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RESEARCH ARTICLE

Research on Pattern Matching of Dynamic Sustainable Procurement Decision-Making for Agricultural Machinery Equipment Parts

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ABSTRACT With the digital transformation of the manufacturing industry and the diversification of production methods of agricultural machinery and equipment, external purchase, external coordination, and self-made products continue to increase. If agricultural machinery manufacturing enterprises want to maintain maximum benefits in the fierce competition, they must pay attention to the collaborative procurement decision-making model and the relationship between production, supply, and marketing, and seek a comprehensive dynamic sustainable procurement strategy under the supply chain environment. In this paper, from the manufacturers of agricultural machinery manufacturing enterprises, firstly, three procurement strategies based on line-side inventory supply, third-party logistics supply, and dynamic sustainable supply are studied respectively, while a system dynamics model of collaborative procurement strategy for the agricultural machinery supply chain is constructed and the three procurement strategy models are simulated and analyzed Secondly, the simulation results are analyzed to establish the measurement indexes for evaluating sustainable procurement model matching, and a procurement model matching measurement model based on the topological superiority of object elements combined with the topological hierarchical analysis method and CRITIC comprehensive assignment method is proposed to determine the index weights. And using the correlation function calculation, we get the comprehensive superiority ranking of procurement patterns and the correlation comparison of individual indicators and output the optimal procurement matching pattern and pattern recognition degree. Finally, an application example is given to verify the correctness and practicability of the proposed decision-making model, to provide a qualitative and quantitative dynamic sustainable procurement multi-attribute decision-making tool for the procurement management of agricultural machinery equipment manufacturing enterprises.

INDEX TERMS Agricultural machinery supply chain, dynamic sustainability, system dynamics, extension theory, procurement decision model.

I. INTRODUCTION

With the diversification of agricultural equipment production methods, and the increasing number of outsourcing, outsourcing orders, and self-made products, the reliance of the demand side of the agricultural machinery manufacturing industry on the procurement model has gradually increased, and the upstream procurement suppliers in the agricultural machinery supply chain nodes have become more closely monitored [1]. Like most manufacturing industries, the material cost of agricultural equipment enterprises is the main cost, generally accounting for about 45% to 65% of the total cost. The reasonable choice of procurement mode makes every penny of procurement cost savings directly into profit, and the huge leverage on the profit of agricultural machinery enterprises makes its role increasingly prominent [2], [3], [4]. To provide products and services to the market, agricultural machinery manufacturing companies must rely on the

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procurement of raw materials and components [5]. However, due to the rising cost of raw materials, labor, logistics, and other various resources, as well as the impact of the epidemic and the adjustment of the supply structure, agricultural machinery manufacturing enterprises want to maintain the maximum benefit in the fierce competition, they must pay attention to the matching relationship between the collaborative procurement decision-making model and production, supply and sales. At the same time, strive to seek dynamic and sustainable collaborative procurement strategies for comprehensive competitiveness in the supply chain environment, to ensure that suppliers achieve the goals of bulk procurement of materials, rapidity, and consistency of customer order demand information under the premise of obtaining lower cost products, and to provide important decisions and basis for global manufacturing companies to achieve the goal of efficient supply chain procurement management.

Agricultural machinery manufacturing service enterprises through the selection of a suitable competitive procurement plan model to match the ''production-supply-sales'' three stages of various raw materials procurement and parts orders demand [6], to achieve the maximum reduction of the enterprise backlog of product inventory, highlight the competitive scale of product procurement advantages, shorten the production supply chain response time, reduce the product order completion lead time and production time, improve the accuracy of the procurement plan, the enterprise on-time delivery rate, inventory turnover utilization frequency, and enterprise production turnover efficiency, reduce the cost of inventory of agricultural equipment products, reduce inventory capital occupation, thereby increasing prof-its [7]. The procurement model assumes the role of intermediary services and coordinates the three stages of ''production-supply-sales'', which constitute the business process of procurement, production, and sales from raw materials to finished products through the sales-driven production, production-driven procurement process, and procurement-driven supply [8], [9]. Procurement activities are the basis of the entire activity of the enterprise, whether it is the production and processing of products, distribution, subassembly, and sales, all based on material procurement, so the core of the supply chain is the procurement of raw materials.

Through reviewing literature and combining with practical research, it is found that the procurement mode of agricultural machinery manufacturing enterprises mostly stays in the traditional procurement mode, which has a single form of procurement, poor flexibility, low dynamic sustainability, and a low degree of collaborative service information. Taking the system automatic price comparison procurement mode with product price as a single factor and the multi-attribute price comparison procurement mode judged by experts in the field as examples, these modes are usually chosen by the procurement salesmen of agricultural machinery manufacturing enterprises according to the procurement BOM list and experience, and the subjective un-controllable factors are prominent, so it is impossible to make a timely and accurate judgment on the procurement mode comprehensively and scientifically [10]. Meanwhile, the evaluation decision methods used by research scholars, such as hierarchical analysis, fuzzy evaluation method, topological evaluation method, principal component analysis, and combined assignment method, have problems such as strong subjectivity and unbalanced weight distribution in the evaluation decision process, relying on experts' knowledge of the weights of evaluation indexes. In the evaluation decision results, only the comprehensive ranking of matching patterns is shown, and the affiliation between individual indicators and evaluation levels is missing, which is not the very objective for the credibility of indicator data. And the Extension of the Analytic Hierarchy Process (EAHP) considers the qualitative and quantitative changes of things based on the general decision-making method, which makes the final evaluation results more objective and fair, and combines Criteria Importance Through Inter-criteria Correlation (CRITIC) to make the weight coefficients more objective and to reflect the degree of correlation of individual indicators to the comprehensive value. The process and advantages of the study are reflected in the following: firstly, the EAHP method is used to determine the subjective weights of each index, and the judgment matrix is constructed with interval numbers, so that the weight calculation and the consistency test are carried out simultaneously, avoiding the problem of multiple calculations when the consistency test is not passed after the calculation of the traditional hierarchical analysis method, secondly, the objective weights of the evaluation indexes are calculated by the CRITIC method, and finally the subjective and objective weight values are coupled and calculated to obtain the comprehensive weights of each index so that the two methods can achieve complementary advantages.

On the other hand, scholars have done a lot of research on procurement models. Banerjee et al. [11] the issue of multi-stage inventory procurement model for purchasers in JIT supply chain environment is studied. Shabani-Naeeni et al. [12] a new multi-objective mixed integer planning model from a supply chain perspective. Erma et al. [13] with the objective of maximizing the manufacturer's expected profit, a dynamic programming model is constructed to analyze the optimal purchasing strategy under uncertain demand. Nikandish et al. [14] the integrated procurement strategy is analyzed taking into account the dynamic and flexible nature of customer demand information in various aspects. Utama et al. [15] the two-stage purchasing decision problem is studied and an integrated purchasing-production inventory model is constructed. Mohammadi [16] study and analyze the differentiated purchasing management strategy proposed by integrated reliability model and MRP system. Dhahri et al. [17] integrated production, integrated procurement and delivery control for unreliable manufacturing systems and multiple suppliers are analyzed, and new optimal control strategies for collaborative production and supply are proposed. Janamanchi [18] using the system dynamics tool, the purchasing lot control model under different demand states is studied and analyzed. Karabag and Tan [19] from the supply chain perspective, the study analyzes the integration model of production, supply and sales. Mangla et al. [20] Analysis of sustainability drivers, considering the ecological, economic, and social aspects of sustainable strategies. Roberto et al. [21] Study of indicator factors for supply chain performance measurement, extending from corporate economic production to market environment to sustainable development strategies. However, the above scholars have focused on supply chain procurement strategy optimization, single analysis of procurement model, optimal order procurement strategy, and risk sharing and profit sharing in the procurement process, ignoring the problem that different procurement decision models must be used at different stages and the matching degree between them., and lacking the study of dynamic and sustainable development strategy.

In this paper, three procurement strategies based on lineside inventory control supply, third-party logistics supply, and dynamic sustainable supply are first studied by the manufacturers of agricultural equipment enterprises. At the same time, the system dynamics (SD) model of collaborative purchasing strategy is constructed, and the three purchasing strategy models are simulated and analyzed. Secondly, the simulation results are analyzed, the measurement indicators for evaluating the matching of collaborative procurement modes are set, and the extension matter-element model is established by using the extension theory. The index weight is determined by the extension optimization of matter-element, the extension analytic hierarchy process, and the critical comprehensive weighting method. The comprehensive optimization ranking of procurement modes and the correlation comparison of single indicators are calculated by the correlation function, and the optimal procurement matching mode and pattern recognition are output. Finally, the validation was carried out in a leading agricultural equipment manufacturing enterprise in China, and the validation results provided a qualitative and quantitative collaborative purchasing decision method for the procurement management of the agricultural equipment manufacturing industry.

The rest of this paper is organized as follows. In Section 2, the system dynamics models of three procurement models from the perspective of the agricultural machinery supply chain are constructed. In Section 3, case simulation and result analysis are carried out for three procurement strategy models. In Section 4, the measurement index system of the collaborative procurement decision-making mode of the agricultural machinery supply chain is constructed. In Section 5, a pattern-matching model for purchasing decision-making in the agricultural machinery supply chain is proposed, and the optimal purchasing matching pattern and pattern recognition degree are obtained based on an example, which verifies the feasibility of the model. In Section 6, the corresponding conclusions are given.

II. BUILDING AN SD MODEL FOR COLLABORATIVE PROCUREMENT STRATEGY OF AGRICULTURAL MACHINERY SUPPLY CHAIN

A. MATERIAL PROCUREMENT MODEL BASED ON LINESIDE INVENTORY CONTROL

1) BASIC ASSUMPTIONS FOR MODEL BUILDING

In the research model, the following relevant assumptions are made for the system to reduce the influence of some unnecessary extraneous factors.

(1) Without considering the source of materials (purchased, outsourced, self-made parts), only one representative material (finished production, parts, raw materials) is considered in the model.

(2) Assume that the finished material or key component product is a single independent demand product, and all finished material and intermediate material component products have the same product demand for the same raw material.

(3) Assume that in the supply chain environment, the delay or fluctuation of information exchange within the production and functional departments at each time node of the enterprise is small, and only the production process delay is considered.

(4) It is assumed that the storage capacity of each inventory within the agricultural equipment enterprise is not limited by quantity.

2) ESTABLISHMENT OF CAUSE-AND-EFFECT FEEDBACK RELATIONSHIPS AND DESIGN OF SYSTEM FLOW DIAGRAMS FOR THE LINESIDE INVENTORY CONTROL PURCHASING MODEL

A comparative study of the main characteristics of the structure of the inventory operation system and the problem of inventory operation influence mechanism in the base of agricultural machinery manufacturing enterprises in China was conducted to derive the common influence mechanism factors among the main structures constituting the inventory system. The structural causality diagram between inventory systems was drawn using the SD nested correlation simulation software from the high correlation between structural factors with each other, as shown in Figure 1.

Since the designed and derived causality diagram only briefly describes the basic properties of the factors at the level of the wire-side inventory feedback model structure, the actual system operation model must focus on the five basic auxiliary factor variables before and after it, namely the actual system rate, state, information flow, material flow, and source-sink flow. The basic properties of these five different factors are not yet able to make a clear distinction, so the SD model flow diagram was designed and derived by itself on the constructed model, as shown in Figure 2.

As shown in table 1, the relationships of the variables in the SD model of the sourcing strategy in this model are also defined to provide a basis for simulation analysis.

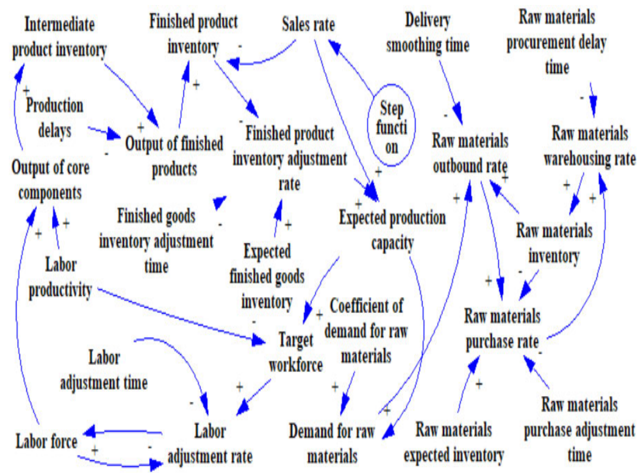

FIGURE 1. Cause-and-effect feedback diagram of the lineside inventory control purchasing model.

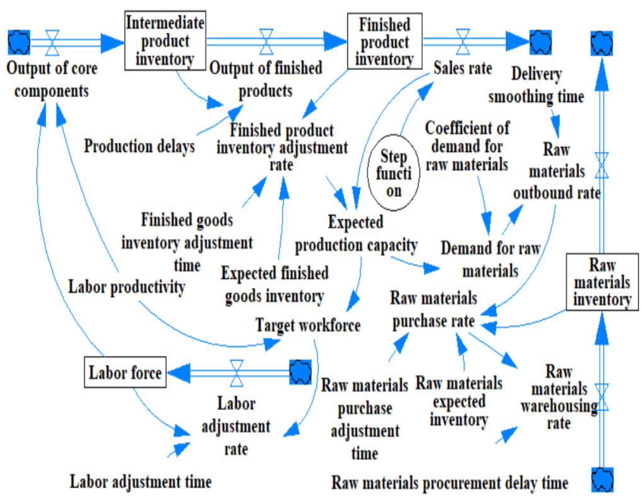

FIGURE 2. System flow diagram of the lineside inventory control purchasing model.

B. PROCUREMENT MODEL OF THIRD-PARTY LOGISTICS MODEL SUPPLY

1) BASIC ASSUMPTIONS FOR MODEL BUILDING

In the research model, the following relevant assumptions are made for the system to reduce the influence of some unnecessary extraneous factors.

(1) Without considering the source of materials (purchased, outsourced, self-made parts), only one representative material (finished production, parts, raw materials) is considered in the model.

(2) It is assumed that after adopting this mode, the annual order processing fee of any representative y materials provided by agricultural machinery manufacturing enterprises is the same.

(3) Assuming that the actual inventory has been determined, the material supplier takes the annual average material demand level of the manufacturing enterprise as the calculation basis.

(4) Assuming that only when the unit price of V materials increases within a certain range, and the marginal increase of the total purchase cost of V materials by the enterprise is less than its inventory cost savings, an agricultural machinery and equipment enterprise reasonably choose this mode, that is

$$(1+\beta_v) P_v D_v \leq P_v D_v + [(Q_{iv}+Q_{ev})/2] \times H_{cv} P_v \quad (1)$$

(5) Assuming that this mode is selected only from the perspective of reducing the unit cost of purchased materials, the actual cost increase rate of the unit price of V

TABLE 1. SD model variable relationships based on sourcing strategy under the lineside inventory control model.

Variable Types	Variable Name	Mathematical Logic Relationships	Initial Value	Unit
Horizontal Variables	Parts Library	INTEG (Parts Production-Finished product yield)	BOM (Bill of materials)	Pieces
	Finished goods inventory	INTEG (Output rate-Sales Rate)	24	Tower
	Raw material storage	INTEG (Inventory rate-Sales Rate)	18	Pieces
Rate variable	Sales Rate	9+Step（8, 30）	9	Tower
	Inventory rate	Delay1(Purchasing Rate-Delay time)	2	Day
	Outbound rate	SMOOTH (Material requirements, Outbound smoothing time)	5	Day
Auxiliary Variables	Parts Production	Labor productivity×Labor force	19	Tower/Day
	Raw material requirements	Raw material requirement factor×Desired production capacity	20	Pieces
Constants	Purchase Delay	2	0	Day
	Production delays	2	0	Day

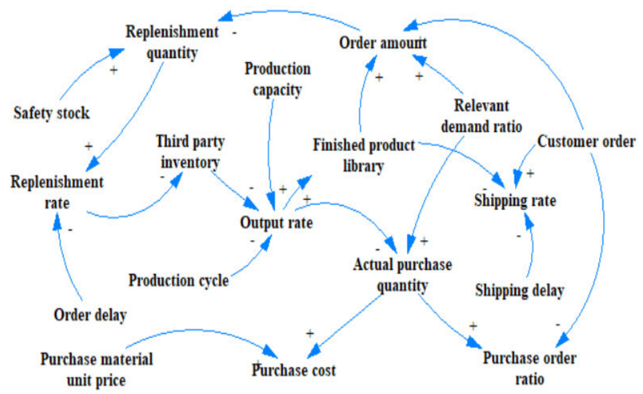

FIGURE 3. Causal feedback relationship diagram of third-party logistics procurement model.

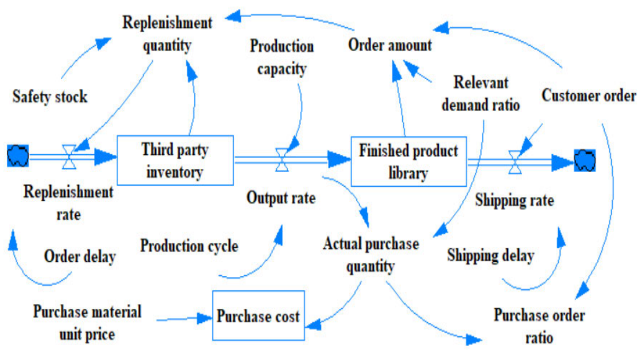

FIGURE 4. System flow diagram of third-party logistics procurement model.

materials is:

$$\beta_v \leq [(Q_{iv} + Q_{ev}) \times H_{cv}] / (2 \times D_v) \tag{2}$$

where, β_v represents the promotion rate of V material unit price level sold by the enterprise; P_v refers to the change range of unit price level of V materials purchased by the enterprise in each period;D_v refers to the annual actual total demand of V materials produced by a production enterprise; Q_{iv} refers to the stock of V materials of an enterprise at the beginning of the year; Q_{ev} refers to the average inventory rate of the year-end inventory of V materials in the inventory of the enterprise unit; H_{cv} refers to the enterprise unit inventory V material inventory management rate.

2) DETERMINATION OF CAUSAL FEEDBACK RELATIONSHIP OF THIRD-PARTY LOGISTICS PROCUREMENT MODEL AND DESIGN OF SYSTEM FLOW DIAGRAM

Making a comparative study on the functional characteristics and internal operation mechanism process of the third-party inventory management operation model system used by an agricultural machinery manufacturing and sales enterprise obtains some influencing factors of each system structure process in the model system and attempts to draw the causal relationship diagram of the operation of the modeling system by using SD nested system simulation software according to the internal causal relationship between these key factors, As shown in Figure 3.

Since the constructed causality diagram only summarizes several basic contents of the supply and feedback system structure of the third-party logistics system, the five-factor variables, namely, operation rate, state, auxiliary factor variables, information flow, material flow, and source-sink flow, should be emphatically considered in the operation of the whole system. They cannot be distinguished one by one due to their different properties, so the SD model flow diagram is designed and constructed, as shown in Figure 4.

The relationships of the variables in the SD model of the sourcing strategy in this model are also defined to provide a basis for simulation analysis, as shown in table 2.

C. PROCUREMENT MODEL FOR DYNAMIC AND SUSTAINABLE SUPPLY

1) BASIC ASSUMPTIONS FOR MODEL BUILDING

(1) Without considering the source of materials (purchased, outsourced, self-made parts), only one representative material (finished production, parts, raw materials) is considered in the model.
(2) Assume that the customer demand is a random integer that fluctuates up and down within some integer interval.
(3) Assume that there are only three suppliers at the same time, which Supplier 1 is the main supplier, and discuss the supply situation without considering the participation of other material suppliers.
(4) Assume that customer demand expectations obey a uniform distribution.
(5) Assuming that the actual inventory has been determined, the main suppliers of materials are calculated based on the average annual demand inventory of manufacturing enterprises.
(6) Assuming that the supply organization model of third-party logistics is adopted and that the headquarters of agricultural machinery supplier enterprises and other agricultural machinery parts manufacturing and processing enterprises are outside the same economic region of the country, the supplier enterprises do not consider transportation delays when supplying directly to processing enterprises at the same time.

Agricultural machinery manufacturers will be affected by customer demand and season for each order production period, assuming that the customer demand forecast delay perimeter is 3 cycles, then the customer demand for each period is

$$k_i = k_{i-1} + \frac{k_{i-1} - k'_{i-1}}{3} \tag{3}$$

where k_i is the customer demand per period;k'_i is the customer demand forecast per period?

The modeling process mainly considers three suppliers, and when supplier 1 has a supply delay or disruption, a co-sourcing strategy is adopted to increase the co-sourcing volume for supplier 2 and supplier 3. Similarly, when supplier 2 and supplier 3 experience supply delays or disruptions, the

TABLE 2. SD model variable relationships for sourcing strategies in the third-party logistics model.

Variable Types	Variable Name	Mathematical Logic Relationships	Initial Value	Unit
Horizontal Variables	Tripartite Inventory	INTEG(Replenishment rate-Outputs)	20	Size
	Finished goods inventory	INTEG(Output rate-Shipping Rate)	Customers Orders	Vehicle
	Purchasing Costs	Actual purchase volume×Unit price of purchased materials	0	Yuan
Rate variable	Replenishment rate	SMOOTH (Replenishment volume, Order Delay)	0	Size/Week
	Output rate	INTEG (Production capacity, Production cycle)	0	Size/Week
Auxiliary Variables	Replenishment volume	MAX(MAX(0, Security Inventory-Tripartite Inventory), Order quantity-Tripartite Inventory)	0	Taiwan/Day
	Actual purchase volume	INTEG (MAX (Output rate× Related Demand Ratio,0))	0	Size
	Customer Orders	INTEG (RANDOR UNIFORM (260,300,15))	20	Pieces
Constants	Purchase Delay	3	0	Day
	Production delay	0.5	0	Day
	Shipping Delays	0.5	0	Day

corresponding co-sourcing strategy is adopted. In particular, to consider another type of sudden supply chain exception, when a supply chain system's normal operation time node table suddenly appeared a supplier delay or supply chain disruption, the supplier supply and the agricultural machinery manufacturer shipments will also usually appear the following changes.

The changes are listed below: Change 1, when the actual current inventory quantity provided by an agricultural machinery manufacturer is much smaller than the actual quantity demanded by the customer, the shipment is calculated according to the former. Change 2, when the actual current inventory quantity of an agricultural machinery manufacturer is much larger than the actual quantity demanded by the customer, the shipment is calculated according to the latter. Change 3, when the customer supply market conditions remain relatively more normal supply situation, three or more suppliers can basically ensure that customers deliver in full and on time and complete the number of agricultural machinery manufacturers' orders demand, the supplier supply also basically maintain and customers' actual market forecast supply-demand equal. That is:

$$\sum_{x=1}^{3} O_{xi} = W_i = k_i' \quad (4)$$

$$F_i = \min(Z_i, k_i) \quad (5)$$

where O_{xi} is the number of total order rates per period for the manufacturer. W_i is the total number of total order completions per period for the manufacturer. F_i is the total number of manufacturer shipments per period. Z_i is the amount of manufacturer inventory per period for the manufacturing company.

2) DETERMINATION OF CAUSAL FEEDBACK RELATIONSHIPS AND DESIGN OF SYSTEM FLOW DIAGRAM FOR DYNAMIC SUSTAINABLE PROCUREMENT MODEL

The main characteristic factors of operational system risks such as delayed operation and service interruption of agricultural machinery supplier system in the supply chain and network of agricultural machinery manufacturing enterprises and the mechanism of risk operation formation were systematically studied, and the cause-effect relationship of each element in the operating system was derived, as shown in Figure 5.

Since the designed causality diagram only briefly describes the causal loop in a dynamic and sustainable supply and feedback structure, it does not explicitly express the five different properties of the various factor variables that may be involved in the model flow, i.e., rate, state, auxiliary variable information flow, material flow, and source-sink information flow, and therefore also designs and draws the SD model flow diagram, as shown in Figure 6.

III. SD MODEL EXAMPLE SIMULATION AND RESULT ANALYSIS

In this paper, we take a domestic agricultural machinery manufacturer (M) as an example, because it is a leading enterprise, it has certain representativeness. Due to the complex product characteristics of the manufacturing equipment itself and the high level of production costs, market demand volatility, and

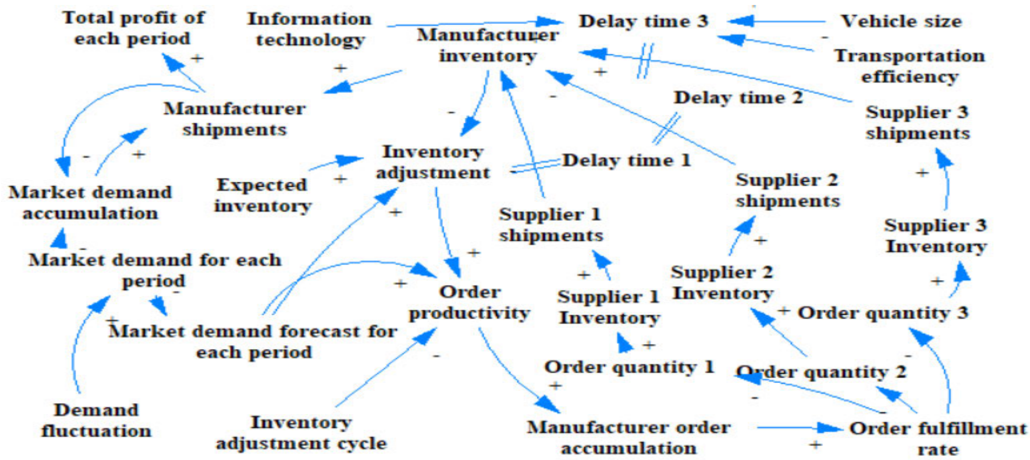

FIGURE 5. Cause-and-effect feedback relationship of dynamic sustainable procurement model.

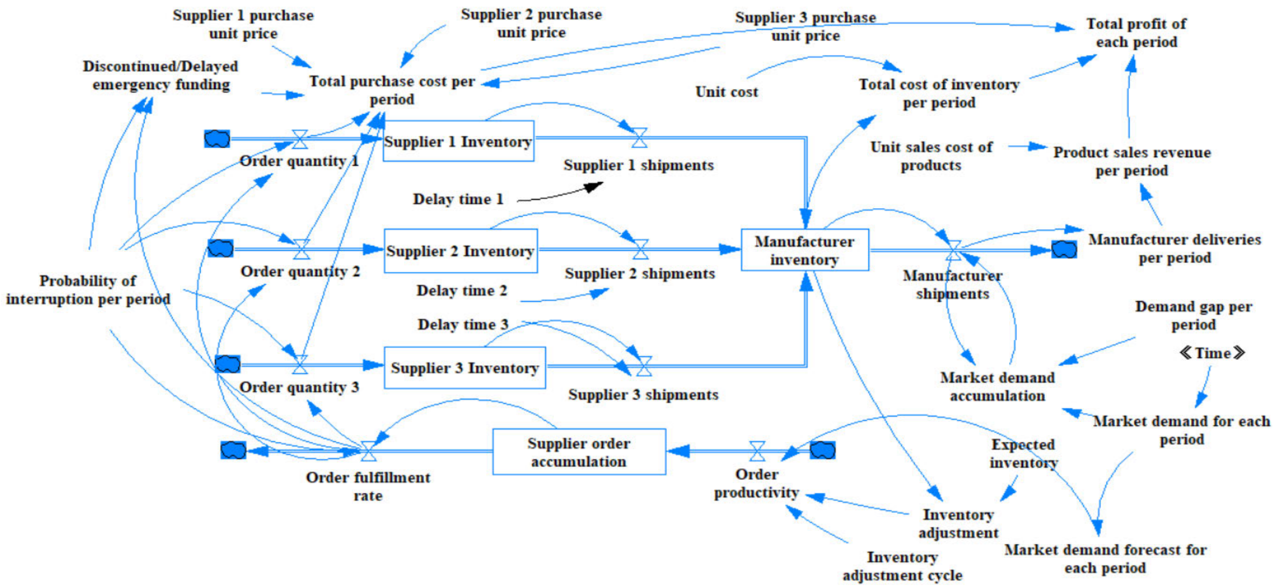

FIGURE 6. System flow diagram of dynamic sustainable procurement model.

other reasons, making the industry's leading manufacturing services company M had to implement the order "pull" supply chain management operating strategy, procurement, inventory integration management mode of operation also with the three models built to maintain consistency. To obtain better model simulation results, a certain type of finished power rake products and important raw material components with relevant performance demand characteristics of M enterprises with the most representative characteristics of the industry were selected as important target objects for the study, and the SD model construction and simulation analysis of relevant products were carried out by combining the relevant product data of M enterprises.

A. SIMULATION AND RESULT ANALYSIS OF MATERIAL PROCUREMENT MODEL BASED ON LINESIDE INVENTORY CONTROL

The simulation results of the SD model based on the lineside inventory control theory for manufacturing firm M when there is a large abrupt change in the market demand structure and the sales rate is still running at a stepwise growth are shown in Figure 7.

It is clear from the above graph that when the sales rate fluctuates abruptly on the 30th day and increases by a small amount, the corresponding intermediate product inventory, finished goods inventory, and main raw material inventory all fluctuate abruptly to a large or certain extent 100 days before, where only the product inventory price of raw intermediate goods remains in a state of steady increase and change, while the finished goods inventory price and other raw material inventory are in a state of sharp decline. After a comprehensive analysis of procurement, production, sales, inventory fluctuations, and other factors, the lineside inventory control system can provide data feedback and adjust inventory production, thus gradually making the three types of product inventory price fluctuation cycle gradually converge, the three types of enterprise inventory indicators can maintain a stable operation after 150 days of operation. From the analysis results, it can be seen that the SD model of lineside inventory control in the agricultural machinery manufacturing industry constructed in this paper is consistent with the production and operation management model of the real system adopted by the enterprise production to.

B. THIRD-PARTY LOGISTICS MODEL SUPPLY PROCUREMENT MODEL SIMULATION AND RESULTS ANALYSIS

The simulation analysis of the third-party logistics model supply procurement model in terms of shipment rate, customer orders, output rate, and delivery rate is as follows.

From Figure 8, it is obvious that the relative fluctuation frequency between customer order quantity and delivery rate is basically at the same level, which indicates that the customer order demand can be satisfied in a more timely, accurate, and reasonable way by using this procurement combination strategy. However, most of the products of the companies related to the manufacture of agricultural machinery parts and components still experience both lower receipt rates and corresponding delays in the time completion points of customer orders in the actual commercial operation data.

Similarly, Figure 9 illustrates that in a third-party logistics supply model, the frequency of fluctuations between the shipment rate and the actual output rate will not be significant, further demonstrating that the output rate can be quickly calculated based on a single customer order.

At the same time, the simulation results further show that: from the viewpoint of the operation law of agricultural machinery supply chain system, the overall agricultural material production and procurement behavior of M-type enterprises is based on the customer order plan to drive the realization, and the centralized supply of material demand is based on the order production and supply plan formulated by the customer enterprise as a whole for overall coordination, to effectively ensure the organic consistency between the overall material purchase order quantity and market demand.

C. SIMULATION OF DYNAMIC SUSTAINABLE SUPPLY PROCUREMENT MODEL AND ANALYSIS OF RESULTS

In the dynamic sustainable supply procurement model, the main consideration is the fluctuation of the impact on the overall supply chain operation of M enterprises when there is a disruption or delay in supply. The simulation of the impact of the model on the inventory in case of disruptions and delays in the supply of each of the three suppliers is shown in Figure 10 and Figure 11.

The model assumes that Supplier 1 is the main supplier, whose sales volume is relatively lower than the rest of the suppliers in terms of market order share ratio, and when a supply disruption period occurs in the market, it is affected by the excess capacity supply of the remaining two suppliers and cannot meet the declining market demand volume, resulting in higher out-of-stock costs. When supplier 2 and supplier 3 have supply interruptions or even shortages are more serious, flexible, and reasonable dynamic centralized procurement of raw materials for the main supplier's products can effectively control costs and temporarily make up for the gap in market demand for products caused by short-term supply-demand interruptions, which has less impact on the actual cost control and future product profit margins of M enterprises' overall raw material procurement. It is also further shown that when considering that the main supplier has sufficient stable supply capacity, the manufacturer inventory level tends to be significantly higher than the inventory level

TABLE 3. SD model variable relationships for sourcing strategy under dynamic sustainability model.

Variable Types	Output rate Variable Name	Mathematical Logic Relationships	Initial Value	Unit
Horizontal Variables	Manufacturer Inventory	INTEG(Supplier shipment volume, Manufacturer shipments)	Order volume	Size
	Supplier Inventory	INTEG (Manufacturer purchasing volume, Supplier shipment volume)	0	Pieces
	Purchasing Costs	Actual purchase volume×Unit price of purchased materials	0	Yuan
Rate variable	Market Demand Rate	SMOOTH(Customer Needs，time)	0	Size/Week
	Output rate	INTEG (Production capacity, Production cycle)	0	Size/Week
Auxiliary Variables	Order quantity	INTEG (Order completion rate, Order decision factor)	0	Taiwan/Day
	Actual purchase volume	INTEG(MAX(Output rate× Related Demand Ratio,0))	0	Size
	Shipping volume	INTEG(Manufacturer Inventory, Accumulated market demand)	0	Pieces
Constants	Purchase Delay	3	0	Day
	Production delays	0.5	0	Day
	Supply Delay	0.5	0	Day

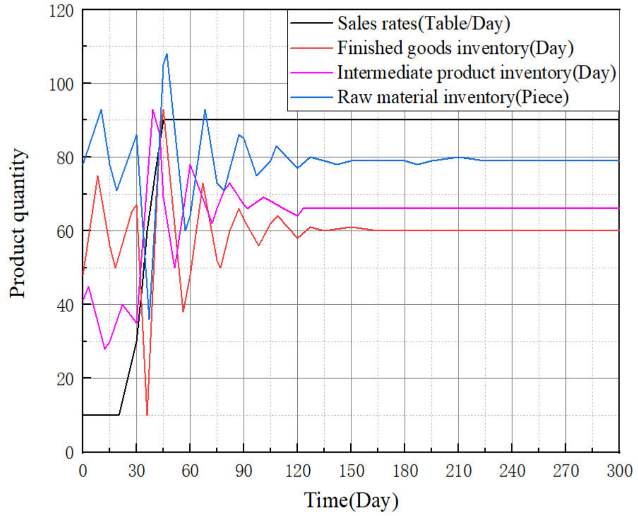

FIGURE 7. Simulation results of SD model for lineside inventory control.

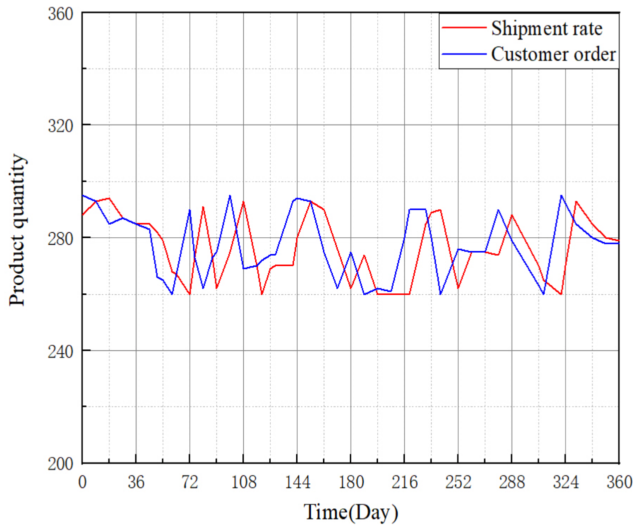

FIGURE 8. Simulation results of SD model of customer orders and delivery rate under third-party logistics.

of main supplier 1 for both supplier 2 and supplier 3 due to supply disruptions, and the corresponding zero inventory frequency is not high.

Similarly, the model can further assume the delay time of each supplier's actual delivery cycle per year, which corresponds to 1, 2, and 3 in the above figure. from Figure 11, it can be seen that when the supplier's delivery cycle becomes longer in a year, the delivery time of the actual delivery cycle will therefore be extended, and the range of variation and fluctuation of the actual supply inventory quantity per year also becomes larger, while the actual inventory quantity per period per year of the manufacturer The actual amount of inventory per period per year for the manufacturer also changes accordingly.

The three procurement models correspond to the three stages of production, inventory, and supply and sales decisions for parts and components. The material procurement model based on lineside inventory control addresses the

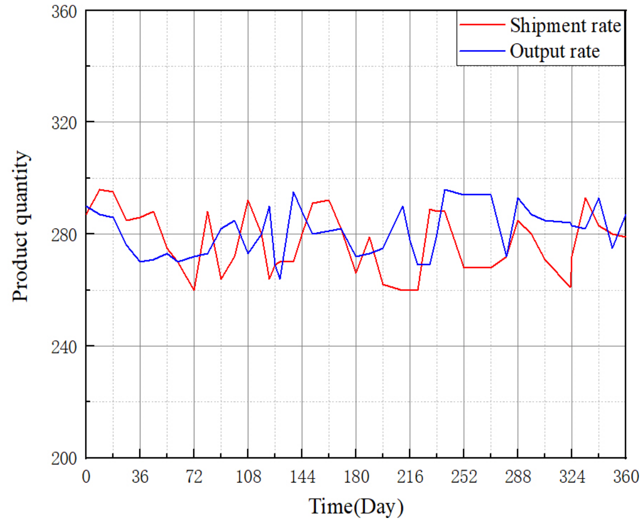

FIGURE 9. Simulation results of SD model of output rate and shipment rate under third-party logistics.

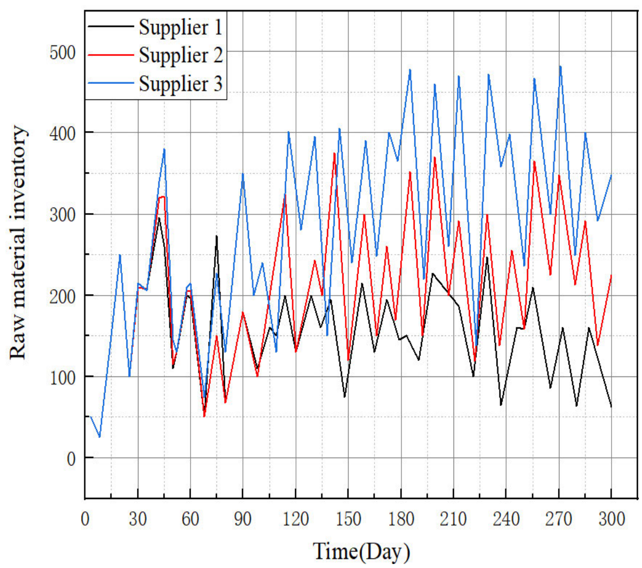

FIGURE 10. Simulation results of SD model of inventory change under different supplier supply disruptions.

uncertainties of market demand changes and sales changes and analyzes whether intermediate product inventory, finished goods inventory, and raw material inventory will change in the face of uncertainties and whether they are the same as when the enterprise is running production. The third-party logistics supply procurement model emphasizes the analysis of manufacturing and supply companies' delivery rates and customer orders, and the magnitude of change between output rates and delivery rates to determine whether the overall material procurement order quantity production and market demand quantity supply is consistent. The dynamic sustainable supply procurement model addresses interruptions and delays in the production and supply process and uses a manufacturing company and three suppliers as study subjects to analyze the impact that interruptions and delays in the cycle have on the company's procurement cycle, on-time

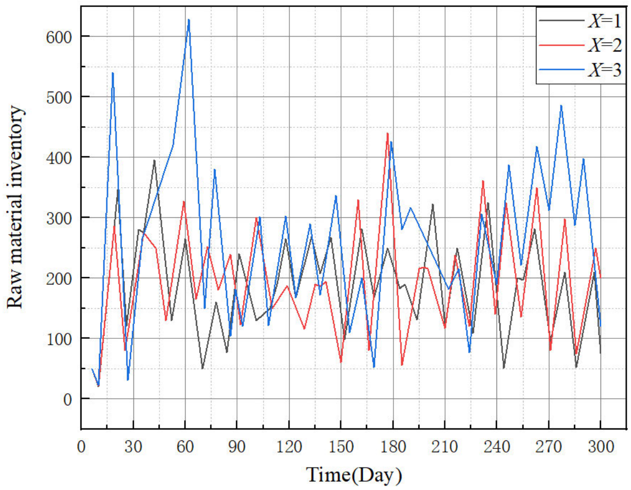

FIGURE 11. Simulation results of SD model of inventory change under different supply delay cycles.

delivery rate, production cycle, and inventory operating costs. Through example simulation analysis, the applicability and rationality of the three procurement models are verified to help manufacturing enterprises clarify the influencing factors of uncertainty at each stage, to improve the competitiveness of their products.

Finally, the analysis of the three models shows that enterprises should adhere to flexible, dynamic, and collaborative sustainable strategies, and adopt different purchasing decision models according to different stages and different situations. At the same time, enterprises should also coordinate the matching relationship between different purchasing decision models and product supply and sales.

IV. THE MEASUREMENT INDEX AND SYSTEM CONSTRUCTION OF COLLABORATIVE PROCUREMENT DECISION MODEL OF AGRICULTURAL MACHINERY SUPPLY CHAIN

A. ANALYSIS OF FACTORS INFLUENCING THE MEASUREMENT INDICATORS OF PURCHASING DECISION MODEL

Through the analysis of the cause-effect feedback relationship diagrams constructed by the previous three procurement strategy models, it is learned that there are many factors of measurement indexes affecting the collaborative procurement decision model of agricultural machinery supply chain, but after the analysis of simulation results, the influencing factors can be systematically divided into internal and external factors, with internal factors including expected inventory, supplier inventory, supplier supply capacity, and delay cycle, and external factors including demand fluctuation factors, supply delays, and supply interruptions, as detailed in table 4.

B. CONSTRUCTION OF PURCHASING DECISION MODEL MEASUREMENT INDEX SYSTEM

Other scholars have done the following studies on the construction of metrics for collaborative purchasing models. Duan et al. [22] analyzed the metrics under the online purchasing model and constructed metrics from the analysis of product name, degree of supplier information, product quality, delivery time, and order quantity. Smeltzer and Carr [23] studied a performance evaluation model for order allocation within a cluster, constructing performance metrics from

TABLE 4. Influencing factors of procurement strategy measurement index of agricultural machinery supply chain.

Factor Type		Specific influencing factors
Internal influencing factors	Manufacturer	Manufacturer Inventory, Inventory reconciliation cycle, Manufacturer shipments, Inventory reconciliation volume, Production delays, Production cycle, Order quantity etc.
	Suppliers	Supplier order volume, Order production capacity, Supplier Order Inventory, Shipping volume, Delayed cycle, Outbound smoothing time, Core component production, Order Completion Rate etc.
External influencing factors	Fluctuating market demand, Product Market Price, Inventory costs, Market demand forecast per period, Information Technology, Transportation efficiency etc.	

TABLE 5. Agricultural machinery supply chain procurement decision model measurement index system.

Objective	Tier 1 Indicators	Secondary indicators
Farm Machinery Supply Under the chain Sourcing Decision-making Model Measurement Indicators	Order Service Indicators U1	On-demand arrival rate Z1
		On-time delivery rate Z2
		Inventory Advantages Z3
	Value Added Metrics U2	Order production capacity Z4
		Price Discount Z5
		Shipping Costs Z6
		Production cycle Z7
	Quality Control Indicators U3	Product Qualification Rate Z8
		Product Matching Rate Z9
		Product Quality System Z10
	Market Forecast Indicators U4	Fluctuating market demand Z11
		Product Market Price Z12
		Information Technology Z13
	Sustainable Cooperation Indicators U5	Historical Performance Z14
		Informatization level Z15
		Supplier reputation Z16

an analysis of five dimensions: capacity advantage, product quality, supplier reliability, order sourcing, and inventory flexibility. Butdee et al. [24] evaluated the supply chain performance based on inventory sourcing strategy in four stages: manufacturer, distributor, wholesaler, and retailer, and the selected performance indicators were supply chain fill rate, total inventory quantity, and delay period. George and Pillai [25] used grey correlation analysis to evaluate and analyze serial supply chain performance in terms of different inventory locations, order quantities, and market demand flow strategies to construct performance indicators in terms of four aspects: availability rate, risk of stock-out, bullwhip effect and total supply chain cost. George and Pillai [26] studied the assessment of raw material delivery quality in manufacturing companies from a supply chain perspective, constructing evaluation metrics in terms of the type of product ordered, the location of production, the quality of the supplier, and the method of distribution to the customer. Marcin et al. [27] used an optimization model combining subjective hierarchical analysis and objective entropy value method to classify and study raw materials, and constructed procurement model measures in terms of capital consumption, outbound smoothing time, order lead time, and purchase quantity. Zeng and Jiang [28] proposed a new joint purchasing model and algorithm by forming a purchasing alliance of SMEs to integrate scattered purchase orders and considered several influencing factors such as minimum order quantity, inventory limit, a quantity discount, and transportation distance in the joint purchasing model, which provided a theoretical basis for practical purchasing decisions of SMEs. Yuyang et al. [29] developed a stochastic bi-objective mixed integer programming model from a supply chain environment that provides the methodology and timing for using proactive and reactive strategy decisions in supplier selection and order allocation. Factors such as supplier reliability, inventory capability, rapid response capability, information technology, and delay risk prediction capability were considered.

Combined with the analysis of other scholars and influencing factors, this paper constructs the procurement strategy measurement index system of the agricultural machinery supply chain from five aspects: order serviceability, value-added ability, quality control ability, sustainable cooperation ability, and market forecast ability, as shown in Table 5.

V. MATCHING MODEL CONSTRUCTION FOR COLLABORATIVE PROCUREMENT DECISION MODEL OF AGRICULTURAL MACHINERY SUPPLY CHAIN

A. ESTABLISHMENT OF EXTENSION MATCHING MODEL

(1) Classical domain element model

Based on the topological substance theory, N is used to denote the matching object, C denotes the feature name of the object and v denotes the quantity value taken by the matching object N concerning to the feature C. Assuming that the measurement index levels are divided into m levels and the matching indexes are n, the classical domain object element model is:

$$R_{\mathrm{j}} = \left(N_j, c_i, v_{ji}\right) = \begin{bmatrix} N_j & C_1 & \left[a_{j1}, b_{j1}\right] \\ & C_2 & \left[a_{j2}, b_{j2}\right] \\ & \vdots & \vdots \\ & C_n & \left[a_{jn}, b_{jn}\right] \end{bmatrix} \tag{6}$$

In Equation (6): R_j means the object element model for the j th procurement model. $N_j\ (j = 1, 2, \cdots, m)$ is the match level. $C_i\ (i = 1, 2, \cdots, n)$ is the matching indicator. v_{ji} is the value interval of the ith indicator in the j-rank. The meanings of a_{ji} and b_{ji} are the minimum and maximum values in the interval of matching index values corresponding to the matching level.

(2) Section domain object element model

The nodal domain refers to the value domain of the whole collaborative purchasing model corresponding to each metric. Assuming that the matching level is, the nodal domain object element model can be expressed as:

$$R_p = \begin{bmatrix} N_p & C_1 & v_{p1} \\ & C_2 & v_{p2} \\ & \vdots & \vdots \\ & C_n & v_{pn} \end{bmatrix} = \begin{bmatrix} N_p & C_1 & \left[a_{p1}, b_{p1}\right] \\ & C_2 & \left[a_{p2}, b_{p2}\right] \\ & \vdots & \vdots \\ & C_n & \left[a_{pn}, b_{pn}\right] \end{bmatrix} \tag{7}$$

In Equation (7): N_p means the pre-selection program matching level for the procurement model. v_{pi} means the maximum interval of values of the measure C_i.The meanings of a_{pi} and b_{pi} are the maximum and minimum values in the interval of the measure.

(3) Establishing the element model of the object to be matched

Assuming that the model evaluation scheme to be matched is N_0, the actual values of the obtained measures are expressed in terms of the object element R_0.

$$R_0 = \begin{bmatrix} N_0 & C_1 & v_1 \\ & C_2 & v_2 \\ & \vdots & \vdots \\ & C_n & v_n \end{bmatrix} \tag{8}$$

Formula (8): c means the indicators to be evaluated; v means the actual value of each indicator.

B. CALCULATION OF WEIGHTS OF MEASUREMENT AND EVALUATION INDICATORS

1) CALCULATION OF SUBJECTIVE WEIGHT BY EXTENSION OF ANALYTIC HIERARCHY PROCESS

(1) Construction of extension judgment matrix

This paper uses the reciprocal scaling method [30] proposed by Saaty as the scalar method of the extension analytic hierarchy process. At the level of the established evaluation system, experts in relevant fields are invited to compare the relative importance of indicators belonging to the same level, and a positive reciprocal matrix A is established through the extension interval number. $A = (a_{ij})_{n\times n}, a_{ij} = 1, a_{ij} = a_{ji}^{-1} =< 1/a_{ij}^{+}, 1/a_{ij}^{-} >$ Where $a_{ij} =< a_{ij}^{-}, a_{ij}^{+} >$ is the extension interval number. To quantify each element in the matrix, the median value $(a_{ij}^{+}+a_{ij}^{-})/2$ of the extension interval is taken as the integer value in the reciprocal 1-9 scale [31].

(2) Calculation of comprehensive extension judgment matrix and weight vector

The extension interval number judgment matrix established by interval value is $A = [A^{-}, A^{+}]$, where A^{+} and A^{-} are the matrices formed by the upper and lower points of the interval respectively. The steps to calculate the weight of each index and make the judgment matrix meet the consistency conditions are as follows [32]:

Step 1: Solve for the left and right matrices A^{-}, A^{+}, respectively, corresponding to the normalized eigenvectors with positive components of the largest eigenvalue as x^{-}, x^{+}.

Step 2: From $A^{-} = (a - ij)_{n\times n}, A^{+} = (a + ij)_{n\times n}$, find the values of k and m according to Equation (9), and if the inequality condition is satisfied, prove that the consistency of the interval judgment matrix is good.

$$\begin{cases} k = \sqrt{\sum_{j=1}^{n}\left(\frac{1}{\sum_{i=1}^{n} a_{ij}^{+}}\right)} \\ m = \sqrt{\sum_{j=1}^{n}\left(\frac{1}{\sum_{i=1}^{n} a_{ij}^{-}}\right)} \end{cases} \tag{9}$$

Step 3: Deriving the weight vector.

$$S = (S_1, S_2, S_3, \cdots, S_{nk})^T = \left[kx^{-}, mx^{+}\right] \tag{10}$$

(3) Hierarchical single-level sorting

Supposing $S_i =< S_i^{-}, S_i^{+} >, S_j =< S_j^{-}, S_j^{+} >$,if the possible degree of $S_i \geq S_j$ is denoted by $E(S_i \geq S_j) \geq 0 (i \neq j)$, then.

$$\begin{cases} P_j = 1 \\ P_j = E\left(S_i \geq S_j\right) = \frac{2\left(S_i^{+}-S_j^{-}\right)}{\left(S_j^{+}-S_j^{-}\right)+\left(S_i^{+}-S_i^{-}\right)} \end{cases} \tag{11}$$

In $i, j = 1, 2, \cdots, n; i \neq j; P = (p_1, p_2, \cdots, p_n)^T; P_i$ denotes the single ranking of the ith indicator on a layer to some indicator on the previous level, which is normalized to further obtain the weight vector ranking $P = (p_1, p_2, \cdots, p_n)^T$ of each indicator on a layer. $S_i^{-}, S_i^{+}, S_j^{-}, S_j^{+}$ represent the upper and lower points of two single-layer weight vector extension interval numbers.

(4) Hierarchical comprehensive sorting

Ranking the index weight vector, P can get $p_h^k = \left(p_{1h}^k, p_{2h}^k, \cdots, p_{nh}^k\right)^T$ after normalization, which represents the single ranking weight vector of each factor on the k-th layer to the h-th factor on the $k-1$ level. When $h = 1, 2, \cdots, n_{k-1}$, the $n_k \times n_{k-1}$-order matrix is obtained:

$$p^k = \left(p_1^k, p_2^k, \cdots, p_{nk-1}^k\right) \tag{12}$$

If the sorting weight vector of n_{k-1} elements of layer $k-1$ to the total target is $W^{k-1} = \left(W_1^{k-1}, W_2^{k-1}, \cdots, W_{n_{k-1}}^{k-1}\right)^T$, the synthetic sorting W^k of all elements on layer k to the total target can be obtained from formulas (13) and (14), namely.

$$W^k = \left(W_1^{k-1}, W_2^{k-1}, \cdots, W_{nk}^{k}\right)^T = p^k W^{k-1} \tag{13}$$

By further simplifying the above formula, it can be concluded that:

$$W^k = p^k p^{k-1} \cdots p^3 W^2 \tag{14}$$

2) OBJECTIVE WEIGHT CALCULATION BY CRITIC METHOD

CRITIC method uses the variability of evaluation indicators and the conflict between indicators to measure the objective weight of indicators [33]. The basic steps are as follows:

(1) Forward or reverse processing

If the value of the used indicator is larger the better (positive indicator)

$$x_{ij}' = \frac{x_j - x_{min}}{x_{max} - x_{min}} \tag{15}$$

If the value of the indicator used is as small as possible (inverse indicator)

$$x_{ij}' = \frac{x_{max} - x_j}{x_{max} - x_{min}} \tag{16}$$

(2) Indicator variability is expressed in the form of standard deviation

$$\begin{cases} \bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij} \\ S_j = \sqrt{\frac{\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2}{n-1}} \end{cases} \tag{17}$$

where, S_j denotes the standard deviation of the jth indicator.

1) Indicator conflict variability is expressed by the correlation coefficient:

$$R_j = \sum_{i=1}^{p}(1 - r_{ij}) \tag{18}$$

where r_{ij} denotes the correlation coefficient between the measures i and j.

(3) Seeking the amount of information

$$C_j = S_j \sum_{i=1}^{p}(1 - r_{ij}) = S_j \times R_j \tag{19}$$

The greater the information content of an indicator, the greater the role and weight of the indicator in the overall evaluation index system.

(4) Calculating the weights

Bring C_j into equation (20) to find the objective weights.

$$W_j = \frac{C_j}{\sum_{j=1}^{p} C_j} \tag{20}$$

TABLE 6. Classification of agricultural machinery supply chain collaborative procurement mode matching level.

Metrics		Purchasing Model I	II	III	Classic Domain Difference	General	Good	Excellent	Nodal Domain
U1	Z1	6.0	7.4	8.6	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z2	8.0	8.5	9.0	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z3	7.4	6.5	8.0	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
U2	Z4	7.3	7.8	4.4	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z5	8.3	6.7	7.2	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z6	6.7	4.8	7.7	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z7	7.1	7.2	8.3	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
U3	Z8	7.2	5.3	8.7	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z9	7.0	5.5	8.8	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z10	6.9	7.3	7.6	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
U4	Z11	4.7	7.2	9.2	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z12	7.1	4.9	8.9	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z13	6.9	7.6	8.3	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
U5	Z14	5.1	7.9	8.5	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z15	6.8	7.7	8.3	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]
	Z16	7.1	8.6	9.1	[0,2.5)	[2.5,5)	[5,7.5)	[7.5,10]	[0,10]

3) CALCULATION OF INTEGRATED WEIGHTS

The subjective and objective weights of each index obtained by the extension analytic hierarchy process and CRITIC method are coupled to obtain the comprehensive weight. The coupling calculation method is as follows:

$$\omega_i = \frac{\omega_i'\omega_i''}{\sum_{i=1}^{n} \omega_i'\omega_i''}, (j = 1, 2, 3, \cdots, n) \tag{21}$$

where ω_i' is the index weight obtained by the extension analytic hierarchy process, and ω_i'' is the index weight obtained by the CRITIC method.

C. CALCULATING THE MATCHING DEGREE OF EVALUATION INDICATORS

The distance from v_i to the finite interval v_{ji} is $\rho\left(v_i, v_{ji}\right)$ and the distance from v_i to the finite interval. v_{pi} is $\rho\left(v_i, v_{pi}\right)$, where v_i, v_{ji} and v_{pi} are the quantified index value of the evaluation element to be matched, the quantified interval value of the classical domain and the quantified interval value of the nodal domain, respectively. The equation for the correlation function $k_j(v_i)$ between the evaluation index i and the rank j is [34].

$$k_j(v_i) = \begin{cases} \dfrac{-\rho\left(v_i, V_{ji}\right)}{\left|V_{ji}\right|}, v_i \in V_{ji} \\ \dfrac{\rho\left(v_i, V_{ji}\right)}{\rho\left(v_i, V_{pi}\right) - \rho\left(v_i, V_{ji}\right)}, v_i \notin V_{ji} \end{cases} \tag{22}$$

$$\begin{cases} \rho\left(v_i, V_{ji}\right) = \left|v_i - \dfrac{\left(a_{ji} + b_{ji}\right)}{2}\right| - \dfrac{\left(b_{ji} - a_{ji}\right)}{2} \\ \rho\left(v_i, V_{pi}\right) = \left|v_i - \dfrac{\left(a_{pi} + b_{pi}\right)}{2}\right| - \dfrac{\left(b_{pi} - a_{pi}\right)}{2} \end{cases} \tag{23}$$

D. CALCULATING THE COMPREHENSIVE RECOGNITION DEGREE OF PROCUREMENT MODEL

A weighted correlation function is applied to calculate the combined correlation $K_j(N_0)$ between the evaluation element N_0 to be matched and the rank j, i.e, the pattern recognition degree. The pattern recognition degree is the approximation degree of matching evaluation objects about different matching evaluation levels. The higher the correlation value with a model, the better the match, and the more relevant the collaborative purchasing decision model is to the company's target needs. The calculation formula is:

$$K_j(N_0) = \sum_{i=1}^{n} \omega_i k_j(v_i) \tag{24}$$

where, the meaning of ω_i is the weight, $\sum_{i=1}^{n} \omega_i = 1$;$k_j(v_i)$; the meaning of $k_j(v_i)$ is the correlation degree of each rank.

E. EVALUATION AND VERIFICATION OF EXTENSION MATCHING

Based on the above analysis and research, the procurement mode of finished products of a model of power harrow and related raw materials and components required by a domestic agricultural machinery manufacturing enterprise (M) is also taken as the research object. According to the measurement index system of collaborative procurement decision-making mode, and through the historical data, the field survey and interview data of the management personnel and front-line workers of agricultural machinery enterprises on the development of enterprises, the production and after-sales service of main models, as well as the division method of index field values in the literature, the three modes of online inventory procurement mode I, third-party logistics procurement mode II and dynamic sustainable procurement mode III, Using matter-element extension optimality combined with extension analytic hierarchy process to determine the index weight, evaluate and output the optimal procurement matching mode

TABLE 7. Subjective weight values of measurement indicators.

Indicators	Subjective weights	Indicators	Subjective weights	Indicators	Subjective weights	Indicators	Subjective weights
Z1	0.081	Z5	0.072	Z9	0.691	Z13	0.078
Z2	0.142	Z6	0.279	Z10	0.091	Z14	0.226
Z3	0.26	Z7	0.649	Z11	0.287	Z15	0.101
Z4	0.517	Z8	0.218	Z12	0.635	Z16	0.674

TABLE 8. Objective weight values of measurement indicators.

Indicators	Objective weights	Indicators	Objective weights	Indicators	Objective weights	Indicators	Objective weights
Z1	0.044	Z5	0.129	Z9	0.048	Z13	0.042
Z2	0.042	Z6	0.059	Z10	0.045	Z14	0.059
Z3	0.055	Z7	0.041	Z11	0.044	Z15	0.046
Z4	0.183	Z8	0.053	Z12	0.053	Z16	0.054

TABLE 9. Comprehensive weight value of measurement indicators.

Indicators	Combined weights	Indicators	Combined weights	Indicators	Combined weights	Indicators	Combined weights
Z1	0.011	Z5	0.029	Z9	0.102	Z13	0.010
Z2	0.018	Z6	0.051	Z10	0.013	Z14	0.041
Z3	0.044	Z7	0.082	Z11	0.039	Z15	0.014
Z4	0.292	Z8	0.036	Z12	0.104	Z16	0.112

and pattern recognition degree. The specific steps are as follows:

(1) Determine the classical domain element model, the nodal domain element model and the element model to be matched

The measurement indicators constructed in Table 5 are divided into four grades: poor, general, good and excellent, which correspond to each classical domain respectively; The range of nodes consists of the minimum and maximum values of each classical domain; The value of matter-element to be evaluated is obtained through literature query and interview data processing.

Combined with the measurement index system established by formulas (6) ∼ (8) and Figure 12, taking the order service index U1 corresponding to procurement mode I as an example, the classical domain matter-element model is determined as follows:

$$R_1(U1) = \begin{bmatrix} N_1 & C_1 & [7.5, 10] \\ & C_2 & [7.5, 10] \\ & C_3 & [7.5, 10] \\ & C_4 & [7.5, 10] \end{bmatrix} R_2(U1) = \begin{bmatrix} N_1 & C_1 & [5, 7.5] \\ & C_2 & [5, 7.5] \\ & C_3 & [5, 7.5] \\ & C_4 & [5, 7.5] \end{bmatrix}$$

$$R_3(U1) = \begin{bmatrix} N_1 & C_1 & [2.5, 5] \\ & C_2 & [2.5, 5] \\ & C_3 & [2.5, 5] \\ & C_4 & [2.5, 5] \end{bmatrix} R_4(U1) = \begin{bmatrix} N_1 & C_1 & [0, 2.5] \\ & C_2 & [0, 2.5] \\ & C_3 & [0, 2.5] \\ & C_4 & [0, 2.5] \end{bmatrix}$$

Taking the order service index U1 as an example, the matter-element model of the section is as follows:

$$R_p(U1) = \begin{bmatrix} N_1 & C_1 & [0, 10] \\ & C_2 & [0, 10] \\ & C_3 & [0, 10] \\ & C_4 & [0, 10] \end{bmatrix}$$

Taking the order service index U1 as an example, the matter-element model to be matched and evaluated is as follows:

$$R(U1) = \begin{bmatrix} N_1 & C_1 & [6] \\ & C_2 & [8] \\ & C_3 & [6.5] \\ & C_4 & [4] \end{bmatrix}$$

Table 1 shows the classic field, section field and the actual quantity value of each index of the finally determined evaluation indexes at all levels.

(2) Weight calculation of measurement and evaluation indicators

The extension analytic hierarchy process is used to determine the subjective weight, and the subjective weight of each index is calculated according to formula (9) ∼ (14), as shown in Table 2.

The objective weight is determined by CRITIC method, and the objective weight of each index is calculated according to formula (15) ∼ (20), as shown in Table 3.

TABLE 10. Comprehensive matching degree of pattern matching measurement indicators.

Indicators	Mode I				Mode II				Mode III			
	Difference	General	Good	Excellent	Difference	General	Good	Excellent	Difference	General	Good	Excellent
Z1	-0.467	-0.200	0.400	-0.273	-0.653	-0.480	0.040	-0.037	-0.813	-0.720	-0.440	0.440
Z2	-0.733	-0.600	-0.200	0.200	-0.800	-0.700	-0.400	0.400	-0.867	-0.800	-0.600	0.400
Z3	-0.653	-0.480	0.040	-0.037	-0.533	-0.300	0.400	-0.222	-0.733	-0.600	-0.200	0.200
Z4	-0.640	-0.460	0.080	-0.069	-0.707	-0.560	-0.120	0.120	-0.302	0.240	-0.120	-0.413
Z5	-0.773	-0.660	-0.320	0.320	-0.560	-0.340	0.320	-0.195	-0.627	-0.440	0.120	-0.097
Z6	-0.560	-0.340	0.320	-0.195	-0.324	0.080	-0.040	-0.360	-0.693	-0.540	-0.080	0.080
Z7	-0.613	-0.420	0.160	-0.121	-0.627	-0.440	0.120	-0.097	-0.773	-0.660	-0.320	0.320
Z8	-0.627	-0.440	0.120	-0.097	-0.373	-0.060	0.120	-0.319	-0.827	-0.740	-0.480	0.480
Z9	-0.600	-0.400	0.200	-0.143	-0.400	-0.100	0.200	-0.308	-0.840	-0.760	-0.520	0.480
Z10	-0.587	-0.380	0.240	-0.162	-0.640	-0.460	0.080	-0.069	-0.680	-0.520	-0.040	0.040
Z11	-0.319	0.120	-0.060	-0.373	-0.627	-0.440	0.120	-0.097	-0.893	-0.840	-0.680	0.320
Z12	-0.613	-0.420	0.160	-0.121	-0.329	0.040	-0.020	-0.347	-0.853	-0.780	-0.560	0.440
Z13	-0.587	-0.380	0.240	-0.162	-0.680	-0.520	-0.040	0.040	-0.773	-0.660	-0.320	0.320
Z14	-0.347	-0.020	0.040	-0.329	-0.720	-0.580	-0.160	0.160	-0.800	-0.700	-0.400	0.400
Z15	-0.573	-0.360	0.280	-0.179	-0.693	-0.540	-0.080	0.080	-0.773	-0.660	-0.320	0.320
Z16	-0.613	-0.420	0.160	-0.121	-0.813	-0.720	-0.440	0.440	-0.880	-0.820	-0.640	0.360

TABLE 11. Evaluation results of extension matching of procurement mode.

Indicators	Mode I				Mode II				Mode III			
	Difference	General	Good	Excellent	Difference	General	Good	Excellent	Difference	General	Good	Excellent
U1	-0.235	-0.169	0.026	-0.021	-0.252	-0.195	-0.024	0.032	-0.146	0.021	-0.060	-0.100
U2	-0.101	-0.071	0.020	-0.011	-0.084	-0.042	0.017	-0.032	-0.117	-0.094	-0.027	0.028
U3	-0.091	-0.062	0.028	-0.020	-0.062	-0.018	0.026	-0.044	-0.124	-0.111	-0.071	0.067
U4	-0.082	-0.043	0.017	-0.029	-0.066	-0.018	0.002	-0.039	-0.131	-0.121	-0.088	0.061
U5	-0.092	-0.053	0.024	-0.030	-0.131	-0.113	-0.057	0.057	-0.143	-0.131	-0.093	0.062
Results	-0.601	-0.397	0.114	-0.111	-0.595	-0.386	-0.037	-0.026	-0.661	-0.435	-0.339	0.118

According to formula (21), the subjective and objective weights of each index obtained by the extension analytic hierarchy process and critical method in tables 2 and 3 are coupled to obtain the comprehensive weight. The index weight results are shown in Table 4.

(3) Calculation of comprehensive matching degree of measurement indicators

Bring the measurement index value and classical field of the three agricultural machinery supply chain collaborative procurement mode matching into formulas (22) and (23), and get the comprehensive correlation degree of each index and each level of the three mode matching. The results are shown in table 5.

(4) Calculation of comprehensive recognition

Bring the data in tables 4 and 5 and the weights of each index into formula (24), and sum the weighted comprehensive matching degree of each index under different levels to obtain the recognition degree and priority ranking of the purchase mode and each level, as shown in Table 6.

(5) Result analysis

One: As can be seen from Table 6, the matching degree of procurement mode I, II and III with excellent grade are -0.111, -0.026 and 0.118 respectively, although they are all in excellent grade, the matching degree from high to low is: mode III > mode II > mode I, it shows that all three modes are feasible, but the comprehensive matching degree

FIGURE 12. Comparison of single indicator matching.

of mode III is obviously the highest, so it can be concluded that mode I is selected as the enterprise Therefore, it can be concluded that mode I is selected as the core procurement strategy mode in the production, supply and marketing stage.

Second: Comparing the single index matching degree of the three procurement modes, as shown in Figure 12, it can be intuitively seen that all the five indexes of Mode I are in the medium to high degree, indicating that enterprises can adopt them in the stage of orientation. Model II has advantages in order service index price, value-added index, quality control index and sustainable cooperation index, but it needs to further strengthen the optimization of market demand fluctuation and information technology in the market forecast index. Similarly, Model III is higher than other models in value-added indicators, quality control indicators, sustainable cooperation indicators and market forecast indicators, but is at the lowest level in terms of order service indicators, and should strengthen the optimization of order service capabilities. Finally, summing up the above two points, we can know that the optimal purchasing strategy mode is Mode III, which corresponds to the optimal recognition degree of 0.118.

VI. CONCLUSION

In this paper, we analyze the multi-attribute procurement decision model based on system dynamics of agricultural machinery supply chain procurement in the three stages of ''production-supply-sales'' from the perspective of agricultural machinery equipment manufacturers. After research, we found that whether it is the traditional procurement strategy model, third-party logistics procurement model, dynamic sustainable procurement model based on lineside inventory model, or collaborative procurement model emerged not overnight, but gradually and successively after the market environment reached certain conditions. Therefore, if agricultural machinery manufacturers want to maintain the maximum benefit in the fierce competition, they must study the matching relationship between the different stages of collaborative purchasing decision mode and production, supply and sales. Through the numerical simulation calculation analysis, we know that enterprises should use modern supply chain technology to strengthen the competitive leadership of enterprise procurement based on the changes of product market price and demand fluctuation. Shorten the response time of the production supply chain, reduce the completion lead time of product orders and production time, improve the accuracy of procurement plans, on-time delivery rate, inventory turnover utilization frequency and enterprise production turnover efficiency, reduce the cost of inventory of agricultural equipment products, reduce inventory capital occupation, thereby increasing profits. In order to achieve the maximum extent to ensure that customers can achieve the consistency between the bulk procurement needs of materials and bulk order needs under the premise of obtaining lower cost materials.

Finally, the factors affecting procurement strategy are analyzed from three aspects of manufacturers, suppliers and customer groups in the supply chain link, and a measurement system of agricultural machinery supply chain procurement strategy indicators with order service indicators, value-added indicators, quality control indicators, market forecast indicators and sustainable cooperation as 1-level measurement indicators is constructed. At the same time, a matter-element extension matching evaluation model based on combination weighting is constructed. In order to avoid too strong subjectivity in the evaluation process, the index weights of each level are determined by combining the extension analytic hierarchy process and CRITIC method. The combination weighting results are introduced into the matter-element extension matching evaluation method for comprehensive matching evaluation of the procurement mode, which effectively reduces the subjectivity and uncertainty in the decision-making process of matching evaluation. The matching evaluation results produced by the evaluation model not only reflect the overall advantages and disadvantages of the model, but also output the optimal procurement strategy model in the production, supply and marketing matching stage, and also reflect the recognition degree of each single index on each level. The feasibility and practicability of this method are proved by an example, which provides a systematic and scientific multi-attribute decision-making tool for the manufacturing industry to achieve better procurement management. Future research should focus on incorporating big data-driven, considering more sample data for validation, and adding dynamic factor indicators to improve the applicability and stability of dynamic sustainability models. The background should focus more on the transformation from product service supply chain to green supply chain perspective to analyze and research, and build an intelligent model to assess the matching degree of procurement mode of agricultural machinery enterprises.

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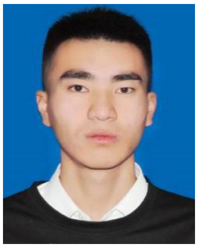

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