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# Analysis of the stability of cooperation between public railway transportation enterprises

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***Abstract:*** *In the context of the "Belt and Road" initiative, actively promoting cooperation between public railway transportation enterprises can not only accelerate the transformation and upgrading of China's logistics and transportation structure, but also further promote the development of the public railway intermodal transport market. In order to strengthen the stability of cooperation between railway transport enterprises and improve the cooperation efficiency between public railway transport enterprises, an evolutionary game model of cooperation between the two is constructed by using evolutionary game theory, the evolutionary equilibrium strategies of road transport enterprises and railway transport enterprises are analyzed, and finally simulation experiments are carried out to verify the validity and reliability of the research results.*

***Keywords:*** *Highway transportation enterprises, Railway transportation enterprises, Cooperation stability*

## 1. Introduction

In recent years, with the economic transformation and upgrading, the social division of labor has become increasingly refined, the scope of enterprise cooperation has been expanding, and the alliance of public railway transportation enterprises has been deepened, accelerating the transformation and upgrading of public railway logistics and transportation enterprises and promoting the marketization process of public railway combined transport, reducing the cost of cooperative logistics and transportation of public railway logistics and transportation enterprises, improving the cooperation efficiency of public railway logistics and transportation enterprises, and solving the conflict of interests of all participants in public railway combined transport has become an important research hotspot. At present, the academic community has some research results on the cooperation mechanism between logistics enterprises, and the literature[1] establishes a simulation model of public railway intermodal logistics service with the participation of non-vehicle carriers based on multi-agent modeling technology, and uses the Any logic platform to simulate the behavior rules and mutual relationships of participants, and analyzes the mechanism of synergy formation of public railway intermodal logistics services. The literature[2] uses the MNL model to construct the shipper's mode selection model, and constructs a game model of the pricing strategy of road direct transportation and public railway intermodal transport by analyzing the income of each carrier between the starting points. Literature[3] Based on the non-cooperative game theory, the supply chain coordination of public railway intermodal logistics services with the participation of railway logistics centers with alternative public railway transport enterprises is studied, and game models under centralized decision-making and decentralized decision-making are constructed. Literature[4] Based on evolutionary game theory, the evolutionary game law of cooperative innovation subjects adopting cooperation strategies under government intervention is studied, and the evolutionary game law of cooperative innovation subjects adopting cooperative strategies under government intervention is analyzed by system dynamics. Literature[5] analyzes the possibility of cooperation between high-speed rail express and express delivery enterprises based on the idea of evolutionary game, and concludes that reasonable punishment contracts can effectively promote the evolution of both parties to cooperation. The literature[6] studies the cooperation between the two logistics service providers, and concludes that the cooperation between the two parties can effectively reduce costs and improve corporate profits. The literature[7] discusses the cooperation between logistics enterprises and cloud computing service providers in terms of ability and trust. These studies have achieved many results in the cooperation between railway transport enterprises and road transport enterprises, but there are not many studies on the factors influencing the evolution of cooperation between public railway transport enterprises, such as trust and risk level, and relatively few studies on the competition and

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cooperation between railway and road freight transportation services. Based on this, this paper attempts to identify the factors affecting the cooperation between the two sides from the perspective of competition and cooperative relationship of public railway transport enterprises, analyzes the evolutionary strategy of railway transport enterprises and road transport enterprises in choosing whether to become a partnership, integrates the willingness of cooperation, risk, cost, profit and trust level into the model for research, discusses reasonable revenue distribution and cooperation cost sharing mechanism, and seeks appropriate trust level and risk level of cooperation between the two sides.

## 2. Model building

Evolutionary game theory is based on the assumption of bounded rationality, analyzing the game equilibrium problem of the gamer's strategy choice for the game in which the player is located[8]. Under the premise of assuming that the subjects of the game are limited rationality, the player cannot find the optimal stable strategy in a game, but with the continuous adjustment of the player in each game, after a long period of evolution, the two sides of the game will converge in a certain direction, and finally reach a certain stable state, and obtain a stable strategy satisfactory to all parties to the game, that is, the evolutionary stability strategy (ESS).

### *2.1. Problems and Assumptions*

Railway transport enterprises and road transport enterprises to form a collaborative partnership, can give full play to the railway transport safety, fast, environmental protection and road transport widely distributed, flexible and agile advantages, cooperation is a win-win game, from the perspective of railway transport enterprises and road transport enterprises cooperation, based on the evolutionary game theory to build a model of cooperative evolution game between railway transport enterprises and road transport enterprises. The main players of the game are railway transport companies (R) and road transport companies (H). The strategic choices of rail transport companies and road transport companies are cooperation, not cooperation of the two strategies.

Hypothesis 1: Assume that the probability of cooperation by railway transport enterprises is x; The probability of road transport companies taking cooperation is y. Among them $0 \leq x, y \leq 1$,at that time$x, y = 0$ ,the two sides did not cooperate at all; At that time$x, y = 1$,both parties took full cooperation; The greater the case$x, y$,the greater the probability of cooperation between the two parties.

Hypothesis 2: Railway transport enterprises and road transport enterprises have their own business scope, and when the two parties adopt a non-cooperative strategy, the profits when operating independently are$\pi_1, \pi_2$. where$\pi_1, \pi_2 \geq 0$.

Hypothesis 3: Suppose that when a railway transport company and a road transport company cooperate, both parties can obtain excess returns $\pi$. The distribution ratio for obtaining excess earnings at this time is$a, (1-a), \pi > 0, 0 < a < 1$.

Hypothesis 4: When railway transport enterprises and road transport enterprises cooperate, they need to incur negotiation costs, logistics costs and related management costs. If one party's willingness to cooperate is greater than that of the other, the party that prefers to cooperate will generate a certain upfront investment to promote cooperation. Therefore, regardless of whether the two parties eventually reach a cooperation or not, costs will be incurred, and the cost sharing ratio between railway transport enterprises and road transport enterprises is as follows$b, (1-b), C > 0, 0 < b < 1$.

Hypothesis 5: Since the cooperation between railway transport enterprises and road transport enterprises will promote both sides to learn from each other's advanced technology and logistics management experience, resulting in the enhancement of each other's strength, there is a certain risk of technological spillover. Therefore, there will be risks r after the cooperation between the two parties. where$r > 0$.

Hypothesis 6: The cooperation between the two parties is related to the degree of trust between each other, and if the public railway transport company trusts each other more, the probability of reaching cooperation will increase. Therefore, assume that the trust coefficient of railway transport enterprises to road transport enterprises is$t_{r,h}$,and the trust coefficient of road transport enterprises to railway transport enterprises is $t_{h,r}$, where $0 < t_{r,h}, t_{h,r} < 1$.

### *2.2. Model building*

Based on the above assumptions and evolutionary game theory ideas, a payment matrix is established. The payment matrix is shown in Table 1.

*Table 1: Payout matrix of both sides of the game*

| H \ R | cooperate | Non-cooperation |
|---|---|---|
| cooperate | $\pi_1 + a\pi - (1-t_{h,r})ra\pi - bC$<br>$\pi_2 + (1-a)\pi - (1-t_{h,r})r(1-a)\pi - (1-b)C$ | $\pi_1 - bC$<br>$\pi_2$ |
| Non-cooperation | $\pi_1$<br>$\pi_2 - (1-b)C$ | $\pi_{1,}$<br>$\pi_2$ |

In the above game matrix, it can be obtained that the replication dynamic equation of the cooperation strategy adopted by railway transport enterprises is:

$$F(x)=\frac{dx}{dt}=x(E_{rc}-E_r)=x(1-x)[ya\pi-y(1-t_{r,h})ra\pi-bC] \tag{1}$$

The replication dynamic equation for road transport companies is

$$F(y)=\frac{dy}{dt}=x(E_{hc}-E_h)=y(1-y)[x(1-a)\pi-x(1-t_{h,r})r(1-a\pi)-(1-b)C] \tag{2}$$

## 3. Model analysis

### *3.1. Equilibrium point analysis of evolutionary processes*

The local equilibrium point obtained by copying the dynamic equation is not necessarily the evolutionary stability strategy (ESS) of the system, according to the method proposed by Friedman, the stability of the evolutionary equilibrium point can be derived from the Jacobian Jacobian matrix local stability analysis of the system. If $F(x)=0, F'(x)<0, x$ x is the evolutionary stability strategy (ESS) of the system. The equilibrium points of the resulting system are as follows:

O(0,0)A(0,1)B(1,0)C(1,1)D(p, q).

where $p=\frac{(1-b)C}{(1-a)\pi[1-(1-t_{h,r})r]}, q=\frac{bC}{a\pi[1-(1-t_{r,h})r]}$

### *3.2. Local stability analysis of equilibrium points*

The partial derivatives with respect to x, y are obtained for F(x) and F(y), respectively, to obtain the Jacobi matrices of the two-party replicated dynamic equations. Then the Jacobi matrix is:

$$\begin{bmatrix} (1\text{-}2x)(ya\pi g-bC) & x(1-x)atg \\ y(1-y)(1-a)\pi h & (1-2y)[x(1-a)\pi h-(1-b)C] \end{bmatrix}$$

*Table 2: Local stability analysis of equilibrium points*

| balance point | Det(J) | Tr(J) | local stability |
|---|---|---|---|
| O | + | - | ESS |
| A | + | + | instability |
| B | + | + | instability |
| C | + | - | ESS |
| D | - | 0 | saddle point |

Accordingly, the values of Det(J) and Tr(J) are obtained for the five local equilibrium points of the system. A quantitative analysis of the local stability of the equilibrium points of the system based on the sign of the determinant and the trace allows one to determine the local stability of the five equilibrium points mentioned above, the $a\pi>bC,(1-a)\pi>(1-b)C$ . The local stability analysis of the equilibrium point is shown in Table 2. The evolutionary game process of public-rail transportation enterprises about forming a partnership, the system evolution phase diagram is shown in Figure 1.

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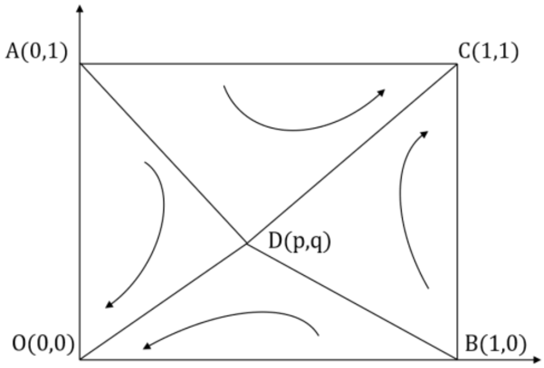


*Figure 1: Phase diagram of system evolution*

## 4. Evolutionary Simulation

According to the actual operation of the public-rail transportation enterprises, it is assumed that the excess benefit $\pi \in [60,80]$ million dollars and the cost of cooperation $C \in [10,20]$ million dollars obtained by both parties' cooperation. With a number of different sets of assignment parameters selected in the context of determining the range of values, the evolutionary paths of the groups of road transport enterprises and railroad transport enterprises will gradually converge to the equilibrium of the system along the fluctuations that do not include the stationary point type.

### *4.1. The effect of initial willingness to cooperate on evolutionary strategies*

Given the initial values for the simulation, $\pi=70, C=15, a=0.5, b=0.5, r=0.85, t_{r,h}=0.4, t_{h,r}=0.6$. The initial willingness x=0.2, y=0.6; x=0.5, y=0.6. The evolution results of the system are shown in Fig. 2 and Fig. 3. It can be seen that if the probability of one party to choose to cooperate is smaller than the other party, then the cooperative party will tend to choose not to cooperate due to the choice of cooperation to pay the effort, and ultimately the two sides of the evolution of the strategy of non-cooperation; if both sides of the probability of choosing to cooperate are larger, then it will be obtained in excess of the benefit, with the evolution of the game both sides of the probability of choosing to cooperate will gradually increase, and ultimately both sides of the stabilization of the strategy of choosing to cooperate.

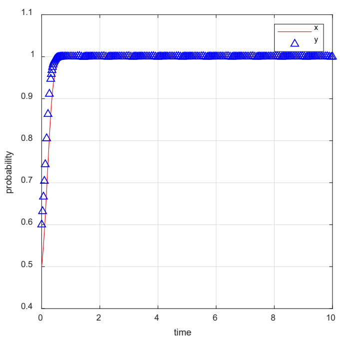


*Figure 2: x=0.2, y=0.6 Simulation results*

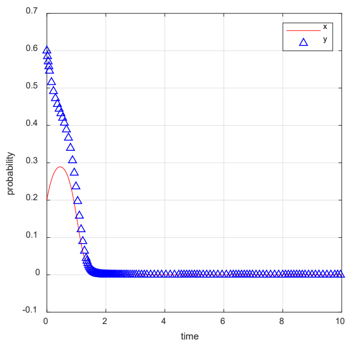


*Figure 3: x=0.5, y=0.6 Simulation results*

### *4.2. Effect of Excess Profit Allocation Coefficients on Evolutionary Strategies*

Keeping other parameters unchanged, the excess profit distribution coefficient of cooperation between public and railway transportation enterprises is set to a = 0.2 respectively, and the results are shown in Fig. 4 and Fig. 5, when the excess profit distribution coefficient a = 0.2, the simulation results of the two sides of the game tends to be uncooperative. When the excess profit distribution coefficient a = 0.5, the simulation results of both sides of the game tend to be cooperative. The simulation results show that the existence of a makes the two sides of the game tend to cooperate.

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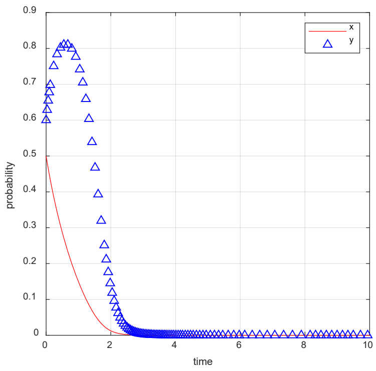

*Figure 4: a=0.2 Simulation results*

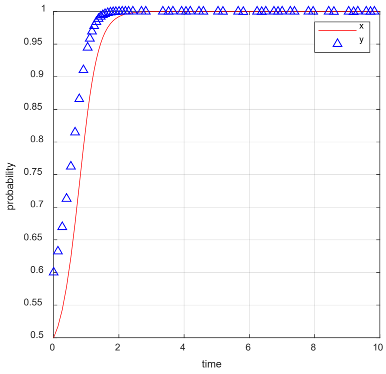

*Figure 5: a=0.5 Simulation results*

## 5. Conclusions

(1) Initial willingness to cooperate is a prerequisite for the final cooperation between public and rail transport enterprises, and the partnership between public and rail transport enterprises should first be based on voluntary alliance, and the degree of initial willingness to cooperate should be assessed according to their own actual operation after detailed understanding of each other's operation status quo, development prospect, business model, organizational culture and other aspects of the company.

(2) As a rational economic man, the public railway transportation enterprises will first consider the cooperation with each other in choosing partners can bring much benefit to themselves, and in most cases the rupture of cooperation stems from the uneven distribution of benefits. Therefore, in order to let the public railway transportation enterprises to form a long-term effective partner, according to the two sides of the business contribution value and in the cooperation of transportation in the risk of cargo transportation to set up a reasonable proportion of excess earnings distribution, improve the degree of orientation to the partner.

(3) After the cooperation agreement is reached by the public-rail transport enterprises, the risk control organization should be established or the professional risk control platform organization should be applied directly to ensure the normal operation of the cooperative transport business of the public-rail transport enterprises, and to build a risk control platform organization with "advance estimation in advance, active identification in the course of the incident, and exhaustive reflection after the incident", so as to monitor and control the whole life-cycle of the whole process of public-rail intermodal transport. It carries out the monitoring of the whole life cycle of public-rail transportation.

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