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Article

Resource Matching in the Supply Chain Based on Environmental Friendliness under a Smart Contract

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Abstract: This study aims to solve the problem of environmental pollution caused by industry through the upgrading and transformation of the supply chain, supply chain resource allocation, and related aspects. Specifically, environmental friendliness is added to the resource-matching problem of the cloud platform supply chain. Additionally, learning theory and dynamic evaluation systems are introduced when creating a preference sequence. The deferred-acceptance algorithm is used for matching. Finally, the automatic matching of blockchain smart contracts ensures the interests of both matching parties. Through the analysis of the example at the end of the study, we found that (1) the deviation table of demand side 5 and supply side 7 in the example shows that the deviation between demand side 5 as demand side and supply side 7 is only 11.55186, and the deviation between supply side 7 as demand side and demand side 5 is only 6.56778, and both sides form a high-quality pairing when matched with other partners. No excessive waste of its resources occurs. (2) Effectively ensure the openness and transparency of the supply chain production process; (3) The impact of environmental factors on enterprises is fully considered. In the analysis of the calculation cases, it can be found that demand side 10 has extremely high requirements for the environmental friendliness of its partners, and although supplier 2 has a very high preference for demand side 10, it is not successfully matched because the environmental friendliness of its own enterprise is not up to the standard, while supplier 1 has an environmental friendliness of up to 92 and is finally matched with Demand side 10; (4) Through the comparison test in the appendix, it can be found that the improved GS algorithm achieves the distinction between positive and negative partners. After multiple rounds of scoring, positive demand side 1, 3 was matched with positive supply side 2, 4, which can strengthen the enthusiasm of both partners and avoid negative cooperation.

Keywords: two-sided matching; delay acceptance algorithm; carbon emissions; learning theory; smart contract

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Citation: Wei, J.; Liang, Z.; Liu, Y.; Yang, X. Resource Matching in the Supply Chain Based on Environmental Friendliness under a Smart Contract. *Sustainability* **2023**, *15*, 1505. https://doi.org/10.3390/su15021505

Academic Editors: Ray Qing Cao, Vicky (Ching) Gu and Dara G. Schniederjans

Received: 23 November 2022
Revised: 17 December 2022
Accepted: 29 December 2022
Published: 12 January 2023

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1. Introduction

The manufacturing industry plays an important role in the development of the national economy and is the foundation of building a country and making it strong. However, unquestionably, industry has also produced a large amount of resource consumption, pollutant, and greenhouse gas emissions [1]. In 2021, the state formally required China's industrial industry to strictly implement The "Fourteenth Five Year" Industrial Green Development Plan and actively promote efficient, low-carbon, and green industrial energy use. Under the requirements of policies and regulations, enterprises are gradually attaching importance to low-carbon production. Suppliers have begun to produce low-carbon raw materials to accurately reduce emissions. Manufacturers actively invest in emission reduction research and development costs and explore the low-carbon road from various aspects [2].

The manufacturing industry is an important component of the industrial chain and supply chain system. It covers a wide range of supply chain links, so it can be combined with low carbon practices in many aspects. At present, many scholars have accomplished significant achievements in exploring the path of low-carbon manufacturing. For example, Zheng et al. proposed a design framework based on the concept of low carbon, through which designers can create a qualified and environmentally friendly product with the assistance of a computer [3]. Guo et al. [4] built a dynamic evolution game model of emission reduction for duopoly enterprises under the carbon quota and trading mechanism and found that the equilibrium result of the system was affected by both the enterprise's carbon emission cost per unit and consumer's carbon emission sensitivity coefficient. Xu et al. [5] and others studied the joint production and pricing of multi-product manufacturers under the quota trading system and carbon tax system and compared the impact of the two systems on total carbon emissions, corporate profits, and social welfare. It can be seen that many scholars have made outstanding contributions to enterprise technology innovation and the relationship between enterprise revenue and low-carbon emission reduction policies. On the other hand, from the perspective of the supply chain, exploring the enterprise's emission reduction decisions has become another hot spot for scholars to explore the enterprise's low-carbon practices [6]. For example, Yu et al. studied the polluter's carbon emission decision when they adopt either centralization or decentralization in a two-chain system under a carbon tax. It is shown that when serious polluters choose the decentralized supply chain to reduce environmental pollution, the government must levy a lower carbon tax [7]. Wei et al. discussed the choice of a coordination mechanism for a green supply chain in the manufacturing industry from the perspectives of consumer green preference, cost sharing of supply chain members, and revenue sharing [8]. However, through an extensive review of the literature, we found that few studies consider the impact of supply chain resource matching on the environment from the perspective of the supply chain and low-carbon integration.

With the deepening integration of the supply chain and low carbon emission reduction, how to solve the current challenges faced by the transformation of the manufacturing industry through effective methods and means has gradually received wide attention from scholars. Among them, the cloud manufacturing mode with a cloud platform as a carrier can break through the limitation of time and space to provide efficient and rapid services for traders to become the key to the intelligent, digital, and green transformation of the manufacturing industry [9]. In particular, some scholars believe that cloud manufacturing, as a service-oriented manufacturing model, aims to meet user needs and select suitable manufacturing services from different candidate services [10]. Therefore, the platform should start from user needs; train a professional inspection team to conduct a strict, professional, and unified evaluation of the key points; and widely search for qualified suppliers in the target area of suppliers set by enterprises to match quality supply chain resources [11]. At the same time, some scholars, starting from matching methods, consider two-sided matching as an effective way to optimize resource matching on the cloud platform, emphasizing the optimal selection through intermediaries to achieve the final matching that maximizes the satisfaction of both parties [12]. For example, Wang et al. recognized the influence of a fuzzy environment on the evaluation and selection of supply chain partners and used the combination of fuzzy hierarchical analysis and TOPSIS (technique for order preference by similarity to ideal solution) to rank all alternatives [13]. Yue et al. discussed the two-sided matching problem in a hesitant fuzzy language environment based on the two-sided decision-maker weight obtained by the AHP method [14]. Morizumi et al. [15] constructed a decision-making method based on a network graph, processed the preference order information with network graph technology, and investigated the two-sided matching problem under strong preference order information. Knoblauch [16] established a two-sided matching model based on an improved g–s algorithm, analyzed the properties of the traditional deferred acceptable algorithm (g–s algorithm), and solved the two-sided matching problem under random preference order information. Liang et al. developed a quantitative matching decision model to balance evaluative criteria in the two-sided matching (TSM) decision [17]. Yang et al. constructs a two-sided matching model introducing prospect theory to solve the suitability of the shared Hitch car service, and verifies the feasibility of the model and solution with MATLAB [18]. However, most scholars set the application scenario of two-sided matching to single matching, which is different from the multiple, repeated matching to be performed by the platform.

Additionally, the cloud manufacturing platform has problems such as long service selection time and low information transparency due to the limitation of arithmetic power, which causes inefficiency in enterprise production and manufacturing [19], and data security is difficult to guarantee [20]. The blockchain, as a distributed digital ledger, can effectively ensure the transparency of information in the chain and be fair. Therefore, some scholars believe that blockchain technology can be embedded in the process of cloud manufacturing service selection, and the platform security can be enhanced with the decentralized, transparent, and traceable characteristics of blockchain, and then the data security problem can be effectively solved. Among them, Leng [21] builds a distributed production digital platform by embedding blockchain smart contracts into manufacturing to realize the automatic execution of production process informatization, which enhances trust among users while effectively guaranteeing the information security of the platform. Yu [22] proposes a blockchain-enabled QoS(Quality of Service)-aware service combination model in the cloud manufacturing scenario, which improves the model Li [23] proposed of a distributed peer-to-peer cloud manufacturing structure based on blockchain technology, which was subdivided into five layers based on hardware configuration, with each layer functioning independently to improve scalability and collaborating to improve security. Wang [24] designed a cloud manufacturing service supporting smart contracts to solve the trust problem of matching supply and demand for cloud manufacturing service transactions. Kushetri [25] studied the role of blockchain technology in tracking insecure factors in the Internet of Things (IoT) supply chain, and further explored IoT security vulnerabilities through blockchain technology with the aim to prevent security vulnerability. Meanwhile, other scholars believe that the upstream and downstream resources of the blockchain can be used to effectively reduce transaction costs and protect the environment [26,27].

After combing through the above literature, we found that to solve the carbon emission problem of enterprises from the perspective of resource matching in the supply chain, the existing research is still insufficient. Firstly, few researchers have tried to solve the carbon emission problem of enterprises from the perspective of the supply chain using blockchain, and there is not much help in the subdivision of the three that can help the above problem. Secondly, in terms of resource matching, the research on two-sided matching is mostly based on a static matching process, ignoring the fact that two-sided matching should be considered from the perspective of long-term cooperation under the application scenario of cooperation, and is not a single-matching behavior, but a multi-repetition, dynamic adjustment process. Finally, not many scholars have tried to introduce the concepts of blockchain, smart contracts, etc., into the supply chain resource matching problem. Therefore, to address the above problems, this paper adds environmental factors to two-sided matching, establishes a supply chain resource matching model considering environmental friendliness, and adds a dynamic update mechanism to automatically adjust the matching model, while uploading the whole matching process to the cloud platform using blockchain technology and using smart contracts to ensure the security, openness and transparency of the whole matching process, to propose a concrete solution for the intelligent transformation of the manufacturing supply chain. The solution is to promote the sustainable development of the manufacturing industry.

A review of the above-mentioned literature reveals that the existing research remains inadequate to address the carbon emission problem of enterprises from the perspective of resource matching in the supply chain. Firstly, few studies try to use the blockchain as a means to solve the problem of enterprise carbon emissions from the perspective of the supply chain, and there is not much help to the above problem either in terms of blockchain or supply chain composition or the segmentation of carbon emission problem. Secondly, in terms of resource matching, the research on two-sided matching is mostly based on a static matching process, ignoring the fact that two-sided matching should be considered from the perspective of long-term cooperation under the application scenario of cooperation, and is not a single-matching behavior, but a multi-repetition, dynamic adjustment process. Finally, not many scholars have tried to introduce the concepts of blockchain, smart contracts, etc., into the supply chain resource matching problem. Therefore, to address the above problems, the research line of this paper is shown in Figure 1, this paper adds environmental factors to two-sided matching, establishes a supply chain resource matching model considering environmental friendliness, and adds a dynamic update mechanism to automatically adjust the matching model, while uploading the whole matching process to the cloud platform using blockchain technology and smart contracts to ensure the security, openness and transparency of the whole matching process, to propose a concrete solution for the intelligent transformation of the manufacturing supply chain. The solution is to promote the sustainable development of the manufacturing industry.

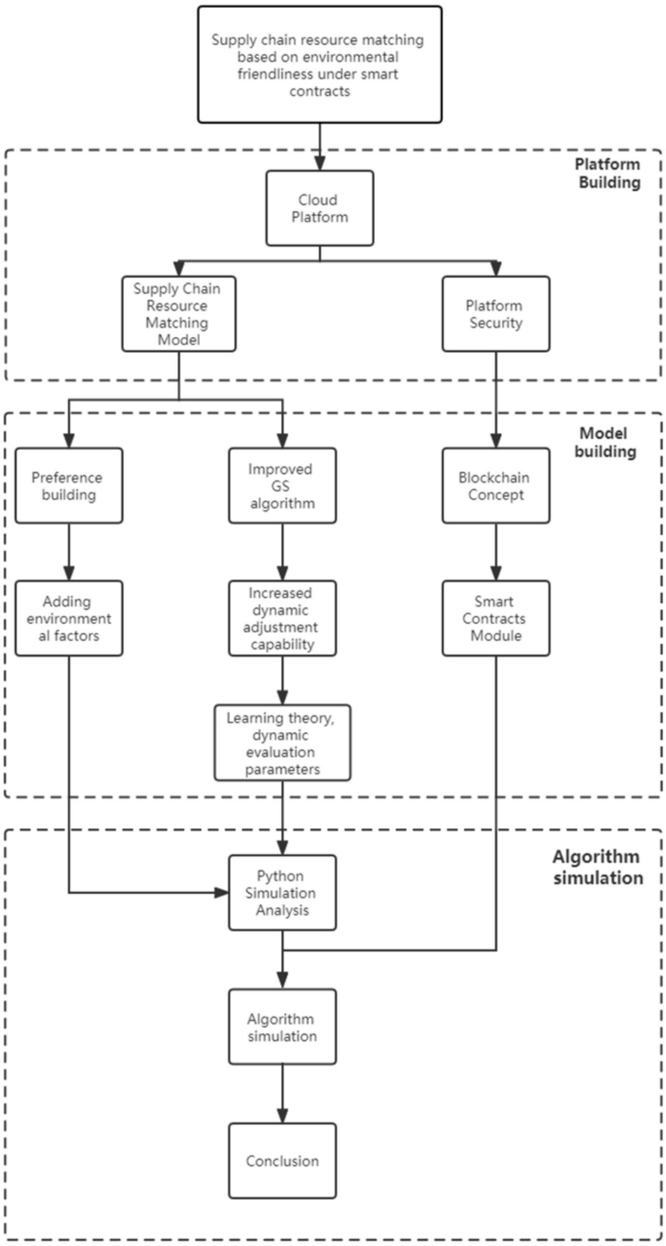

Figure 1. Research Road Map.

2. Research Hypothesis

2.1. Establishment of a Two-Sided Matching Model

With the transformation of the industrial model and rise of the Internet platform, the cloud service platform plays an irreplaceable role in the process of task operation, such as resource sharing, network effect, mutual intercourse, and cooperation, etc. As shown in the schematic diagram in Figure 2. The matching task carried out by the cloud manufacturing service platform in this study is a multiple matching problem, considering that the service level of both parties should undergo dynamic changes after multiple matching is carried out, so the learning effect model is now introduced to dynamically evaluate the learning ability of both parties. However, since the learning ability is a monotonically increasing function, it does not fully reflect the dynamic evaluation ability of the system. Therefore, this study also introduces dynamic evaluation parameters to evaluate the ability value of both parties from multiple perspectives to positively influence the preference calculation of both parties; both parties are matched by the GS algorithm after obtaining the preference calculation; and finally, to guarantee the openness, transparency and security of the data, the whole process of this matching is completed in the smart contract module under the blockchain.

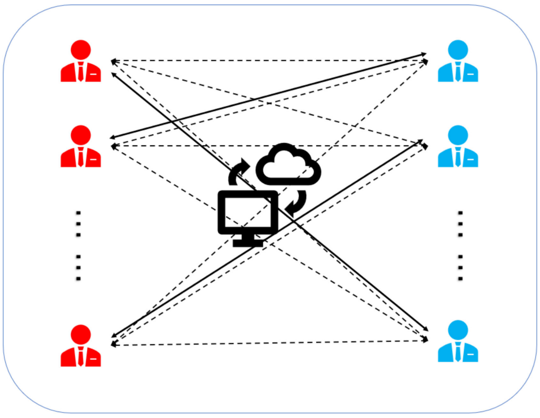

Figure 2. Schematic diagram of the two-sided matching problem under smart contracts.

2.2. Logical Flow Design for Deploying Smart Contracts

The smart contract design in this paper requires the joint participation of the service demander, i.e., the demand side, service provider (i.e., the supplier and cloud platform). However, considering that not all companies are clear about smart contracts and the logic of blockchain operation, the platform is required to assist both parties to complete the specified writing of smart contracts and post-maintenance. The logical process of developing smart contracts for three parties can be referred to Figure 3. Step 1: The demand side, supply side, and platform need to participate in the formulation of the smart contract, which should contain all the transaction information and specify the automatic execution trigger conditions of the smart contract. Step 2: The cloud platform should be responsible for the coding of the smart contract after the three parties confirm the content of the contract. Step 3: The platform uploads the completed compiled smart contract to the Alliance Chain block platform. Step 4: The verification node inside the Alliance Chain accepts the contract and performs initial verification; if there is no problem with the smart contract, the contract is officially effective and both parties start production work. Step 5: The smart contract periodically checks whether there is an event that meets the trigger conditions. Step 6: If an event occurs, the smart contract automatically uploads the event to the validation node and arranges the event into the validation queue waiting to be validated by the validation node in the federation. Step 7: After verification, the verification node sends the result and signature of the verification node back to the smart contract, and if the verification fails the smart contract will return. Step 8: Wait for the event to be triggered; if the verification is successful, the blockchain will automatically execute the contract.

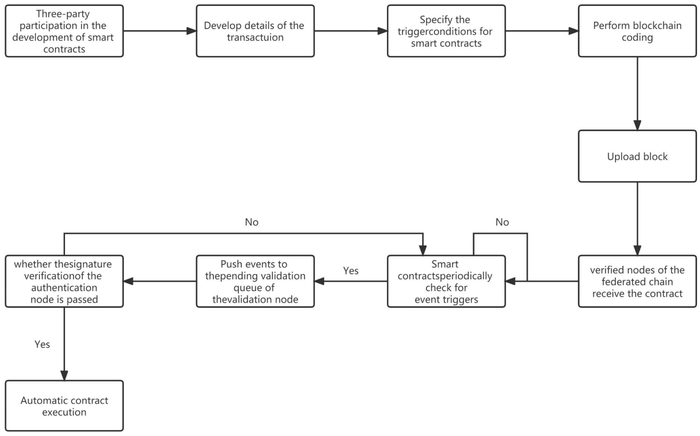

Figure 3. Logic flowchart for developing smart contracts.

2.3. System Flow Design of Smart Contracts

After the two-sided matching is completed, both parties confirm the partners and discuss the details. After the information of both parties is imported into the cloud manufacturing platform system, the certificate center is responsible for providing the generated public key, private key and version number, and other authentication information to the person in charge of both parties; and the person in charge of both parties confirm the details of the transaction and then generate their respective digital signature certificates to confirm the transaction, while both parties remit the funds to the designated bank account. Then, the production starts. During the production process, the supplier uploads the manufacturing information to the smart contract module in real-time through RFID or QR code, NFC, or other related technologies; and the demand side can view the manufacturing progress and other related information in real-time by calling the application in the smart contract module. The smart contract module is responsible for receiving the implementation progress from the supplier, judging whether the production is normal or not, and controlling the bank account specified by both parties, and automatically operates the wire transfer matters if the production is completed or there is a violation, while the smart contract module will package and encrypt all the information and upload it to the blockchain for data preservation. The system flow design of smart contract is shown in Figure 4.

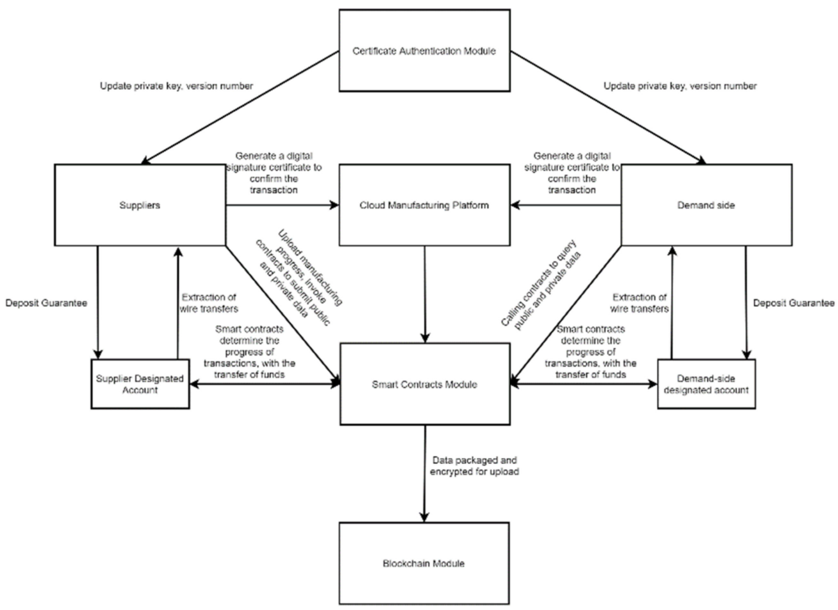

Figure 4. System flow design for smart contracts.

3. Matching Model Construction

3.1. Preference Calculation Based on Learning Theory

Based on the above analysis, this paper constructs a two-sided matching model based on learning theory [28], which is widely used in pricing decisions, inventory management, and other research fields. Its default unit processing time will continue to decrease with the increase in processing units and when production proficiency reaches a peak manufacturing efficiency will tend to a steady state, and the learning ability of both matching subjects is also dynamically enhanced with the increase in the number of matching tasks, thus improving the level of service quality; and when the cumulative dynamic learning ability reaches a certain level will tend to stabilize the phenomenon. The formula is as follows:

$$QoM_{it} = \overline{qom}_i \left[t^{-\frac{ln(b)}{ln2}} \right] \tag{1}$$

where QoM_{it} denotes the current service capability of the ith service item at the end of the tth matching task, $\overline{qom}_i$ is the basic learning capability possessed by the ith service, which also represents the initial skill value of the subjects of both matching parties, and $b \in [0,\ 1]$ is called the learning rate; and when b is smaller, $-\frac{ln(b)}{ln2}$ will be larger; and the learning rate level of both subjects is assessed by the literature and historical experience in general due to the differences in resource endowment and their characteristics, thus forming the service capability matrix $B = [b_1, b_2, \ldots b_m]$, where b_i denotes the learning rate level of the ith service.

3.1.1. Cumulative Dynamic Learning Capability Calculation Based on Learning Effects on the Demand Side

During the operation of the platform, the number of service demanders' participation in matching is represented as a matrix $TM = [tm_1, tm_2, \ldots tm_m]$, where tm is the number of participants in matching; the learning level is represented as a matrix $MB = [mb_1, mb_2 \ldots mb_m]$, where $mb_i \in [0,1]$ represents the learning rate level of the ith service demander; and QoM_i^{now} is the cumulative dynamic learning ability of the ith service demander after the tm_ith matching, where qom_i represents the basic learning ability of the ith service demander. According to the theoretical model of the learning effect given above, the current cumulative dynamic learning ability of the service demander after matching can be calculated as follows:

$$Qom_i^{now} = qom \left[tm_i^{-\frac{ln(mb_i)}{ln2}} \right] \tag{2}$$

3.1.2. Cumulative Dynamic Learning Capability Calculation Based on Learning Effects on the Supply Side

Similarly, the number of project participants of the service provider is represented as a matrix $TN = [tn_1, tn_2, \ldots tn_n]$, and tn is the number of project participants; the learning level is represented as a matrix $NB = [nb_1, nb_2, \ldots nb_n]$, and $nb_j \in [0,1]$ represents the learning rate level of the jth service provider; QoN_j^{now} is the cumulative dynamic learning ability of the jth service provider after the tn_jth matching, where qon_j represents the basic learning ability of the jth service provider. Similarly, the current cumulative dynamic learning capability of the service provider after matching can be calculated as follows:

$$QoN_j^{now} = qon_j \left[tn_j^{-\frac{ln(nb_j)}{ln2}} \right] \tag{3}$$

3.2. Calculation of Preference Based on Dynamic Evaluation Parameters

Since the learning theory curve is a monotonically increasing curve, it does not accurately summarize the state of the object. Therefore, in addition to the learning theory, dynamic evaluation parameters are introduced in this paper. Dynamic evaluation parameters can dynamically adjust the evaluation parameters of the service provider. This adjustment depends on the scores of the service recipient at the end of the service. When a service scores a lower score, the system will lower the dynamic evaluation parameter of that service after the run, to safeguard the legitimate interests of both partners. This process can also prevent incidents such as some large companies not caring about small business orders or starting to not care about customer evaluations after multiple task matches. The following formula can be calculated as:

$$QoX_t = QoX_{t-1} + qox_t \tag{4}$$

$$qox_t = \frac{0.6QoX_{t-1} + 0.4B}{(t-5) \times \mathrm{SC}} \tag{5}$$

QoX_t denotes the evaluation parameter calculated by the above equation at the end of the tth service; QoX_{t-1} indicates the evaluation parameter when the tth service is performed, and when t = 1, it means that the subject is its first match, and the default QoX_{t-1} = 50; qox_t is the variable calculated after scoring by the client; $B \in [0, 100]$ is the service rate of the firm determined by the subject's circumstances, such as public reputation, the importance attached to customer opinions, etc., which are generally fixed values; SC indicates the rating of this service by this cooperative customer, SC $\in [0, 100]$ and SC $\neq 50$, which will be converted to -0.5~0.5 by the system; t is the number of matches.

The inverse proportional function is chosen as the basis of qox_t to make the first few results of this dynamic evaluation parameter larger, but the fluctuation of the subsequent results decreases with the rise in the number of times when a new company joining the platform completes the first cooperation; because the number of matches is 0, the overall function will calculate a larger result. Compared with the evaluation calculation function with a fixed score, this function can be simultaneously used to quickly evaluate the service-level position of the company by the first few large fluctuations. The calculation of the evaluation parameters is controlled by four variables: the current rating of the company, service rate, number of matches, and customer's rating. When the customer completes the collaboration according to the partners assigned by the system, the system will automatically follow up with the customer rating. As an external evaluation mechanism, the customer rating will control the positive and negative output of the evaluation parameter. When the customer scores less than 50, it means that the customer is not satisfied with the service of this partner, and the evaluation parameter of this partner will be reduced through the system operation.

The reference of the evaluation parameters is equivalent to a reputation system; for companies with too low a reputation will face matching with companies of the same reputation or be eliminated from the platform. In this study, by applying learning effects and dynamic evaluation indexes to construct the satisfaction of both service supply and demand subjects, not only the matching subjects' own various service capabilities are considered but also external evaluation, making the model more effective and persuasive.

3.3. Multi-Dimensional Matching Model Construction

The model established this time is a strict two-sided matching model, so the first step should be to establish the preference sequence of both sides; because the number of supply and demand sides on the platform is extremely large and it is unrealistic for all enterprises on both sides to give a complete reference sequence based on the preferences of both sides, this model starts from an overall, multi-angle perspective to facilitate the calculation of the preference sequence. The overall idea is to first establish the basic information radar chart of both sides; the radar chart comparison can clearly and completely compare the preferences of both sides as well as the differences in capabilities. The radar simulation diagram of demand-side demand and supply-side capacity is shown in Figure 5.

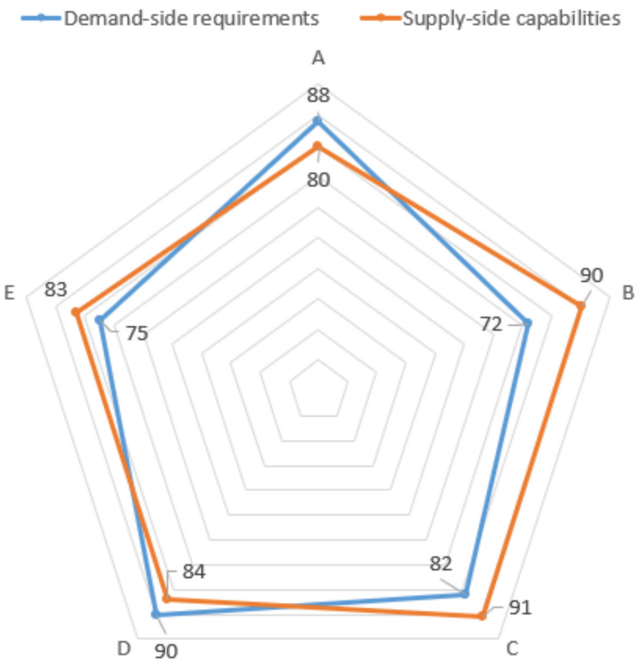

Figure 5. Illustration of demand-side demand and supply-side capacity radar diagram.

After the comparison, we determined the difference in each aspect, because different companies have different needs for each indicator, as some high-end products will pay more attention to the reputation of their suppliers, and are not sensitive to price, while some civilian products have higher requirements for price and production scale, and are not particularly sensitive to reputation, so the concept of weight is introduced again; multiply the above differences by the weight and then sum up, and the smaller the sum, the higher the match between the two companies; and the preference ranking can be obtained by arranging the sum from the largest to the smallest.

3.3.1. Establishment of Reference Sequences

Before the demand side enters the platform matching, the platform should examine the demand side and score all aspects of the enterprise situation. The following Table 1 is assumed to examine the following aspects (Note: Acs, Bcs, Ccs, Dcs, can be any evaluation index such as payment terms, demand, company size, etc., for the convenience of arithmetic; Acs, Bcs, Ccs, Dcs, and service rate are calculated in (percentage system, learning rate $\in [0, 1]$).

Table 1. Demand-side status evaluation table.

	Condition Acs	Condition Bcs	Condition Ccs	Condition Dcs	Environmental Friendliness	Evaluation Parameters	Service Rate	Service Level	Learning Rate	Number of Matches
Demand side										

At the same time, the demand side, after passing the inspection, can put forward requirements for this need for products and product-related issues. Table 2 below still uses Acr, Bcr, Ccr, Dcr instead of evaluation indicators such as product quality, production reputation, production scale, etc. (Note: For the convenience of the calculation, Acr, Bcr, Ccr, Dcr are calculated on a percentage basis).

Table 2. Demand-side needs evaluation table.

	Acr	Bcr	Ccr	Dcr
Demand side				

Before the supplier enters the platform matching, the same need for the platform to conduct a comprehensive examination of its situation and score the supplier, the following Table 3 is assumed to examine from the following aspects (Note: Ass, Bss, Css, Dss, can be any evaluation indicators such as product quality, production reputation, production scale, etc. For the convenience of calculation, Ass, Bss, Css, Dss, and service rate are calculated in percent, learning rate ∈ [0, 1]).

Table 3. Supplier status evaluation table.

	Condition Ass	Condition Bss	Condition Css	Condition Dss	Environmental Friendliness	Evaluation Parameters	Service Rate	Service Level	Learning Rate	Number of Matches
Supply side										

At the same time, after the supplier has passed the assessment, it can also put forward some requirements to the demand side, and the following Table 4 continues to assume several requirements (Note: For the convenience of calculation, Asr, Bsr, Csr, Dsr are calculated in percent).

Table 4. Supplier Needs Evaluation Form.

	Asr	Bsr	Csr	Dsr
Supply side				

Additionally, for some suppliers and demand-side service the focus is different, such as demand-side production is several high-end market goods that often need suppliers to have good product quality and reputation, while other demand-side production is only involves civilian low-end products, the quality and reputation are not big requirements, but the demand for demand and demand stability has high requirements. The demand side can decide to increase the weight of the system; likewise, the supplier also has a certain focus on the demand side due to its enterprise positioning and production demand, so it can also increase the weight of the aspects they consider important through the system, as shown in Table 5, the evaluation table of the demand side. It should be noted that the sum of the weights of Acw, Bcw, Ccw, Dcw, and environmental friendliness should be 1, while the weights of the evaluation parameters and service level are fixed values.

Table 5. Table of demand-side weights (template).

	Acw	Bcw	Ccw	Dcw	Environmental Friendliness	Evaluation Parameters	Service Level
Demand side							

The weighting table of the suppliers is shown in Table 6 to note that the sum of the weights of Asw, Bsw, Csw, Dsw, and Esw should be 1.

Table 6. Supplier weighting table (template).

	Asw	Bsw	Csw	Dsw	Environmental Friendliness	Evaluation Parameters	Service Level
Supply side							

After importing the above table into the program, the system will automatically retrieve the Excel table and start calculating the reference sequence.

The demand-side specific calculation process is:

$$\sum_{K=A}^{D}(|K_{\mathrm{cr}}-K_{\mathrm{ss}}|)\times K_{cw}+(\text{The difference in environmental friendliness})\times\text{Environmental friendliness weighting}+(\text{Difference in evaluation parameters }+\text{The difference in service level})\times 0.2 \quad (6)$$

The above formula can calculate the matching degree of the demand and supply side when the demand side is the main body, and repeat the above process until the matching degree of the demand side and all suppliers are calculated and arranged in order from smallest to largest, and then we can get the preference sequence of the demand side.

The specific calculation process for the supply side is:

$$\sum_{K=A}^{D}(|K_{cr}-K_{cs}|)\times K_{sw}+\text{The difference in environmental friendlines}\times\text{Environmental friendlines weighting}+(\text{Difference in evaluation parameters }+\text{Difference in service level})\times 0.2 \quad (7)$$

The above formula can calculate the matching degree of the supplier and the demand side when the supply side is the main body, and repeat the above process until the matching degree of the supplier and all the demand sides are calculated and arranged in order from smallest to largest to get the preference sequence of the supplier.

3.3.2. GS Algorithm Matching

The GS matching algorithm (i.e., Gale-Shapley matching algorithm, also known as a delayed matching algorithm) simply means that an object Ai (i = 1,2, ... ,m) on one side of the set sends an invitation to an object Bj (j = 1,2, ... ,n) on the other side, and each Bj compares the received invitations and keeps the one which is best for him and rejects the others. The Ai whose invitation is rejected continues to send new invitations to other Bj's until no Ai wants to send another invitation. At this point, each Bj finally accepts its reserved offer. As shown in Figure 6. A key aspect of the algorithm is that the accepted invitations are not immediately accepted, but are only temporarily kept from being rejected until all matches are completed and the results are output.

The unilateral advantage is the disadvantage of the algorithm, i.e., the party that sends the invitation first will get the optimal match for itself in the stable situation of the group, while the party that passively accepts the invitation generally does not match the optimal solution for itself, which is the reason why the GS algorithm is not applicable in many two-sided matching models; however, the GS algorithm is chosen in the matching phase of this model because the demand side plays the role of the buyer in selecting the supplier. At this time, the demand side has a lot of initiative, and there are very few cases in the market where suppliers actively select partners, while the GS algorithm is less computationally intensive and runs faster than approximation-type multi-objective optimization matching algorithms such as genetic algorithms. The improved GS algorithm with the introduction of learning theory and dynamic evaluation parameters already has the feature of screening positive and negative partners, which will greatly enhance the matching accuracy of this matching algorithm and ensure the positivity of the platform to prevent the negative cooperation phenomenon; see Appendix A for the detailed comparison process.

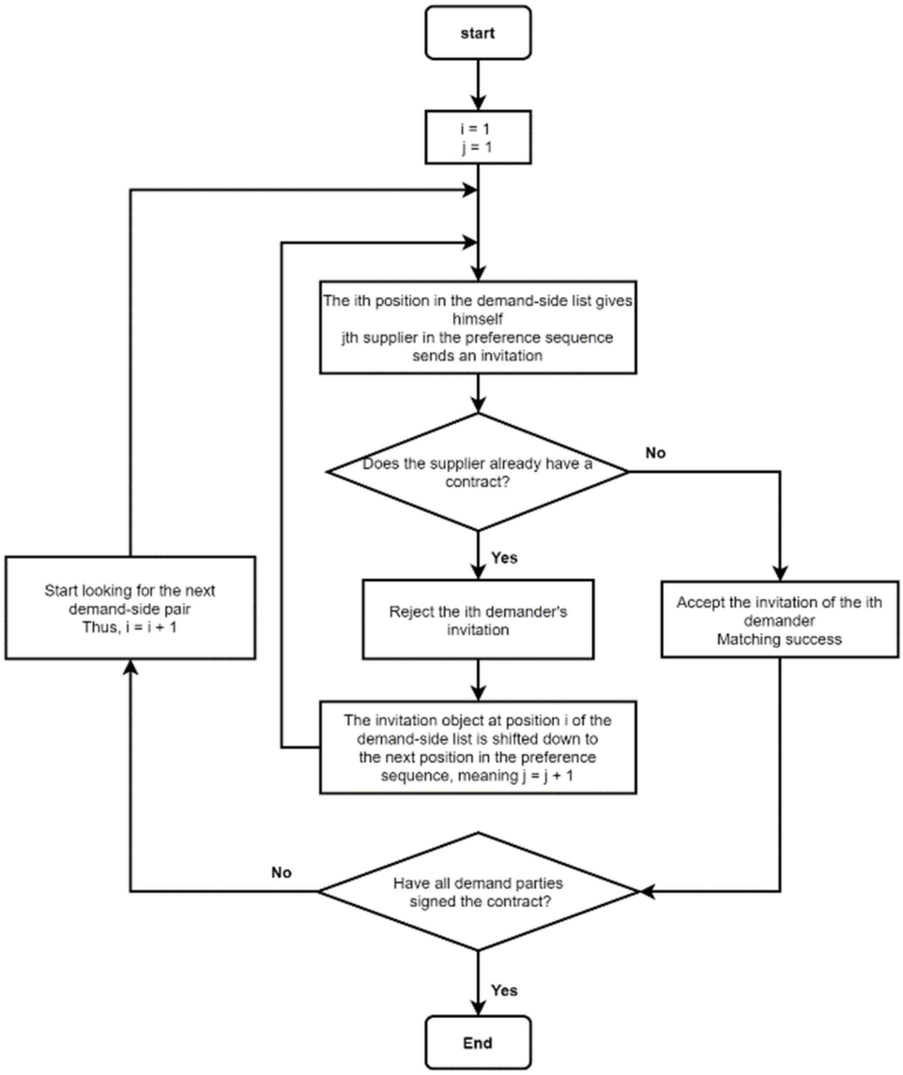

Figure 6. GS algorithm logic flowchart.

4. Calculation Example Analysis

4.1. Introduction of Tianjin Industrial Cloud Platform

"Tianjin Industrial Cloud" [29] was officially launched on 5 December 2017 and has been committed to industrial field automation systems, information systems, intelligent equipment, intelligent sensing, industrial interconnection, low-carbon production, and other product development and technical services, smart factories, and smart manufacturing solutions in recent years. Combined with their own advantages of layout of industrial big data applications and the industrial cloud services industry, Tianjin has launched the "China Steel Research Cloud", "equipment cloud", "energy cloud" and other innovative service platforms, and cooperates with several large enterprises to carry out intelligent manufacturing demonstration application construction.

The "Tianjin Industrial Cloud Platform" will focus on the core business needs of the whole life cycle of product design, R&D, production, supply chain, service, and marketing in the manufacturing field to create a comprehensive integrated application platform to help enterprises (industries) form new capabilities and new models in intelligent manufacturing, network collaborative manufacturing, high-volume customization, and remote operation and maintenance services. The new model will provide comprehensive services for the transformation and upgrading of traditional manufacturing industries in Tianjin, and even in China.

Due to the influence of multiple factors such as data sources and measurement methods, in the past monitoring scenarios of the park, problems very easily arose such as inaccurate carbon emission monitoring measurement data and difficulty monitoring and controlling carbon emission sources. The "Tianjin Industrial Cloud" platform grasps the pain points and needs of double carbon work, and by building carbon monitoring thematic modules, converges all carbon monitoring related data internally, and builds an integrated three-dimensional monitoring system from point to surface based on the end monitoring network, and conducts statistical analysis of carbon emission and energy use data, meeting the management needs from macroscopic to microscopic. It can meet management needs from the macroscopic-to-microscopic scale and truly achieve three-dimensional, real-time, multi-dimensional, and accurate monitoring and control of carbon emissions.

4.2. Tianjin Industrial Cloud Example Analysis

Tianjin industrial cloud platform has a matching demand; there are 10 demand parties (i.e., demand party 1, demand party 2 . . . demand party 10) demanding the same workpiece; after the initial screening, the system will be able to manufacture the workpiece of the supplier to fill the system; the initial screening is to prevent the service involved in some qualifications such as environmental certification, ISO9001, etc. some suppliers can not provide. After system screening, 10 suppliers have the ability and meet the production demand (i.e., Supplier 1, Supplier 2 . . . Supplier 10), and now we need to match these 20 platform users two-sidedly and sign a smart contract to guarantee production.

Step 1. First, before matching begins, create Table 7 supplier information table, Table 8 demand side information table, Table 9 supplier requirement information table, Table 10 demand-side demand information table, Table 11 Supplier weighting table, Table 12 demand-side weights. as shown in Section 3.3.1.

Table 7. Supplier information table.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Supplier 1	80	73	95	77	92	81.2	95	65	273.9094	0.75	32
Supplier 2	96.4	72	94	81	76	89.3	88	75	263.4757	0.77	29
Supplier 3	79	79	79	83	81	82	80	72	306.8538	0.69	16
Supplier 4	85	87	75	89	82	77	90	83	310.397	0.75	25
Supplier 5	82	88	80	88	84	71	87	71.5	294.4248	0.74	27
Supplier 6	71	82	91	80	90	65	73	82	260.7033	0.79	31
Supplier 7	77	73	90	75	82	84	90	81	254.4274	0.8	35
Supplier 8	80	90	75	89	83	83.5	85	77	322.0914	0.65	11
Supplier 9	82	80	77	72	75	86.7	91	75	294.5309	0.75	28
Supplier 10	82	85	75	79	95	80	90	66	303.4389	0.72	26

Table 8. Demand-side information table.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Demand side 1	92	90	88	82	88	82	88	82	211.595	0.85	58
Demand side 2	89	89	90	90	76	89	94	64	279.9149	0.75	35
Demand side 3	82	98	90	77	77	76.8	89	85	306.8382	0.69	12
Demand side 4	79	92	93	75	71	87.5	87	74	295.0235	0.75	29
Demand side 5	70	73	91	96	75	60.2	91	77	257.0367	0.76	21
Demand side 6	72	82	80	70	72	69.9	90	86	283.9475	0.78	29
Demand side 7	79	89	75	79	78	81.8	82	60	316.7637	0.71	30
Demand side 8	80	91	79	82	80	83.5	85	59	267.8598	0.73	29
Demand side 9	78	81	79	87	70	88	87	85	276.4568	0.8	40
Demand side 10	82	86	93	81	81	81.7	86	70	291.118	0.75	32

Table 9. Supplier requirement information table.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness
Supplier 1	81	90	91	81	79
Supplier 2	82	88	92	75	79
Supplier 3	89	92	87	79	72
Supplier 4	84	91	88	85	75
Supplier 5	88	91	85	80	76
Supplier 6	80	88	86	87	76
Supplier 7	68	75	94	96	72
Supplier 8	79	83	83	86	75
Supplier 9	76	86	86	90	79
Supplier 10	90	82	85	82	71

Table 10. Demand-side demand information table.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness
Demand side 1	83	91	72	80	84
Demand side 2	95	75	90	67	73
Demand side 3	80	90	75	76	79
Demand side 4	84	88	86	85	80
Demand side 5	88	89	77	84	79
Demand side 6	82	83	80	90	82
Demand side 7	81	82	85	92	83
Demand side 8	89	89	81	82	86
Demand side 9	90	75	83	79	81
Demand side 10	80	71	98	76	94

Table 11. Supplier weighting table.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness	Evaluation Parameters	Service Level
Supplier 1	0.1	0.2	0.2	0.3	0.2	0.2	0.2
Supplier 2	0.25	0.15	0.3	0.1	0.2	0.2	0.2
Supplier 3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Supplier 4	0.2	0.15	0.25	0.3	0.1	0.2	0.2
Supplier 5	0.3	0.3	0.1	0.1	0.2	0.2	0.2
Supplier 6	0.15	0.32	0.13	0.18	0.22	0.2	0.2
Supplier 7	0.15	0.1	0.35	0.35	0.05	0.2	0.2
Supplier 8	0.18	0.26	0.19	0.21	0.16	0.2	0.2
Supplier 9	0.32	0.17	0.21	0.19	0.11	0.2	0.2
Supplier 10	0.21	0.25	0.17	0.17	0.2	0.2	0.2

Table 12. Demand-side weights.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness	Evaluation Parameters	Service Level
Demand side 1	0.2	0.1	0.3	0.2	0.2	0.2	0.2
Demand side 2	0.4	0.2	0.35	0.05	0.2	0.2	0.2
Demand side 3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Demand side 4	0.4	0.1	0.4	0.1	0.2	0.2	0.2
Demand side 5	0.25	0.25	0.1	0.1	0.3	0.2	0.2
Demand side 6	0.33	0.22	0.2	0.1	0.15	0.2	0.2
Demand side 7	0.15	0.21	0.32	0.15	0.17	0.2	0.2
Demand side 8	0.35	0.22	0.18	0.11	0.14	0.2	0.2
Demand side 9	0.2	0.18	0.2	0.24	0.18	0.2	0.2
Demand side 10	0.05	0.05	0.45	0.05	0.4	0.2	0.2

Step 2. Calculate the reference sequence.

Run the pre-programmed program, the program will enter the information in the above table, according to the operation method mentioned in Chapter 3 to complete the operation, and output Table 13 difference between demand-side demand and supply-side status quo comparison (absolute value), Table 14 difference between supply-side demand and demand-side status quo comparison (absolute value) as follows

Table 13. Difference between demand-side demand and supply-side status quo comparison (absolute value).

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Supplier 6	Supplier 7	Supplier 8	Supplier 9	Supplier 10
Demand side 1	23.96288	28.88614	24.85176	23.4604	19.16596	20.46166	20.09648	25.03928	23.30718	24.51878
Demand side 2	11.7011	7.14784	16.38778	21.29642	15.80198	17.35232	10.9475	23.5053	10.5832	22.0048
Demand side 3	17.08576	26.3325	5.00312	4.91176	6.68268	19.20698	19.96216	5.04064	6.74146	7.57986
Demand side 4	13.22282	18.26956	7.16606	8.7747	2.71974	15.47404	15.43922	10.09358	7.75852	13.18308
Demand side 5	15.97454	14.7478	14.76342	13.97206	11.42762	12.73332	11.55186	17.50094	13.91884	17.33044
Demand side 6	12.50762	18.60436	7.78126	8.9899	4.14546	12.89884	14.20402	11.01878	8.83668	11.99828
Demand side 7	17.47086	23.9176	6.38198	7.87334	7.41778	17.96208	19.27726	5.30554	12.84656	12.81496
Demand side 8	11.00992	13.83682	13.3988	14.20744	8.613	11.7113	12.45648	16.48632	13.53422	14.11582
Demand side 9	8.90948	10.70622	10.6794	14.38804	10.9436	14.0107	9.78588	18.74692	10.07482	15.49642
Demand side 10	5.14172	17.53846	12.74716	20.3558	11.41136	13.87294	12.95812	17.48468	11.28258	14.16418

Table 14. Difference between supply-side demand and demand-side status quo comparison (absolute value).

	Demand Side 1	Demand Side 2	Demand Side 3	Demand Side 4	Demand Side 5	Demand Side 6	Demand Side 7	Demand Side 8	Demand Side 9	Demand Side 10
Supplier 1	16.26288	14.32614	22.25176	23.5604	27.26596	18.68166	15.31648	25.18928	23.72718	20.31878
Supplier 2	7.3011	7.88784	8.58778	8.34642	14.00198	11.26232	13.0475	13.6753	11.3932	6.7948
Supplier 3	11.58576	11.9225	4.60312	5.51176	16.58268	17.50698	16.78216	8.36064	11.27146	6.80986
Supplier 4	8.72282	9.15956	6.56606	8.8747	11.11974	15.94404	15.86922	9.27358	6.53852	6.08308
Supplier 5	7.57454	4.3378	14.36342	16.62206	20.67762	9.34332	6.02186	16.65094	15.64884	14.32044
Supplier 6	7.90762	7.99436	9.98126	11.9399	11.19546	12.48884	12.90402	11.42878	6.07668	8.02828
Supplier 7	22.57086	20.6076	14.98198	12.67334	6.56778	20.55208	28.41726	14.45554	13.74656	12.87496
Supplier 8	8.70992	6.97682	14.9988	16.05744	12.813	6.7313	8.68648	15.50632	7.57422	12.24582
Supplier 9	7.50948	8.09622	13.4794	15.33804	11.1936	10.9507	12.90588	14.31692	8.13482	9.77642
Supplier 10	9.24172	10.12846	11.14716	11.6558	12.16136	11.81294	14.58812	12.91468	7.01258	8.67418

The system will then calculate the preference sequences for both parties and output the complete preference sequence table as shown in Table 15.

Table 15. Complete preference order list for both sides.

The preference sequence for demand side 1 is: [5, 7, 6, 9, 4, 1, 10, 3, 8, 2]
The preference sequence for demand side 2 is: [2, 9, 7, 1, 5, 3, 6, 4, 10, 8]
The preference sequence for demand side 3 is: [4, 3, 8, 5, 9, 10, 1, 6, 7, 2]
The preference sequence for demand side 4 is: [5, 3, 9, 4, 8, 10, 1, 7, 6, 2]
The preference sequence for demand side 5 is: [5, 7, 6, 9, 4, 2, 3, 1, 10, 8]
The preference sequence for demand side 6 is: [5, 3, 9, 4, 8, 10, 1, 6, 7, 2]
The preference sequence for demand side 7 is: [8, 3, 5, 4, 10, 9, 1, 6, 7, 2]
The preference sequence for demand side 8 is: [5, 1, 6, 7, 3, 9, 2, 10, 4, 8]
The preference sequence for demand side 9 is: [1, 7, 9, 3, 2, 5, 6, 4, 10, 8]
The preference sequence for demand side 10 is: [1, 9, 5, 3, 7, 6, 10, 8, 2, 4]
The preference sequence for supplier 1 is: [2, 7, 1, 6, 10, 3, 4, 9, 8, 5]
The preference sequence for supplier 2 is: [10, 1, 2, 4, 3, 6, 9, 7, 8, 5]
The preference sequence for supplier 3 is: [3, 4, 10, 8, 9, 1, 2, 5, 7, 6]
The preference sequence for supplier 4 is: [10, 9, 3, 1, 4, 2, 8, 5, 7, 6]
The preference sequence for supplier 5 is: [2, 7, 1, 6, 10, 3, 9, 4, 8, 5]
The preference sequence for supplier 6 is: [9, 1, 2, 10, 3, 5, 8, 4, 6, 7]
The preference sequence for supplier 7 is: [5, 4, 10, 9, 8, 3, 6, 2, 1, 7]
The preference sequence for supplier 8 is: [6, 2, 9, 7, 1, 10, 5, 3, 8, 4]
The preference sequence for supplier 9 is: [1, 2, 9, 10, 6, 5, 7, 3, 8, 4]
The preference sequence for supplier 10 is: [9, 10, 1, 2, 3, 4, 6, 5, 8, 7]

The system then imports the preference sequences of demanders and suppliers into the system and completes two-sided matching through the system, with the following matching results: the first one is the demander and the last one is the supplier.

[(1, 6), (2, 2), (3, 4), (4, 3), (5, 7), (6, 8), (7, 5), (8, 10), (9, 9), (10, 1)].

Here the two-sided matching is over and both parties can cooperate according to the matching result; next, the program will simulate the evaluation session after the cooperation by asking about the satisfaction of the participants and entering the satisfaction in the form of scoring, as shown in Table 16, and taking a random number for each scoring result.

Table 16. Scoring results.

	Score		Score
Demand side 1	65	Suppliers 1	60
Demand side 2	79	Suppliers 2	41
Demand side3	45.5	Suppliers 3	47
Demand side4	52	Suppliers 4	68
Demand side5	39	Suppliers 5	90
Demand side6	77	Suppliers 6	40
Demand side7	90	Suppliers 7	62
Demand side8	58	Suppliers 8	61.5
Demand side9	41	Suppliers 9	42
Demand side10	40	Suppliers 10	84

After entering the rating, the system will recalculate the service parameters and service levels of both parties and return the corresponding table, as shown in Tables 17 and 18 for the parameters that have been returned.

Table 17. Supplier status evaluation table.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Supplier 1	80	73	95	77	92	81.43437838	95	65	273.9095	0.75	33
Supplier 2	96.4	72	94	81	76	89.06499412	88	75	266.9852	0.77	30
Supplier 3	79	79	79	83	81	81.884	80	72	317.7008	0.69	17
Supplier 4	85	87	75	89	82	77.4932	90	83	315.7008	0.75	26
Supplier 5	82	88	80	88	84	71.9675	87	71.5	299.2916	0.74	28
Supplier 6	71	82	91	80	90	64.81055556	73	82	263.6267	0.79	32
Supplier 7	77	73	90	75	82	84.2592	90	81	254.4274	0.8	36
Supplier 8	80	90	75	89	83	84.10446875	85	77	341.7466	0.65	12
Supplier 9	82	80	77	72	75	86.48564848	91	75	299.0103	0.75	29
Supplier 10	82	85	75	79	95	81.19225806	90	66	309.132	0.72	27

Table 18. Demand-side status evaluation table.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness	Evaluation Parmeters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Demand side 1	92	90	88	82	88	82.20095238	88	82	212.4596414	0.85	59
Demand side 2	89	89	90	90	76	89.65975	94	64	279.9149626	0.75	36
Demand side 3	82	98	90	77	77	76.58378824	89	85	321.4688469	0.69	13
Demand side 4	79	92	93	75	71	87.55135294	87	74	299.3516992	0.75	30
Demand side 5	70	73	91	96	75	59.89318462	91	77	257.0367731	0.75	22
Demand side 6	72	82	80	70	72	70.51893529	90	86	287.5416898	0.78	30
Demand side 7	79	89	75	79	78	82.69788324	82	60	322.114489	0.71	31
Demand side 8	80	91	79	82	80	83.69788235	85	59	272.1616691	0.73	30
Demand side 9	78	81	79	87	70	87.8248	87	85	278.7193026	0.8	41
Demand side 10	82	86	93	81	81	81.47454054	86	70	294.9794239	0.75	33

And then, both sides negotiate the details and receive the public key, private key, and version number from the certificate authentication module. After a successful negotiation, Tianjin Industrial Cloud Platform will write the smart contract module according to the negotiated details; and both parties agree to write the smart contract and confirm that it is correct after remitting the guaranteed money and other amounts to the designated account, and then generate their respective self-signed certificates; and the smart contract is formally established. And then, the smart contract will automatically detect the manufacturing progress and other related information, and encrypt the data packaged and uploaded.

After the matching between the two parties has been completed, it is obvious that demand side 2 is a more typical matching result with supplier 2. From the demand side's demand table, we can see that demand side 2 has higher requirements for product quality and production scale; and also in the weight table of demand side 2, we can see that these two items occupy a higher result, so demand side 2 is simulating a high-end brand of basic components, which are characterized by good quality and high demand. Matching with demand-side 2 is supplier 2. From the data, the supplier has more mediocre production conditions except for product quality and production scale. On the contrary, Supplier 2 has very high requirements for demand stability, which is also in line with the basic information of Demand Side 2. It can be seen that both sides are matched to a better result in meeting their requirements, and there is no excessive waste of resources for either side.

At the same time, the system also automatically modifies the evaluation parameters according to the input ratings, with the current service level parameters. Since the preference sequence sorting of this system is based on the difference of each item, it can be seen that when there is a big difference in one evaluation parameter, several other items will not be matched together even if they are very close. The advantage of this is that most of the companies with high evaluation parameters will be matched together with other companies with high evaluation parameters. Even if they are somewhat lacking in one aspect, they can reach a deal by mutual negotiation. Companies with low evaluation parameters are mostly unhappy and unwilling to coordinate with their partners because of certain defects so even if the company's technical level is high enough, it is not a good deal, and companies with high evaluation parameters and low evaluation parameters will hardly be matched together. This will effectively ensure the sincerity of both sides in the communication process, with enthusiasm.

The Tianjin Industrial Cloud Platform has developed rapidly in the past few years, and with the increasing number of online users, the traditional matching algorithm can no longer meet the current matching needs. The GS algorithm designed in this study not only solves the problem of slow and inaccurate matching rates after too many online users but also takes into account the dynamic changes of the platform and friendliness of the environment to make the matching results more accurate. In the matching process, the industrial cloud platform should try its best to assume the responsibility of the third-party intermediary, whether in the preparation of smart contracts or the supervision of the program, service provision should be dutiful to ensure that user information security is not leaked. I believe that under such a premise, the industrial cloud platform will be able to win more opportunities with quality services and better meet the needs of users.

5. Conclusions

This study analyzes the supply chain resource matching problem considering enterprise carbon emissions under smart contracts. Compared with the traditional low-carbon supply chain or blockchain problem, this study organically combines the carbon emission problem of enterprises, blockchain platform, and supply chain upgrading and transformation. Firstly, in the supply chain, a cloud platform is introduced, and the preliminary work of matching is completed with the help of the platform, such as the inspection and mutual selection of both suppliers and demanders. Secondly, in the matching technology, the parameter of environmental friendliness is added for the carbon emission problem, and the dynamic adjustment of the reference sequence by the GS algorithm is realized through the introduction of learning theory and dynamic evaluation system, which makes the overall bilateral matching process reusable, while the dynamic evaluation system can make the matching result more accurate in the matching process, and also has a supervisory and promotional effect on the cooperation parties, which has a positive impact on the whole platform environment. Additionally, to ensure that the whole transaction process is open and transparent, we deploy the whole model in the smart contract system under the blockchain, so that the subsequent cooperation between the two parties is under the supervision of the platform through the technical means of the smart contract.

Finally, in the case analysis, we use the python programming language to build a complete matching model and simulate the whole process, which guarantees the openness and transparency of the transaction between the two parties by simulating the process of a smart contract and makes the overall transaction process traceable to prove the practicability of the model.

Through the above study, the following suggestions are made to manage future carbon emissions of the manufacturing supply chain: firstly, the upstream and downstream of the manufacturing supply chain cover a wide area and involve a large number of enterprises, and each relevant industry should formulate meticulous and uniform processes and environmental protection standards, to lay a good foundation for the later application of digital platforms equipped with blockchain technology. Secondly, the manufacturing industry should complete the digital supply chain transformation as soon as possible to realize the blockchain platform for real-time monitoring of manufacturing activities. Finally, the manufacturing industry should strictly control the quality and environmental protection of its products; and once the supply chain platform equipped with blockchain technology is online, the product data of the enterprise will be clearly shown in the form of data, and the merits and demerits of the products will be clear at a glance. Secondly, the manufacturing industry should complete the digital supply chain transformation as soon as possible to realize the blockchain platform for real-time monitoring of manufacturing activities. Finally, the manufacturing industry should strictly control the quality and environmental protection of its products, and once the supply chain platform equipped with blockchain technology is online, the product data of the enterprise will be clearly shown in the form of data, and the merits and demerits of the products will be clear at a glance.

Author Contributions: J.W. was responsible for the idea design of the paper. Z.L. was responsible for model building and paper writing. Y.L. and X.Y. was responsible for the paper adjustment. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Social Science Fund of China, grant (21AGL001).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to platform confidentiality principles.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

To demonstrate the importance of learning theory and dynamic evaluation parameters, a simple simulation of matching is now available, 4×4 matching. For space reasons, the complete data of either side will not be shown here.

Table A1. Simulation of the current supplier status parameter table.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness
Supplier 1	80	90	76	69	80
Supplier 2	74	86	75	81	75
Supplier 3	79	82	79	83	72
Supplier 4	75	87	92	89	91

Table A2. Simulated demand-side status quo parameter table.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness
Demand side 1	90	90	88	82	88
Demand side 2	78	89	90	90	76
Demand side 3	84	98	90	88	91
Demand side 4	79	92	93	75	75

The environment now assumed is the most basic GS algorithm matching, not involving learning theory and dynamic evaluation parameters. The following figure shows the preference sequence and matching results output by the system.

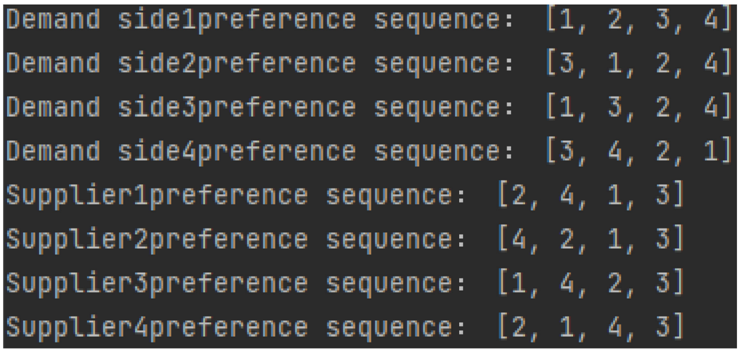

Figure A1. Preference sequence output after python run.

The pairing results are (1, 2), (2, 1), (3, 4), (4, 3).

It can be seen that due to the dataset, the preference of the demand side for supplier 4 is extremely low. At this time, dynamic evaluation parameters and a dynamic scoring mechanism are added, and the scoring of suppliers 2 and 4 are set above 85; meanwhile, the scoring of suppliers 1 and 3 are set below 70, simulating suppliers 2 and 4 as positive collaborators and suppliers 1 and 3 as negative collaborators. On the demand side, similarly, the scores of demand sides 1 and 3 are set above 85 to simulate positive cooperators, and the scores of demand sides 2 and 4 are set below 70 to simulate negative cooperators. The following parameters are set.

Table A3. Simulation of demand-side parameter settings.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness	Evaluation Parmeters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Demand side 1	90	90	88	82	88	75.24412	80	65.23	65.23	0.77	1
Demand side 2	78	89	90	90	76	75.24412	78	65.23	65.23	0.81	1
Demand side 3	84	98	90	88	91	75.24412	81	65.23	65.23	0.78	1
Demand side 4	79	92	93	75	75	75.24412	82	65.23	65.23	0.79	1

Table A4. Analog supplier parameter setting.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Supplier 1	80	90	76	69	80	75.24412	82	65.23	65.23	0.75	1
Supplier 2	74	86	75	81	75	75.24412	81	65.23	65.23	0.69	1
Supplier 3	79	82	79	83	72	75.24412	75	65.23	65.23	0.73	1
Supplier 4	75	87	92	89	91	75.24412	77	65.23	65.23	0.78	1

As can be seen from the above figure, the values of the evaluation parameters, initial service rate, and current service rate are all the same, which is because this experiment is to verify that the evaluation parameters, and service level, have a positive impact on the matching results and can distinguish positive cooperative vendors from negative cooperative vendors. To ensure the accuracy of the experiment, the data of all experimenters are therefore given the same parameters. The matching is now started as shown in the figure for the first scoring.

Table A5. Simulated scoring results.

	Score		Score
Demand side 1	95	Supplier 1	70
Demand side 2	60	Supplier 2	88
Demand side 3	89	Supplier 3	65
Demand side 4	40	Supplier 4	87

Table A6. Demand-side status evaluation table modified after scoring.

	Payment Terms	Pickup Time	Demand Volume	Demand Stability	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Demand side 1	90	90	88	82	88	81.0301054	80	65.23	84.71429	0.77	2
Demand side 2	78	89	90	90	76	76.5165612	78	65.23	86.97333	0.81	2
Demand side 3	84	98	90	88	91	70.2036125	81	65.23	85.82895	0.78	2
Demand side 4	79	92	93	75	75	73.9450121	82	65.23	82.56962	0.79	2

Table A7. The evaluation table of the current situation of the supply side after scoring.

	Product Quality	Product Reputation	Production Scale	Registered Capital	Environmental Friendliness	Evaluation Parameters	Service Rate	Initial Service Level	Current Service Level	Learning Rate	Number of Matches
Supplier 1	80	90	76	69	80	77.84233573	82	65.23	86.97333	0.75	2
Supplier 2	74	86	75	81	75	80.15539656	81	65.23	89.35616	0.69	2
Supplier 3	79	82	79	83	72	77.1227818	75	65.23	89.35616	0.73	2
Supplier 4	75	87	92	89	91	79.92748577	77	65.23	83.62821	0.78	2

As shown, the parameters of both sides start to change after several continuous repetitions of the experimental results as follows.

```
Demand side1preference sequence: [2, 4, 1, 3]
Demand side2preference sequence: [1, 3, 2, 4]
Demand side3preference sequence: [4, 2, 2, 1, 3]
Demand side4preference sequence: [3,1, 2, 4]
Supplier1preference sequence: [2, 4,1, 3]
Supplier2preference sequence: [1,3,2,4]
Supplier3preference sequence: [4, 2,1, 3]
Supplier4preference sequence: [3, 1, 4, 2]
The results of this match are as follows:
[(1,2),(2,1),(3,4),(4,3)]
```

Figure A2. Numbering sequence and matching results after multiple rounds of evaluation.

As shown, positive collaborators demander 1, 3 and supplier 2, 4 have been matched together; while negative collaborators demander 2, 4 and supplier 1, 3 have been matched together, which indicates that with the addition of learning theory and dynamic evaluation parameters, the GS algorithm already has the feature of screening positive and negative collaborators, which will greatly enhance the matching accuracy of this matching algorithm, while ensuring the positivity of the platform and preventing the emergence of negative collaboration.

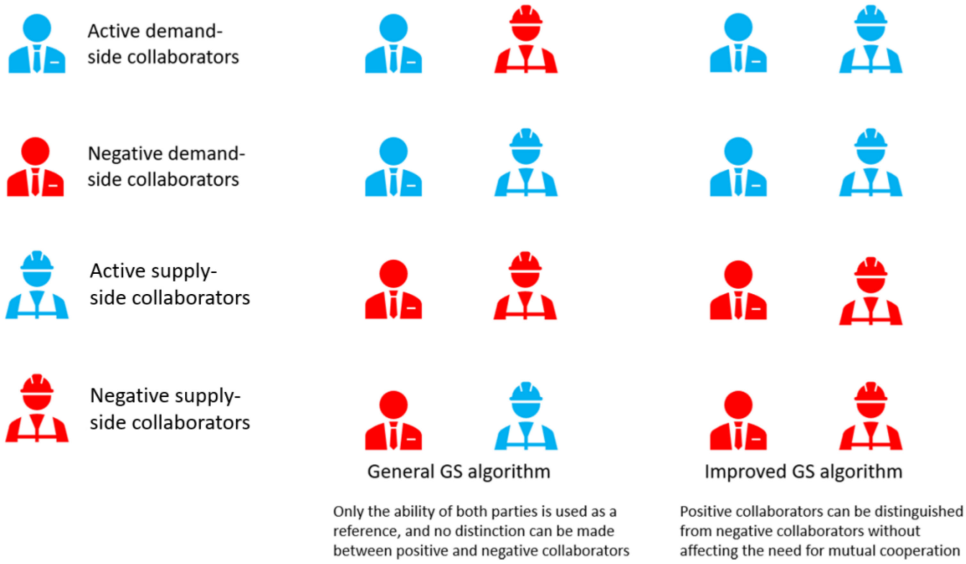

Figure A3. Schematic diagram of the advantages of the improved GS algorithm.

At the end of matching the system asks for scoring results and after entering the results the system modifies the service level and evaluation parameters of all participants according to the learning theory formula and dynamic evaluation formula above.

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