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RESEARCH ON THE MECHANISM OF GOVERNMENT INCENTIVE MEASURES TO RAIL TRANSIT STATION RENEWAL BASED ON TOD MODE – AN EVOLUTIONARY GAME ANALYSIS

Abstract. *Rail transit station renewal based on the TOD mode is an important path to achieve effective urban renewal. In the renewal process, the strategic choice and mechanism of local governments, rail enterprises, and residents need to be further clarified. This paper constructs an evolutionary game model among the local government, rail enterprises, and residents, and determined the limit condition for the stability of stakeholder game system. The evolution process of the three parties reaching the unique stable strategy set (1,1,1) is "local government → rail enterprises → residents". The results reveal that the government's floor area ratio (FAR) bonus and public financial subsidy are helpful for rail enterprises to actively participate in the renewal of rail transit stations. Residents incorporate the increase of land value from high-density development and improvement of the public environment into the main objective function based on the maximisation of their own utility, and supervise the behaviour of rail enterprises. In the case of asymmetric information, residents have become an important boosting force for the government. Simulation and case analysis show that the incentive mechanism and the compensation mechanism formulated by the government can effectively promote the active participation of rail enterprises and residents in rail transit station renewal.*

Keywords: *Urban Renewal, Transit-oriented Development, Floor Area Ratio Bonus, Evolutionary Game, System Dynamics*

JEL Classification: R14, R15, R48

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1. Introduction

Urbanisation is the development trend of global cities. However, urban development inevitably faces the problem of urban recession, so a growing number of urban renewal projects are taking place around the world. Nowadays, the process of urban renewal in many large cities is slow, mainly because urban renewal needs a lot of financial support, and the impact of land rezoning and redevelopment on residents and the surrounding environment should be considered. Therefore, how to formulate incentive mechanisms to guide private sector investment and attract the active participation of residents, while balancing land redevelopment and public environment optimisation, has become a necessary issue for the government. The rapid development of rail transit based on the TOD mode and the land renewal around the station have become a new engine of urban renewal development.

This paper will be based on the contradiction between the pursuit of economic benefits by rail enterprises and the improvement of residents' living environment in rail transit station renewal, and will discuss how the government incentive mechanism balances the interests of all participants, so as to promote all parties to actively participate in urban renewal. In this paper, the evolutionary game method is used to construct an evolutionary game model to analyse the stability of the three parties' interests, and the system dynamics simulation is used to simulate the influence of exogenous variables on strategy selection, so as to explore the influence of each participant's different benefit strategy choices on the stability of the system.

2. Literature review

2.1. Urban renewal stakeholder game

The relationship between urban renewal stakeholders has been changing dynamically(X. Li et al., 2018), and the imbalance of interests will make urban renewal projects unsustainable. Excessive reliance on developers will lead to blind pursuit of economic benefits and neglect of the sustainable development of urban areas(Wang et al., 2019; Liu et al., 2021). The lack of public participation will lead to the lack of understanding and support of residents and society in the policies formulated by the government(Shi et al., 2019). Therefore, the interest balance and game among various subjects are the main topics(Jung et al., 2015; Jiang et al., 2020; Shen et al., 2021). Many papers focus on the role positioning and interest demands of stakeholders in urban renewal. Some papers have emphasised the important role of traditional urban renewal leaders, such as the government, local organisations, and developers(Mirzakhani et al., 2021; L. Li et al., 2022). It is worth noting that more and more studies have focused on the assisting and supervising role of public participation in urban renewal, and analysed the modes and forms of public participation(X. Li et al., 2020; Alvanchi et al., 2021; Hui et al., 2021).Therefore, the interest balance and game among various subjects are the main topics.

In the multi-agent game of urban renewal, the government plays a leading role and is located at the core node of the urban renewal cooperation network(W. Zhang et al., 2021). Improper government system design will cause serious system uncertainty, system conflict, and crisis of trust among stakeholders, thus increasing transaction costs and leading to project failure (Kuyucu, 2022). The incentive mechanism can promote developers' active participation (Zhu et al., 2022). And the government used flexible land use management systems(Lin et al., 2022), such as the development right transfer mechanism (Hou et al., 2018) and the FAR bonus mechanism (Donaldson and Plessis, 2013), which not only improves the FAR of developed areas, but also protects the interests of original landowners.

2.2. Rail transit station renewal based on TOD mode

Rail transit TOD is a rail transit-oriented land development mode with high density and mixed functions (Calthorpe, 1993).It represents the result of compact and mixed land use and non-motorised transportation within a radius of 500m to 800m around the rail station. Rail transit station renewal is also faced with multi-agent game. The goal consistency of all stakeholders is very important for TOD development (Hrelja et al., 2022), and the cooperation among stakeholders is a necessary condition for the success of TOD (Dorsey and Mulder, 2013). For this reason, some scholars use literature review, expert interviews and other methods to study the interests of stakeholders (Guthrie and Fan ,2016), network governance (Dirgahayani et al., 2020) and mechanism design (Tan et al.,2013) in the process of TOD renewal. Most studies believe that the government plays a leading role in promoting the rail transit station renewal (Abdi, 2021), especially the incentive measures can effectively improve the participation level of enterprises.

3. Research methods

3.1. The demands and influencing factors of stakeholders

In order to realise win-win cooperation among local government, rail enterprises and residents in rail transit station renewal, this paper analyses the participation strategy decision of each participant from the respective interests of the three parties.

3.1.1. Analysis of stakeholders' interest demands

The direct stakeholders of rail transit station renewal at the core layer include the local government, rail enterprises and residents. Local governments pay attention to the social and public interests, improve the community environment and public infrastructure, and promote urban development. The rail enterprises are responsible for the construction and comprehensive land development along the rail lines. Their basic purpose is to maximise economic benefits. And the residents hope to get appropriate financial compensation to ensure their own interests.

3.1.2. Influence factors of stakeholders' strategy choice

According to the demands of stakeholders, and in combination with relevant literature. We find that the influencing factors of local government's strategic choice mainly include economic benefits, social welfare, incentive, and compensation costs. The influencing factors of the rail enterprises' strategic choice mainly include economic benefits, investment costs. The influencing factors of rail transit enterprises' strategic choice mainly include economic benefits, indirect benefits, and supervision costs.

3.2. Model assumption

There are two possible strategies for local governments: coordination and regulation, or uncoordinated and unregulated. Let α denote the probability that the government chooses the "coordination and regulation" strategy. When the government chooses the strategy of "coordination and regulation", it means that the government will encourage rail enterprises and compensate residents. We use C_1 to represent the cost of coordination and supervision, C_2 to represent the cost of stimulating the active participation of rail enterprises, such as FAR bonus, and C_3 to represent the subsidy cost of residents' participation in supervision. At the same time, the local government received certain social welfare R_2. When the government chooses "uncoordinated and unregulated", C_1 will cease to exist, and so will C_2 and C_3. No matter whether it is coordinated or not, the government will get economic benefits, such as tax revenue in the region.

There are two possible strategies for rail enterprises: TOD development or not TOD development. Let β indicates the probability of rail enterprises choosing the strategy of " station renewal with TOD mode". Assume that the operating profit of the rail enterprises without TOD comprehensive development is R_3 and the cost is C_4, but the loss of urban development effect will be C_6 due to missing the best opportunity for TOD development. While, land value improvement and increased passenger ticket revenue due to TOD development is R_4, the cost is C_5, and at the same time, the enterprise's popularity and reputation are enhanced by R_5. From the practice of railway enterprises such as Tokyu Corporation, $R_3 > R_4$, $C_4 > C_5$. Rail enterprises improved the local environment, bright public benefits to local residents R_7, and received floor area ratio bonus C_2 from government's incentives.

There are two possible strategies for residents: actively participating and supervising or non-participating and non- supervising. γ indicates the probability of residents choosing the strategy of "actively participating and supervising". Residents receive a share of the project's operating profit of R_6, regardless of whether they are regulated or not. If residents actively participate and supervise urban renewal, they will gain subsidies C_3 from government, and the supervision cost is C_7, and obtain indirect benefits R_7 such as improving accessibility, improving public facilities, and continuing traditional culture. The relevant parameters of the evolutionary game model and their settings are shown in Table 1.

Table 1. Parameter setting and meaning

Stakeholder	Parameter	Influence factor	Meaning
Government	R_1	Economic benefits	Tax
	R_2	Social welfare	Political achievements, public interests, social values
	C_1	Coordination and regulation costs	Labour costs, energy and other costs
	C_2	Incentive cost	The cost of incentivising investment in rail enterprise, such as floor area ratio bonus
	C_3	Compensation cost	The cost of compensating and encouraging residents to supervise
Rail enterprise	R_3	Normal economic benefit	Operating profit for general station development
	R_4 ($R_4 > R_3$)	Economic benefits of TOD development	Operating profit for TOD development (including increasing land price and increased ticket revenue)
	R_5	Social welfare	Enterprise popularity, reputation
	C_4	General development investment cost	Development, construction and operation costs
	C_5 ($C_5 > C_4$)	TOD development investment cost	TOD development cost (including public space built for FAR reward)
Resident	R_6	Economic benefits	Profits or dividends
	R_7	Indirect benefit	Improve public facilities and continue traditional culture
	C_6	Urban development loss	Opportunity cost of urban development caused by not carrying out TOD development
	C_7	Supervision cost	The cost of supervising the behavior of rail enterprise

3.3. Build evolutionary game payoff matrix

When the government chooses α, the government gets R_1+R_2 and pays C_1+C_2+C_3.There are two situations for rail enterprises and residents. When the rail enterprises choose β, they will get R_4+R_5, and gain the bonus C_2 from the government, and spends C_5; When they choose $(1-\beta)$, they will get R_3 ($R_3 < R_4$), and pays C_4 ($C_4 < C_5$). At the same time, residents will bear the loss of public interest C_6 without TOD development. When residents choose γ, they will get R_6+R_7, and pay C_7, and gain subsidy C_3 from the government; When residents choose $(1-\gamma)$, they can only get the original economic income R_6.

When the government choose $(1-\alpha)$, the government will get R_1. There are two situations for rail enterprises and residents. When the rail enterprises choose β, they will get R_4+R_5 and spend C_5; When the rail enterprises choose $(1-\beta)$, they will get R_3 and pay C_4, and residents will bear the loss of public interest C_6 without TOD development. When residents choose γ, they will get R_6+R_7 and pay C_7; When residents choose $(1-\gamma)$, they can only get R_6. Based on the above assumptions, we get an evolutionary game model of government, rail enterprises and residents.

In the (0,1) interval, the weights of the probability of government coordination regulation (x), the probability of active participation of rail enterprises (y) and the probability of resident participation and supervision (z) are assigned, respectively. The payoff matrix is shown in Table 2 as follows:

Table 2. Evolutionary game payoff matrix

Game strategy				Government: Coordination and regulation (α)	Government: Uncoordinated and unregulated (1-α)
Rail enterprise	TOD Development (β)	Resident	Actively participate in and supervise (γ)	(R_1+R_2-C_1-C_2-C_3, R_4+R_5+C_2-C_5, R_6+R_7+C_3-C_7)	(R_1,R_4+R_5-C_5,R_6+R_7-C_7)
			Not participating (1-γ)	(R_1+R_2-C_1-C_2, R_4+R_5+C_2-C_5,R_6)	(R_1,R_4+R_5-C_5,R_6)
	Without TOD development (1-β)	Resident	Actively participate in and supervise (γ)	(R_1+R_2-C_1-C_3, R_3-C_4,R_6+C_3-C_7-C_6)	(R_1,R_3-C_4,R_6-C_6-C_7)
			Not participating (1-γ)	(R_1+R_2-C_1, R_3-C_4, R_6-C_6)	(R_1,R_3-R_4,R_6-C_6)

3.4. Build and solve the evolutionary game models

First, we calculate the expected returns of the government, rail enterprise, and residents under different strategic choices. U_{11} and U_{12} represent the government's expected returns of "coordination and regulation" and "uncoordinated and unregulated", respectively, and U_1 represents the average return. The expected payoffs for local governments are shown in equations (1-3).

$$U_{11} = \beta\gamma(R_1 + R_2 - C_1 - C_2 - C_3) + \beta(1-\gamma)(R_1 + R_2 - C_1 - C_2) + (1-\beta)\gamma(R_1 + R_2 - C_1 - C_3) + (1-\beta)(1-\gamma)(R_1 + R_2 - C_1) = R_1 + R_2 - C_1 - \beta C_2 - \gamma C_3 \quad (1)$$

$$U_{12} = \beta\gamma R_1 + \beta(1-\gamma)R_1 + (1-\beta)\gamma R_1 + (1-\beta)(1-\gamma)R_1 = R_1 \quad (2)$$

$$U_1 = \alpha U_{11} + (1-\alpha)U_{12} \quad (3)$$

U21 and *U22* represent the rail enterprise's expected returns of " TOD development " and " non-TOD development " respectively, and *U2* represents the average return. The expected payoffs for rail enterprise are shown in equations (4-6).

$$U_{21} = \alpha\gamma(R_4+R_5 + C_2 - C_5) + \alpha(1-\gamma)(R_4+R_5 + C_2 - C_5) + (1-\alpha)\gamma(R_4+R_5 - C_5) + (1-\alpha)(1-\gamma)(R_4+R_5 - C_5) = R_4+R_5 + \alpha C_2 - C_5 \quad (4)$$

$$U_{22} = \alpha\gamma(R_3 - C_4) + \alpha(1-\gamma)(R_3 - C_4) + (1-\alpha)\gamma(R_3 - C_4) + (1-\alpha)(1-\gamma)(R_3 - C_4) = R_3 - C_4 \quad (5)$$

$$U_2 = \beta U_{21} + (1-\beta)U_{22} \quad (6)$$

U31 and *U32* represent the residents' expected returns of "participation and supervision" and "not participating" respectively, and *U3* represents the average return. The expected payoffs for residents are shown in equations (7-9).

$$U_{31} = \alpha\beta(R_6+R_7 + C_3 - C_7) + \alpha(1-\beta)(R_6 + C_3 - C_7 - C_6) + (1-\alpha)\beta(R_6+R_7 - C_7) + (1-\alpha)(1-\beta)(R_6 - C_6 - C_7) = R_6 - C_7 + \beta R_7 + \alpha C_3 + (\beta - 1)C_6 \quad (7)$$

$$U_{32} = \alpha\beta R_6 + \alpha(1-\beta)(R_6 - C_6) + (1-\alpha)\beta R_6 + (1-\alpha)(1-\beta)(R_6 - C_6) = R_6 + (\beta - 1)C_6 \quad (8)$$

$$U_3 = \gamma U_{31} + (1-\gamma)U_{32} \quad (9)$$

Secondly, based on the expected payoffs function of the government, rail enterprises and residents, we solved the evolutionary stability strategy and obtained the replication dynamic equation of each participant.

Firstly, the replicating dynamic equation (10) of the local government is constructed as follows:

$$F_{(\alpha)} = \frac{d\alpha}{dt} = \alpha(U_{11} - U_1) = \alpha(1-\alpha)(U_{11} - U_{12}) = \alpha(1-\alpha)[(R_2 - C_1) - \beta C_2 - \gamma C_3] \quad (10)$$

When $\beta = \beta^* = \frac{R_2 - C_1 - \gamma C_3}{C_2}$, $F_{(\alpha)} \equiv 0$, indicating that when the active participation of rail enterprises in construction reaches β^*, the government's coordinated regulatory behavior reaches a stable equilibrium state and local governments no longer change their strategy choices.

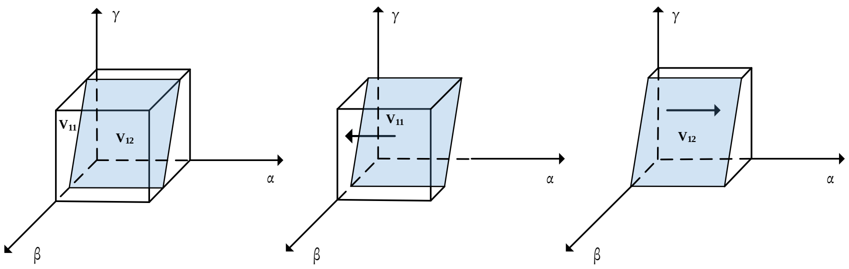
When $\beta \neq \frac{R_2-C_1-\gamma C_3}{C_2}$, let $F_{(\alpha)}=0$, we can get two stable balance points, $\alpha=0$ and $\alpha=1$, if the local government has made a strategy for whether to coordinate and regulate, the government will choose its initial strategy in the absence of a sudden change.

According to Friedman's theory, when the derivative of F at the stable equilibrium point is negative, the equilibrium point is the agent's stable strategy in the process of evolution. The derivative of $F_{(\alpha)}$ is shown in formula (11).

$$\frac{dF_{(\alpha)}}{d\alpha}=(1-2\alpha)[(R_2-C_1)-\beta C_2-\gamma C_3] \tag{11}$$

When $\beta > \frac{R_2-C_1-\gamma C_3}{C_2}$, we can get $\left.\frac{dF_{(\alpha)}}{d\alpha}\right|_{\alpha=0}<0$, $\left.\frac{dF_{(\alpha)}}{d\alpha}\right|_{\alpha=1}>0$. It shows that the evolution rate of government is decreasing when $\alpha=0$. As α increases to 1, the evolutionary rate of government is increasing. At this point, $\alpha=0$ is the stable equilibrium point for government, and the government's strategy tends to be uncoordinated and unregulated.

When $\beta < \frac{R_2-C_1-\gamma C_3}{C_2}$, we can get $\left.\frac{dF_{(\alpha)}}{d\alpha}\right|_{\alpha=0}>0$, $\left.\frac{dF_{(\alpha)}}{d\alpha}\right|_{\alpha=1}<0$. It follows that when $\alpha=0$, the evolution rate of government is increasing. As α increases to 1, the evolution rate of the government is decreasing. At this point, $\alpha=1$ is the stable equilibrium point for the government to choose a coordinated regulation strategy. The replication dynamic phase diagram of government strategy is shown in Figure 1.



(a) $\beta = \frac{R_2-C_1-\gamma C_3}{C_2}$ b) $\beta > \frac{R_2-C_1-\gamma C_3}{C_2}$ (c) $\beta < \frac{R_2-C_1-\gamma C_3}{C_2}$

Figure 1. Replication dynamic phase diagram of government's strategy

Second, the replication dynamic equations (12) of the rail enterprise is constructed as follows:

$$F_{(\beta)}=\frac{d\beta}{dt}=\beta(U_{21}-U_2)=\beta(1-\beta)(U_{21}-U_{22})=\beta(1-\beta)(R_4+R_5-R_3+C_4-C_5+\alpha C_2) \tag{12}$$

When $\alpha = \alpha^* = \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$, $F_{(\beta)} \equiv 0$, It shows that when the coordinated regulation by government reaches α^*, the active participation behavior of rail enterprises reaches a stable equilibrium state and rail enterprises no longer change their choices.

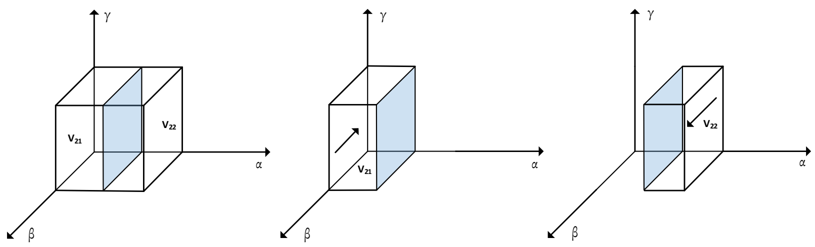
When $\alpha \neq \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$,let $F_{(\beta)} = 0$, we can get two stable equilibrium points, $\beta = 0$ and $\beta = 1$, if the rail enterprises have made a strategy for whether to active participate, the rail enterprises will choose its initial strategy in the absence of a sudden change.

The derivative of $F_{(\beta)}$ is shown in formula (13):

$$\frac{dF_{(\beta)}}{d\beta} = (1 - 2\beta)(R_4 + R_5 - R_3 + C_4 - C_5 + \alpha C_2) \tag{13}$$

When $\alpha > \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$, we can get $\left.\frac{dF_{(\beta)}}{d\beta}\right|_{\beta=0} > 0$, $\left.\frac{dF_{(\beta)}}{d\beta}\right|_{\beta=1} < 0$. It shows that the evolution rate of rail enterprises' behaviour increases when $\beta = 0$. When β increases to 1, the evolution rate of rail enterprises' behavior is decreasing. $\beta = 1$ is the stable equilibrium point for rail enterprises, and rail enterprises choose the strategy of TOD development.

When $\alpha < \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$, we can get $\left.\frac{dF_{(\beta)}}{d\beta}\right|_{\beta=0} < 0$, $\left.\frac{dF_{(\beta)}}{d\beta}\right|_{\beta=1} > 0$, It shows that the evolution rate of rail enterprises' behavior is decreasing when $\beta = 0$. When β increases to 1, the evolution rate of rail enterprises' behaviour is increasing. When $\beta = 0$, the rail enterprises reached equilibrium. $\beta = 0$ is a stable equilibrium point for the rail enterprises, and the rail enterprises will choose the strategy of non-TOD development. The replication dynamic phase diagram of rail enterprise strategy is shown in Figure 2.



(a) $\alpha = \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$ (b) $\alpha < \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$ (c) $\alpha > \frac{R_3 - R_4 - R_5 + C_5 - C_4}{C_2}$

Figure 2. Replication dynamic phase diagram of rail enterprise's strategy

Third, the replication dynamic equations (14) of local residents are constructed as follows:

$$F_{(\gamma)} = \frac{d\gamma}{dt} = \gamma(U_{31} - U_3) = \gamma(1 - \gamma)(U_{31} - U_{32}) = \gamma(1 - \gamma)(-C_7 + \beta R_7 + \alpha C_3) \tag{14}$$

When $\alpha = \alpha^* = \frac{C_7 - \beta R_7}{C_3}$, $F_{(\gamma)} \equiv 0$. It shows that when the local government coordination and regulation reaches α^*, the regulatory behavior of residents reaches a stable equilibrium state and residents no longer change their strategic choices.

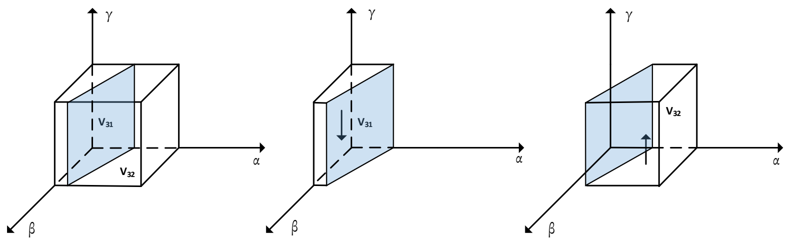
When $\alpha \neq \frac{C_7 - \beta R_7}{C_3}$, let $F_{(\gamma)} = 0$, we can get two stable equilibrium points $\gamma = 0$ and $\gamma = 1$. If the residents have already made a strategy on whether to supervise or not, the residents will stick to the original strategy rather than suddenly change the choice.

The derivative of $F_{(\gamma)}$ is shown in the formula:

$$\frac{dF_{(\gamma)}}{d\gamma} = (1 - 2\gamma)(-C_7 + \beta R_7 + \alpha C_3) \tag{15}$$

When $\alpha > \frac{C_7 - \beta R_7}{C_3}$, we can get $\left.\frac{dF_{(\gamma)}}{d\gamma}\right|_{\gamma=0} > 0$, $\left.\frac{dF_{(\gamma)}}{d\gamma}\right|_{\gamma=1} < 0$. When $\gamma = 0$, the evolution rate of residents' behavior is increasing. When γ increases to 1, the evolution rate of residents' behavior is decreasing. At this time, $\gamma = 1$ is the stable point of residents, and residents will choose the supervision strategy.

When $\alpha < \frac{C_7 - \beta R_7}{C_3}$, we can get $\left.\frac{dF_{(\gamma)}}{d\gamma}\right|_{\gamma=0} < 0$, $\left.\frac{dF_{(\gamma)}}{d\gamma}\right|_{\gamma=1} > 0$. When $\gamma = 0$, the evolution rate of residents' behavior is decreasing. When γ increases to 1, the evolution rate of residents' behavior is increasing. At this time, $\gamma = 0$ is the stable point of residents, and residents will choose the supervision strategy. The replication dynamic phase diagram of residents' strategy is shown in Figure 3.



(a) $\alpha = \frac{C_7 - \beta R_7}{C_3}$ (b) $\alpha < \frac{C_7 - \beta R_7}{C_3}$ (c) $\alpha > \frac{C_7 - \beta R_7}{C_3}$

Figure 3. Replication dynamic phase diagram of residents' strategy

3.5. Evolutionary stability analysis of the participation strategy

Assuming that the result of the replication dynamic equation is 0, eight local strategy Nash equilibrium points can be obtained, which are (0,0,0), (0,1,0), (0,0,1), (1,0,0), (0,1,1), (1,1,0), (1,0,1), (1,1,1). Friedman proposed to judge the stability of the local equilibrium point by the Jacobian matrix in the evolutionary model, so as to obtain the evolutionarily stable strategy (ESS) of the system. The Jacobian matrix (16) can be obtained by referring to (10-15).

$$J2 = \begin{bmatrix} \frac{\partial F(\alpha)}{\partial \alpha} & \frac{\partial F(\alpha)}{\partial \beta} & \frac{\partial F(\alpha)}{\partial \gamma} \\ \frac{\partial F(\beta)}{\partial \alpha} & \frac{\partial F(\beta)}{\partial \beta} & \frac{\partial F(\beta)}{\partial \gamma} \\ \frac{\partial F(\gamma)}{\partial \alpha} & \frac{\partial F(\gamma)}{\partial \beta} & \frac{\partial F(\gamma)}{\partial \gamma} \end{bmatrix} = \begin{bmatrix} (1-2\alpha)[(R_2 - C_1) - \beta C_2 - \gamma C_3] & -\alpha(1-\alpha)C_2 & -\alpha(1-\alpha)C_3 \\ \beta(1-\beta)C_2 & (1-2\beta)(R_4 + R_5 - R_3 + C_4 - C_5 + \alpha C_2) & 0 \\ \gamma(1-\gamma)C_3 & \gamma(1-\gamma)R_7 & (1-2\gamma)(-C_7 + \beta R_7 + \alpha C_3) \end{bmatrix} \tag{16}$$

We analysed the stability of eight local equilibrium points using the Jacobian matrix. According to Lyapunov stability condition. Mark the positive eigenvalue as (+), the negative eigenvalue as (-) and the uncertain eigenvalue as (u), and get eight local equilibrium points and their eigenvalue analysis, as shown in Table 3.

Table 3. Stability of the equilibrium point of the Jacobian matrix

Balance point	λ_1	λ_2	λ_3	Condition
$E_1(0,0,0)$	$R_2 - C_1(+)$	$R_4 + R_5 - R_3 + C_4 - C_5(+)$	$-C_7(-)$	saddle point
$E_2(1,0,0)$	$C_1 - R_2(-)$	$R_4 + R_5 - R_3 + C_4 - C_5 + C_2(+)$	$C_3 - C_7(u)$	unstable
$E_3(0,1,0)$	$R_2 - C_1 - C_2(+)$	$-R_4 - R_5 + R_3 - C_4 + C_5(-)$	$R_7 - C_7(+)$	unstable
$E_4(0,0,1)$	$R_2 - C_1 - C_3(+)$	$R_4 + R_5 - R_3 + C_4 - C_5(+)$	$C_7(+)$	unstable
$E_5(1,1,0)$	$-R_2 + C_1 + C_2(-)$	$-R_4 - R_5 + R_3 - C_4 + C_5 - C_2(-)$	$-C_7 + R_7 + C_3(+)$	unstable
$E_6(1,0,1)$	$-R_2 + C_1 + C_3(-)$	$R_4 + R_5 - R_3 + C_4 - C_5 + C_2(+)$	$C_7 - C_3(u)$	unstable
$E_7(0,1,1)$	$R_2 - C_1 - C_2 - C_3(+)$	$-R_4 - R_5 + R_3 - C_4 + C_5(-)$	$C_7 - R_7(-)$	unstable
$E_8(1,1,1)$	$-R_2 + C_1 + C_2 + C_3(u)$	$-R_4 - R_5 + R_3 - C_4 + C_5 - C_2(-)$	$C_7 - R_7 - C_3(-)$	unstable

In Table 3, since $\lambda_i > 0$ exists in E_1-E_7, therefore the sufficient necessary conditions for stability cannot be met. When$-R_2 + C_1 + C_2 + C_3 < 0$, $E_8(1,1,1)$ meet stability requirements. So $-R_2 + C_1 + C_2 + C_3 < 0$ is an important constraint condition of the stability of the three-party game, which determines the decisionmaking of the participants. In the process of rail transit station renewal based on TOD mode, the only stable strategy of the stakeholder game is (Coordinated and supervision, Active participation, Supervision), and the evolution sequence of stability strategy set is "local government → rail enterprises→ residents". The theoretical results are consistent with practice.

4. Simulation and results

4.1. SD model of evolutionary game

This paper used Vensim PLE software to establish a system dynamics model of evolutionary game to analyse the decisions of various stakeholders, as shown in Figure 4.

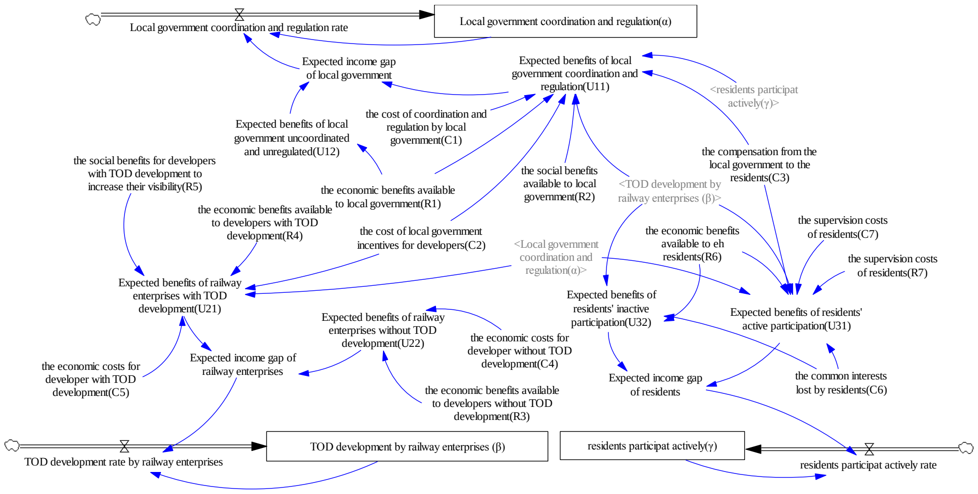


Figure 4. SD model for government, rail enterprise and residents in rail transit station renewal

SD model consists of 3 stock variables, 3 rate variables, 6 intermediate variables and 14 exogenous variables. The stock variable refers to the behavioural probability of participating, such as α, β and γ. The rate variable refers to the change rate of participants' behaviour. Exogenous variables refer to the parameters in the process of evolutionary game. According to references (Zhu et al.,2022) and expert suggestions, determine the parameter values, as shown in Table 4. The intermediate variable is the difference between the expected returns in the evolutionary game. Use $\frac{d\alpha}{dt}$, $\frac{d\beta}{dt}$, $\frac{d\gamma}{dt}$ represent the change rate of government supervision, rail enterprises participation, and resident supervision respectively.

Table 4. Parametric simulation data

parameter	simulation data	parameter	simulation data
R_1	30	R5	30
R_2	80	C4	20
C_1	30	C5	50
C2	10	R6	20
C3	5	R7	30
R3	80	C6	10
R4	120	C7	10

4.2. Stability strategy simulation analysis

In the process of simulation, set the simulation INITIAL TIME = 0, the simulation FINAL TIME = 40, and the simulation step TIME STEP = 0.5. Suppose that the initial intention of the three parties is $x = y = z = 0.5$. Then, the evolutionary strategy is simulated to obtain the evolutionary results that are consistent with reality. The results are shown in Figure 5.

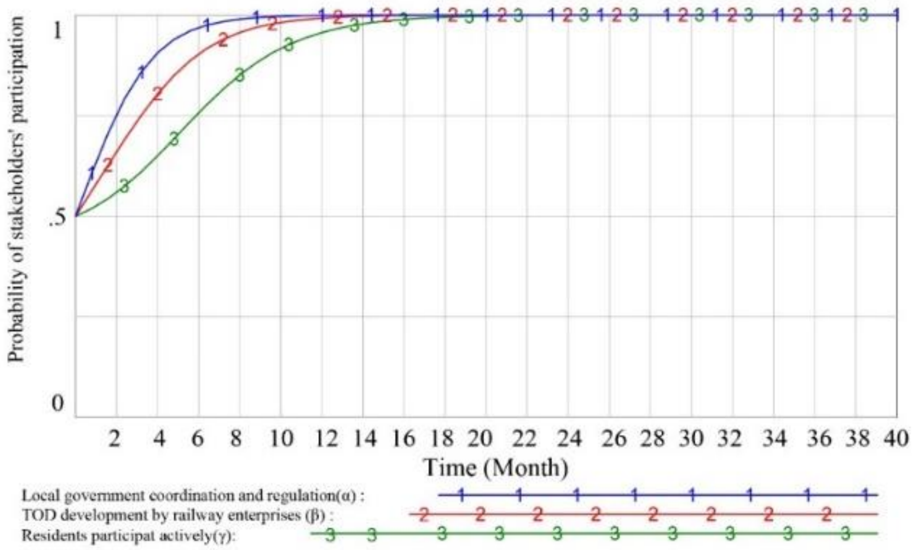


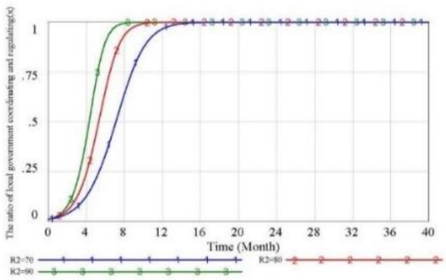
Figure 5. Probability trend diagram of strategy choice of different stakeholders

As shown in Figure 5, local governments, rail enterprises and residents will realise a stable strategy (1,1,1). The government will reach a stable balance at a faster speed, followed by rail enterprises and finally residents, which is consistent with theoretical analysis.

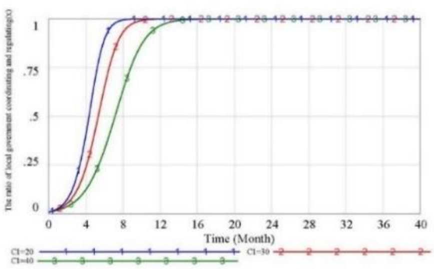
4.3. Simulation analysis of exogenous variables for stakeholder strategy choice

4.3.1. Influence factors of local government's strategic choice

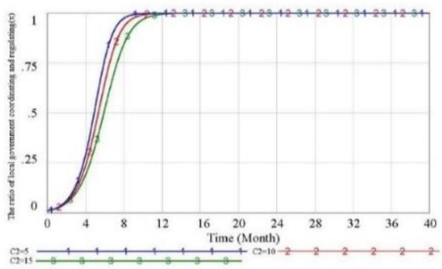
We set α changed from 0.01. The simulation analysis shows that the parameters of social welfare R_2, coordination and regulation cost C_1 and incentive cost C_2 directly affect the local government's strategy choice, as shown in Figure 6.



(a) R_2

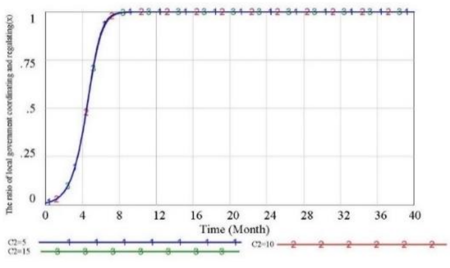


(b) C_1

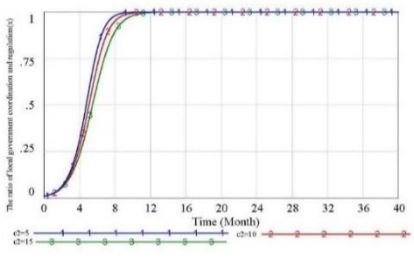


(c) C_2

Figure 6. Influence of exogenous variables on the government's strategic choice

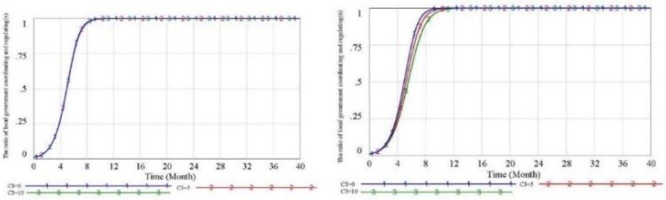


(a) $\beta = 0.01$



(b) $\beta = 0.3$

Figure 7. When β changes, the influence of exogenous variables on government strategic choice



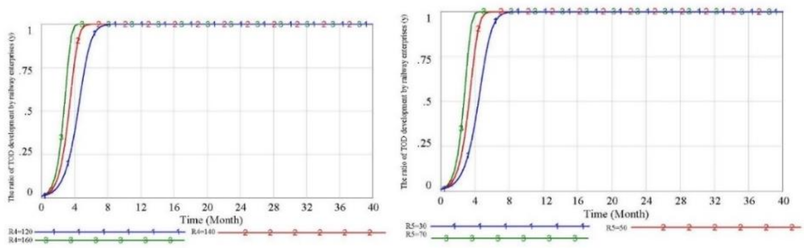
(a) $\gamma = 0.01$ (b) $\gamma = 0.3$

Figure 8. When γ changes, the influence of exogenous variables on the government's strategic choice

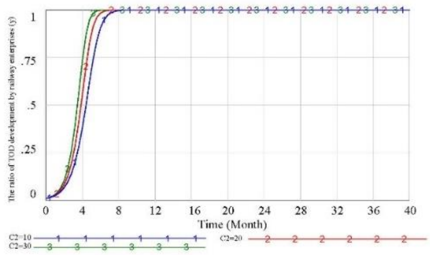
As seen in Figure 6, the evolutionary trends of R_2, C_1, and C_2 in the choice of the government election strategy are similar. When the social benefit increases, the cost of coordination and supervision decreases, and the incentive cost decreases, the government tends to choose coordination and supervision. As seen in Figure 7, when β increases to 0.3, the government can reduce the incentive cost. As seen in Figure 8, when γ increases to 0.3, increased compensation costs C_3 will slow government options for regulation.

4.3.2. Influence factors of rail enterprises' strategic choice

We set β changes from 0.01. As shown in Figure 9 (a) and (b), the economic benefit R_4 of TOD development and the social welfare R_5 have the same evolution trend in the probability of developers' active participation. Figure(c) shows that when the government's incentive policy C_2 increases, rail enterprises will be more active in TOD development.



(a) R_4 (b) R_5

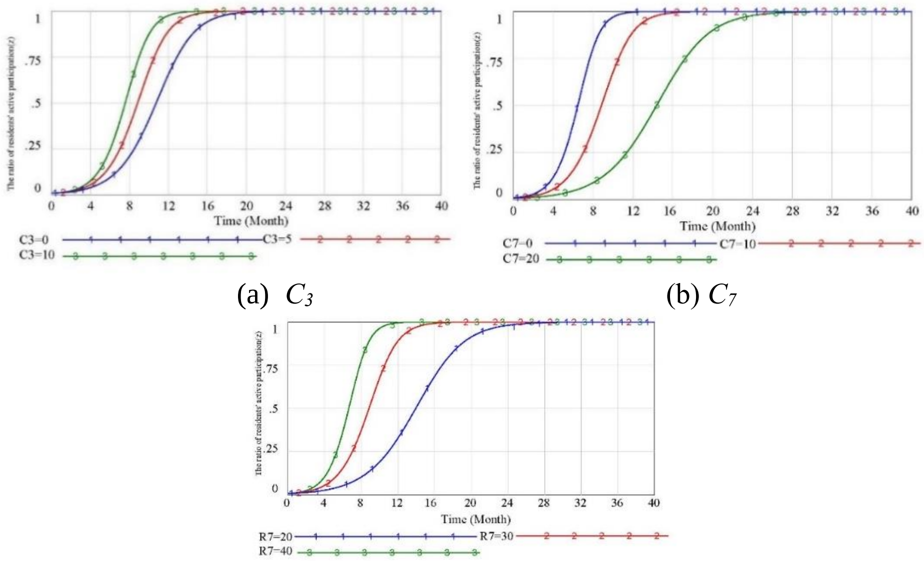


(c) C_2

Figure 9. Influence of exogenous variables on the strategic choice of rail enterprises

4.3.3. Influence factors of residents' strategic choice

Through simulation analysis, compensation cost C_3, supervision cost C_7 and indirect benefit R_7 directly affect the probability of residents' active participation, as shown in Figure 10. When the compensation or indirect income of residents increases, residents tend to actively supervise. When the cost of supervision increases, residents will delay their participation in supervision.



(a) C_3 (b) C_7

(c) R_7

Figure 10. Influence of exogenous variables on residents' strategic choices

5. Case analysis

In Japan, the Futako Tamagawa station renewal project is located at the former site of Futako Tamagawa Park on the east side of Futako Tamagawa station. The Futako Tamagawa station is the interchange station for line DT and line OM of Tokyu Corporation. The project was initiated by the Setagaya District Government in 1979, and was led by Tokyu Corporation. According to statistics, the project covers an area of 11.2hm^2, with over 400,000 m^2 of residential, store, office buildings, and leisure facilities.

The renewal project was first proposed by the Setagaya District Government in 1979. 1987, the “Futako Tamagawa East Area Redevelopment Preparation Group" was formally established, which is composed of Tokyu Corporation with 85% land property rights and retail investors with 15% land property rights. Tokyu Corporation actively led the formulation of the project facilities planning scheme, wrote the environmental impact assessment and worked out the redevelopment design scheme, and continuously adjusted the planning scheme with the goal of maximising economic benefits. The government's incentive mechanism, such as the FAR bonus, has further improved the enthusiasm of Tokyu Corporation.

During the development of the project, the local residents experienced a change from opposition movement to participation in supervision. At first, most residents did not support the renewal project because they were worried that the super high-rise buildings in redevelopment projects would bring environmental deterioration. Finally, the government came forward to coordinate and asked Tokyu Corporation to provide about 50 m^2 of the redeveloped building space for the library as compensation for the residents. Then, the residents stop the opposition movement and participate in the redevelopment project.

It can be seen that the Futako Tamagawa station renewal project evolved according to the order of local government-rail enterprises-residents, and finally achieved a stable result (government coordination, rail enterprises' active participation, residents' participation in supervision).

6. Conclusions and suggestions

This paper establishes a stakeholder game model among local government, rail enterprises and residents, and explores the mechanism of the government incentive system affecting the participation of rail enterprises and residents. The limit conditions of the stability of stakeholder game system is $-R_2 + C_1 + C_2 + C_3 < 0$. The only stable strategy set in stakeholder game is that the government, rail enterprises and residents choose the strategies of coordination and supervision, active participation, and supervision, respectively. The evolution sequence of the stable strategy set is "local government-rail enterprises-residents". It is found that in the case of asymmetric information, the government's incentive mechanism, such as FAR bonus, can greatly improve the investment and cooperation intention of rail transit enterprises. In the absence of the government subsidies, residents' willingness to participate and supervision is insufficient, and the government's subsidy policy and coordination mechanism can effectively improve residents' willingness to cooperate. Residents choose to participate and supervise based on their own utility maximisation, so as to balance the contradiction between the high-density development of rail transit station renewal and the public environment, which has become an important driving force for the government to promote urban renewal.

The specific conclusions are as follows:

(1) The simulation results show that when the initial strategy of the three parties is (0.5, 0.5, 0.5), the three parties will reach an evolutionary stable state (1, 1, 1) in a certain period of time, and the rate is local government > rail enterprises > residents, which is consistent with the actual evolutionary rate of the three parties.

(2) Discuss the results according to the factors that affect the probability of local government coordination and regulation, the probability of developers' active participation, and the probability of street owners' supervision. The social benefit of the local government (R_2), the economic benefit of the rail enterprises (R_4) and the

supervision cost of residents (C_7) are the most sensitive to the strategic choice of stakeholders, and they are the key factors that affect the strategic choice.

(3) When the incentive cost (C_2) increases, the rail enterprises reach the equilibrium point of evolutionary stability faster, which indicates that incentive policies can effectively promote rail enterprises to join renewal projects more quickly. When the compensation cost (C_3) increases, residents reach the equilibrium point of evolutionary stability faster, which shows that the government's compensation for residents' supervision can improve residents' enthusiasm for participating in renewal project supervision.

(4) The residents' supervision cost (C_7) and indirect income (R_7) will directly affect residents' choices. When C_7 increases, residents will be less motivated to participate in supervision. When R_7 decreases, residents will also delay their participation in supervision.

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