

# Research on Benefit Distribution in Pallet Pooling Alliances based on an Improved Shapley Value

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## Abstract

Against the backdrop of dual carbon goals, pallet pooling alliances have emerged as a crucial solution to address severe pallet wastage, extremely low utilization rates, and inadequate standardization. This paper analyzes the operational model of pallet pooling alliances, fully considers their characteristics, proposes an improved Shapley value benefit distribution model, and analyzes and verifies the model's effectiveness and rationality. Results indicate that the improved benefit distribution model can satisfy the benchmark rates of return for different stakeholders while fully considering the impact of factors such as resource investment, risk bearing, and actual contributions on benefit distribution within pallet pooling alliances. This provides valuable reference for promoting the development of pallet pooling alliances.

## Keywords

Pallet Pooling Alliance; Cooperative Game; Benefit Distribution; Shapley Value.

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## 1. Introduction

As a foundational and strategic industry within the national economy, the logistics sector plays a vital role in reducing societal logistics costs and driving high-quality economic development through efficiency improvements. Standardized pallets and their circulation and sharing systems (referred to as “pallet pooling”) are recognized as a key breakthrough for standardizing logistics operations and achieving cost reduction and efficiency gains. Practice has demonstrated that the independent construction and operation of pallet pools by individual enterprises is costly and efficiency-constrained. Consequently, the cross-enterprise, cross-industry pallet pooling alliance model has gradually emerged as the mainstream approach. However, significant disparities exist among alliance members regarding pallet investment costs, usage intensity, management capabilities, and risk-bearing capacity. Designing a fair, reasonable, and incentive-compatible benefit distribution mechanism has thus become the core challenge for sustaining stable alliance operations and motivating members' continued participation.

Existing research has primarily focused on barriers to promoting pallet sharing, network layout optimization, and technological applications, with insufficient attention to the complex internal benefit distribution issues within alliances. The Shapley value method, with its rigorous axiomatic foundation and fairness, is widely applied in benefit distribution across cooperative alliances. However, its classical model assumes homogeneous members with equal contributions, making it ill-suited for the heterogeneous characteristics of pallet pooling alliances-where members differ in pallet resource investment intensity, operational risk sharing, and actual contributions. Therefore, it is imperative to refine the traditional Shapley value approach to align with the specific features of pallet pooling alliances.

This paper addresses the profit distribution challenges in pallet pooling alliances. By thoroughly analyzing key factors affecting distributive fairness-resource investment, risk sharing, and actual contributions-it constructs an improved Shapley value distribution model. Empirical validation through case studies demonstrates its superiority and applicability, aiming to provide theoretical foundations and management insights for the healthy and stable development of pallet pooling alliances.

## 2. Review of Relevant Research Literature

In recent years, research on pallet pooling alliances has increased significantly. Zhang Xueyan<sup>[1]</sup> proposed a conceptual model for pallet pooling systems comprising three major modules: an operational platform, standardization, and an information platform. Luo Zhiwen<sup>[2]</sup> identified issues within China's pallet industry, including limited ownership, inconsistent specifications, restricted applicability, Zhou Ying<sup>[3]</sup> proposed a three-step strategy for establishing China's pallet recycling consortium system: first, pallet standardization; second, establishing a pallet pooling system; third, establishing a pallet consortium organization. Tang Ying<sup>[3]</sup> proposes that the strategic goal for standardizing China's pallet sharing system is to use standards to integrate non-standard elements in logistics processes. The standard system for the sharing system includes five categories: general foundational standards, technical standards, information standards, management standards, and service standards. Wang Shipeng<sup>[4]</sup> points out that for China's pallet circulation system, although the pallet market is developing rapidly, issues still exist that constrain the establishment of the system, such as outdated concepts and insufficient understanding; low pallet standardization levels; and an underdeveloped service system. Based on China's national conditions, he proposed a construction approach for the pallet circulation system: adopting the 1200mm×1000mm specification as the sole operational standard, establishing a state-supported and state-participated joint-stock pallet company with participation from various enterprises and ensuring state-owned absolute controlling interest, and constructing a pallet sharing system suited to China's national conditions in three phases: initial construction, development, and maturity. Li Mingzhao<sup>[5]</sup> proposed five recommendations for China's pallet sharing system: strengthen organizational coordination and policy support; encourage industry-led development and enhance logistics standardization; improve relevant standards and service specifications; prioritize pallet certification systems and corporate integrity frameworks; cultivate operational entities for pallet circulation and sharing to elevate utilization rates; and promote intermodal coordination across logistics segments while expanding palletized transport throughout supply chains. Sun Xijun<sup>[6]</sup> analyzed factors influencing the pallet market-including raw material costs, market demand, and policy standards-and projected future trends, particularly regarding circulation sharing and green sustainable development.

Regarding benefit distribution methods, the Shapley value method has gained widespread application. Li Xiao, Jin Shousong, Feng Dingzhong et al.<sup>[10]</sup> investigated revenue distribution strategies for pallet leasing alliances based on cooperative games. By incorporating Shapley value construction principles and AHP analysis, they developed a rational revenue distribution model that integrates quantifiable and non-quantifiable benefits with risk-bearing capacity. This model ensures fairness and efficiency in distribution while enhancing alliance stability. He Yandong, Wang Xu, Lin Yun et al.<sup>[9]</sup> delved into the operational mechanisms and profit distribution issues of pallet sharing service alliances. By incorporating the Raiffa solution model and Shapley value method, and adhering to the principle of “profit sharing, risk sharing, and sustainable development,” they developed a scientific and rational profit distribution model. This model not only accounts for investment amounts but also integrates sustainability concepts, ensuring the stable operation and long-term development of the alliance. Li Hanxiao<sup>[8]</sup> applied the Shapley value method to the profit distribution within a cotton industry alliance. By quantifying the contribution levels of each entity, the approach ensures fair and reasonable profit allocation. The study revealed existing imbalances in distribution. After optimization using the Shapley value method, a more equitable distribution scheme was proposed. Du Zhiping and Zhang Meng<sup>[7]</sup> developed a profit distribution method for 4PL cross-border e-

commerce logistics alliances based on IAHP-Shapley values. The IAHP method determines the weighting factors influencing benefit distribution, addressing the inaccuracy issues of traditional AHP methods, and quantifies factors such as actual investment, performance contribution, risk assumption, and service quality. Combined with the Shapley value method, it refines the benefit distribution strategy to ensure fairness and rationality. Through case studies, this method demonstrates its validity and rationality, providing a scientific basis for benefit distribution in 4PL cross-border e-commerce logistics alliances.

In summary, Current literature on alliance profit distribution has established a relatively comprehensive knowledge system. From theoretical frameworks to empirical analyses and the proposal of specific application models, it demonstrates strong systematicity and depth. However, given the complexity of alliance profit distribution influenced by multiple intertwined factors, future research should comprehensively consider operational risks, stakeholder contributions, capital investments, and other elements. This will enable the construction of more comprehensive and dynamic alliance profit distribution models to better guide alliance practices and promote their long-term stable development. However, pallet pooling system alliances face challenges such as low profit margins, numerous participants, and low levels of trust among enterprises. These factors lead to issues like extended payback periods, difficulties in profit distribution, and unstable alliance cooperation. Therefore, this paper aims to refine the profit distribution mechanism within pallet pooling alliances, enhance trust levels among enterprises, and facilitate the establishment of pallet pooling alliances.

### **3. Pallet Pooling Alliance Operating Model**

#### **3.1 Pallet Pooling Alliance Operating Model.**

The Pallet Pooling Alliance is a consortium comprising pallet suppliers, pallet leasing companies, and pallet pooling operation platforms. Its operating model is as follows: After leasing standard pallets, pallet lessees can reuse them within their operations. Upon completion of use, pallets are not discarded as scrap but can be exchanged for an equivalent number and quality of empty pallets. Alternatively, lessees may transfer usage rights to the receiving party for their own use or return the pallets to the leasing company for recycling. Users only pay rental fees during the usage phase. After recovery, the leasing company can rent the pallets to other users, enabling continuous circulation throughout the system.

#### **3.2 Factors Influencing Benefit Distribution.**

In determining benefit distribution within the pallet pooling alliance, factors such as resource investment, risk assumption, and actual contribution are considered based on the characteristics of each stakeholder.

##### **3.2.1 Resource Investment.**

Resource investment in the pallet pooling alliance encompasses capital investment, pallet investment, and warehouse facility investment. The level of resource investment is directly linked to the benefits received by participating parties. To facilitate quantification of each party's resource contribution: Capital investment is quantified by the enterprise's initial investment amount and additional investment amounts. Pallet investment is quantified by the number of standardized pallets the enterprise can provide. Warehouse facilities are quantified by storage area.

##### **3.2.2 Risk Assumption.**

Establishing a pallet pooling alliance requires substantial investment with a long payback period. Given multiple participants and unstable returns, various risks must be addressed. To ensure reasonable returns for all parties, the alliance is formed through cooperation and establishes a fair and reasonable risk-sharing framework. Under the principle of matching risk with reward, returns are balanced according to the extent of risk borne.

### 3.2.3 Actual Contribution.

Introducing the actual contribution dimension into the pallet pooling alliance's profit distribution is fundamentally necessary: by precisely quantifying operational efficiency metrics such as member enterprises' pallet turnover rates and network synergy value, it effectively breaks the “high-asset, low-efficiency” distribution trap caused by relying solely on resource input, preventing high-investment, low-efficiency members from monopolizing limited alliance profits. Simultaneously, this dimension serves as a dynamic efficiency engine, powerfully driving members to optimize operations, expand intermodal networks, and correct the incentive failures of traditional Shapley values toward hidden contributors. More profoundly, by linking to green metrics like carbon reduction, it aligns the distribution mechanism with national “dual carbon” policies, ultimately propelling the alliance from a static cost-sharing entity to a value-creation-centered development community.

## 4. Research Design on Benefit Allocation in a Three-Pallet Sharing Alliance

The Shapley value method is equally applicable to benefit distribution among multiple stakeholders in a pallet sharing alliance. However, due to limitations in the traditional Shapley value approach, this paper proposes an improved version of the Shapley value method.

### 4.1 Standard Shapley Value Model.

The Shapley value is the most commonly used benefit allocation model in cooperative games. Its principle involves allocating benefits by calculating the proportional contribution of each participant. It remains the most reasonable and widely adopted benefit distribution model today.

Fundamental Principle of the Shapley Value Method: Let  $N=\{1,2, \dots, n\}$  denote the  $n$  stakeholders participating in the cooperation. The total number of cooperative scenarios among these stakeholders is  $n!$ ; these scenarios form a subset of  $N$ , denoted as  $S$ , where  $|S|$  represents the number of elements in the set. Let  $B(S)$  denote the benefit obtained under each cooperation scenario, where  $i$  represents all members included in  $S$ . Based on the principles of symmetry, non-infeasibility, and additivity in cooperative games,  $B(S)$  must satisfy the following constraints:

$$B(\emptyset)=0$$

$$B(S)\geq\sum_{i\in S} B(i)$$

Furthermore, the total number of possible scenarios where member  $i$  participates in cooperation  $S$  is  $(|S|-1)!$ . The remaining members can be combined in  $(n-|S|)!$  ways. Thus, the probability of member  $i$  participating in cooperation  $S$  across all possible scenarios is  $(|S|-1)! (n-|S|)!/n!$ . The marginal contribution created by member  $i$  participating in cooperation  $S$  is obtained by subtracting the contribution when member  $i$  does not participate from the contribution of  $S$ , i.e.,  $B(S) - B(S - \{i\})$ .

Ultimately, the benefit allocation for each participant in the set is:

$$U(i) = \sum_{S \in N, i \in S} \frac{(|S| - 1)! (n - |S|)!}{n!} [B(S) - B(S - \{i\})]$$

### 4.2 Modified Shapley Value Model.

The Shapley value method distributes benefits solely based on marginal contributions. However, in practice, contributions may overlap and be influenced by social environments, policies, and alliance operational models. Considering only marginal contributions from an economic perspective is unreasonable. Therefore, this paper considers factors influencing profit distribution within pallet pooling alliances and modifies the original Shapley value method to achieve fairer and more reasonable profit allocation.

Based on the analysis of factors affecting pallet pooling alliances, an improved Shapley value method is established. This involves adding correction factors  $\alpha_j$  ( $j=1,2,3$ ) to the standard Shapley value method, representing resource investment, risk bearing, and actual contribution, respectively. Assuming that within the pallet pooling alliance, the relative influence of different factors on benefit distribution is  $\beta_i$  ( $i=1,2,3$ ), and after model modification, the comprehensive influence level of benefit distribution for stakeholders is  $\omega_i$  then

$$\omega_i = \alpha \times \beta$$

After modification, the change in benefit distribution for each stakeholder is:

$$\Delta\omega_i = \omega_i - \frac{1}{n}$$

To maintain equal net gains/losses before and after adjustment while preserving total benefits, the influence factor  $\omega_i$  is balanced by subtracting  $1/n$ , yielding the final benefit adjustment weight  $\Delta\omega_i$ . Thus, the final benefit adjustment for the pallet pooling alliance is  $B(S) \times \Delta\omega_i$ . The adjusted benefit allocation values for each stakeholder are:

$$V(i) = U(i) + B(S) \times \Delta\omega_i$$

#### 4.2.1 Resource Contribution Adjustment Model.

Within the pallet pooling alliance, resource contribution shares consider both initial capital investment and infrastructure investment. Fully accounting for the principle that investment and returns are proportional, the adjustment factor for investment shares must be calculated based on the magnitude of investment proportions, namely:

$$\alpha_{i1} = \frac{I(i) + J(i)}{\sum_i (I(i) + J(i))}$$

Where  $I(i)$  represents the initial capital investment of stakeholder  $i$  in the pallet pooling alliance project,  $J(i)$  denotes the infrastructure investment of stakeholder  $i$  in the alliance, and  $\sum \alpha_{i1} = 1$

#### 4.2.2 Risk-Sharing Adjustment Model.

To share benefits, alliance members must collectively bear various operational risks-high risk brings high returns, while low risk yields low gains. Despite rapid growth in recent years, pallet pooling remains a high-risk industry with unresolved challenges in policy, technology, and resources. Examples include difficult pallet repairs, deficiencies in pallet information technology, and incomplete government regulations. This paper categorizes risks encountered in pallet pooling alliance operations into three types: physical risk  $\delta_i$  (pallet damage and repair), operational risk  $\sigma_i$  (standard deviation of demand fluctuations), and credit risk  $\vartheta_i$  (probability of partner default).

Comprehensive risk value:

$$K_i = \mu_1 \delta_i + \mu_2 \sigma_i + \mu_3 \vartheta_i \quad (\mu_1 + \mu_2 + \mu_3 = 1)$$

Risk adjustment factor:

$$\alpha_{iz} = \frac{K_i}{\sum_{i=1}^n K_i}$$

#### 4.2.3 Contribution-Based Adjustment Model.

During the alliance's development, the actual contribution rates of each stakeholder must be considered to ensure fair and reasonable benefit distribution. Such adjustments also incentivize stakeholders to actively participate in alliance operations, enhancing overall efficiency. Alliance performance evaluation involves multiple factors, but the selection of indicators should be moderate. Representative metrics should be chosen to comprehensively reflect the true performance of the pallet pooling alliance with a minimal number of indicators, thereby improving evaluation efficiency.

##### (1) Selection of Evaluation Indicators

A scientifically sound performance evaluation system provides the pallet pooling alliance with effective feedback and improvement directions. It also assists alliance members in optimizing resource utilization and elevating service standards, thereby boosting the alliance's overall efficiency and competitiveness. Furthermore, evaluation outcomes serve as a basis for internal distribution and management within the alliance, strengthening members' sense of belonging and cooperative awareness.

To determine the actual contribution levels of each participating party, an indicator system tailored to pallet pooling alliances was constructed. This system was developed based on literature review and tailored to the alliance's characteristics—specifically the needs for resource integration, market opportunities, and sustainable development during its growth. Key factors in the alliance's sustainable operational development were analyzed and summarized. This study selected 12 indicators specific to pallet sharing alliances and employed the G1-entropy weighting method for indicator evaluation, establishing a performance evaluation system for pallet sharing alliances. As shown in the table below:

**Table 1.** Comprehensive Evaluation Indicator System for Stakeholder Actual Contributions

Indicator	Indicator Meaning	Indicator Attribute
Pallet Turnover Rate (times/year) M1	Reflects asset utilization efficiency	Positive
Proportion of Idle Pallets M2	Evaluates financial risk and asset quality	Negative
Return on Investment (ROI) M3	Specialized financial assessment for alliance expansion or technological upgrades	Positive
Material Recycling Rate M4	Proportion of discarded pallets recycled	Positive
Technology Investment Ratio M5	Reflects emphasis on intelligent and informatized development	Positive
Number of Covered Cities M6	Measures market scale and resource integration capability	Positive
Standardized Pallet Coverage Rate M7	Promoting industry standardization is a core mission of the alliance	Positive
Abnormal Event Resolution Time M8	Demonstrates service quality resilience	Negative
Palletized Transport Rate M9	Drives supply chain standardization	Positive
Average Pallet Lifespan M10	Reflects maintenance quality and cost	Positive
Customer Satisfaction M11	End-user feedback is critical	Positive
Carbon Emissions Reduction (tons CO <sub>2</sub> ) M12	Carbon reduction in corporate operations	Positive

##### (2) Weighting Determination via G1 Expert Method Combined with Entropy Weighting

Subjective weighting methods rely on human judgment to evaluate and assign importance to different metrics. However, varying subjective perceptions and experiences among individuals can lead to significant assessment discrepancies, compromising reliability and objectivity. Objective weighting methods employ mathematical techniques and models to determine indicator weights based on their characteristics and correlations. This computational approach yields relatively stable and reliable outcomes. Nevertheless, mathematical methods remain constrained by uncertainties and may sometimes fail to fully reflect the relative importance and practical demands of different indicators. Therefore, this paper adopts an objective weighting method combining the G1 method and entropy weighting to ensure the scientific validity of evaluation results.

The G1 method is a subjective weighting approach that compares the importance levels of indicators across tiers without requiring consistency tests. It avoids the drawback of the Analytic Hierarchy Process (AHP), where excessive pairwise comparisons become unmanageable with numerous factors and large scales.

**Determining Order Relations:** When indicator  $M_k$  is no less important than  $M_{k'}$  relative to a specific evaluation criterion, it is denoted as  $M_k > M_{k'}$ . If indicators  $M_1, M_2, \dots, M_k$  exhibit an order  $M_1 > M_2 > \dots > M_k$  relative to a criterion, then an order relation is established among these indicators.

**Relative Importance Ratio Judgment:** Conduct pairwise comparisons for each indicator, then generate a sequence based on the results. The importance ratio between adjacent indicators is defined as  $g_t = \frac{M_{k-1}}{M_k}$ , where  $t = 1, 2, \dots, k-1$ . The values of  $g_t$  are specified in the table below:

**Table 2.** Explanation of Evaluation Indicator Importance Levels

$g_t$	Explanation
1.0	Indicators $M_{k-1}$ and $M_k$ are equally important
1.1	The ratio of $M_{k-1}$ to $M_k$ lies between equal importance and slightly more important
1.2	Indicator $M_{k-1}$ is slightly more important than $M_k$
1.3	The ratio of $M_{k-1}$ to $M_k$ lies between slightly more important and significantly more important
1.4	Indicator $M_{k-1}$ is significantly more important than $M_k$
1.5	The ratio of indicator $M_{k-1}$ to $M_k$ lies between markedly important and strongly important
1.6	Indicator $M_{k-1}$ is strongly more important than $M_k$
1.7	The ratio of indicator $M_{k-1}$ to $M_k$ lies between strongly important and extremely important
1.8	Indicator $M_{k-1}$ is extremely more important than $M_k$

**Indicator Weight Calculation:** Use the formula  $\omega'_m = (1 + \sum_{k=2}^m \prod_{i=k}^m g_t)^{-1}$  to obtain the subjective weight for the  $m$ th indicator. Then, based on the defined formula for the ratio of importance between two adjacent indicators, determine the weights for the other  $m, m-1, \dots, 1$  indicators using

$$\omega'_{m-1} = \omega'_m \times g_t$$

### (3) Entropy Weighting Method for Determining Indicator Weights

Assuming  $m$  evaluation indicators and  $n$  stakeholders, the initial matrix  $Q = [M_{kj}]_{m \times n}$  is constructed from survey-derived indicator evaluation results.

**Normalization:** Normalization converts indicators with different units to a common numerical range, facilitating information entropy calculations and indicator comparisons. Negative indicators require positive transformation; after processing, these indicators remain positive when calculating weights. The formula for standardizing the range of each indicator is as follows:

Positive indicators:  $Z_{kj} = \frac{M_{kj} - \min\{M_{1j} \dots M_{1n}\}}{\max\{M_{1j} \dots M_{1n}\} - \min\{M_{1j} \dots M_{1n}\}}$

Negative indicators:  $Z_{kj} = \frac{\max\{M_{1j} \dots M_{1n}\} - M_{kj}}{\max\{M_{1j} \dots M_{1n}\} - \min\{M_{1j} \dots M_{1n}\}}$

Normalize the indicators:  $W_{kj} = \frac{Z_{kj}}{\sum_{k=1}^m Z_{kj}}$

Calculate the entropy value for each indicator:  $E_k = -\frac{\sum_{k=1}^m W_{kj} \ln W_{kj}}{\ln n}$

Calculate the weight for the kth indicator:  $\omega_k = \frac{1 - E_k}{m - \sum_{k=1}^m E_k}$

(4) Determination of the Composite Indicator

In statistical description, variance is one of the measures used to quantify the dispersion of a data set, representing the degree of deviation from its mean. This paper employs variance maximization to derive combination weights. Let  $\rho_m$  denote the combination weight for the mth indicator, with  $\sigma$  and  $\tau$  representing subjective and objective weights, respectively. Let  $\gamma_m$  denote the mth decision scheme and  $\bar{\gamma}_m$  denote the arithmetic square root of  $\gamma_m$ . Let  $\omega'_m$  be the subjective weight for the mth indicator and  $\omega_m$  be the objective weight for the mth indicator. Then:  $\omega'_m$  denotes the subjective weight of the mth indicator, and  $\omega_m$  denotes the objective weight of the mth indicator. Then:

$$\rho_m = \sigma \omega'_m + \tau \omega_m$$

$$\sigma = \frac{1}{\sqrt{1 + \frac{\sum_{m=1}^t (\gamma_m - \bar{\gamma}_m)^2 \omega'_m}{\sum_{m=1}^t (\gamma_m - \bar{\gamma}_m)^2 \omega_m}}}$$

$$\tau = \frac{1}{\sqrt{1 + \frac{\sum_{m=1}^t (\gamma_m - \bar{\gamma}_m)^2 \omega_m}{\sum_{m=1}^t (\gamma_m - \bar{\gamma}_m)^2 \omega'_m}}}$$

From the formula  $B_j = \rho_k \times Q$ , the comprehensive evaluation value for each cooperating party can be derived, thus:

$$\alpha_{i3} = \frac{B_j}{\sum_{j=1}^n B_j}$$

4.2.4 Final Three-Stage Adjusted Benefit Allocation Model.

$$U(i) = \sum_{SEN,IES} \frac{(|S| - 1)! (n - |S|)!}{n!} [B(S) \quad B(S \quad \{I\})] \mid B(S) (\alpha_{i1} \beta_1 \mid \alpha_{i2} \beta_2 \mid \alpha_{i3} \beta_3 \quad \frac{1}{n})$$

The three-stage profit distribution adjustments correspond to different lifecycle phases of the pallet pooling alliance, serving as adaptive tools tailored to distinct core needs at each stage. Practical implementation requires selecting and executing strategies based on the alliance's developmental stage, operational pain points, and data capabilities. Decisions should align with the alliance's actual conditions. During the initial establishment phase (0-1 years), the core task is "infrastructure development"-such as pallet procurement, warehouse upgrades, and network expansion. At this stage,

the alliance lacks stable operations, experiences fewer risk events, and struggles to quantify tangible contributions. Members primarily focus on questions like "Can initial investments be recovered?" and "whether high investment corresponds to high returns." Therefore, the  $\beta_1$  weight should be set highest to increase the correction factor for resource investment. During the trial operation phase (1-2 years), infrastructure is complete and pallet leasing begins. However, operational risks gradually emerge (e.g., pallet damage, demand fluctuations, member defaults). Members' core demand shifts from "cost compensation" to "risk-reward alignment." The alliance must establish a "risk assessment system" to quantify risk-bearing and increase the weight of risk factors, ensuring stable operations. When the alliance enters its mature phase (after 2 years of operation), with stable performance (e.g., pallet turnover rates and customer satisfaction meeting targets) and high trust among members, the core demand shifts from "basic safeguards" to "efficiency enhancement and value creation." At this stage, incentivizing members to optimize operations requires increasing the weighting of actual contributions.

## 5. Case Analysis

### 5.1 Basic Data Processing.

Assume a pallet pooling alliance comprising pallet supplier A, operating platform B, and pallet leasing company C, with total revenue  $B(S) = ¥180$  million. During the alliance's construction phase, the following factor weights were negotiated:  $\beta_1$  (resource input) = 0.5,  $\beta_2$  (risk assumption) = 0.3,  $\beta_3$  (actual contribution) = 0.2.

The revenues for each stakeholder operating independently and in pairwise collaborations are set as follows (in millions of yuan):

$$B(A)=0, B(B)=0, B(C)=0, B(A \cup B)=60, B(A \cup C)=45, B(B \cup C)=75, B(A \cup B \cup C)=180.$$

According to the standard Shapley model, the benefit allocation value for the pallet supplier (Stakeholder 1) is calculated as shown below:

**Table 3.** Standard Shapley Value Benefit Allocation Calculation for Pallet Supplier

Calculation Content	Stakeholder			
	A	$A \cup B$	$A \cup C$	$A \cup B \cup C$
S	A	$A \cup B$	$A \cup C$	$A \cup B \cup C$
B(S)	0	60	45	180
B(S-1)	0	0	0	75
B(S)- B(S-1)	0	60	45	105
S	1	2	2	3
$\frac{( S  - 1)! (n -  S )!}{n!}$	1/3	1/6	1/6	1/3
$\frac{( S  - 1)! (n -  S )!}{n!} \times [B(S) - B(S - \{i\})]$	0	10	7.5	35

Summing the data in the last row yields the initial benefit allocation for the pallet supplier:  $U(A) = 52.5$ . Similarly, the benefit allocations for the other two stakeholders are:  $U(B) = 67.5$  and  $U(C) = 60.0$ .

### 5.2 Adjusted Shapley Value Benefit Allocation.

#### 5.2.1 Resource Contribution Adjustment Factors.

The resource contributions of each participant include initial investment and facility investment, as detailed in Table 4:

**Table 4.** Resource Investment Data

Participant	Pallet Purchase	Network Construction	Warehouse Renovation	Total Investment	Share $\alpha_{i1}$
Pallet Supplier	10000			10000	47.6%
Operating Platform		2800		2800	13.3%
Pallet Lessor			8200	8200	39.1%

After the first-stage adjustment, the benefit distribution values for each party are (65.3, 49.5, 65.2).

#### 5.2.2 Risk-bearing Adjustment Factors.

The risk-bearing indicators for each participant are shown in Table 5 below:

**Table 5.** Risk weights

Risk Type	Weight	A	B	C	$K_i$	$\alpha_{i2}$
Physical Risk	0.4	0.18	0.12	0.05	0.114	32.0%
Operational Risk	0.4	0.08	0.25	0.15	0.168	47.2%
Credit Risk	0.2	0.05	0.10	0.2	0.074	20.8%

After the second stage of adjustment, the benefit allocation values for each party are (64.6, 57.0, 58.4).

#### 5.2.3 Actual Contribution Adjustment Factors.

The actual contribution evaluation metrics for each participant are shown in Table 6 below:

**Table 6.** Actual contribution weights

Metric	A	B	C	Subjective Weight	Objective Weight	Combined Weight
M <sub>1</sub>	0.8	0.9	0.7	0.12	0.13	0.1255
M <sub>2</sub>	0.6	0.8	0.7	0.08	0.07	0.0745
M <sub>3</sub>	0.7	0.8	0.6	0.10	0.11	0.1055
M <sub>4</sub>	0.8	0.7	0.9	0.09	0.10	0.0955
M <sub>5</sub>	0.6	0.9	0.7	0.11	0.12	0.1155
M <sub>6</sub>	0.5	0.9	0.6	0.1	0.09	0.0945
M <sub>7</sub>	0.7	0.8	0.8	0.08	0.07	0.0745
M <sub>8</sub>	0.6	0.9	0.7	0.07	0.08	0.0755
M <sub>9</sub>	0.8	0.7	0.8	0.09	0.10	0.0955
M <sub>10</sub>	0.7	0.8	0.6	0.06	0.05	0.0545
M <sub>11</sub>	0.6	0.9	0.7	0.07	0.08	0.0755
M <sub>12</sub>	0.8	0.7	0.9	0.05	0.06	0.0555

Calculate the comprehensive evaluation value  $B_j$  for each participant.

$$B_A = 0.698, B_B = 0.852, B_C = 0.725.$$

Actual contribution adjustment factors:

$$\alpha_{A3} = 29.1\%, \alpha_{B3} = 35.6\%, \alpha_{C3} = 30.3\%.$$

Through the three-stage benefit allocation model adjustment, the final benefit allocation values for each stakeholder are:  $U(A)=63.1$ ,  $U(B)=57.8$ ,  $U(C)=57.3$ .

## 6. Conclusion and Recommendations

### 6.1 Conclusion

The changes in benefit allocation reveal that the resource-adjusted values shift from (52.5, 67.5, 60.0) to (65.3, 49.5, 65.2). Since pallet supplier A invested heavily in the early alliance development phase, this adjustment increases its returns, aligning with the “cost-benefit matching” principle. After risk adjustment, the benefit distribution becomes (64.6, 57.0, 58.4). Since Platform B bears the highest operational risk, it requires risk compensation to avoid “high risk, low return.” Finally, after actual contribution adjustment, the benefit distribution is (63.1, 57.8, 57.3). Since the actual contributions of all parties are relatively similar, the final allocation outcome shows minimal fluctuation. The overall three-stage benefit distribution reveals that, as the alliance is in its construction phase, the importance of resource investment is amplified. Consequently, pallet supplier A receives the largest benefit compensation. The adjusted results align highly with the operational requirements of the pallet-sharing alliance during its construction phase, providing a practical implementation plan for the alliance: “distributing basic returns based on investment, compensatory returns based on risk, and incentive returns based on contribution.”

### 6.2 Recommendations

#### (1) Refine the Benefit Distribution Mechanism

Optimize the distribution model: Adopt an improved Shapley value model that comprehensively considers factors such as resource investment, risk-bearing capacity, and actual contributions. Flexibly adjust the weighting of each factor based on the alliance's development stage—for instance, emphasizing resource investment weighting during the construction phase and highlighting actual contribution weighting during the mature operational phase—to ensure benefit distribution aligns more closely with the alliance's actual circumstances.

Regular Evaluation and Adjustment: Establish a dynamic assessment mechanism to periodically review changes in member contributions, market fluctuations, and policy impacts. Timely optimize benefit allocation schemes to ensure fairness and rationality, sustaining member motivation.

#### (2) Optimizing Alliance Operational Models

Expand Service Scope: Offer diversified services beyond pallet leasing, recycling, and maintenance. Explore value-added services like custom pallet design, logistics consulting, and supply chain finance to broaden revenue streams and enhance alliance competitiveness.

Strengthen Member Collaboration: Build an information-sharing platform among members to facilitate communication and collaboration, achieving efficient resource allocation. For example, sharing data on pallet inventory, usage status, and maintenance needs improves pallet turnover rates and reduces operational costs.

### (3) Strengthen Industry Collaboration and Standardization

**Participate in Standard Setting:** Actively engage in developing industry standards for pallet sharing, covering specifications, quality, and operational procedures. This advances standardization, reducing communication barriers and operational costs caused by inconsistent standards.

**Enhance Industry Self-Regulation:** Establish a self-regulatory body to formulate industry norms and guidelines. This constrains member behavior, prevents unfair competition, maintains market order, and elevates the alliance's overall credibility.

### (4) Promote Technological Innovation and Application

**Adopt Smart Technologies:** Leverage IoT, big data, and blockchain technologies to enable real-time pallet monitoring, intelligent scheduling, and management. For instance, embedding RFID chips allows tracking pallet locations and statuses in real time, optimizing logistics routes, and improving operational efficiency.

**Conduct R&D:** Increase investment in developing new pallet materials and technologies to enhance quality, reduce costs, and extend service life. Examples include researching biodegradable, high-strength pallet materials that meet environmental and logistics requirements.

### (5) Securing Policy Support and Financial Investment

**Policy Support:** Monitor national policy trends and actively seek government backing through tax incentives, fiscal subsidies, and streamlined project approvals to reduce operational costs and boost development momentum.

**Expanding Financing Channels:** Attract investments from private capital and venture capital to address funding gaps. Utilize equity financing, bond issuance, and industrial funds to provide robust financial backing for alliance growth.

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