# Research on the Regional Benefit Sharing Mechanism of China-Europe Railway Express under Cooperative Game

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## Abstract

My country's economic and trade exchanges with Europe and countries along the route have developed rapidly with the construction of the "Belt and Road", and there is a strong demand for logistics, and trade channels and trading methods are constantly enriched and improved, creating good development opportunities for the development of China-Europe Railway Express, also put forward higher requirements for the development of China-Europe Express. However, it should also be noted that the development of the China-Europe Railway Express is still in its infancy, with vicious competition, homogeneous supply of goods, duplication of routes, and serious local protectionism among local governments. These problems limit the efficiency and effectiveness of the China-Europe Express. Hindering the process of China's "One Belt One Road" construction. Therefore, it is extremely urgent to realize the benefit-sharing of all regions in the development of China-Europe Express. Based on this, this article conducts research from the perspective of China-Europe Express regional benefit sharing. With the joint support of the research background, basic theory and research methods, the current development status of China-Europe Express Railway has established a regional benefit-sharing mechanism. First of all, based on interest-related Employer theory and interdependence theory have determined the horizontal and vertical stakeholders of the China-Europe Railway Express and the stakeholders of the vertical game. The stakeholders of the vertical game are the consignor, the operating company and the surrounding residents, and the stakeholders of the horizontal game are the local government; At the same time, based on the theory of welfare economics, it introduces the method of quantifying the regional benefits of the China-Europe Railway Express from three levels of producer surplus, consumer surplus and external effects. Secondly, based on the principles of fairness and efficiency, multi-factor optimization, and information sharing, the Shapley value method of cooperative game theory was selected as the benefit sharing method, and the China-Europe Express regional benefit sharing mechanism was constructed. It is estimated that the economic benefits of the alliance in 2020 will be 29,693,600 US dollars, of which Chengdu should share 11,923,100 US dollars in benefits, Zhengzhou should share 6,623,000 US dollars in benefits, and Chongqing should share 29,693,600 US dollars in benefits. In order to achieve the coordination of interests and support areas with poorly developed train lines, Chongqing City should transfer USD 544,400 to Zhengzhou City and USD 39,600 to Chengdu City in the form of transfer payments.

## Keywords

China-Europe Express; Interest Coordination; Cooperative Game; Shapley Value Method.

## 1. Introduction

The key to the conflict of interest among the various regions in the development of China-Europe Express is the uneven coordination of interests. Each region wants to extract the

greatest benefits from the development of China-Europe Express, such as collecting goods from surrounding areas, occupying China-Europe Express transportation hub nodes, give strong subsidies to local enterprises to improve competitiveness, etc. The process of competition among regions for the resources of the China-Europe Railway Express project can be regarded as a process of regional strategy games. Each local government satisfies the assumption of "economic man" under the game conditions and improves local economic benefits through strategic choices. In the current stage of development, the China-Europe Express has shown a trend of linkage development, such as the establishment of the China-Europe Express International Supply Chain Alliance, the establishment of the Chengdu-Chongqing-China-Europe Express Line, etc., and the China National Railway Administration has also vigorously promoted the integration of China-Europe Express. As early as 2016, the China-Europe Express Train planned to operate in accordance with the mechanism of "six unifications" (unified brand logo, unified transportation organization, unified full price, unified service standard, unified management team, unified coordination platform), and gathered forces from all over the world. Enhance market competitiveness. Therefore, the establishment of a sound benefit-sharing mechanism in regional cooperation is the key to benefit coordination. The benefit-sharing mechanism should be used to ensure a balanced distribution of benefits and strengthen the driving force for cooperation.

## 2. Game Analysis of Benefit Sharing in Various Regions

### 2.1. Model Building

Defining the basic form of the regional cooperation game in the development of China-Europe trains is: $G = \{N, (v_i)_{i \in N}\}$, where N={1,2,…,n} consists of n The set of regions, S is a subset of N, representing the alliance between the regions, namely $S \subseteq N$; $(v_i)_{i \in N}$ is the alliance S with each of N (including the major alliance itself) Corresponding characteristic function, characteristic function is an important basis for measuring the value of alliances, especially for transfer utility games that can adjust the unbalanced interests of alliance members through internal transfer payments, characteristic functions have a decisive effect on the formation of alliances and the outcome of the game. In this article, the characteristic function of the alliance game is the above-mentioned profit quantification function (Equation 4.4). v(S) is the utility that can be obtained if the participants i in the alliance cooperate with each other. The utility may be a benefit or a cost (negative utility).

Cooperative games must have some properties, namely, vector configurability, super additivity, and convexity, for game analysis to be meaningful, that is, the following definition:

Definition 1: If the benefit vector satisfies $x_i \geq v(\{i\})(\forall i \epsilon N \ and \ \sum_{i=1}^{n} x_i = v(N))$, then this vector is called a configuration of a cooperative game.

Definition 2: Cooperative game $(N, v)$ is superadditive. If for any alliance S, $, T \epsilon 2^N, and \ S \cap T = \emptyset, then \ v(S) + v(T) \leq v(S \cup T)$.

Definition 3: Cooperative game$(N, v)$ is a convex game, if for any $S, T \epsilon 2^N, then \ have \ v(S) + v(T) \leq v(S \cup T) + v(S \cap T)$; convex game the intuitive meaning of is that the marginal contribution of participants to a certain alliance increases as the size of the alliance increases.

Under the premise of no confusion, this paper will use the characteristic function $v$ instead of$(N, v)$to represent a cooperative game, and record all the game combinations of each area set $N$ as $G^N$. In addition, if the alliance is $S = \{i_1, i_2, …, i_k\}$, this article will use $v(i_1, i_2, …, i_k)$ instead of $v(\{i_1, i_2, …, i_k\})$ to represent $v(S)$. The basic assumption of the cooperative game is that large alliances can be formed. When a large alliance is not necessarily formed, not only the equilibrium allocation of benefits, but also the alliance or the division of the alliance in equilibrium should be considered. That is the problem to be considered in the theory of alliance formation and will not be considered here.

## 2.2.   Solving the Cooperative Game Model

This paper uses the Shapley value method to solve the cooperative game model. This method is that Shapley proposed in 1953 to analyze the solution of the cooperative game from the perspective of axiomatization. Shapley first gave three axioms of Shapley value. The first axiom is the symmetry axiom, which means that the Shapley value of the alliance has nothing to do with the order of the players, or the change in the order of the players does not affect the value obtained in the game. The second axiom is the validity axiom, which means that the sum of the Shapley values of all players has allocated the value of the alliance, that is, the value of the characteristic function. The third axiom is the axiom of additivity, meaning that when two independent games are merged, the Shapley value of the merged game is the sum of the Shapley values of the two independent games.

(1) Symmetry axiom: the two stakeholders in the alliance system set $i$ and $j$ when the marginal contributions paid by all the alliance system subsets $S$ meet the equality condition, they are symmetrical, that is, they are obtained in benefit sharing the shares should satisfy consistency, have nothing to do with the order of their sharing, and are only related to the marginal contribution.

$$v(s \cup i_1) = v(s \cup i_2)$$

(2) Validity Axiom: The sum of the benefits shared by the stakeholders in the collection must be equal to the total benefits generated by the project under the joint participation of all stakeholders, and the value of the shared benefits should be 0 for the stakeholders without any contribution.

$$\sum_{i \in S} \varphi_{i(v)} = V(S)$$
$$\varphi_{i(v)} = 0$$

When $n$ all regions participate in the cooperation and form the Sino-European Development Regional Cooperation Alliance, regard it as the core member of the benefit-sharing for benefit-sharing, and use $N$ as the symbol of the union members, that is, N = {1,2,⋯, n}, and there exists any subset $S \in$ set $N$, which corresponds to a real number function $V(S_i)$, and when the set is an empty set, the corresponding real number function is zero. It can be seen from this that the China-Europe Railway Express Development Regional Cooperation Alliance is composed of two elements: the game subject and the shared interests. It can also be called the $n$ cooperation alliance strategy $(N, V)$, where $V$ is the characteristic function under the strategy. At the same time, the corresponding characteristic function $V(S_i)$ under any subset $S$ can be understood as the benefit generated by the player's participation in a certain stage (link) of cooperation.

(3) Additivity axiom: When the $i$ subject participates in any independent subset $A$ and the subset $B$ to merge, the total benefit shared should be the sum of the benefits of the subset $A$ and the subset $B$. The two parameters $\varphi_{i(v)}$ )and $\varphi_{i(v')}$ are expressed as the lower Shapley values of the subsets $A$ and $B$.

$$\varphi_i(v + v') = \varphi_{i(v)} + \varphi_{i(v')}$$

When the feature function satisfies the condition of formula, it can be said that the feature function $V(S_i)$ corresponding to each subset $S$ is super-additive. In layman's terms, it means that when the benefits shared by various stakeholders in the cooperative alliance are greater than the benefits obtained without cooperation, that is, the characteristic function $V(S_i)$ is

considered to be super-additive. It shows that when the cooperative alliance system satisfies the validity, the corresponding feature functions $V(Si)$ in each subset $S$ included are also accompanied by super additivity characteristics.

Sharpley proved that it meets the above three axioms at the same time, describing the unique index vector$(\varphi_1, \ldots, \varphi_n)$ of the value of each game subject in the alliance game $G = \{N, (v_i)_{i \in N}\}$,

$$\varphi_i = \sum_{S \subset N} \frac{(n-k)!\,(k-1)!}{n!}[v(S) - v(S\{i\})]$$

## 3. Analysis of Regional Benefit Sharing Calculation Examples

### 3.1. Quantification of Overall Regional Benefits

Through calculation, we can obtain the total benefit of each train line for the local area, as shown in Table 1.

**Table 1.** The overall situation of the regional interests of the three train lines

Unit: ten thousand USD/year

| | Member | Dimension | Benefits |
|---|---|---|---|
| China-Europe Railway Express Regional Cooperation Alliance | Chengdu~Tilburg | Consignor benefit | 492.49 |
| | | Operating company benefits | 529.44 |
| | | Positive external benefits | 269.17 |
| | | Negative external benefits | 118.46 |
| | Total benefits | 1172.64 | |
| | Zhengzhou~Hamburg | Consignor benefit | 147.89 |
| | | Operating company benefits | 335.53 |
| | | Positive external benefits | 90.70 |
| | | Negative external benefits | 36.35 |
| | Total benefits | 537.77 | |
| | ⋮ | | |
| | Chongqing ~ Duisburg | Consignor benefit | 529.15 |
| | | Operating company benefits | 367.69 |
| | | Positive external benefits | 296.4 |
| | | Negative external benefits | 117.08 |
| | Total benefits | 1076.16 | |
| Total benefits | 2786.57 | | |

### 3.2. Benefit Sharing among Regions in the Development of China-Europe Railway Express

The consumer surplus for the three train lines to implement independent point-to-point transportation is: 4,924,900 U.S. dollars, 1,478,900 U.S. dollars, and 5,291,500 U.S. dollars. Assuming that the train line 1 and train line 2 form a cooperation, and equilibrium pricing is adopted, the external quotation after the cooperation is 6000 US dollars/FEU, and the total consumer surplus after the cooperation is calculated to be 6.0144 million US dollars; assuming

that the train line 1 and the train Train line 3 forms a cooperation and adopts equilibrium pricing. After the cooperation, the external quotation is 5880 US dollars/FEU, and the total consumer surplus after cooperation is calculated to be 10.8623 million US dollars. Assuming that train line 2 and train line 3 form a cooperation, adopt Equilibrium pricing, the external quotation after cooperation is US$5,980/FEU, and the total consumer surplus after cooperation is calculated to be US$6.4376 million; assuming that train line 1, train line 2 and train line 3 form an alliance, adopt balanced pricing , The external quotation after cooperation is 5,953 US dollars/FEU, and the total consumer surplus after cooperation is calculated as 11.81,700 US dollars; the distribution of consumer surplus among the three trains is shown in Table 2.

**Table 2.** The distribution of consumer surplus based on the level of shippers
Unit: ten thousand US dollars

| Stakeholder | Consumer surplus |
|---|---|
| Train line 1 | 492.49 |
| Train line 2 | 147.89 |
| Train line 3 | 529.15 |
| {Class Line 1, Class Line 2} | 601.44 |
| { Class Line 1, Class Line 3} | 1086.23 |
| {Class Line 2, Class Line 3} | 643.76 |
| {Class Line 1, Class Line 2, Class Line 3} | 1108.17 |

According to the above-mentioned cooperation game model of China-Europe train: $\varphi_i = \sum_{S \subset N} \frac{(n-k)!(k-1)!}{n!} [v(S) - v(S\{i\})]$, the regional benefit distribution of consumer surplus for each train is calculated as shown in Table 3 below.

**Table 3.** Consumer surplus sharing plan of Chengdu-Tilburg train based on Shapely value
Unit: USD 10,000

| Interests combination($S$) | 1 | {1,2} | {1,3} | {1,2,3} |
|---|---|---|---|---|
| $V(S)$ | 492.49 | 601.44 | 1086.23 | 1108.17 |
| $V(S \backslash i)$ | 0 | 147.89 | 529.15 | 643.76 |
| $V(S) - V(S/i)$ | 492.49 | 453.55 | 557.08 | 464.41 |
| $|S|$ | 1 | 2 | 2 | 3 |
| $w(|S|)$ | 1/3 | 1/6 | 1/6 | 1/3 |
| | | | | |
| $w(|S|) \times [V(S) - V(S/i)]$ | 164.16 | 75.59 | 92.85 | 154.80 |
| Share of gross | 487.40 | | | |

According to the above table, the total consumer surplus sharing value of the Chengdu-Tilburg train line based on the Shapely value is 4.874 million US dollars. Similarly, the total consumer surplus sharing value of the Zhengzhou-Hamburg train line is 938,100 US dollars. ; In the same way, the total value of consumer surplus sharing on the Chongqing-Duisburg train is US$5,261,800.

The producer surplus of the three train lines implementing independent point-to-point transportation is: 5,294,400 U.S. dollars, 3,355,300 U.S. dollars, and 3,676,900 U.S. dollars. Assuming that train line 1 and train line 2 form a cooperation with balanced pricing and unified subsidies, the external quotation after the cooperation is 6000 USD/FEU, and the unified subsidy amount is 340,000 yuan/train, so as to calculate the total producer after the cooperation The remaining amount is 9.403 million US dollars; assuming that the train line 1

and train line 3 form a cooperation, using balanced pricing and unified subsidies, the external quotation after the cooperation is 5880 US dollars/FEU, and the unified subsidy amount is 295,000 yuan/train, so as to calculate After the cooperation, the total producer surplus is USD 8,928,200; assuming that train line 2 and train line 3 form a cooperation, with balanced pricing and unified subsidies, the external quotation after the cooperation is 5980 USD/FEU, and the unified subsidy amount is 340,000 / Train, so as to calculate the total producer surplus after the cooperation is 8.2552 million US dollars; assuming that train line 1, train line 2 and train line 3 form an alliance, adopt equilibrium pricing and uniform subsidies, then the external quotation after cooperation is 5953 USD/FEU, the unified subsidy amount is 316,700 yuan per column, so that the total producer surplus after cooperation is calculated to be 13.6372 million US dollars; the consumer surplus distribution of the three train lines is shown in Table 4.

**Table 4.** The Chengdu-Tilburg Line Producer's Residual Sharing Plan Based on Shapely Value Unit: Ten Thousand U.S. Dollars

| Interests combination($S$) | 1 | {1,2} | {1,3} | {1,2,3} |
|---|---|---|---|---|
| $V(S)$ | 529.44 | 940.30 | 892.82 | 1363.72 |
| $V(S\backslash i)$ | 0 | 335.53 | 367.69 | 825.52 |
| $V(S) - V(S/i)$ | 529.44 | 604.77 | 525.13 | 538.20 |
| $|S|$ | 1 | 2 | 2 | 3 |
| $w(|S|)$ | 1/3 | 1/6 | 1/6 | 1/3 |
| $w(|S|) \times [V(S) - V(S/i)]$ | 176.48 | 100.80 | 97.52 | 179.40 |
| Share of gross | 554.20 | | | |

According to the above table, the total surplus sharing value of producers on the Chengdu-Tilburg train line based on the shapely value is US\$5.542 million. Similarly, the total value of consumer surplus sharing on the Zhengzhou-Hamburg train line is US\$4.206 million. ; In the same way, the total value of consumer surplus sharing on the Chongqing-Duisburg train line is 4.0925 million US dollars.

# 4. Conclusion

Assuming that the China-Europe Express trains unify the brand logo and transport organization to form a scale effect, it is of great significance to the convenience of surrounding cargo transportation, the integration of railway logistics resources, and the development of the logistics industry. However, in order to simplify the analysis, this article will no longer consider the changes in external benefits. According to the above, the Chengdu-Tilburg train can generate economic benefits of US\$11,276,400 for the local area, and the Zhengzhou-Hamburg train can generate economic benefits of US\$5.377 million for the local area. Chongqing-Duisburg the alignment can generate an economic benefit of US\$10,761,600 for the local area. The overall economic benefit generated was US\$27,865,700.

According to the additivity axiom of Shapley value, it is calculated that the total benefit for the local area of the Chengdu-Tilburg train after the cooperation is 11,923,100 US dollars, and the Zhengzhou-Hamburg train can generate 6.623 million US dollars of economic benefits for the local area. Chongqing-Duisburg train can generate 11.147 million US dollars in economic benefits for the local area. The economic benefit generated by the alliance is 28,445,300 US dollars. The specific situation is shown in Figure 1 below.
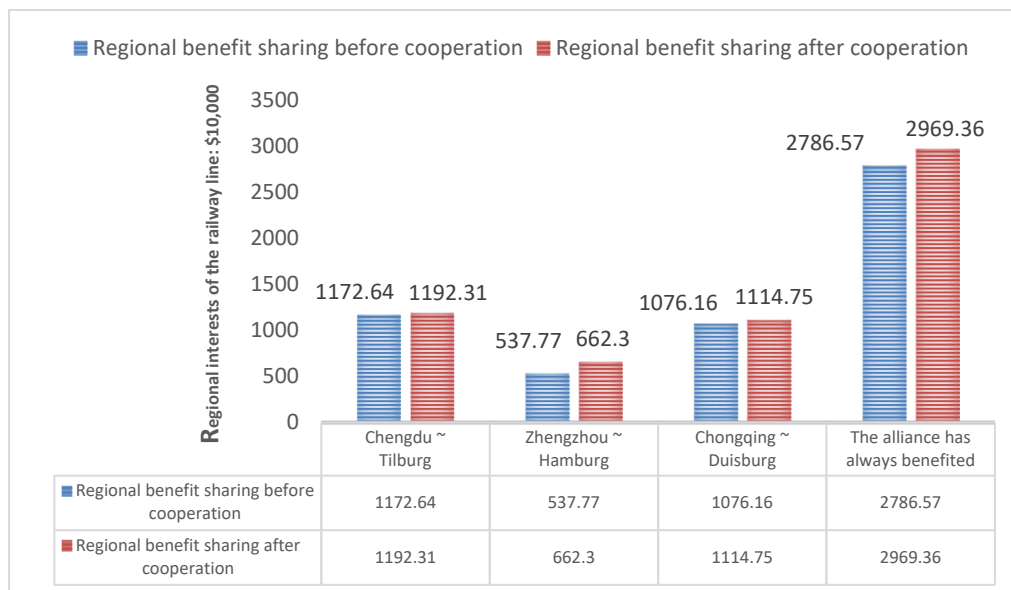
**Figure 1.** The regional benefit sharing diagram of the three train lines based on the shapely value

When the China-Europe Express Regional Cooperation Alliance adopts the strategy of unified pricing and unified subsidies, the consumer surplus generated by the Chengdu-Tilburg line will be reduced by 50,900 US dollars, and the consumer surplus generated by the Zhengzhou-Hamburg line will be reduced by 540,800. In US dollars, the surplus generated by the Chongqing-Duisburg train will be reduced by 29,700 dollars, and the consumer surplus of the alliance will be reduced by 608,700 dollars. The strategy of unified pricing is not conducive to the benefit of China-Europe trains from the level of cargo owners. As far as the cargo owners are concerned, differential pricing should be adopted to maximize the consumer surplus of each line of trains, and the strategy of unified pricing is effective for those with higher prices. The influence of train lines is relatively large. However, the producer surplus generated by the Chengdu-Tilburg train will increase by 247,600 US dollars, the producer surplus generated by the Zhengzhou-Hamburg train will increase by 850,700 US dollars, and the producers generated by the Chongqing-Duisburg train The surplus will increase by USD 415,600, and the producer surplus of the alliance will increase by USD 1.5139 million. The strategy of unified pricing and unified subsidies is conducive to the profitability of China-Europe freight train operating companies. As far as the freight train company is concerned, unified pricing and unified subsidies should be implemented in accordance with the "Plan", so as to reduce the vicious competition generated by each freight train company for supply. Reduce the waste of railway logistics resources.

Based on the "marginal contribution" of the three express lines in the alliance, the Shapley value method is used to share the interests of the alliance, so that the Chengdu Municipal Government, Zhengzhou Municipal Government, and Chongqing Municipal Government can obtain US$11,923,100 and 662.3 respectively from China-Europe Express Transportation. 10,000 US dollars and 11.147,500 US dollars of interest.

## 5. Policy Suggestion

The China-Europe Express International Supply Chain Alliance implements the "six unifications" (unified brand logo, unified transportation organization, unified full price, unified service standard, unified management team, unified coordination platform) in accordance with the "China-Europe Express Development Plan". At that time, the Chengdu-Tilburg train generated a benefit of US$11,923,100 for the local area, an increase of 196,700 US dollars

compared to the stand-alone operation; the Zhengzhou-Hamburg train generated a benefit of US$6.623 million for the local area, which was an increase compared to the stand-alone operation. US$1,245,300; The Chongqing-Duisburg line generated US$11,147,500 in benefits for the local area, an increase of US$385,900 compared to the stand-alone operation; the alliance generated US$29,693,600 in benefits, an increase of US$1.8279 million compared with the stand-alone operation. Although the Six Unification Strategy has reduced the consumer surplus of China-Europe Express trains, it has greatly increased producer surplus and external benefits. Therefore, China-Europe Railway Express should expand the radiation area of the international supply chain alliance, absorb more members to join, and adopt the mode of consolidation and transportation to maximize the operating income of the company, and unify the brand logo and transport organization. The formation of scale effect is of great significance to the convenience of surrounding cargo transportation, the integration of railway logistics resources, and the development of logistics industry.

The China-Europe Express International Supply Chain Alliance is a manifestation of a regional cooperation alliance. It is the key to responding to the concept of shared and co-construction in the national "Belt and Road" development initiative. It is a beneficial means to gather various resources and fully complement each other's advantages. In the alliance, the results of the China-Europe Express Transport Coordination Committee based on the quantification of benefits are required Share the interests of the China-EU Regional Cooperation Alliance in a fair and equitable manner, so as to achieve a balance of the alliance's benefit sharing and promote its long-term effectiveness and stability. The China-Europe Railway Express Transportation Coordination Committee shall urge the members of the alliance to sign cooperation agreements, share interests in an input-output manner, share the benefits generated by China-Europe Railway Express in a fair and equitable manner, and establish a supervisory department to give unconstrained local governments Administrative penalties, economic penalties for unconstrained operating companies and related departments. On the other hand, in the National Development and Reform Commission's support for the construction of the China-Europe Railway Express hub node city, part of it should be used to establish a platform based on information sharing and benefit sharing, and promote the mode of platform operation through mechanisms to expand the radiation of the international supply chain alliance. Area, attract more members to join, and strengthen the economic benefits brought by the China-Europe Express.

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