sales risks caused by excessive assets and liabilities of collaborative enterprises, a threshold \( \ell \) can be preset in the platform. When \( \frac{\partial}{\psi} \times 100% > \ell \) is detected, the platform automatically triggers the sales warning risk control prompt information to the core enterprise \( \Psi_a \).

At this time, the first strategy that can be adopted is to promptly urge the dealer enterprise \( \Psi_a^X \) to carry out asset risk
management and control. Secondly, since the $\Psi_a$ usually sells the ex-factory vehicles on credit to various dealer enterprises first, after the dealer enterprises sell the vehicles, the vehicle arrears will be returned to the core enterprises $\Psi_a$. Therefore, at this time, the number of auto reservations of dealer $\Psi_a$ should be reduced in a timely manner, and the number of auto reservations should be controlled within a safe range, so as to prevent $\Psi_a$ from being unable to repay the arrears of the vehicle ordered due to excessive asset and liability.

4) VEHICLE RETURN RATE

If during the $\tilde{t} = t_\beta - t_\alpha$ time period, $\Psi_a^\times$ orders $p$ kinds of vehicles from $\Psi_a$ via the cloud platform. It constitutes a corresponding set of models: $\Omega = \{\sum CT_i|i = 1, 2, \ldots, p\}$. The number of orders corresponding to the model can be extracted via the cloud platform, respectively: $CT_1^{m1}, CT_2^{m2}, \ldots, CT_p^{mp}$. During this period, $\Psi_a^\times$ retreated $q$ kinds of vehicles to $\Psi_a$ via the cloud platform ($q \leq p$).

This constitutes a corresponding set of models: $\Phi = \{\sum CT_j^p|j = 1, 2, \ldots, q\}$. The number of retreats corresponding to the model can be extracted via the cloud platform, respectively: $CT_1^{m1}, CT_2^{m2}, \ldots, CT_q^{mq}$. Then in the time period of $\tilde{t}$, the return rate of $\Psi_a^\times$, vehicles can be expressed as:

$$Q_1^\times(\Psi_a) = \frac{\sum_{CT_i \in \Phi} CT_i^{mq}}{\sum_{CT_i \in \Omega} CT_i^{mi}} \times 100\% \quad (4)$$

B. MARKETING TREND FORECAST INDEX SYSTEM

1) GROWTH RATE OF AUTOMOBILE ORDERING AMOUNT

If during the $\tilde{t} = t_\beta - t_\alpha$ time period, $\Psi_a^\times$ orders $n$ kinds of vehicles from $\Psi_a$ via the cloud platform. It constitutes a corresponding set of models: $\Omega = \{\sum CT_i|i = 1, 2, \ldots, n\}$. The ordering quantity corresponding to the ordering vehicle type set $\Omega$ is $Veh_1^{m1}, Veh_2^{m2}, \ldots, Veh_n^{mn}$ respectively, and the corresponding unit price of the ordering vehicle type is $OP_1, OP_2, \ldots, OP_n$ respectively. In the previous time period $t' = t_\beta' - t_\alpha'$ of $\tilde{t}$, the quantity ordered by the above-mentioned corresponding vehicle types is $Veh_1^{m1'}, Veh_2^{m2'}, \ldots, Veh_n^{mn'}$ and the corresponding unit price is $OP_1', OP_2', \ldots, OP_n'$.

The total amount of vehicles ordered by the $\Psi_a$ from the $\Psi_a^\times$ can then be expressed as follows in the $\tilde{t}$ and $t'$ periods:

$$P_a^\times(\tilde{t}) = \sum_{Veh_i \in \Omega} Veh_i^{m1} \times OP_i \quad (5)$$

$$P_a'(t') = \sum_{Veh_i \in \Omega} Veh_i^{m1'} \times OP_i' \quad (6)$$

Therefore, the growth rate of the automobile ordering amount is:

$$Q_2^\times(\Psi_a) = \left(\frac{P_a^\times(\tilde{t})}{P'_a(t')} - 1\right) \times 100\% \quad (7)$$

2) SALES GROWTH RATE

Similar to the growth rate of the subscription amount, $\Psi_a'$ sold $k$ types of $\Psi_a$ sales vehicles $\Omega' = \{k \cup Veh_i\}$ in the $\tilde{t}$ and $t'$ time periods, and the sales volumes in these two time periods were $Veh_1^{c1}, Veh_2^{c2}, \ldots, Veh_k^{ck}$ and $Veh_1^{c1'}, Veh_2^{c2'}, \ldots, Veh_k^{ck'}$, respectively. Without considering the promotion discount, the vehicle sales prices corresponding to each element in the $\Omega'$ is $\{k \cup Veh_i\}$ of these two time periods are $P_1, P_2, \ldots, P_k$ and $P_1', P_2', \ldots, P_k'$ respectively.

Then the total amount of vehicles sold by $\Psi_a'$ can be expressed as follows in the $\tilde{t}$ and $t'$ periods:

$$P_a^\times(\tilde{t}) = \sum_{Veh_i \in \Omega'} Veh_i^{cj} \times OP_j \quad (8)$$

$$P_a'(t') = \sum_{Veh_i \in \Omega'} Veh_i^{cj'} \times OP_j' \quad (9)$$

Therefore, the sales growth rate of $\tilde{t}$ and $t'$ time period can be calculated as follows:

$$Q_2^\times(\Psi_a) = \frac{P_a^\times(\tilde{t}) - P_a'(t')}{P_a^\times(\tilde{t})} \times 100\% \quad (10)$$

C. PROFITABILITY INDEX SYSTEM

1) PROFIT RATE

If $\Psi_a'$ sales $n$ kinds of vehicles during the $\tilde{t} = t_\beta - t_\alpha$ time period. It constitutes a corresponding set of models: $\Omega = \{\sum CT_i|i = 1, 2, \ldots, n\}$. The Ex-factory price and sales price corresponding to the ordering vehicle type set $\Omega$ are $p_1, p_2, \ldots, p_n$ and $p_1', p_2', \ldots, p_n'$ respectively, and the corresponding sales quantities are $CT_1, CT_2, \ldots, CT_n$ respectively. Then the profit rate is as follows:

$$Q_3^\times(\Psi_a) = \frac{\sum_{i=1}^{n} CT_i \times (p_i' - p_i)}{\sum_{i=1}^{n} CT_i \times p_i} \times 100\% \quad (11)$$

2) RETURN ON INVESTMENT

Return on Investment (ROI) is a comprehensive index to measure the operation effect and efficiency of any dealer enterprise, and it is also an important indirect index reflecting the profitability of dealers. The “ROI” is expressed in combination with $Q_3^\times(\Psi_a)$, and its calculation method is as follows: (annual profit before tax / total investment) * 100%. It can be seen that the index is measured annually. If $\Psi_a^\times \in \Psi_a$, $\Psi_a^\times$ is required to enter the total annual investment $\sum(\Psi_a')$ through the cloud platform. If there are $(t_\beta - t_\alpha)$ days in $\tilde{t}$ period, the corresponding pretax profit is $\sum_{i=1}^{n} CT_i \times (p_i' - p_i)$.

Then the secondary index $Q_3^\times(\Psi_a)$ corresponding to ROI can
be expressed as follows:

$$Q_3^x(\Psi^x_a) = \frac{\sum_{i=1}^{\infty} CT_i \times (p'_i - p_i)}{\sum_{\Psi}^x} \times \frac{365}{t_\beta - t_\alpha} \times 100\%$$ (12)

3) PROFIT GROWTH RATE
In two consecutive periods of time \(t = t_2 - t_1 = 2(t_\beta - t_\alpha)\), it is assumed that the ex-factory price and sales price corresponding to each element of \(\Omega\) remain unchanged. The sales volume in the previous \(t_1\) period is \(CT^{1}_i, CT^{2}_i, \ldots, CT^{n'}_i\) respectively, and the sales volume in the next \(t_2\) period is \(CT^{1}_i, CT^{2}_i, \ldots, CT^{n''}_i\) respectively. Then the profit growth rate is as follows:

$$Q_3^3(\Psi^x_a) = \left( \frac{\sum_{i=1}^{\infty} CT'_i \times (p'_i - p_i)}{\sum_{i=1}^{\infty} CT'_i \times p'_i} - \frac{\sum_{i=1}^{\infty} CT^{i'}_i \times (p'_i - p_i)}{\sum_{i=1}^{\infty} CT^{i'}_i \times p'_i} \right) \times 100\%$$ (13)

D. AUXILIARY WEAK SUPPORT MARKETING INDEX SYSTEM
In order to facilitate the description below, the following relevant conventions are first given. If during the \(t = t_\beta - t_\alpha\) time period, \(\Psi^x_a\) orders \(n\) kinds of vehicles from \(\Psi_a\) through the cloud platform. It constitutes a corresponding set of models: \(\Omega = \{ n \cup Veh_i \}_{i=1}^n \). If at the starting time \(t_\alpha\) the number of real-time inventory corresponding to the ordered vehicle type set is \(Veh^{m1}_i, Veh^{m2}_i, \ldots, Veh^{mn}_i\). The order quantity corresponding to the ordered vehicle type set can be extracted through the cloud platform, namely \(Veh^{m1}_i, Veh^{m2}_i, \ldots, Veh^{mn}_i\). According to the above formal semantic convention, the unit price corresponding to the ordered vehicle type set \(\Omega = \{ n \cup Veh_i \}_{i=1}^n \) is \(OP, OP_2, \ldots, OP_n\) respectively.

During the above period, \(\Psi^x_a\) sold \(k\) vehicle types of \(\Psi_a\) to form a set \(\Omega' = \{ k \cup Veh_j \}_{j=1}^k \). The sales quantity corresponding to the sales vehicle type set can be extracted in the cloud platform by using the collaboration relationship, namely \(Veh^{m1}_j, Veh^{m2}_j, \ldots, Veh^{mn}_j\) respectively. According to the formal semantic convention mentioned above, the vehicle sales prices corresponding to each element in the \(\Omega' = \{ k \cup Veh_j \}_{j=1}^k \) is \(P_1, P_2, \ldots, P_k\) respectively.

1) QUANTITY OF VEHICLES ORDERED
During the \(t\) period, the total number of vehicles ordered by \(\Psi^x_a\) from \(\Psi_a\) through the cloud platform is: \(\Phi^x_a = \sum_{i=1}^{\infty} Veh^{mi}_i\).

2) AMOUNT OF VEHICLES ORDERED
During the \(t\) period, the total amount of vehicles ordered by \(\Psi^x_a\) from \(\Psi_a\) through the cloud platform can be expressed as follows:

$$P^x_a = \sum_{Veh_i \in \Omega} Veh^{mi}_i \times OP_i, \quad i \in (1, \ldots, n)$$ (14)

3) NUMBER OF VEHICLES SOLD
During the \(t\) period, the total number of vehicles sold by \(\Psi^x_a\) from \(\Psi_a\) can be expressed as follows: \(S^x_a = \sum_{j=1}^{k} Veh^{mj}_j\).

4) TOTAL AMOUNT OF VEHICLES SOLD
During the \(t\) period, the total amount of vehicles sold by \(\Psi^x_a\) from \(\Psi_a\) through the cloud platform can be expressed as follows:

$$P'^x_a = \sum_{Veh_j \in \Omega'} Veh^{mj}_j \times P_j, \quad j \in (1, \ldots, n)$$ (15)

5) REAL-TIME INVENTORY QUANTITY
\(Vt = t_\beta - t_\alpha\), undoubtedly, the inventory quantity at time \(t_\beta\) should be taken as the real-time inventory to be calculated. At time \(t_\alpha\), the initial inventory should be \(\phi^x_a = \sum_{mathit{Veh}_j \in \Omega} \mathit{Veh}^{mi}_j\). According to the above semantic definition, the real-time inventory of \(t\) period can be expressed as follows:

$$\mathbb{R}^x_a = \sum_{j=1}^{n} \left( Veh^{mi}_j + Veh^{mj}_j \right) - \sum_{j=1}^{k} Veh^{mj}_j \quad i \in (1, \ldots, n), \quad j \in (1, \ldots, k)$$ (16)

6) QUANTITATIVE SCHEME OF AUXILIARY WEAK SUPPORT INDEX DATA
For the above secondary index data sources, it is obvious that they can not be directly used in the calculation of the index system, but also need to be re-quantified. Since the above five indexes are all auxiliary weak support indexes, this article adopts fuzzy processing. That is to say, the threshold value is set in the way of the index data range, so as to form the index data value that can be directly substituted into the index system for calculation.

In this article, according to the conventional 5-segment separation method, then 4 thresholds will be needed to complete the separation of 5 interval segments. Using the two consecutive thresholds of \(\mathbb{X}^i(\Psi^x_a), \mathbb{X}^{i+1}(\Psi^x_a) (1 \leq i \leq 5, 0 \leq j \leq 3)\) involved in each interval segment, the segment in the \(\mathbb{X}^i(\Psi^x_a), \mathbb{X}^{i+1}(\Psi^x_a)\) interval is quantified into actual index data values, so that the index data sources in different interval segments are sequentially quantified into 5 different index data values. Undoubtedly, the starting threshold is \(\lambda^0(\Psi^x_a) \equiv 0\).

Quantization starts from the initial value 0, and is used to represent the threshold involved. Then the threshold set of \(\Phi^x_a\) forms a five-dimensional vector such as \(\Phi^x_a \propto (0, \lambda^1(\Psi^x_a), \lambda^2(\Psi^x_a), \lambda^3(\Psi^x_a), \lambda^4(\Psi^x_a))\).
Similarly, we can obtain:

\[ P_a^x \propto (0, \lambda_1^x(\Psi_a^x), \lambda_2^x(\Psi_a^x), \lambda_3^x(\Psi_a^x), \lambda_4^x(\Psi_a^x)), \]

\[ S_a^x \propto (0, \lambda_1^x(\Psi_a^x), \lambda_2^x(\Psi_a^x), \lambda_3^x(\Psi_a^x), \lambda_4^x(\Psi_a^x)), \]

\[ P_a^y \propto (0, \lambda_1^y(\Psi_a^y), \lambda_2^y(\Psi_a^y), \lambda_3^y(\Psi_a^y), \lambda_4^y(\Psi_a^y)), \]

\[ R_a^x \propto (0, \lambda_2^x(\Psi_a^x), \lambda_3^x(\Psi_a^x), \lambda_4^x(\Psi_a^x), \lambda_5^x(\Psi_a^x)). \]

By analyzing the threshold sets of \( \Phi_a^x, P_a^x, S_a^x, P_a^y, R_a^x \) from the vertical and horizontal dimensions, a matrix of 5 \times 5 dimension is formed. Then the corresponding thresholds of \( \Phi_a^x, P_a^x, S_a^x, P_a^y, R_a^x \) constitute a matrix as follows:

\[
\begin{pmatrix}
\Phi_a^x & P_a^x & S_a^x & P_a^y & R_a^x \\
0 & \lambda_1^x(\Psi_a^x) & \lambda_2^x(\Psi_a^x) & \lambda_3^x(\Psi_a^x) & \lambda_4^x(\Psi_a^x) \\
0 & \lambda_1^y(\Psi_a^y) & \lambda_2^y(\Psi_a^y) & \lambda_3^y(\Psi_a^y) & \lambda_4^y(\Psi_a^y) \\
0 & \lambda_1^x(\Psi_a^x) & \lambda_2^x(\Psi_a^x) & \lambda_3^x(\Psi_a^x) & \lambda_4^x(\Psi_a^x) \\
0 & \lambda_1^y(\Psi_a^y) & \lambda_2^y(\Psi_a^y) & \lambda_3^y(\Psi_a^y) & \lambda_4^y(\Psi_a^y) \\
0 & \lambda_2^x(\Psi_a^x) & \lambda_3^x(\Psi_a^x) & \lambda_4^x(\Psi_a^x) & \lambda_5^x(\Psi_a^x)
\end{pmatrix}
\]

At the same time, using the semantic mapping relationship involved in quantization, \( \Phi_a^x, P_a^x, S_a^x, P_a^y, R_a^x \) can be sequentially mapped into a 5-dimensional vector: \((\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4, \varepsilon_5)\). Then there are as follows:

\[
\begin{pmatrix}
Q_1^x(\Psi_a^x) \\
Q_2^x(\Psi_a^x) \\
Q_3^x(\Psi_a^x) \\
Q_4^x(\Psi_a^x) \\
Q_5^x(\Psi_a^x)
\end{pmatrix}
= \begin{pmatrix}
\varepsilon_1 \\
\varepsilon_2 \\
\varepsilon_3 \\
\varepsilon_4 \\
\varepsilon_5
\end{pmatrix}
\]

\( \forall \varepsilon_k (k = 1, 2, \ldots, 5) \), the quantization method adopted is as follows:

\[
\begin{aligned}
\varepsilon_1 &= \left\{ \begin{array}{l}
0 \leq \left( \Phi_a^x = \sum_{i=1}^{n} Veh_i^m \right) < \lambda_1^x(\Psi_a^x) \\
0 \leq \left( P_a^x = \sum_{Veh_i \in \Omega} Veh_i^m \times OP_i \right) < \lambda_2^x(\Psi_a^x) \\
0 \leq \left( S_a^x = \sum_{j=1}^{k} Veh_j^m \right) < \lambda_3^x(\Psi_a^x) \\
0 \leq \left( P_a^y = \sum_{Veh_j \in \Omega} Veh_j^m \times P_j \right) < \lambda_4^x(\Psi_a^x) \\
\lambda_5^x(\Psi_a^x) \leq \left( R_a^x = \sum_{i=1}^{n} Veh_i^o + Veh_i^m - \sum_{j=1}^{k} Veh_j^m \right)
\end{array} \right. \\
\varepsilon_2 &= \left\{ \begin{array}{l}
\lambda_1^x(\Psi_a^x) \leq \left( \Phi_a^x = \sum_{i=1}^{n} Veh_i^m \right) < \lambda_1^x(\Psi_a^x) \\
\lambda_2^x(\Psi_a^x) \leq \left( P_a^x = \sum_{Veh_i \in \Omega} Veh_i^m \times OP_i \right) < \lambda_2^x(\Psi_a^x) \\
\lambda_3^x(\Psi_a^x) \leq \left( S_a^x = \sum_{j=1}^{k} Veh_j^m \right) < \lambda_3^x(\Psi_a^x) \\
\lambda_4^x(\Psi_a^x) \leq \left( P_a^y = \sum_{Veh_j \in \Omega} Veh_j^m \times P_j \right) < \lambda_4^x(\Psi_a^x) \\
\lambda_5^x(\Psi_a^x) \leq \left( R_a^x = \sum_{i=1}^{n} Veh_i^o + Veh_i^m - \sum_{j=1}^{k} Veh_j^m \right)
\end{array} \right. \\
\varepsilon_3 &= \left\{ \begin{array}{l}
\lambda_1^x(\Psi_a^x) \leq \left( \Phi_a^x = \sum_{i=1}^{n} Veh_i^m \right) < \lambda_1^x(\Psi_a^x) \\
\lambda_2^x(\Psi_a^x) \leq \left( P_a^x = \sum_{Veh_i \in \Omega} Veh_i^m \times OP_i \right) < \lambda_2^x(\Psi_a^x) \\
\lambda_3^x(\Psi_a^x) \leq \left( S_a^x = \sum_{j=1}^{k} Veh_j^m \right) < \lambda_3^x(\Psi_a^x) \\
\lambda_4^x(\Psi_a^x) \leq \left( P_a^y = \sum_{Veh_j \in \Omega} Veh_j^m \times P_j \right) < \lambda_4^x(\Psi_a^x) \\
\lambda_5^x(\Psi_a^x) \leq \left( R_a^x = \sum_{i=1}^{n} Veh_i^o + Veh_i^m - \sum_{j=1}^{k} Veh_j^m \right)
\end{array} \right. \\
\varepsilon_4 &= \left\{ \begin{array}{l}
\lambda_1^x(\Psi_a^x) \leq \left( \Phi_a^x = \sum_{i=1}^{n} Veh_i^m \right) < \lambda_1^x(\Psi_a^x) \\
\lambda_2^x(\Psi_a^x) \leq \left( P_a^x = \sum_{Veh_i \in \Omega} Veh_i^m \times OP_i \right) < \lambda_2^x(\Psi_a^x) \\
\lambda_3^x(\Psi_a^x) \leq \left( S_a^x = \sum_{j=1}^{k} Veh_j^m \right) < \lambda_3^x(\Psi_a^x) \\
\lambda_4^x(\Psi_a^x) \leq \left( P_a^y = \sum_{Veh_j \in \Omega} Veh_j^m \times P_j \right) < \lambda_4^x(\Psi_a^x) \\
\lambda_5^x(\Psi_a^x) \leq \left( R_a^x = \sum_{i=1}^{n} Veh_i^o + Veh_i^m - \sum_{j=1}^{k} Veh_j^m \right)
\end{array} \right. \\
\varepsilon_5 &= \left\{ \begin{array}{l}
\lambda_1^x(\Psi_a^x) \leq \left( \Phi_a^x = \sum_{i=1}^{n} Veh_i^m \right) < \lambda_1^x(\Psi_a^x) \\
\lambda_2^x(\Psi_a^x) \leq \left( P_a^x = \sum_{Veh_i \in \Omega} Veh_i^m \times OP_i \right) < \lambda_2^x(\Psi_a^x) \\
\lambda_3^x(\Psi_a^x) \leq \left( S_a^x = \sum_{j=1}^{k} Veh_j^m \right) < \lambda_3^x(\Psi_a^x) \\
\lambda_4^x(\Psi_a^x) \leq \left( P_a^y = \sum_{Veh_j \in \Omega} Veh_j^m \times P_j \right) < \lambda_4^x(\Psi_a^x) \\
\lambda_5^x(\Psi_a^x) \leq \left( R_a^x = \sum_{i=1}^{n} Veh_i^o + Veh_i^m - \sum_{j=1}^{k} Veh_j^m \right)
\end{array} \right.
\]

\[151837\]
For the above quantization scheme, since the larger the value of $\Phi^x_a$ is, the weaker the sales ability is, the threshold corresponding to $\Phi^x_a$ needs to be inverse quantified.

Moreover, for the threshold matrix:

$$
\begin{pmatrix}
\lambda_1^x(\Psi^x_a) & \lambda_2^x(\Psi^x_a) & \lambda_3^x(\Psi^x_a) & \lambda_4^x(\Psi^x_a) \\
0 & \lambda_1^x(\Psi^x_a) & \lambda_2^x(\Psi^x_a) & \lambda_3^x(\Psi^x_a) \\
0 & 0 & \lambda_1^x(\Psi^x_a) & \lambda_2^x(\Psi^x_a) \\
0 & 0 & 0 & \lambda_1^x(\Psi^x_a) \\
0 & \lambda_2^x(\Psi^x_a) & \lambda_3^x(\Psi^x_a) & \lambda_4^x(\Psi^x_a) \\
\end{pmatrix}
$$

it is only necessary to configure the $\Phi^x_a$, $P^x_a$, $S^x_a$, $P^x_a$, $R^x_a$ involved in the $\Psi^x_a$ by $\Psi_a$ through the cloud platform. For $(e_1, e_2, e_3, e_4, e_5)$, users of $\Psi_a$ can configure them as unified specific values through the cloud platform, that is, $\forall \Psi^x_a$, $\forall e_1, e_2, e_3, e_4, e_5$ have the same values.

V. CONSTRUCTING INDEX WEIGHT SYSTEM BASED ON MULTI-CORE AND CROSS-CHAIN

The evaluation of multi-core and cross-chain is analyzed from the actual marketing needs of the core enterprises to the cooperative enterprise clusters. As a result, it may be large differences in the weight distribution of the same index between different core enterprises, which makes the traditional construction mode with fixed weight can not meet the evaluation needs of multi-core and cross-chain.

$\forall \Psi_a$, the key metric values corresponding to the first-level indexes $Q_1, Q_2, Q_3, Q_4$ are $\delta_1^a, \delta_2^a, \delta_3^a, \delta_4^a$. In order to achieve multi-core and cross-chain marketing evaluation based on cloud platforms, it is necessary to perform normalization processing and the establishment of weight system separately.

As mentioned above, the weight of the same index needs to be flexibly configured according to different core enterprises in the cloud platform, which makes it difficult to integrate the marketing chain enterprise clusters to build a unified and flexible evaluation system. From the analysis of the construction requirements of multi-core and cross-chain weight system, $\forall \Psi_a$, the weight systems correspond to a set of $n$-dimensional vectors respectively, then $m$ core enterprises constitute the weight system matrix of $m \times n$.

$\forall \Psi_a$, all involving four first-level indexes $Q_1, Q_2, Q_3, Q_4$. Obviously, $n = 4$, so in the cloud platform environment, the first-level index weight system supporting multi-core and cross-chain evaluation can be expressed as:

$$
\begin{pmatrix}
Q_1 \\
Q_2 \\
Q_3 \\
Q_4
\end{pmatrix}
= \begin{pmatrix}
\omega_{11} & \omega_{12} & \omega_{13} & \omega_{14} \\
\vdots & \vdots & \vdots & \vdots \\
\omega_{m1} & \omega_{m2} & \omega_{m3} & \omega_{m4}
\end{pmatrix} \\
\forall i, \omega_{11} + \omega_{12} + \omega_{13} + \omega_{14} = 1.
$$

$\forall Q_i$, there are several secondary index elements involved. From the perspective of semantic relationship, $\forall Q_i$, there is a $Q_i = \bigcup_{j=1}^{n'} Q'_i$ relationship, which constitutes a weight system matrix of $m \times n'$. $\forall \Psi_a$, the weight corresponding to any secondary index $Q'_i$ is $\omega_{ij}$. Therefore, the secondary index weight system supporting multi-core and cross-chain evaluation in the cloud platform environment can be expressed as follows:

$$
\begin{pmatrix}
Q'_1 \\
Q'_2 \\
\vdots \\
Q'_{n'}
\end{pmatrix}
= \begin{pmatrix}
\omega_{11} & \omega_{12} & \cdots & \omega_{1n'} \\
\omega_{11} & \omega_{12} & \cdots & \omega_{1n'} \\
\vdots & \vdots & \ddots & \vdots \\
\omega_{11} & \omega_{12} & \cdots & \omega_{1n'}
\end{pmatrix} \\
\forall \Psi_a$ and $\forall Q'_i$, both satisfy $\sum_{j=1}^{n'} \omega_{ij} = 1$.

VI. MULTI-CORE AND CROSS-CHAIN EVALUATION MODEL BASED ON COLLABORATIVE RELATIONSHIP

In the wide-area cloud manufacturing environment, the multi-core and cross-chain evaluation model of discrete distributed core vehicle enterprise clusters and discrete distributed dealer cooperative enterprise clusters can be constructed as follows. The cloud platform integrates multiple core vehicle enterprises and multiple dealer collaborative enterprises. It is not hard to find that any one core enterprise will cooperate with multiple dealer enterprises in sales business. At the same time, any dealer enterprise may cooperate with multiple core vehicle enterprises. Therefore, the multi-core network cross-chain collaboration relationship formed between the core enterprise and the dealer enterprise is a many-to-many complex relationship. In order to reduce the coupling degree between the cooperation relationship of the industry chain members and the business cooperation relationship, it is necessary for the cloud platform to separately construct an industry chain cooperation relationship database between the integrated core enterprises and dealer enterprises. In this way, it not only achieves the independent management of cross-chain collaboration members, but also achieves the
goal of supporting multi-core network cross-chain collaboration, so as to provide complex relationship support for the multi-core and cross-chain evaluation studied in this article.

The data generated by the business cooperation between core enterprises and dealers is stored in the cloud platform data center, forming the original data source of multi-core and cross-chain evaluation. Using the subject-object relationship of cross-chain evaluation (that is, the cross-chain cooperative relationship model between core enterprises and cooperative enterprises) as the constraint condition, the cloud platform source data center is screened and extracted. Then the extracted data will be cleaned to remove the data that does not meet the requirements and the dirty data that is useless for evaluation. On this basis, according to the quantification parameters set by the core enterprise users of the cloud platform, as well as the initial and end thresholds of interval quantification, the data after cleaning is quantified for the calculation of secondary indexes.

After the completion of data quantification, according to the multi-core and cross-chain collaborative relationship constructed by the cloud platform database and the secondary index calculation rules formulated by the index system, the data value of each secondary index can be calculated in turn. At the same time, combined with the weight factors of each secondary index, and according to the calculation rules of the first-level index, each first-level index value can be calculated separately. Finally, by using the linear weighting relationship between the first-level index elements and the weighting factors, the evaluation result value of the dealer cooperative enterprise can be obtained. For other dealer collaboration enterprises under the jurisdiction of core vehicle enterprises, it only needs to use the specific subject-object collaboration relationship when extracting source data, combined with the low-coupling multi-core mesh collaboration relationship database constructed by the cloud platform. As shown in Fig. 5, according to the above scheme, iterative traversal can obtain the evaluation results of other dealers in turn.

According to the first-level index and the final evaluation result mentioned in the cross-chain evaluation model, the solution method is as follows:
Assuming that the core enterprise $\Psi_a$ evaluates its dealer collaboration enterprise $\Psi_a^y$, using the linear correlation between the element values of the first-level index and the second-level index and the weighting factors, the solution method of the first-level index should be expressed as follows:

$$Q_1(\Psi_a^x) = Q_1^1(\Psi_a^x) \times \omega_1^{a1} + Q_1^2(\Psi_a^x) \times \omega_1^{a2} + Q_1^3(\Psi_a^x) \times \omega_1^{a3}$$

Similarly, $Q_2(\Psi_a^x), Q_3(\Psi_a^x), Q_4(\Psi_a^x)$ can be obtained, which is as follows:

$$Q_2(\Psi_a^x) = 2 \sum_{j=1}^{2} Q_2^j(\Psi_a^x) \times \omega_2^{gj}$$

$$Q_3(\Psi_a^x) = 3 \sum_{j=1}^{3} Q_3^j(\Psi_a^x) \times \omega_3^{gj}$$

$$Q_4(\Psi_a^x) = 4 \sum_{j=1}^{4} Q_4^j(\Psi_a^x) \times \omega_4^{gj}$$

According to the weak support index data quantization scheme, $Q_4(\Psi_a^x)$ can also be obtained by $\sum_{j=1}^{5} e_j \times \omega_4^{gj}$.

Based on the index system, using the obtained evaluation values $Q_1(\Psi_a^x), Q_2(\Psi_a^x), Q_3(\Psi_a^x), Q_4(\Psi_a^x)$ of each first-level index, the final evaluation value of $\Psi_a^x$ can be obtained:

$$Q(\Psi_a^x) = Q_1(\Psi_a^x) \times \omega_a1 + Q_2(\Psi_a^x) \times \omega_a2 + Q_3(\Psi_a^x) \times \omega_a3$$

$$+ Q_4(\Psi_a^x) \times \omega_a4 = \sum_{j=1}^{4} Q_j(\Psi_a^x) \times \omega_{ai}$$

Similarly, according to the above calculation scheme, it can obtain the evaluation results of dealers other than $\Psi_a^x$.

**VII. CROSS-CHAIN COLLABORATIVE EVALUATION ALGORITHM**

To facilitate the description of the algorithm, first of all, some symbols and relationships are defined and explained separately. Among them, $\Gamma(\text{DataList}[i])$ to $\text{DataList}[i]$, it means that the original data set (DataList[i]) extracted by the cloud platform is quantified into a data set $\text{DataList}[i]$ that can be directly used by the index system according to the specified quantization rules. $i$ refers to the number of corresponding second-level indexes contained in first-level index $Q_i$. Different first-level index may have different number of second-level index $Q_i^j$. Then $\forall Q_a^x$, it must be $Q_i(\Psi_a^x) = \sum_{j=1}^{i} Q_i^j(\Psi_a^x) \times \omega_i^{gj}, i \in \{1, 2, 3, 4\}, j \in \{2, 3, 4, 5\}$ linear relationship between the first-level index factor $Q_i(\Psi_a^x)$ and the second-level index factor $Q_i^j(\Psi_a^x)$. The inherent linear relationship between the final evaluation result value and the first-level index factor can be expressed as follows: $Q(\Psi_a^x) = \sum_{i=1}^{4} Q_i(\Psi_a^x) \times \omega_{ai}, \forall i \in \{1, 2, 3, 4\}$ These relationships will be applied in the evaluation algorithm. The detailed algorithm process is as shown in Algorithm 1:

**Algorithm 1 Collaborative Evaluation Algorithm Based on Reverse Feedback Transfer**

**Input:** Original data set stored in cloud platform $\text{DataSet}(\Psi_a)$.

**Output:** Evaluation result set $\{Q(\Psi_a^x) | \Psi_a^x \in \Psi_a\}$.

1. for all $\text{DataSet}(\Psi_a^x)$ in $\text{DataSet}(\Psi_a)$ do

2. DataList[i] = Find Direct DataSource from $\text{DataSet}(\Psi_a^x)$ by search criteria;

3. for each $(\text{DataList}[i]) \in \text{DataList}$ do

4. if $(\text{DataList}[i])$ Need quantification then

5. $\Gamma(\text{DataList}[i])$ to $\text{DataList}[i]$, Add $\text{DataList}[i]$ into $\text{DataList}:Q(\Psi_a^x)$;

6. else

7. Add $(\text{DataList}[i])$ into $\text{DataList}:Q(\Psi_a^x)$;

8. end if

9. end for

10. for each $Q_i(\Psi_a^x) \in Q_i(\Psi_a^x)i = 1, 2, 3, 4$ do

11. for each $Q_i^j(\Psi_a^x) \in Q_i^j(\Psi_a^x)i = 1, 2, 3, 4; j = 1, \ldots, \hat{i}$ do

12. Using the calculation formula of each secondary index, Obtain $Q_i^j(\Psi_a^x)$ from the dataset $\text{DataList}:Q(\Psi_a^x)$ by search criteria;

13. end for

14. Calculate $Q_i(\Psi_a^x)$ by all $Q_i^j(\Psi_a^x) \in Q_i(\Psi_a^x)$;

15. Calculate $Q(\Psi_a^x)$ by all $Q_j(\Psi_a^x)$;

16. end for

17. end for
The weight matrix of the secondary indicators is as follows:

\[
\Psi_\alpha \times Q_1 = \begin{bmatrix}
0.174 \\
0.297 \\
0.436 \\
0.093 
\end{bmatrix}
\]

The weight matrix of the secondary indicators is as follows:

\[
\Psi_\alpha \times Q_i = \begin{bmatrix}
0.359 & 0.210 & 0.316 & 0.115 & 0 \\
0.596 & 0.404 & 0 & 0 & 0 \\
0.548 & 0.097 & 0.355 & 0 & 0 \\
0.230 & 0.351 & 0.168 & 0.189 & 0.062 
\end{bmatrix}
\]

The key calculation process of the index is as follows:

First, from the cloud platform data center, the target data source is selected according to the collaboration relationship and related initial conditions of the core vehicle enterprise and the collaborative enterprise. After quantization, each index value is calculated according to the definition of each second-level index element \(Q_i(\Psi_\alpha)\).

Using the calculation formula \(Q_i(\Psi_\alpha) = \frac{1}{i} \sum (\Psi_\alpha^j) \times \omega_1^{aj}\), \(i \in (1, 2, 3, 4), i \in (2, 3, 4, 5)\) combined with the index system constructed in Sec IV, the first-level index factor values can be expressed as the following relationship:

\[
\psi_1 = \left\{ \begin{array}{l}
Q_1(\Psi_\alpha) = \sum_{j=1}^{4} Q_i(\Psi_\alpha^j) \times \omega_1^{aj} \\
Q_2(\Psi_\alpha) = \sum_{j=1}^{2} Q_i(\Psi_\alpha^j) \times \omega_2^{aj} \\
Q_3(\Psi_\alpha) = \sum_{j=1}^{3} Q_i(\Psi_\alpha^j) \times \omega_3^{aj} \\
Q_4(\Psi_\alpha) = \sum_{j=1}^{5} Q_i(\Psi_\alpha^j) \times \omega_4^{aj} 
\end{array} \right. \tag{18}
\]

Substituting the second-level index elements and corresponding second-level index weighting factors of Table 2 to Table 5 into the above relationship in sequence, which can be obtained in turn: \(Q_1(\Psi_\alpha) = 0.671\), \(Q_2(\Psi_\alpha) = 0.587\), \(Q_3(\Psi_\alpha) = 0.450\), \(Q_4(\Psi_\alpha) = 0.835\).

The above-mentioned first-level index elements \(Q_1(\Psi_\alpha)\), \(Q_2(\Psi_\alpha)\), \(Q_3(\Psi_\alpha)\), \(Q_4(\Psi_\alpha)\) and the first-level index weighting factors \(\omega_{a1} = 0.174\), \(\omega_{a2} = 0.297\), \(\omega_{a3} = 0.436\), \(\omega_{a4} = 0.093\) provided by the expert assignment method are respectively substituted into the evaluation result linear calculation formula \(Q(\Psi_\alpha) = \sum_{i=1}^{4} Q_i(\Psi_\alpha) \times \omega_{ai}\). Finally, the final evaluation result value of \(Q(\Psi_\alpha)\) can be obtained, which is \(Q(\Psi_\alpha) = 0.565\).

The above discussion takes the specific core enterprise \(\Psi_\alpha\) appraisal dealer cooperation enterprise \(Q(\Psi_\alpha)\) as an example to show the detailed calculation process of the index system. The evaluation algorithm is based on the multi-core and cross-chain network collaboration relationship of the cloud platform. Therefore, whether it is other sales collaboration enterprises affiliated with \(\Psi_\alpha\), or the multi-core and cross-chain evaluation of other core enterprises, the calculation process is consistent with this.

**IX. SIMULATION ANALYSIS**

Randomly selecting a core vehicle manufacturer \(\Psi_\phi\) as an example to verify the feasibility of the method proposed in this article. Through the conditional search of the cloud platform collaboration relationship, it can be obtained that there are 582 auto dealers with industrial chain cooperation. In order to qualitatively process the quantitative evaluation results, the final collaborative sales evaluation results are classified into five categories: excellent, good, qualified, unqualified, and poor. Then the corresponding interval can be expressed by the following relationship:

\[
\begin{cases}
\text{excellent} & 0.8 \leq Q(\Psi_\phi) < 1.0 \\
\text{good} & 0.6 \leq Q(\Psi_\phi) < 0.8 \\
\text{qualified} & 0.4 \leq Q(\Psi_\phi) < 0.6 \\
\text{unqualified} & 0.2 \leq Q(\Psi_\phi) < 0.4 \\
\text{poor} & 0 \leq Q(\Psi_\phi) < 0.2
\end{cases}
\tag{19}
\]

Then using the system method constructed in this article to evaluate its 582 dealers. By collecting and quantifying the original data source based on cloud platform and combining with the cooperative evaluation algorithm proposed in this article, the distribution of evaluation results as shown in Fig. 6 is simulated by Matlab. The average value of the evaluation results of all dealers managed by

| TABLE 2. Second-level index \(Q^1_1\) and weighting factor of \(\psi^1_1\). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \(Q^1_1\)       | \(Q^2_1\)       | \(Q^3_1\)       | \(Q^4_1\)       | \(\omega^{a1}_1\) | \(\omega^{a2}_1\) | \(\omega^{a3}_1\) | \(\omega^{a4}_1\) |
| 1.000           | 0.776           | 0.461           | 0.030           | 0.359           | 0.210           | 0.316           | 0.115           |

| TABLE 3. Second-level index \(Q^1_2\) and weighting factor of \(\psi^1_2\). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \(Q^1_2\)       | \(Q^2_2\)       | \(\omega^{a1}_2\) | \(\omega^{a2}_2\) |
| 0.493           | 0.726           | 0.596           | 0.404           |

| TABLE 4. Second-level index \(Q^1_3\) and weighting factor of \(\psi^1_3\). |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \(Q^1_3\)       | \(Q^2_3\)       | \(Q^3_3\)       | \(\omega^{a1}_3\) | \(\omega^{a2}_3\) | \(\omega^{a3}_3\) | \(\omega^{a4}_3\) |
| 0.385           | 0.341           | 0.579           | 0.548           | 0.097           | 0.355           |
TABLE 5. Second-level index $Q_i^j$ and weighting factor of $\psi_2^j$.

| $Q_1^j$ | $Q_2^j$ | $Q_3^j$ | $Q_4^j$ | $Q_5^j$ | $\omega_{21}^j$ | $\omega_{22}^j$ | $\omega_{23}^j$ | $\omega_{24}^j$ | $\omega_{25}^j$ |
|---------|---------|---------|---------|---------|---------------|---------------|---------------|---------------|---------------|
| 1.000   | 0.900   | 0.750   | 0.750   | 0.350   | 0.230         | 0.351         | 0.168         | 0.189         | 0.062         |

$\Psi_\phi$ is $\overline{Q}(\Psi_\phi) = \frac{1}{N} \sum_{i=1}^{N} Q(\Psi_\phi^i) = 0.5937$. It shows that the quality and level of auto collaborative sales of the $\Psi_\phi$ needs to be further improved in the future, and the key target of the improvement is the dealer enterprises whose evaluation value is less than 0.5937.

$\forall Q(\Psi_\phi^i)$, using the relationship

$$\Omega = \begin{cases} 
1, & \text{iff}: Q(\Psi_\phi^i) < \overline{Q}(\Psi_\phi) \\
0, & \text{iff}: Q(\Psi_\phi^i) \geq \overline{Q}(\Psi_\phi)
\end{cases}$$

and traversing all dealers under its jurisdiction in turn, the number of dealer enterprises below the average value of evaluation can be obtained: $\Omega' = \left( Q(\Psi_\phi^i) < \overline{Q}(\Psi_\phi) \right) = 251$. For these 251 dealers below the average, core enterprise $\Psi_\phi$ can issue corresponding rectification measures according to the evaluation results of the first-level indexes calculated by the cloud platform. For the dealer enterprises whose evaluation results are not qualified, $\Psi_\phi$ can further issue more specific rectification opinions according to the evaluation result value of the secondary index calculated by the cloud platform. For example, if a disqualified dealer $\Psi_\phi^a$ has a low evaluation result of the second-level index $Q_2^a$ it indicates that $\Psi_\phi^a$ has a long-term problem of untimely payment. Therefore, a warning or corresponding punishment shall be given to $\Psi_\phi^a$ for the issue of payment in the rectification opinion.

In order to provide further qualitative decision support for the collaborative marketing situation, a pie chart of the corresponding evaluation results was generated, as shown in Fig. 7. It can be seen from the figure that there are 30 dealer enterprises with the evaluation result value calculated by using the cloud platform data source in the interval $(0, 0.2)$, accounting for 5.155%. There are 76 dealers in the interval $[0.2, 0.4)$, accounting for 13.06%. Located in the interval...
[0.4, 0.6) accounted for 152 dealers, 26.12%. Located in the interval [0.6, 0.8) accounted for 238 dealers, 40.89%. Located in the interval [0.8, 1) accounted for 86 dealers, 14.78%.

It can be seen that the overall sales level of most dealers’ cooperative enterprises is good, which is also in line with \( \Psi^\phi \)'s marketing management goals, which indirectly shows that \( \Psi^\phi \)'s sales management strategy has basically achieved the expected results. In spite of this, about one-quarter of the dealers’ evaluation results are qualified, and these dealers will be the objects that \( \Psi^\phi \) needs to focus on and improve in the future. It can make use of the secondary index value calculated by the algorithm in this article to propose corresponding improvements in time for the individual secondary index values that are too low. Secondly, excellent and unqualified dealers account for about one-seventh, that is, there are fewer dealers with very good comprehensive marketing level, which also indirectly shows that the management methods of \( \Psi^\phi \) need to be further improved. For unqualified dealers, \( \Psi^\phi \) should give targeted warnings based on the specific secondary index values, and give appropriate penalties in combination with \( \Psi^\phi \)'s marketing rules and regulations. For those dealers with poor evaluation results, \( \Psi^\phi \) can release the collaboration with them and re-select new dealers to join the sales collaboration chain.

In the above-mentioned marketing collaboration chain, some dealer enterprises must inevitably cross-chain sales collaboration business, which leads to the occurrence of cross-industry chain assessment. In view of this, we select the enterprises participating in the business cooperation of any three sales industry chains from the above dealers, and make a comparative analysis of their cross-chain evaluation, as shown in Fig. 8. The abscissa is composed of three-dimension triplets \( \Psi^\phi (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \), \( x = 1, 2, \ldots, 7 \). The first dimension \( \Psi^\phi \) represents any dealer participating in the three cross-chain interactions at the same time, and the other dimension \( (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \) represents the three industry chains involved in the corresponding dealer. The vertical coordinate represents the corresponding business evaluation results of different dealer enterprises in different industrial chains.

According to the above semantics, there are 7 dealers participating in the collaboration of the 3 industrial chains at the same time, indicating that these 7 dealers have sales business synergies with the 3 core vehicle manufacturers. Then, we compared and analyzed from the dimensions of dealer and industrial chain.

Firstly, comprehensively compare the evaluation results of \( \Psi^1, \Psi^2, \Psi^3, \Psi^4, \Psi^5, \Psi^6, \Psi^7 \) with the three industrial chain \( (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \) in terms of sales collaboration in the cloud platform. It can be seen from the figure that the evaluation results of \( \Psi^\phi (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \) are all excellent, indicating that dealer \( \Psi^\phi \) pay special attention to the management of sales collaboration business. The evaluation results of \( \Psi^6 (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \) are all lower than 0.6, which is the lowest comprehensive evaluation among the seven dealers. It shows that dealer \( \Psi^\phi \) does not pay attention or lacks effective sales collaboration management methods, which results in the majority of its comprehensive sales evaluation being in the unqualified range. In order to improve and enhance the sales cooperation quality of \( \Psi^\phi \), the dealer can make specific improvement measures by querying and analyzing the evaluation value of each secondary index on the cloud platform. For \( \Psi^5 \), its three evaluation results \( \Psi^5 (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \) fluctuate greatly. For example, its evaluation result in the industrial chain \( \overline{\Psi}_\alpha \) is the lowest, but its evaluation result in the industrial chain \( \overline{\Psi}_\beta \) is the highest. It shows that \( \Psi^5 \)'s industry chain collaboration level has great growth potential, and it can strengthen sales collaboration management with industry chain \( \overline{\Psi}_\alpha \) in the future.

Comprehensive comparison of the evaluation results of the three industrial chains \( (\overline{\Psi}_\alpha, \overline{\Psi}_\beta, \overline{\Psi}_\gamma) \). It is not difficult to see...
from the figure that the evaluation results of the industrial chain $\mathcal{W}_\alpha$ are relatively low overall, which indicates that the core vehicle manufacturer in $\mathcal{W}_\alpha$ may not attach importance to the management of its dealers. The evaluation results of the industrial chain $\mathcal{W}_\beta$ are relatively highest, indicating that the core vehicle manufacturer in $\mathcal{W}_\beta$ attaches great importance to the management of its dealers. It indirectly shows that the evaluation results of the sales risk, sales trend and profitability of the industrial chain $\mathcal{W}_\beta$ are in line with the expected objectives, showing a better marketing control and development trend.

Through the above analysis and simulation, it can be seen that compared to the traditional single-industry chain evaluation method, the multi-core and cross-chain evaluation method has more extensive advantages. From different dimensions, the advantages summarized are as shown in Table 6.

The multi-core and cross-chain evaluation method based on the multi-core network collaboration relationship makes up for the limitation that the traditional method only supports single-core industry chain evaluation. In the cloud environment, collaborative dealers use the horizontal comparison of cross-industry chain evaluation values, which not only make the evaluation results more instructive, but also provide more objective decision support for improving the marketing level. The cross-chain evaluation of core vehicle manufacturers not only facilitate efficient management and control of dealership enterprises, but also facilitate the elimination or selection of cooperative enterprises in other industrial chains. Therefore, the multi-core and cross chain evaluation method proposed in this article provides an effective solution for the large-scale division and cooperation of upstream and downstream enterprises in the future.

| Evaluation mode | Evaluation of single industry chain | Evaluation of multi-core and cross-chain |
|-----------------|------------------------------------|----------------------------------------|
| Software support conditions | Single software system | Cloud platform |
| Database support conditions | Single database | Database cluster |
| Number of core enterprises | 1 | $n(n \geq 2)$ |
| Collaboration | Traditional two-way collaboration | Multi-core meshed vertical and horizontal bidirectional complex relationship |
| Evaluation relationship | One-to-many simple evaluation | Many-to-many cross evaluation |
| First-level and second-level index weight | Changeless | Dynamic configuration based on cloud platform |
| Horizontal comparison of evaluation results (auto dealers) | Only supports intra-chain comparison | Supporting cross-chain comparison of multiple industry chains |
| Horizontal comparison of evaluation results (core vehicle manufacturer) | Not-support | Support |
| After terminating the cooperation of dealers with poor evaluation results | Difficult to find alternative dealers | Using cloud platform evaluation results to automatically recommend alternative dealers of other industrial chains |
| Decision support for improving cooperation level | Only limited to the single chain | Supporting multi-chain comprehensive comparison and improvement |

X. CONCLUSION

The evaluation of industrial chain cooperative enterprises is an important means to improve the business management of core vehicle manufacturing enterprises, and it is also an important way to strengthen the decision-making control of automobile manufacturing services. However, as the competition in the automotive industry chain continues to intensify, the business interaction between core enterprises and collaborative enterprises in a wide-area cloud manufacturing environment is no longer limited to a single industry chain. In particular, the gradual rise of large-scale cross-industry cluster collaboration has caused severe challenges for the interaction and control of upstream and downstream in the industry chain.

In response to the above problems, this article abandons the traditional single-chain evaluation program, innovatively from the perspective of cross-chain interaction of multiple industry chains, by analyzing the multi-core mess collaboration relationship between the upstream supply chain and downstream marketing chain, and then the multi-core and cross-chain collaboration relationship model is attained. It also constructs a multi-level and cross-chain structure framework based on the sales evaluation decision problem of the automotive marketing chain, combined with the sales evaluation influencing factors and internal relationships. According to the overall decision-making goal of marketing evaluation, it is decomposed into first-level indexes such as marketing risk, marketing trends, profitability and so on.
And further decomposing the first-level indexes into corresponding second-level indexes, meanwhile, the original data source provided by the cloud platform is converted into quantitative information that can be directly used through quantitative methods. Then, the multi-core and cross-chain evaluation model based on collaborative relationship is proposed by combining the qualitative and quantitative methods and the index system. Based on the proposed evaluation model, the algorithm supporting multi-core and cross-chain index system collaborative evaluation is given. Then using the business data source of the cloud platform, the corresponding calculation example analysis and simulation analysis are given, which shows the feasibility of the multi-core and cross-chain collaborative evaluation method proposed in this article.

The multi-core and cross-chain evaluation framework, model and algorithm proposed and constructed in this article are universal for the application of cross-industry chain evaluation. It is not only limited to the cross-chain evaluation of the downstream marketing chain, but also applicable to the cross-chain evaluation of the upstream supply chain. The difference is that the corresponding first-level and second-level index systems need to be constructed separately. Secondly, the adopted cross-chain index system is mainly applicable to the cloud platform, which will need to be supported by the cloud platform software environment.

Despite the above two limitations, with the further refinement of the division of labor and collaboration in the global industry chain, large-scale collaboration in a wide-area environment will gradually replace the collaboration of traditional single industry chains, and cross-chain evaluation based on cloud platforms will also gradually replace the single-chain evaluation of traditional software systems. Therefore, the research work of this article is also prospective. In the future, we will further explore the multi-core and cross-chain method of upstream supply chain business cooperation from the perspective of upstream supply chain, so as to form a complete evaluation system that supports the coordination of cross-chain interaction between the entire upstream and downstream industrial chain.

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