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Retraction

Retracted: Research on Supply Chain Cost Control Method of Intelligent Manufacturing Enterprise Based on Improved IQC Algorithm

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] Y. Shang, "Research on Supply Chain Cost Control Method of Intelligent Manufacturing Enterprise Based on Improved IQC Algorithm," *Journal of Electrical and Computer Engineering*, vol. 2022, Article ID 9020092, 14 pages, 2022.

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Research Article

Research on Supply Chain Cost Control Method of Intelligent Manufacturing Enterprise Based on Improved IQC Algorithm

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In order to improve the cost control effect of the supply chain of intelligent manufacturing enterprises, this paper improves the IQC algorithm. In order to overcome the problem of multitype data processing in the supply chain, this paper describes the high-frequency NCS as a delta arithmetic system with input time-varying delay, high-frequency constraints, and actuator saturation. Moreover, through a double closed-loop feedback configuration, this paper combines the loop structure of the supply chain to analyze the stability of the actuator saturated high-frequency NCS and combines the experiments to verify the reliability of the improved algorithm. In addition, on the basis of the improved algorithm, this paper constructs an intelligent supply chain cost control system, evaluates its functional modules, sets up the system architecture, and analyzes the performance of the system in combination with experimental research. The experimental research results show that the supply chain cost control method of intelligent manufacturing enterprises based on the improved IQC algorithm proposed in this paper has good results and meets the operational needs of intelligent manufacturing enterprises.

1. Introduction

To maintain corporate competitiveness, business managers need appropriate information to make correct decisions. They need information to plan corporate strategy, set goals, and monitor results. Moreover, managers usually have a comprehensive and in-depth understanding of the operations of their companies, understand the key factors and how they interact, monitor how these factors change over time, and compare the company's operating conditions with market competition and industry standards. This information is needed when formulating and implementing business strategic goals and is strategic information [1]. Strategic information is not information about ordering, shipping, handling complaints, or withdrawal from bank accounts used in the daily operations of a company. It is much more important than this information, and it is of great significance to the survival and sustainable and healthy development of the company. The decisive business decision of an enterprise depends on correct strategic information [2]. Therefore, in order to make correct strategic decisions and target setting for the overall situation of the enterprise, it is necessary to integrate the data in all systems so that it can become useful information for enterprise decision analysis. In this context, data warehouse technology and OLAP technology are produced. The good dimensional model can express the various relationships within enterprise data, provide users with clear, accurate, and fast queries, and enable users to organize and analyze business data from different angles and help enterprises make sound business decisions in time [3].

Under the same external environment, in which company's supply chain can better meet customer needs, the company's supply chain is more likely to win the competition. At this time, the competition between enterprises will be more reflected in other aspects besides quality, such as cost. Product quality, reliability, delivery speed, and delivery reliability have long been the qualification criteria for the supply chain to participate in the competition, and the cost of the final product or service of the supply chain has become the key to distinguish the supply chain from other supply chains. It is precisely because of this that the supply chain puts cost reduction to an extremely important position. The ultimate goal of the supply chain is to increase profits, and strengthening cost control is an important means for the supply chain to achieve this goal. Therefore, discussing how to establish a scientific and efficient cost control system that can maximize the profits of the supply chain is an urgent problem to be solved and an innovative research topic. In the environment of fierce competition and global economic integration, the automobile manufacturing industry itself has undergone tremendous changes, making the production, management, and control of the automobile manufacturing industry more dependent on technology and management innovation. Management innovation led by supply chain management ideas has become a reform practice actively promoted by automobile manufacturers worldwide. Its theories and methods have been universally recognized in the automobile manufacturing industry and have been innovated and applied to varying degrees and have gradually become an advanced and effective production operation and management model that adapts to various complex systems.

The operation of the supply chain is inevitably accompanied by various expenses and pivots, which constitute the cost of the supply chain. At present, the more mature point of view on the definition of supply chain costs is all material costs, labor costs, transportation costs, equipment costs, and so forth that occur in the supply chain. In today's fierce market competition, companies must survive and continue to grow. In addition to operating traditional cost management methods to control their internal costs, they should also work with other companies in the supply chain they participate in to reduce unnecessary supply chain costs. When the cost of the entire supply chain is reduced, companies will inevitably maximize profits.

This article combines the improved IQC algorithm to study the supply chain cost control methods of intelligent manufacturing enterprises, improve the current supply chain costs of intelligent manufacturing enterprises, improve the efficiency of enterprise operation, and reduce the cost of enterprise operation.

2. Related Work

Literature [4] proposed an inventory control model for determining reverse logistics demand. In this model, product demand, recovery rate, recovery time, and order time are all known and their values are constant. The recovery cost of product repair and product ordering cost are fixed. Under the premise of the minimum total inventory cost, the recovery batch and product order batch of recycled products are optimized. Literature [5] established a corresponding economic order batch model for the same reverse logistics system containing multiple recycled products and gave the optimal inventory control strategy. Literature [6] applied the traditional economic order batch model to the problem of reverse logistics inventory control, considering that the remanufacturing capacity of recycled products and the production capacity of new products are unlimited. After remanufacturing, recycled products can be the same as newly manufactured products. Sales and the demand rate and recovery rate of the product are continuous and the value is constant. On this basis, the impact of the recovery rate on the reverse logistics inventory control is analyzed, and the corresponding optimal economic order is established for the reverse logistics system of different inventory control strategies batch model. Literature [8] studied a strategic safety inventory control model; it is a multilevel supply chain inventory system with reverse logistics. Literature [9] derived the calculation formula of ordering strategy parameters based on periodic inspection, and the process is based on remanufacturing and new remanufacturing of recycled products under dynamic demand and recycling. At the same time, using Pontryagin's principle, the optimal inventory control method is calculated for the specific recycling system of a product with multiple demand options. Literature [10] assumed that both the number of recycled products and the number of new products demanded are continuous functions of time; the objective function is to minimize the total cost of the supply chain, and the optimal product production and inventory control strategy is given. The stochastic inventory model can be divided into continuous inspection inventory model and periodic inspection inventory model. The research in literature [11] on inventory control theory and methods mainly includes the two following aspects: one is the determination of the optimal parameters under the known structure conditions, and the other is the optimal inventory control structure. The continuity check inventory model and the periodic check inventory model in the demand stochastic model both emphasize the research on the optimal inventory control structure and seldom pay attention to parameter optimization.

Literature [12] established a reverse logistics inventory control model, which is a simple extension of the demand stochastic inventory model, mainly considering the reduction of inventory holding costs and out-of-stock costs, while ignoring the total cost of the system; literature [13] established a model similar to that developed by Cohen. In this model, the recycling process of waste products and the product demand process are independent of each other, and all recycled products can be used for remanufacturing. The model adopts inventory control where the remanufacturing process is completely driven by recycled products. Literature [14] took into account factors such as product demand rate, product recovery rate, out-of-stock situation, and product production to recovery time, established an inventory control model, and analyzed the impact of the above factors on inventory. Literature [15] assumed that both returns and demand obey the Poisson distribution, and returns depend on the demand process; a periodic inventory check model is established; literature [16] assumed that demand and returns obey a normal distribution or Poisson distribution and are independent of each other. The hybrid production system of the remanufacturing process uses simulation analysis methods to conduct in-depth research on its recycling product processing strategy and product batch control strategy; literature [17] proposed a remanufacturing inventory control model in which returns and demand are all subject to Poisson distribution; literature [18] studied the production and remanufacturing levels in the (S, M) control strategy; literature [19] established two newsboy control models that include returns.

3. Application Analysis of Improved IQC Algorithm in Supply Chain Cost Control of Intelligent Manufacturing Enterprises

The IQC algorithm is improved, and the improved algorithm is used as a cost control method for the supply chain of intelligent manufacturing enterprises. The algorithm gives a feedback configuration with high-frequency constraints [20]:

$$\begin{cases} v = G(\delta)w + f \\ w = \Delta(v) + e \end{cases}. \quad (1)$$

In the above formula, $w \in L_2{}^m[0,\infty)$ and $v \in L_2{}^p[0,\infty)$ are feedback inline signals, $f \in L_{2c}{}^p[0,\infty)$ and $e \in L_{2e}{}^m[0,\infty)$ are inline noise, and $G(\delta)$ and Δ are two causal operators. It can be seen from the literature that $\delta = (z-1)/T_s$ is a delta operator variable, which is equivalent to the Laplacian variable s in the continuous system transfer function *G(s)* and the shift operator variable in the discrete system transfer function *G(z)*. $G(\delta) \in RD_{\infty}^{p\times m}$ is the delta operator transfer function, and its state space realization can be expressed as $G(\delta) \in (A_\delta, B_\delta, C_\delta, D_\delta)$. We set $jR \mapsto C^{(m+p)\times(m+p)}$ as a measurable Hermitian function, and the quadratic form of the multiplier is defined as follows [21]:

$$\sigma_{\prod}(v,w) = \int_{w\in\wedge} \begin{bmatrix} \hat{v}(\delta) \\ \hat{w}(\delta) \end{bmatrix}^* \prod(\delta) \begin{bmatrix} \hat{v}(\delta) \\ \hat{w}(\delta) \end{bmatrix} d\omega. \quad (2)$$

In the above formula, $\wedge = \{\omega: \overline{\omega}T_s \le |\omega T| \le \pi\}$, $\delta: = (e^{j\omega T_s} - 1)/T_s$, and $\hat{v}(\delta)$ and $\hat{w}(\delta)$ are the Fourier transforms of signals $v(t_k)$ and $w(t_k)$, respectively. If the delta operator variable δ does not exist in the multiplier Π, the quadratic form $\sigma_{\prod}(v,w)$ can be rewritten as

$$\sigma_{\prod}(v,w) = T_s^2 \sum_{k=0}^{\infty} \begin{bmatrix} v(t_k) \\ w(t_k) \end{bmatrix}^T \prod \begin{bmatrix} v(t_k) \\ w(t_k) \end{bmatrix}. \quad (3)$$

If $\sigma_{\prod}(v,w) \ge 0$, signals $w(t_k)$ and $v(t_k)$ satisfy the high-frequency IQC defined by the multiplier Π. In addition, if the inequality $\sigma_{\prod}(v,w) \ge 0$ is satisfied for any $v \in L_2{}^p[0,\infty)$, then the operator $\triangle$ satisfies the high-frequency IQC defined by the multiplier Π. If the operator (I-GA) (8) in the feedback configuration (1) is causally reversible, then the feedback inline composed of $G(\delta)$ and $\triangle$ is well posed. Moreover, the feedback configuration (1) is stable if and only if $(I - G\Delta)(\Delta\delta)$ is a bounded causal operator on $\prod_i$.

The main feature of high-frequency IQC analysis is to decompose complex dynamic systems into basic blocks. If each basic block of the system has high-frequency IQC, then the stability analysis of the composite system is a relatively simple problem. The operator $\triangle$ is a diagonal block structure composed of n operators $\triangle$, that is, $\Delta = diag\{\Delta_1, \ldots, \Delta_n\}$, and each operator $\triangle i$ satisfies the high-frequency IQC defined as follows:

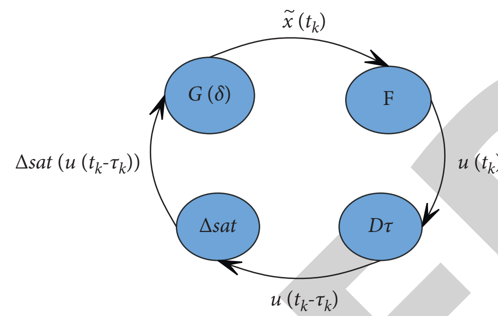

Figure 1: Feedback configuration of system (4-7).

$$\prod_i = \begin{bmatrix} \prod_{i11} & \prod_{i12} \\ \prod_{i12}^{+} & \prod_{i22} \end{bmatrix}. \quad (4)$$

In the above formula, the block structure multiplier Π corresponds to the corresponding operator $\triangle$. Then the multiplier Π corresponding to the operator $\triangle$ is

$$\prod = \begin{bmatrix} \prod_{1(11)} & \prod_{1(12)} \\ \ddots & \ddots \\ \prod_{n(11)} & \prod_{n(12)} \\ \prod_{1(12)}^{*} & \prod_{1(22)} \\ \ddots & \ddots \\ \prod_{n(12)}^{*} & \prod_{n(22)} \end{bmatrix}. \quad (5)$$

Using the high-frequency IQC method introduced in the previous section, the high-frequency NCS (4-7) is rewritten into the feedback configuration form shown in Figure 1, where $G(\delta)$ is the controlled object with high-frequency constraint $\overline{\omega}T_s \le |\omega T| \le \pi$, F is the feedback gain matrix, and the operators d_r and $\triangle_{sat}$ are the delay operator and the saturation operator, respectively, which are specifically expressed as $d_r(v)(t_k) = v(t_k - \tau_k)$ and $\Delta_{sat}(v)(t_k) = sat(v(t_k))$.

We set D as the delay difference operator, expressed as $D_r(\overline{v}_1)(t_k) = (I - d_r)(\overline{v}_1)(t_k) = \overline{v}_1(t_k) - \overline{v}_1(t_k - \tau_k)$, where $\overline{v}_1 \in L_2^n[0,\infty)$ is the external loop feedback inline signal. The saturation operator is given as $\Delta_{sat}(\overline{v}_2)(t_k) = sat(\overline{v}_2(t_k))$, where $\overline{v}_2 \in L_2^m[0,\infty)$ is the inner loop feedback inline signal. Then the high-frequency NCS (4-7) is rewritten as the following double closed-loop feedback configuration form:

$$\begin{aligned}
&\delta\tilde{x}(t_k) = (A+BF)\tilde{x}(t_k) - BF\overline{w}_1(t_k) + B\overline{w}_2(t_k),\\
&\overline{w}_1(t_k) = \overline{v}_1(t_k) - \overline{v}_1(t_k-\tau_k),\\
&\overline{w}_2(t_k) = sat(\overline{v}_2(t_k)) - \overline{v}_2(t_k),\\
&\overline{v}_1(t_k) = \tilde{x}(t_k),\\
&\overline{v}_2(t_k) = F\tilde{x}(t_k) - F\overline{w}_1(t_k).
\end{aligned} \tag{6}$$

From the above formula, $\overline{G}(\delta)$ is a linear time-invariant operator, and $\triangle$ is a bounded gain operator, expressed as $\Delta = diag\{D_r, \Delta_{sat}\}$. The double closed-loop feedback configuration in (6) is shown in Figure 2.

We set $v(t_k) = [\overline{v}_1{}^T(t_k)\overline{v}_2{}^T(t_k)]^T$ and $\overline{w}(t_k) = [\overline{w}_1{}^T(t_k)\overline{w}_2{}^T(t_k)]^T$; the double closed-loop feedback configuration in (6) can be rewritten in the following augmented form:

$$\delta\tilde{x}(t_k) = A\tilde{x}(t_k) - B\overline{w}(t_k), \tag{7}$$

$$\overline{v}(t_k) = \overline{C}\overline{x}(t_k) + \overline{D}\overline{w}(t_k), \tag{8}$$

$$\overline{w}(t_k) = \Delta(\overline{v})(t_k). \tag{9}$$

From the above formulas, we have

$$\overline{A} = A + BF, \overline{B} = \begin{bmatrix} -BF & B \end{bmatrix}, \overline{C} = \begin{bmatrix} I_n \\ F \end{bmatrix}, \overline{D} = \begin{bmatrix} 0 & 0 \\ -F & 0 \end{bmatrix}. \tag{10}$$

It is worth noting that the system in (7–8) is a well-posed linear system and its state space realization can be expressed as $\overline{G}(\delta) = (\overline{A}, \overline{B}, \overline{C}, \overline{D})$. For a given state feedback matrix F, the eigenvalues of matrix $\overline{A}$ are located in a circle with $(-1/T_S, 0)$ as the center and $1/T_S$ radius. According to the literature, it can be known that the delta operator variable of $\begin{bmatrix} G(\delta) \\ I \end{bmatrix}^* \prod(\delta) \begin{bmatrix} \hat{v}(\delta) \\ \hat{w}(\delta) \end{bmatrix}$ is located in the stable region. Therefore, the condition $\overline{G}(\delta) \in RD_\infty^{(n+m)\times(n+m)}$ (to be obvious for the augmented system in (7)–(9)) is established. The following lemma will give the stability criterion of the feedback configuration in (1).

A sufficient condition for the stability of the feedback groupoid (1) with the high-frequency constraint $\overline{\omega}T_s \le |\omega T| \le \pi$ is that the feedback inline of $G(\delta)$ and Δ is fitness and satisfies the two following conditions:

(i) For any $p \in [0,1]$, the operator $\rho\Delta$ satisfies the high-frequency IQC defined by the multiplier Π.

(ii) There exists $\varepsilon > 0$, and it satisfies the following condition:

$$\begin{bmatrix} G(\delta) \\ I \end{bmatrix}^* \prod(\delta) \begin{bmatrix} G(\delta) \\ I \end{bmatrix} \le -\varepsilon I, \forall \overline{\omega}T_s \le |\omega T| \le \pi. \tag{11}$$

In the above formula, $G(\delta) = C_\delta(\delta I - A_\delta)^{-1}B_\delta + D_\delta$.

Using the conclusions in the literature, an upper bound of the delay difference operator D_r will be given in the following lemma.

Lemma 2 is as follows: Considering the feedback configuration in (7)–(9), the delay difference operator $G(\delta) = C_\delta(\delta I - A_\delta)^{-1}B_\delta + D_\delta$ is an L, and the upper bound of the gain is $\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}$; that is, $\|D_r\| \le {}^2\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}$.

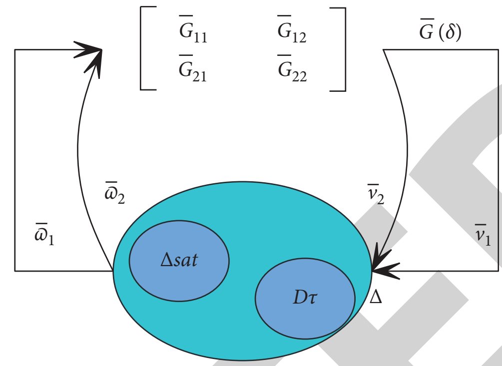

Figure 2: Double closed-loop feedback configuration.

By setting an operator $\Delta_{D_r} := D_r \cdot T_s\delta + 1/\delta$, the following equation can be obtained from the literature:

$$\left\|\Delta_{D_r}\right\| = \frac{T_s\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}}{2}. \tag{12}$$

For feedback configuration in (7)–(9), we can get

$$\begin{aligned}
\|D_r\| &= \left\|\Delta_{D_r}\right\| \cdot \left|\frac{\delta}{T_s\delta + 1}\right| = \left\|\Delta_{D_r}\right\| \cdot \left|\frac{e^{j\omega T_s} - 1}{T_s e^{j\omega T_s}}\right|\\
&= \frac{T_s\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}}{2} \cdot \frac{1}{T_s}\left|(1 - \cos\omega T_s) + j\sin\omega T_s\right|\\
&= \frac{T_s\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}}{2} \cdot \frac{1}{T_s}(2 - 2\cos\omega T_s)^{1/2}\\
&= \frac{T_s\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}}{2} \cdot \frac{1}{T_s}\left|\sin\frac{\omega T_s}{2}\right|\\
&\le \frac{T_s\sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}}{2} \cdot \frac{2}{T_s} = \sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}.
\end{aligned} \tag{13}$$

Considering the high-frequency feedback configuration in (7)–(9), $\wedge(\Phi_\delta, \psi_h)$ represents curves in the complex plane and the eigenvalues of matrix A are not on these curves. For a given symmetric matrix $\Theta \in H_{2n+m}$, the two inequality conditions described below are equivalent.

(i) For any $\omega \in \wedge(\Phi_\delta, \psi_h)$, the following finite frequency domain inequality exists:

$$\begin{bmatrix} (\sigma I - \overline{A})^{-1}\overline{B} \\ I \end{bmatrix}^* \Theta \begin{bmatrix} (\sigma I - \overline{A})^{-1}\overline{B} \\ I \end{bmatrix} < 0. \tag{14}$$

From the above formula, we have

$$\Phi_\delta = \begin{bmatrix} T_s & 1 \\ 1 & 0 \end{bmatrix},$$

$$\psi_h = \begin{bmatrix} 1 & \dfrac{1}{T_s} - \dfrac{\sin(\overline{\omega}T_s)}{\overline{\omega}{T_s}^2} \\ \dfrac{1}{T_s} - \dfrac{\sin(\overline{\omega}T_s)}{\overline{\omega}{T_s}^2} & \dfrac{s2\text{in}(\overline{\omega}T_s)(\cos\overline{\omega}T_s - 1)}{\overline{\omega}{T_s}^3} \end{bmatrix}. \tag{15}$$

(ii) There is a matrix $P, Q \in h_N$ satisfying $O > 0$ and the following inequality:

$$\begin{bmatrix} \overline{A} & \overline{B} \\ I & 0 \end{bmatrix}^T (\Phi_\delta \otimes P + \psi_h \otimes Q) \begin{bmatrix} \overline{A} & \overline{B} \\ I & 0 \end{bmatrix} + \Theta < 0. \tag{16}$$

A sufficient condition for the stability of high-frequency NCS (4-7) is that there is a normal number a that satisfies the following formula:

$$\begin{bmatrix} \overline{G}(\delta) \\ I \end{bmatrix}^* \prod \begin{bmatrix} \overline{G}(\delta) \\ I \end{bmatrix} < -\varepsilon I, \forall \overline{\omega}T_s \leq |\omega T_s| \leq \pi. \tag{17}$$

In the above formula, $\overline{G}(\delta) = \overline{C}(\delta\overline{A} - I)^{-1}\overline{B} + \overline{D}$.

$$\prod = \begin{bmatrix} \Xi_1 + \Xi_2 & 0 & X_2 & 0 \\ 0 & 0 & 0 & -2X_3 \\ X_2^T & 0 & -(X_1 + X_2) & 0 \\ 0 & -2X_3^T & 0 & -4X_3 \end{bmatrix}. \tag{18}$$

From the above formula, there are $\Xi_1 = 2\mathfrak{I}_u(\mathfrak{I}_u - 1)X_1, \Xi_2 = (\mathfrak{I}_u - \mathfrak{I}_1)X_2, X_1 = X_1^T > 0, X_2 = X_2^T > 0, X_3 = X_3^T > 0.$

The outer loop is as follows: for the outer loop feedback configuration, the two delay difference operators are given as

$$\prod_{D_\tau,1} = \begin{bmatrix} \Xi_1 & 0 \\ 0 & -X_1 \end{bmatrix}, \prod_{D_\tau,2} = \begin{bmatrix} \Xi_2 & X_2 \\ X_2^T & -X_2 \end{bmatrix}. \tag{19}$$

It can be obtained that, for any $\tau_{\min} \leq \tau_k \leq \tau_{\max}$, there exist the following inequalities:

$$\|D_\tau\| \leq \sqrt{2\mathfrak{I}_u(\mathfrak{I}_u - 1)}. \tag{20}$$

For the delay difference multiplier II, we have

$$\begin{aligned} \sigma_{\prod_{D_\tau,1}}(\overline{v}_1, \overline{w}_1) &= {T_s}^2 \sum_{k=0}^{\infty} \begin{bmatrix} \overline{v}_1(t_k) \\ \overline{w}_1(t_k) \end{bmatrix}^T \prod_{D_\tau,1} \begin{bmatrix} \overline{v}_1(t_k) \\ \overline{w}_1(t_k) \end{bmatrix} \\ &= X_1\left(2\mathfrak{I}_u(\mathfrak{I}_u - 1)\|\overline{v}_1\|^2 - \|\overline{w}_1\|^2\right) \\ &\geq X_1\left(2\mathfrak{I}_u(\mathfrak{I}_u - 1)\|\overline{v}_1\|^2 - \|D_\tau\|^2\|\overline{v}_1\|^2\right). \end{aligned} \tag{21}$$

Therefore, in the outer loop feedback configuration, the delay difference operator D satisfies the high-frequency IQC defined by the multiplier IIn_. In order to prove that the delay difference operator D satisfies the high-frequency IQC defined by the multiplier IIp.z, we first introduce the delay operator d, which can be expressed as d, (may) (t basis) $= (1 - \text{Tx})$. It is worth noting that the equation d, =I-D, is obviously established. Therefore, in addition, we can get

$$|d_\tau(\overline{v}_1)(t_k)|^2 \leq \sum_{i=\mathfrak{I}_l}^{\mathfrak{I}_u} |\overline{v}_1(t_k - iT_s)|^2. \tag{22}$$

This condition is equivalent to

$$\begin{aligned} |d_\tau(\overline{v}_1)|^2 &\leq T_s^2 \sum_{k=0}^{\infty} |d_\tau(\overline{v}_1)(t_k)|^2 \\ &\leq T_s^2 \sum_{k=0}^{\infty} \left(\sum_{i=\mathfrak{I}_l}^{\mathfrak{I}_u} |\overline{v}_1(t_k - iT_s)|^2 \right) \\ &= \sum_{i=\mathfrak{I}_l}^{\mathfrak{I}_u} \left(T_s^2 \sum_{k=0}^{\infty} |\overline{v}_1(t_k - iT_s)|^2 \right) \\ &= \sum_{i=\mathfrak{I}_l}^{\mathfrak{I}_u} \|\overline{v}_1\|^2 = (\mathfrak{I}_u - \mathfrak{I}_l + 1)\|\overline{v}_1\|^2. \end{aligned} \tag{23}$$

Inequality (23) can be derived from the existence of $k - i < 0$ for any $\overline{v}_1(t_{k-1}) = 0$. We consider the delay multiplier, which is as follows:

$$\prod_{d_\tau,2} = \begin{bmatrix} (\mathfrak{I}_u - \mathfrak{I}_l + 1)X_2 & 0 \\ 0 & -X_2 \end{bmatrix}. \tag{24}$$

It can be obtained that $\|d\|_r \leq \sqrt{\mathfrak{I}_u - \mathfrak{I}_l + 1}$ exists for any $\tau_{\min} \leq \tau_k \leq \tau_{\max}$. We consider the delay difference operator, which is as follows:

$$\prod_{D_\tau,2} = \begin{bmatrix} \Xi_2 & X_2 \\ X_2^T & -X_2 \end{bmatrix} = \begin{bmatrix} I_n & 0 \\ I_n & -I_n \end{bmatrix} \prod_{d_\tau,2} \begin{bmatrix} I_n & 0 \\ I_n & -I_n \end{bmatrix}. \tag{25}$$

Therefore, we can get

$$\begin{aligned} \sigma_{\prod_{D_\tau,1}}(\overline{v}_1, \overline{w}_1) &= {T_s}^2 \sum_{k=0}^{\infty} \begin{bmatrix} \overline{v}_1(t_k) \\ \overline{w}_1(t_k) \end{bmatrix}^T \prod_{D_\tau,1} \begin{bmatrix} \overline{v}_1(t_k) \\ \overline{w}_1(t_k) \end{bmatrix} \\ &= X_2\left(\|v_1\|^2(\mathfrak{I}_u - \mathfrak{I}_l - 1)\|\overline{v}_1 - \overline{w}_1\|^2\right) \\ &\geq X_2\left(\|v_1\|(\mathfrak{I}_u - \mathfrak{I}_l + 1) - \|\mathrm{d}_\tau\|^2\|\overline{v}_1\|^2\right) \\ &= X_2\left((\mathfrak{I}_u - \mathfrak{I}_l - 1) - \|\mathrm{d}_\tau\|^2\right)\|\overline{v}_1\|^2. \end{aligned} \tag{26}$$

Therefore, in the outer loop feedback configuration, the time difference operator D satisfies the high-frequency IQC defined by Πp,. From inequalities (21) and (26), the signal two $\overline{v}_1(t_k)$ and $\overline{w}_1(t_k)$ satisfy the high-frequency IQC defined by the following multipliers:

$$\prod_{D_\tau} = \prod_{D_{\tau,2}} + \prod_{D_\tau,2} = \begin{bmatrix} \Xi_1 + \Xi_2 & X_2 \\ X_2^T & -(X_1 + X_2) \end{bmatrix}. \tag{27}$$

The inner loop is as follows: for the inner loop feedback configuration, for any $(v_2(t_k) - \text{sat}\overline{v}_2(t_k))^T \text{sat}\overline{v}_2(t_k) \geq 0$ there are (two (1x) one sat(v(1))'sat(v(1)) ≥ 0. We consider a saturation multiplier, which looks like the following:

$$\prod_{\Delta_{sat}} = \begin{bmatrix} 0 & -X_3 \\ -X_3^T & -2X_3 \end{bmatrix}. \tag{28}$$

We can get

$$\begin{aligned} \sigma_{\prod_{\Delta_{sat}}}(\overline{v}_2, \overline{w}_2) &= T_s^2 \sum_{k=0}^{\infty} \begin{bmatrix} \overline{v}_2(t_k) \\ \overline{w}_2(t_k) \end{bmatrix}^T \prod_{\Delta_{sat}} \begin{bmatrix} \overline{v}_2(t_k) \\ \overline{w}_2(t_k) \end{bmatrix} \\ &= -2T_s^2 \sum_{k=0}^{\infty} \left[\Delta_{sat}^T(\overline{v}_2)(t_k)(\overline{v}_2(t_k)) + \Delta_{sat}(\overline{v}_2)(t_k)\right] \\ &= T_s^2 \sum_{k=0}^{\infty} \left[(\overline{v}_2(t_k)) - sat(\overline{v}_2(t_k))^T sat(\overline{v}_2(t_k))\right]. \end{aligned} \tag{29}$$

Therefore, in the inner loop feedback configuration, the signal losses $\overline{v}_2(t_k)$ and $\begin{bmatrix} \Omega_{11} & \Omega_{12} & \Omega_{13} \\ \Omega_{12}^T & \Omega_{22} & \Omega_{23} \\ \Omega_{13}^T & \Omega_{23}^T & \Omega_{33} \end{bmatrix} < 0$ satisfy the high-frequency IQC defined by the multiplier Π.

The double loop is as follows: based on the inner and outer loop feedback configurations, the signals $\overline{v}(t_k)$ and $\overline{w}(t_k)$ can meet the high-frequency IQC defined by the following multiplier:

$$\prod = \begin{bmatrix} \Xi_1 + \Xi_2 & 0 & X_2 & 0 \\ 0 & 0 & 0 & -2X_3 \\ X_2^T & 0 & -(X_1 + X_2) & 0 \\ 0 & -2X_3^T & 0 & -4X_3 \end{bmatrix}. \tag{30}$$

Because $\begin{bmatrix} \Xi_1 + \Xi_2 & 0 \\ 0 & 0 \end{bmatrix} \geq 0$ and $\begin{bmatrix} -(X_1 + X_2) & 0 \\ 0 & -4X_3 \end{bmatrix} \leq 0$, it is known from the literature that, for any ρe[0,1], lo-4X,], the operator $p\triangle$ satisfies the high-frequency IQC defined by the multiplier Π. According to Lemma 4.1, condition (4-18) is the stability criterion of high-frequency NCS (4-7). The proof is complete.

$$\begin{bmatrix} \Omega_{11} & \Omega_{12} & \Omega_{13} \\ \Omega_{12}^T & \Omega_{22} & \Omega_{23} \\ \Omega_{13}^T & \Omega_{23}^T & \Omega_{33} \end{bmatrix} < 0. \tag{31}$$

From the above formula, we have

$$\begin{aligned} \Omega_{11} &= (A + BF)^T (T_s P + Q)(A + BF) \\ &\quad + \left(P + \psi_{h_{12}} Q\right)(A + BF) + (A + BF)^T \left(P + \psi_{h_{12}} Q\right) \\ &\quad + \psi_{h_{22}} Q + 2\mathfrak{I}_u(\mathfrak{I}_u - 1)X_1 + (\mathfrak{I}_u - \mathfrak{I}_1)X_2, \\ \Omega_{12} &= -(A + BF)^T (T_s P + Q)BF + \left(P + \psi_{h_{12}} Q\right)^T BF + X_2, \\ \Omega_{13} &= (A + BF)^T (T_s P + Q)B + \left(P + \psi_{h_{12}} Q\right)^T B - 2F^T X_3, \\ \Omega_{22} &= F^T B^T (T_s P + Q)BF - (X_1 + X_2), \\ \Omega_{23} &= -F^T B^T (T_s P + Q)B + 2F^T X_3, \\ \Omega_{33} &= B^T (T_s P + Q)B - 4X_3, \\ \psi_{h_{12}} &= \frac{1}{T_s} - \frac{\sin(\overline{\omega} T_s)}{\overline{\omega} T_s^2}, \\ \psi_{h_{22}} &= \frac{2\sin(\overline{\omega} T_s)(\cos \overline{\omega} T_s - 1)}{\overline{\omega} T_s^3}. \end{aligned} \tag{32}$$

For a given matrix Θ, the finite frequency domain inequality condition can be transformed into a linear matrix inequality condition. For high-frequency NCS (4-7), matrix Θ is selected as

$$\Theta = \begin{bmatrix} \overline{C} & \overline{D} \\ 0 & I \end{bmatrix}^T \prod \begin{bmatrix} \overline{C} & \overline{D} \\ 0 & I \end{bmatrix}. \tag{33}$$

According to the transfer function $\overline{G}(\delta) = \overline{C}(\delta\overline{A} - I)^{-1}\overline{B} + \overline{D}$, the inequality condition (14) in Lemma 3 is transformed into

$$\begin{bmatrix} \overline{G}(\delta) \\ I \end{bmatrix}^* \prod \begin{bmatrix} \overline{G}(\delta) \\ I \end{bmatrix} < -\varepsilon I, \forall \overline{\omega} T_s \leq |\omega T_s| \leq \pi. \tag{34}$$

Considering the stability criterion (17) in Theorem 1, the following stability criterion can be obtained:

$$\begin{aligned} &\begin{bmatrix} \overline{A} & \overline{B} \\ 0 & I \end{bmatrix}^T \begin{bmatrix} T_s P + Q & P + \psi_{h_{12}} Q \\ \left(P + \psi_{h_{12}} Q\right) & \psi_{h_{22}} Q \end{bmatrix} \begin{bmatrix} \overline{A} & \overline{B} \\ 0 & I \end{bmatrix} \\ &+ \begin{bmatrix} \overline{C} & \overline{D} \\ 0 & I \end{bmatrix}^T \prod \begin{bmatrix} \overline{C} & \overline{D} \\ 0 & I \end{bmatrix} < 0. \end{aligned} \tag{35}$$

According to Shannon sampling theory, the sampling frequency should be greater than or equal to twice the system frequency. Because this paper studies the stability of high-frequency NCS, it adopts the delta operator discretization method to improve the coefficient sensitivity of high-frequency sampling. In other words, the delta operator model has better numerical characteristics than the shift operator on a finite word length computer. In addition, some of the difficulties and challenges in this paper are as follows. First of all, the time-varying delay caused by the saturation of the actuator and the network is a nonlinear component, which is difficult to deal with in the high-frequency stability analysis. Secondly, the time-varying delay caused by the network is usually handled by constructing Lyapunov-Razumikhin or Lyapunov-Krasovskii functions, but it is difficult to deal with high-frequency constraints using these two functions. Thirdly, the extension of the quadratic constraint of high-frequency integration in the delta domain is also a challenge for the stability analysis of high-frequency NCS.

The more high-frequency IQC that the verification operator $\triangle$ satisfies, the more beneficial it is to the stability analysis of high-frequency NCS. This paper describes operator D as accurately as possible through high-frequency IQC to obtain a low-conservative stability criterion.

In this section, an inverted pendulum model will be given to prove the validity of the conclusions of this paper. Given that the control input of the system satisfies $|u| \leq 3$, that is, $\beta = 3$, an inverted pendulum model in the form of system (1)-(2) can be obtained. We have

$$A_s = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 29.4 & 0 \end{bmatrix}, \quad B_s = \begin{bmatrix} 0 \\ -1 \\ 0 \\ 3 \end{bmatrix}, \quad C_s = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}. \tag{36}$$

In this example, the upper frequency limit of system (1)-(2) is 100 Hz; that is, $o = 100$ Hz. The covariance matrices O and R are, respectively, $O = \text{diag}\{0.01, 0.01, 0.01, 0.01\}$ and $R = \text{diag}\{0.1, 0.1\}$, and the sampling period $T = 0.01$ s. The gain matrix of the given controller is

$$F = [-31.623 - 20.151 - 72.718 - 13.155]. \tag{37}$$

The upper and lower bounds of the time-varying delay d and r are $d_{\min} = 0$ s, $d_{\max} = 0.04$ s, $c_{\min} = 0$ s, and $c_{\max} = 0.04$ s.

The high-frequency parameters in this example are as follows:

$$A = \begin{bmatrix} 0 & 1.000 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0.147 & 1.001 \\ 0 & 0 & 29.414 & 0.147 \end{bmatrix}, \quad B = \begin{bmatrix} -0.005 \\ -1.000 \\ 0.015 \\ 3.002 \end{bmatrix}. \tag{38}$$

The specific solution can be obtained by solving inequality (31) as follows:

$$P = \begin{bmatrix} -2143 & 551 & -1149 & 187 \\ 551 & -390 & 1315 & -137 \\ -1149 & 1315 & -1531 & 442 \\ 187 & -137 & 442 & -49 \end{bmatrix}, \quad Q = \begin{bmatrix} 2.015 & -0.000 & 1.434 & -0.000 \\ -0.000 & 1.888 & -0.000 & 0.766 \\ 1.434 & -0.000 & 6.39 & -0.000 \\ -0.000 & 0.766 & -0.000 & 0.355 \end{bmatrix},$$
$$X_1 = \begin{bmatrix} 540.053 & 51.986 & 98.861 & 18.550 \\ 51.986 & 496.096 & 105.016 & 157.284 \\ 98.861 & 105.016 & 606.814 & 37.667 \\ 18.550 & 157.284 & 37.667 & 54.182 \end{bmatrix}, \quad X_2 = \begin{bmatrix} 485 & 177 & 688 & 129 \\ 177 & 285 & 416 & 126 \\ 688 & 416 & 1812 & 305 \\ 129 & 126 & 305 & 98 \end{bmatrix}. \tag{39}$$

$X_3 = 0.402$. The initial state of the inverted pendulum model is given as $x_0 = \begin{bmatrix} 0 & -0.2 & 0 & 0 \end{bmatrix}^T$, and the state trajectory curve is shown in Figure 3, where $\widetilde{x}(t_k)$ is composed of $xe_1(t_k)$, $xe_2(t_k)$, $xe_3(t_k)$, and $xe_4(t_k)$.

It can be seen from Figure 3 that the four state curves all converge to the origin. The saturation control input curve $u(t_k)$ is shown in Figures 4 and 5. It can be seen from Figure 4 that the control input is limited to the upper saturation limit. If the inverted pendulum model in this simulation example is considered to be in the entire frequency range, that is, $\overline{\omega} = 0$ Hz, then there is no solution to inequality (31) in Theorem 2. This example shows that the stability criterion is valid for the high-frequency NCS (4-7) in this paper.

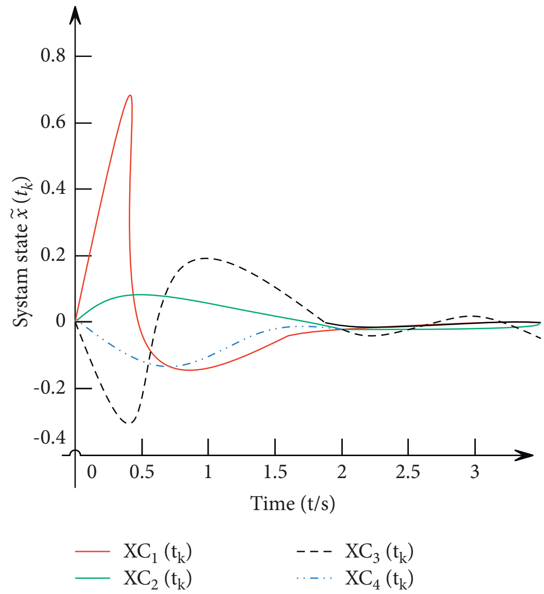

Figure 3: State $\tilde{x}(t_k)$ trajectory.

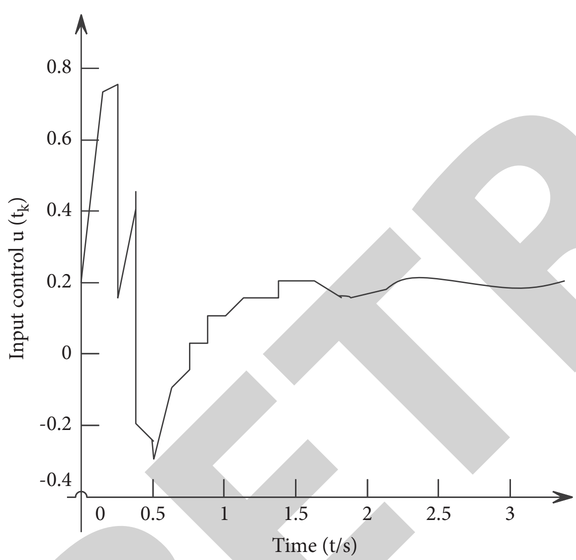

Figure 4: Control input $u(t_k)$ curve.

4. Research on Supply Chain Cost Control Method of Intelligent Manufacturing Enterprise Based on Improved IQC Algorithm

This paper takes automobile companies as an example to study the cost control methods of the supply chain of smart manufacturing companies.

Automobile reverse logistics network refers to a logistics network system established to ensure the orderly and smooth progress of automobile reverse logistics activities. Different from the traditional production and distribution logistics system, the automobile reverse logistics network is closed in form. First, consumers send used cars or parts to recycling centers through recycling outlets. The recycling center sorts, disassembles, inspects, and cleans used cars or parts and sends nonremanufactured parts to the environmental protection treatment center for disposal. Then, it sends remanufactured parts to remanufacturing companies for remanufacturing. In remanufacturing companies, remanufactured parts are repaired, and the processed remanufactured parts can be used in the production of automobile products or sent directly to the distribution center as repair spare parts. In form, this forms a closed-loop logistics system. The whole process is shown in Figure 5.

There are two ways for manufacturers to produce automotive products to meet the needs of sellers and consumers. One is to order raw materials from outside and manufacture new products to meet demand. The second is to use recycled waste parts and components to meet demand through remanufacturing. The framework of the automotive reverse logistics inventory control system is shown in Figure 6.

Aiming at the problem of multilevel inventory control in the automobile supply chain, this paper establishes an automobile reverse logistics inventory model centered on automobile manufacturers, as shown in Figure 7. The control management of the multilevel inventory control system can be divided into the two following situations according to the dominant factors of control: the situation dominated by the inventory of saleable products and the situation dominated by the inventory of recycled products. The former is a pull-type inventory management method, that is, an inventory management mode in which products are produced only when the sellers or consumers put forward the supply needs. This method is conducive to reducing the inventory holding cost of the company's products for sale. The latter is mainly based on the inventory management mode of recycling and remanufacturing based on the inventory of recycled products. Through timely processing of recycled products, it effectively reduces the holding cost of recycled products.

The model of automobile reverse logistics inventory control system based on multiagent theory can be determined, as shown in Figure 8.

Most of the cost management methods only consider the internal costs of the enterprise, dividing costs into direct costs and indirect costs, and do not consider the transaction costs that occur with supply chain member companies such as suppliers and customers. However, in a vertically coordinated organization such as a supply chain, transaction costs are very important costs. Therefore, supply chain costs are divided into three levels: direct costs, operating costs, and transaction costs. Direct cost is the cost of the product entity incurred by a single enterprise during the production of the product, including raw material and labor costs. Operating costs are caused by activities not directly related to product production and are expenses incurred in the management activities of manufacturing and delivering products to customers. These costs vary greatly with the production activities and organizational structure of the enterprise. Transaction costs are the information and coordination costs incurred when negotiating, controlling, and adjusting mutual trading relationships, including all costs incurred in all

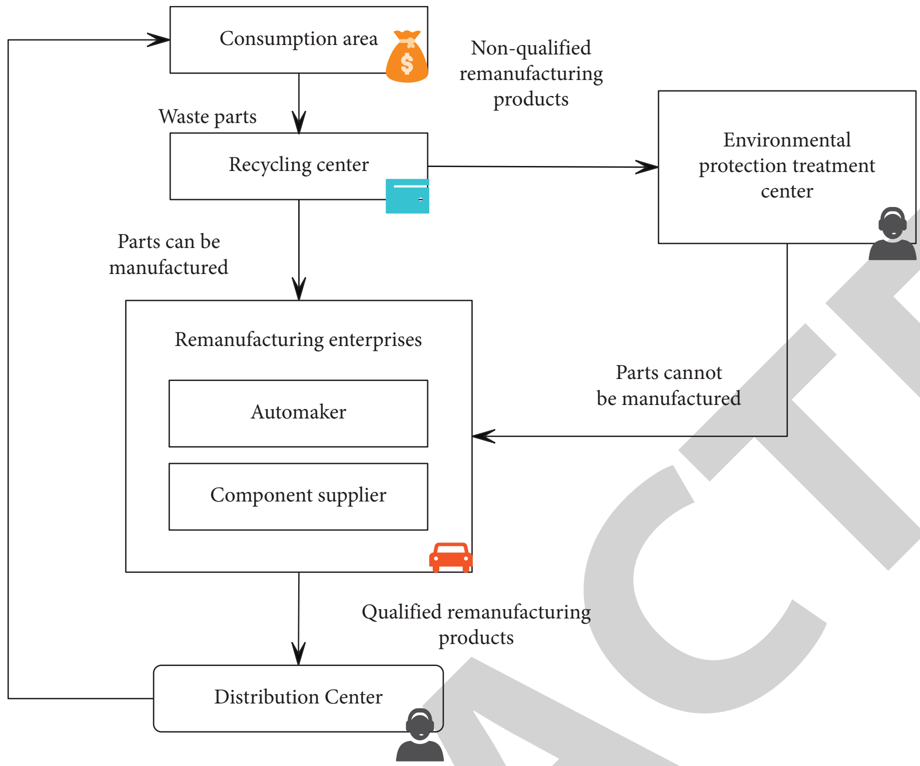

Figure 5: Flow chart of automobile reverse logistics network.

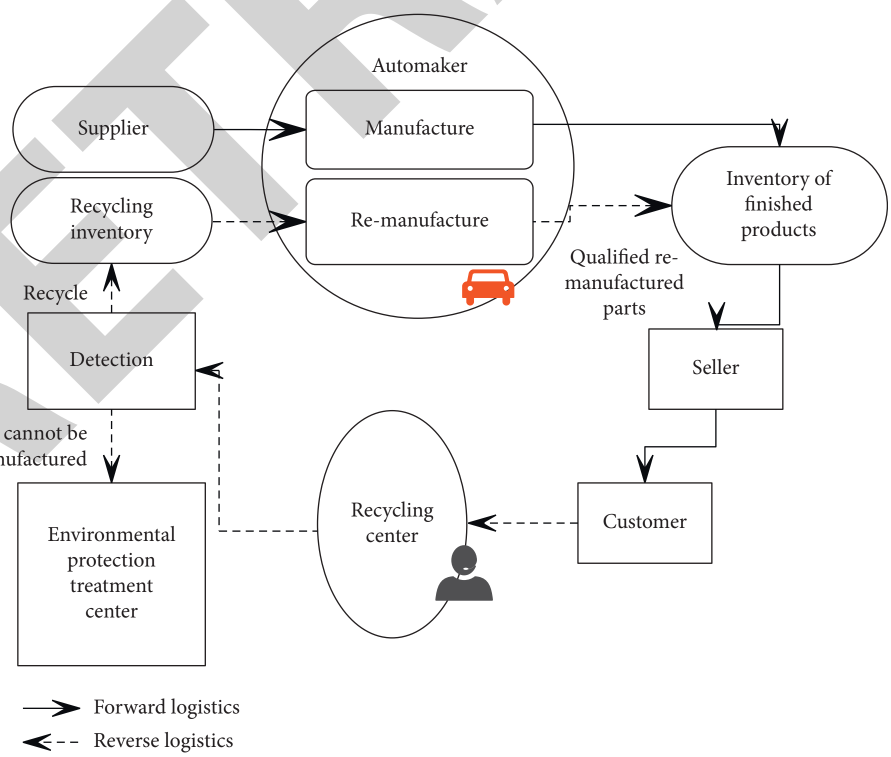

Figure 6: The framework of the automobile reverse logistics inventory control system.

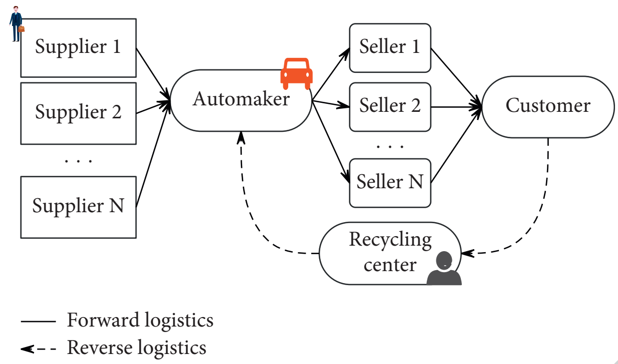

Figure 7: Automobile reverse logistics inventory model.

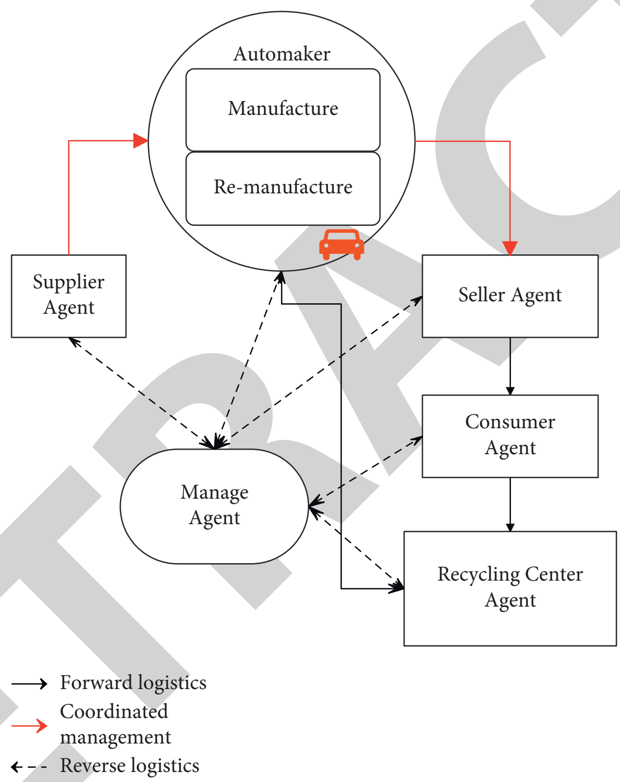

Figure 8: Model of the inventory control system for automobile reverse logistics.

activities of processing information and communications with suppliers and customers. Figure 9 shows the composition of supply chain costs.

This article evaluates the performance of the company's supply chain from four aspects: finance, internal supply chain business processes, customers, and learning and innovation capabilities. The main reason is that the purpose of supply chain and supply chain enterprises is to be profitable, and it is also the most intuitive way of performance. Therefore, the financial perspective is still an important aspect of performance evaluation. The prerequisite for the existence of an enterprise is that the products or services provided can be recognized by customers. Customers are the driving force for the survival and development of the enterprise. Therefore, the enterprise must attach importance to the evaluation of customers. The internal supply chain business process and learning and innovation capabilities of the company evaluate the performance of the company's supply chain from the aspects of the company's operational capabilities and sustainable development capabilities. These two aspects are also very important for automobile manufacturers. Therefore, we design a performance indicator system from the aspects of finance, internal business processes, learning and innovation capabilities, and customers, as shown in Figure 10.

After constructing the above model, this paper designs experiments to verify the performance of the model and evaluates the logistics planning and cost control of the system constructed in this paper. The results are shown in Tables 1 and 2 and Figures 11 and 12.

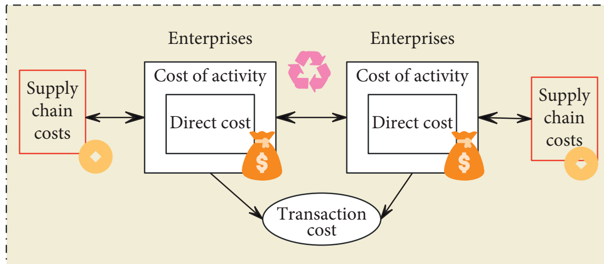

Figure 9: The composition of supply chain costs.

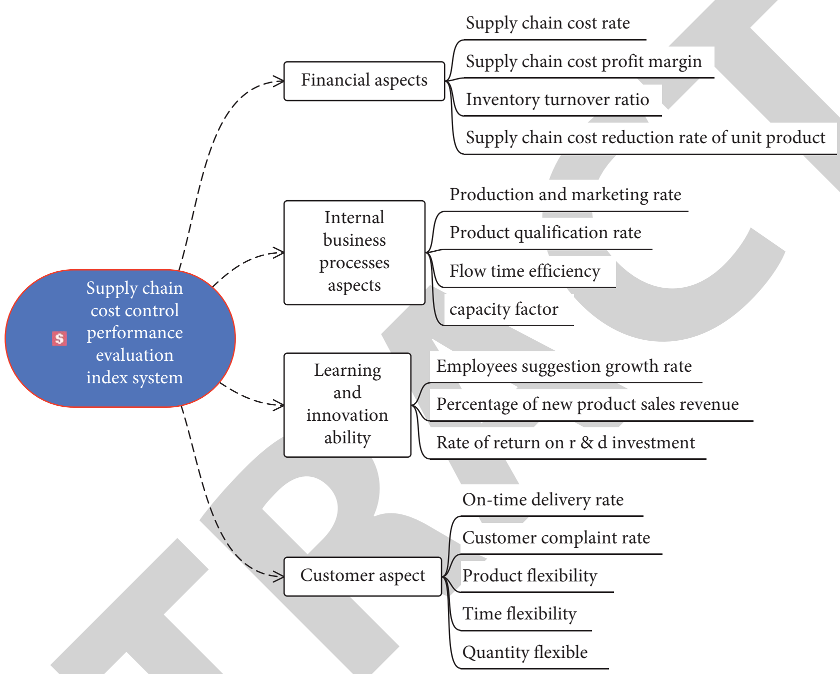

Figure 10: Performance evaluation index system.

Table 1: Evaluation of logistics planning performance.

Number	Logistics planning	Number	Logistics planning
1	93.37	17	91.92
2	89.68	18	87.17
3	93.02	19	92.09
4	88.49	20	87.54
5	86.64	21	95.23
6	93.43	22	88.82
7	96.16	23	90.08
8	95.11	24	95.68
9	86.20	25	95.99
10	86.14	26	87.99
11	93.60	27	94.51
12	92.50	28	87.80
13	88.30	29	92.64
14	95.32	30	89.42
15	89.08	31	96.33
16	87.29	32	94.82

Table 2: Evaluation of cost control performance.

Number	Cost control	Number	Cost control
1	83.46	17	83.25
2	89.27	18	91.01
3	91.56	19	86.49
4	77.08	20	84.81
5	80.33	21	90.91
6	92.59	22	85.45
7	84.70	23	86.61
8	90.31	24	76.55
9	83.62	25	77.22
10	79.85	26	76.27
11	89.82	27	88.77
12	84.67	28	77.39
13	80.35	29	78.35
14	92.05	30	84.18
15	84.37	31	91.16
16	89.96	32	89.74

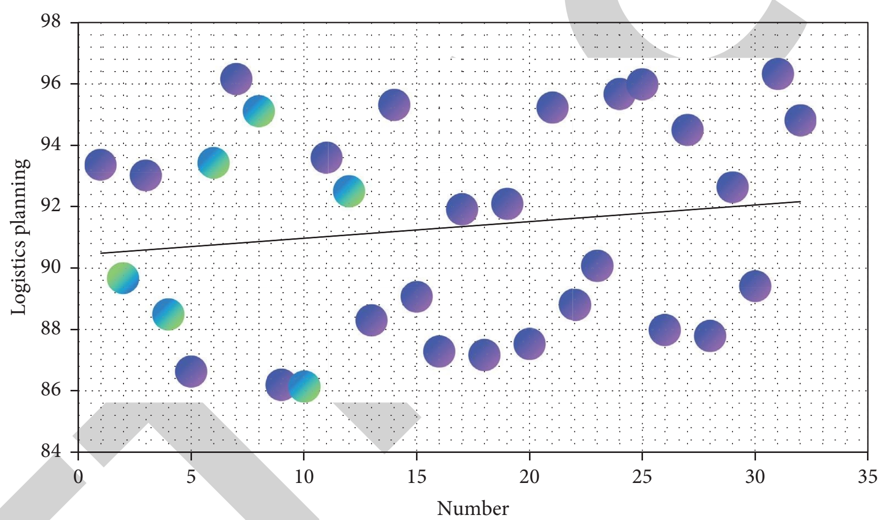

Figure 11: Statistical diagram of logistics planning performance.

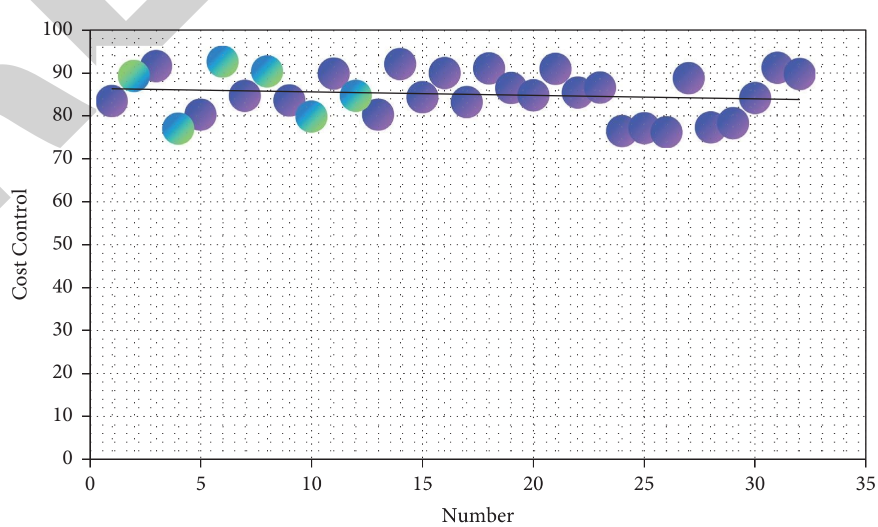

Figure 12: Statistical diagram of cost control performance.

From the above research, it can be seen that the supply chain cost control method of intelligent manufacturing enterprises based on the improved IQC algorithm proposed in this paper has good results and meets the operational needs of intelligent manufacturing enterprises.

5. Conclusion

Intelligent manufacturing enterprises are the main force of the modern economy. The study of this paper emphasizes its existence mechanism from a perspective and pays attention to the external environment such as policy support system, entrepreneurial mechanism, legal guarantee system, and financing issues. Moreover, this paper starts from the focus of supply chain management, which is the focus of the world management community, and takes intelligent manufacturing enterprises as the object to study the supply chain management theory and operation mode suitable for intelligent manufacturing enterprises. At present, with the exception of a small number of companies that passively join the industrial chain, most of the smart manufacturing companies do not realize the advantages of supply chain management and do not have a suitable model to follow. Although many manufacturers have successively launched software and solutions for intelligent manufacturing enterprises, they are only from the perspective of pure information and have not achieved the desired results. This article combines the improved IQC algorithm to study the supply chain cost control methods of intelligent manufacturing enterprises, to improve the current supply chain costs of intelligent manufacturing enterprises, improve the efficiency of enterprise operation, and reduce the cost of enterprise operation.

Data Availability

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

Conflicts of Interest

The author declares no conflicts of interest.

Acknowledgments

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