

# *Relationship between Supply–Demand Structures of Base Metals and the Evolution of Corporate Value*

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**Abstract:** Research has found that the evolution of the supply and demand structure of base metals dynamically affects market value and drives value reassessment through corporate strategic responses (capacity adjustments, technological innovation, supply chain optimization). The dynamic model analysis shows that there are significant differences in the optimal objective function selection strategy under different supply and demand scenarios: maximizing profit rate to improve capital turnover efficiency when supply exceeds demand, maximizing comprehensive matching degree to stabilize strategic synergy effect when supply and demand are balanced, and minimizing empty driving rate to optimize resource utilization efficiency when supply exceeds demand. Market volatility plays a moderating role in the relationship between supply and demand and firm value, with significant heterogeneity in technological pathways, policy environments, and firm attributes. Research and innovate to construct a dynamic analysis framework that incorporates strategic response factors (capacity elasticity, technological efficiency, supply chain resilience), and directly observes dynamic evolution using the market value to book value ratio, providing practical guidance for resource-based enterprise value evaluation theory and commodity market participants.

## 1 Introduction

In the global pattern of base metal trade, the supply and demand structure of basic metals such as copper, aluminum, and zinc is undergoing profound restructuring. The supply and demand fluctuations of these metals as industrial core raw materials directly impact the logic of enterprise value evaluation. Traditional static valuation models are ineffective due to neglecting the dynamic matching mechanism of supply and demand. Existing research mostly focuses on short-term price fluctuations, but rarely explores the dynamic impact path of supply and demand evolution on long-term value creation of enterprises. The challenge of existing literature is that traditional asset pricing frameworks are difficult to capture the non-linear characteristics of supply and demand, historical data prediction models rely on stable market environments, and technological innovation and geopolitical shocks exacerbate their vulnerability; Although the international commodity market will gradually be included in ESG assessments[1] after 2025, the value evolution path of

base metal enterprises will become more complex due to their special characteristics such as resource scarcity, production energy consumption characteristics, and circular economy potential. The motivation for this study is to fill the theoretical gap by empirically exploring how the evolution of supply and demand structure affects market value through corporate strategic responses such as capacity adjustments, technological innovation, and supply chain optimization, thereby driving value reassessment. The research objectives include revealing the linear relationship between supply and demand and enterprise value, analyzing the transmission mechanism of strategic response, verifying the moderating effect of market volatility, and exploring the heterogeneous effects of technological paths, policy environments, and enterprise attributes. The contribution lies in innovating and constructing a dynamic analysis framework, integrating strategic response elements (capacity elasticity, technological efficiency, supply chain resilience) into a unified system, and clarifying the path of value reassessment; By directly observing the dynamic evolution using the ratio of market value to book value, micro evidence is provided for the efficient market hypothesis. This not only enriches the theory of value assessment for resource-based enterprises, but also provides practical guidance for commodity market participants and regulatory authorities, promoting sustainable value creation for base metal enterprises in green transformation and technological revolution.

## 2 Correlation theory

### 2.1 Hungarian algorithm

The Hungarian algorithm [2] is a classic method for solving the bipartite graph matching problem [3], which focuses on gradually optimizing the matching results by finding an augmented path. A bipartite graph consists of two independent sets of vertices  $U$  and  $V$ , as well as edges connecting the two sets. Matching refers to selecting an edge set such that each vertex is associated with at most one edge. The goal includes maximum matching (maximum number of edges) or maximum weight matching (edge weight and maximum). The augmented path is a key concept - starting from an unmatched vertex, alternating between matched and unmatched edges, and finally reaching another unmatched vertex. By flipping the matching state on the path, the matching scale can be expanded. There are two types of algorithms: unweighted and weighted. The unweighted case starts with empty matching and uses breadth/depth first search to find an augmented path and flip the edge state until a new path cannot be found, at which point the matching reaches its maximum; The weighted case introduces vertex labels and equal subgraphs, where the labels satisfy that the edge weights are not greater than the sum of the labels of the two vertices, and the equal subgraphs are composed of edges that satisfy the equal sign condition. The algorithm converges to maximum weight matching through a cyclic process of constructing equal subgraphs, finding augmented paths, and adjusting labels (calculating the minimum adjustment amount to update labels when a path cannot be found to expand equal subgraphs). This algorithm is widely used in fields such as resource allocation, task assignment, and image matching, providing efficient theoretical support for complex optimization problems.

### 2.2 Linear Programming and Kuhn Munkres Algorithm

The linear programming (LP) algorithm[4] optimizes the linear objective function (such as maximizing matching degree or minimizing transportation cost) and satisfies linear constraints (such as load limit, time window, unique matching constraint, etc.), using the simplex method or interior point method to find the optimal solution in the convex polyhedron solution space. Its linear characteristics ensure the accessibility of the global optimal solution, making it suitable for

scenarios such as resource allocation and cost optimization. The Kuhn Munkres (KM) algorithm[5], as an improved version of the Hungarian algorithm, is specifically designed for the maximum matching problem of weighted bipartite graphs. It constructs equal subgraphs (edge sets that satisfy the condition that the sum of vertex weights is equal to the edge weights) by adjusting the vertex weights, and gradually expands the matching set using an augmented path. The algorithm steps include initializing the weight matrix, searching for augmented paths in equal subgraphs, adjusting vertex weights to expand feasible paths, iterating until all left vertices are matched, suitable for large-scale matching problems and maintaining accuracy. Both of them solve complex resource allocation and task assignment problems through mathematical optimization methods, providing efficient theoretical support for fields such as supply chain optimization and transportation scheduling.

### **3 Research method**

#### **3.1 Overview of Vehicle Cargo Matching Theory**

Vehicle cargo matching [6] uses modern information technology to accurately match the transportation needs of shippers with the supply of vehicles, achieving efficient, safe, and cost optimized transportation processes. The core is to solve the information asymmetry problem of traditional freight transportation, such as "difficult to find goods by vehicle" and "difficult to find goods by vehicle". Its business characteristics are significant: the matching mechanism is highly complex, requiring comprehensive consideration of multidimensional factors such as cargo weight, volume, type, vehicle load capacity, location, route planning, and loading and unloading point matching; Long distance transportation requires close coordination between space and time, requiring the planning of the optimal route while taking into account traffic conditions, delivery and arrival times, etc., to ensure on-time delivery; Supply and demand fluctuations (such as seasonal factors and regional differences) and sudden demands (such as emergency orders) pose challenges to matching efficiency and resource scheduling, while specialized services (such as dangerous goods and refrigerated goods transportation) and technical support (such as real-time monitoring and data analysis) ensure transportation safety and compliance. Compared with the ride hailing model, both are based on a two-sided market and achieve real-time supply-demand matching through platforms, reducing information asymmetry, optimizing resource allocation, and serving as intermediaries to collect commissions. But the differences are obvious: vehicle cargo matching requires higher requirements in terms of matching complexity (involving vehicle load and cargo type adaptation), spatial matching (long-distance route planning), time matching (strict delivery and arrival time), target balancing (balancing economic and social benefits), and demand periodicity (seasonal logistics peaks); Online ride hailing focuses on urban travel, with relatively simple matching requirements and a greater emphasis on passenger experience and instant response. Both reflect the common logic of the Internet platform in solving the supply and demand matching problem, but the application scenarios and demand differences shape their own unique operating mechanisms.

#### **3.2 Multi Objective Grey Target Decision Theory and Its Application in Complex Matching Problems**

Multi objective grey target decision-making (MOGT)[7] is a method that combines multi-objective decision-making with grey system theory and is suitable for multi-objective optimization problems under uncertain conditions. The core of it regards the ideal state of each target as the "target center" through the "grey target" model, and evaluates the quality of the plan by measuring

the proximity between the actual plan and the target center. In the matching problem, this method can comprehensively consider multiple objectives such as transportation cost, time, efficiency, and resource utilization, and handle uncertainties such as demand fluctuations and uneven distribution of vehicle sources. There are three types of effect measures: benefit oriented goals (such as maximizing profits) are measured as

$$r_{ij}^k = \frac{u_{ij}^k - \min\{u_{ij}^k\}}{\max\{u_{ij}^k\} - \min\{u_{ij}^k\}} \quad (1)$$

The cost based objective (such as minimizing empty driving rate) is measured as

$$r_{ij}^k = \frac{\max\{u_{ij}^k\} - u_{ij}^k}{\max\{u_{ij}^k\} - \min\{u_{ij}^k\}} \quad (2)$$

Moderate targets (such as moderate service coverage) are measured using upper or lower limit formulas based on the deviation direction between the effect value and the ideal value. The comprehensive effect measurement is obtained by weighted summation

$$r_{ij} = \sum_{k=1}^s \eta_k \cdot r_{ij}^k \quad (3)$$

weight for the target. The advantage of this method lies in handling complex scenarios with incomplete information and conflicting objectives, providing flexible decision support, improving transparency and interpretability, and being suitable for complex business scenarios such as special cargo transportation and multi-dimensional resource matching, promoting a balance between economic and social benefits.

### 3.3 Dynamic selection strategy for vehicle cargo matching objective function

In the scenario of vehicle cargo matching, different supply and demand fluctuations require targeted selection of objective functions to balance the interests of multiple parties. In the scenario of less vehicles and less cargo (FVLC), minimizing the empty driving rate (Z3) shows a balanced performance in terms of profit rate and empty driving rate indicators, with the best comprehensive effect, and is suitable for balancing the interests of car owners and cargo owners; If the platform strategy leans towards the demand of shippers, maximizing the matching degree (Z4) can significantly reduce the probability of cargo damage and enhance the trust of shippers. In the EVC scenario, maximizing the matching degree (Z4) performs outstandingly in controlling the probability of cargo damage and becomes the optimal choice, suitable for platforms that focus on their own growth rather than unilateral demand. In the scenario of multiple vehicles and less cargo (MVLC), the volume of cargo orders becomes a key constraint factor, and it is necessary to focus on improving the service level of shippers. Maximizing the matching degree (Z4) is the optimal way to control the probability of cargo damage, which can effectively attract cargo orders, alleviate the limitation of insufficient orders, and optimize the overall efficiency of the platform and the experience of shippers. The selection of objective functions for each scenario is based on dynamic evaluation of multiple indicators, and priority is adjusted according to the characteristics of the scenario to achieve efficient allocation of resources and balance of interests among multiple parties.

## 4 Results and discussion

### 4.1 Problem description and objective function design of vehicle cargo matching model

A certain freight platform provides whole vehicle transportation vehicle cargo matching services. The shipper publishes orders containing the type, weight, volume, starting and ending locations,

delivery time, and quotation of the goods. The driver inputs the vehicle type, load capacity, current location, and empty driving time and other transportation capacity information. The platform selects the objective function based on the comprehensive supply and demand situation to develop a matching plan and pushes it to the driver. The model assumptions include: the order and vehicle information remain unchanged within the planning cycle; Drivers who comply with platform deployment do not need to return; The platform information fee is affected by the driver's income; Assembly and disassembly of whole vehicle transportation are prohibited; Ignore uncertain factors such as traffic and weather; The driving speed and transportation cost are constant and only fuel consumption is considered; The loading and unloading costs are not borne by the driver; The loading and unloading time for different vehicles is the same. The constraints include type matching degree, weight and volume limitations (the weight of the goods does not exceed the maximum load capacity of the vehicle, and the volume does not exceed the maximum loading space), time window (the vehicle must arrive at the unloading point within the specified time of the order), decision variable 0-1 attribute (one vehicle can only carry one cargo, and one cargo can only be carried by one vehicle), vehicle availability (the task or malfunctioning vehicle cannot respond to new orders), and full load rate (the weight or volume of the goods should account for at least the proportion of the vehicle's capacity  $\gamma$ ). The model sets four objective functions to balance multi-party demands: maximizing profit (contracted driver profit=freight - transportation cost, maximum total profit), maximizing profit rate (maximizing the ratio of profit to transportation time, emphasizing time value), minimizing empty driving rate (minimizing the ratio of empty driving distance to total distance, reducing resource waste), and maximizing matching degree (weighted sum of comprehensive type, weight volume, time, and distance matching degrees, weights determined by analytic hierarchy process). As shown in Figure 1

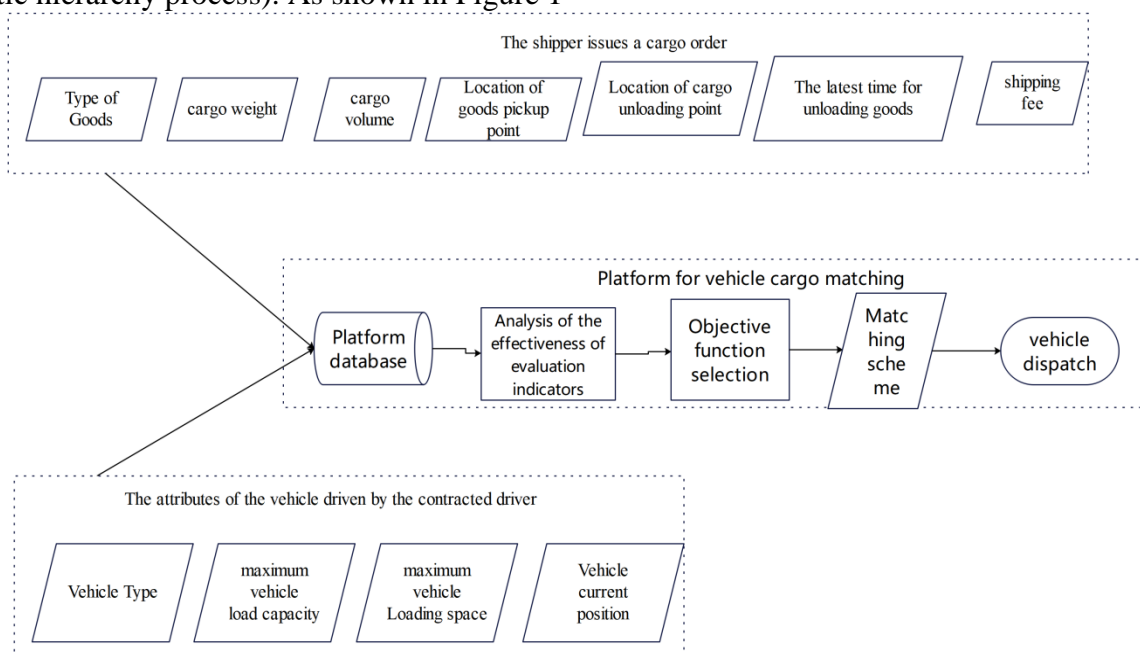


Figure 1 VCM business process diagram of the platform

This model addresses the challenges of supply and demand fluctuations by designing reasonable constraints and objective functions, balancing the interests of platforms, drivers, and shippers, providing efficient and accurate matching solutions, and promoting resource optimization and sustainable value creation.

## 4.2 Model experiment

The scenario data is derived from the actual operational data of the logistics company, and after anonymization, it includes vehicle and cargo source information, such as vehicle type, loading capacity, latitude and longitude coordinates, as well as characteristics such as cargo weight, volume, and transportation time. The parameter settings include the vehicle's driving speed (40km/h from the current location to the pickup point, 80km/h from the pickup point to the unloading point), earth radius of 6371km, loading and unloading time of 3 hours, etc. The weight coefficients are calculated and determined through the Analytic Hierarchy Process. In terms of algorithm selection, the Hungarian algorithm is suitable for small-scale scenarios, with polynomial time complexity and clear logic, but its performance is limited in large-scale problems and its adaptability to complex constraints is weak; Linear programming algorithms can achieve global optimal solutions and flexibly adapt to multidimensional constraints, but solving large-scale problems takes a long time and lacks real-time performance; The Kuhn Munkres algorithm, as a weighted bipartite graph matching method, supports comprehensive modeling of multiple factors such as freight and time, and efficiently handles medium to large-scale problems. However, its implementation is complex and the real-time performance in dynamic environments needs to be improved. Each algorithm needs to balance the selection between scene size and constraint complexity to achieve a balance between solution effectiveness and efficiency.

The comparison of algorithm performance shows that in terms of profit rate indicators, the average value of the Hungarian algorithm is 125.71, while the KM and LP algorithms are both 191.43; In terms of empty driving rate indicators, the average value of the Hungarian algorithm is 0.47, while the KM and LP algorithms are both 0.14. The specific data is shown in Table 1 below:

*Table 1 Comparison of Algorithm Profit Rate and Empty Driving Rate Statistics*

Performance Metrics	Algorithm	Average	Standard Error	Median	Mode	Standard Deviation	Variance
Profit Rate (¥/h)	Hungarian	125.71	11.00	103.31	76.26	69.57	4840.19
	KM	191.43	15.03	173.49	139.11	95.04	9032.80
	LP	191.43	15.03	173.49	139.11	95.04	9032.80
Empty Rate	Hungarian	0.47	0.04	0.50	0	0.25	0.06
	KM	0.14	0.04	0	0	0.23	0.05
	LP	0.14	0.04	0	0	0.23	0.05

In terms of time complexity, linear programming algorithms experience exponential growth as the problem size expands, resulting in a significant increase in computational overhead; The running time of the Hungarian algorithm and the KM algorithm increases steadily, with the KM algorithm slightly better and more suitable for large-scale weighted matching problems.

## 4.3 Effect analysis

The evolution of the supply and demand structure of base metals[8] directly impacts the logic of enterprise value evaluation, and dynamic models are needed to analyze the impact of supply and demand fluctuations[9]. In the scenario of resource supply and demand fluctuations, multi-objective grey target decision-making methods can scientifically select matching objective functions to balance the interests of multiple parties: prioritize meeting the needs of vulnerable parties when supply exceeds demand, and maximize capital turnover efficiency by maximizing profit rates; Maximizing the comprehensive matching degree during supply-demand balance can stabilize the strategic synergy effect; Minimizing the driving rate during oversupply can optimize resource

utilization efficiency. Specific scenario evaluations show that minimizing empty driving rate and maximizing comprehensive matching degree both perform well in the scenario of supply shortage, but the former is more balanced in terms of profit rate and empty driving rate indicators; Maximizing the comprehensive matching degree in the scenario of supply-demand balance has significant advantages in controlling the probability of cargo damage; The scenario of oversupply requires differentiation of customer types, with high-end customers focusing on comprehensive matching degree and ordinary customers focusing on minimizing empty driving rate. The model dynamically evaluates through four-dimensional indicators such as profit, profit rate, empty driving rate, and cargo damage probability, and adjusts target priority based on scene characteristics to achieve a balance between economic and social benefits. Management decisions need to be combined with real-time data and reinforcement learning techniques to enhance the ability to respond to unexpected factors such as market fluctuations and policy changes, and promote sustainable value creation for enterprises in green transformation and technological revolution. In the field of base metals, similar to copper, aluminum, zinc, and other basic metals, the fluctuation of supply and demand requires the construction of a dynamic analysis framework that includes capacity elasticity, technical efficiency, and supply chain resilience. Combined with multi-objective grey target decision-making methods, resource efficiency is emphasized when supply exceeds demand, strategic coordination is taken into account when supply and demand are balanced, and social responsibility is strengthened when supply exceeds demand. Value balance is achieved through dynamic evaluation.

## 5 Conclusion

The evolution of the supply and demand structure of base metals and the revaluation of enterprise value need to be analyzed through dynamic models. In the scenario of resource supply and demand fluctuations, multi-objective grey target decision-making methods can scientifically select matching objective functions[10] to balance the interests of multiple parties. For example, in scenarios where supply exceeds demand (such as a shortage of vehicles and a surplus of goods), the model prioritizes meeting the needs of disadvantaged parties and improves capital turnover efficiency by maximizing profit rates; When the supply and demand are balanced, maximizing the comprehensive matching degree can stabilize the strategic synergy effect; When there is an oversupply, minimizing the empty driving rate can optimize resource utilization efficiency. Specific scenario evaluations show that in the scenario of supply shortage, both minimizing the empty driving rate and maximizing the comprehensive matching degree perform well, but the former is more balanced in terms of profit rate and empty driving rate indicators; In the scenario of supply-demand balance, maximizing the comprehensive matching degree has significant advantages in controlling the probability of cargo damage and becomes the optimal choice; In the scenario of oversupply, it is necessary to distinguish customer types. High end customers focus on comprehensive matching degree, while ordinary customers focus on minimizing empty driving rate. The model dynamically evaluates the four-dimensional indicators of profit, profit rate, empty driving rate, and cargo damage probability, and adjusts the priority of targets based on scenario characteristics. For example, it focuses on resource efficiency when supply exceeds demand, takes into account strategic coordination when supply and demand are balanced, and strengthens social responsibility when supply exceeds demand. Management decisions need to be combined with real-time data and reinforcement learning techniques to enhance the ability to respond to unexpected factors such as market fluctuations and policy changes, and promote sustainable value creation for enterprises in green transformation and technological revolution.

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