# Research on the Synergistic Relationship of Stakeholders in the Construction of Smart Communities— Case in China

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**Abstract.** The construction of smart communities is an important part of the construction of smart China. However, there are still some problems in the construction of smart communities in China, such as lack of participation or lack of trust from the clients. How to make all parties support the construction of smart communities has become one of the most important research topics. In this paper, by exploring the cooperative relationship among the participants, a tripartite game model in the construction of smart community is established, and the cost impact and core stakeholders' income is analyzed. The results of tripartite game show that in the construction of smart communities, moderate government incentives and preferential services from different providers will help all parties to play a synergistic role and jointly support the construction of smart communities.

**Keywords:** Smart community, Stakeholder, Synergistic relationship, Game model.

## 1 INTRODUCTION

In the 21st century China has entered an era of big data. Digital technologies represented by big data, industrial Internet, 5G, artificial intelligence, cloud computing and blockchain are changing the global economy[1]. Information technology is also gradually empowering the social governance field. Since 2012, China has successively introduced a series of policies and procedures to promote the construction of smart communities. In recent years, the successful practice of smart community services, such as community travel code, smart access control, smart logistics, contactless payment, community shopping groups, etc.[2] proved that the emergence of smart communities can effectively solve the issues of outdated management systems and imperfect property controls in current urban communities..It is conducive to improving residents' satisfaction, promoting the long-term effective management of the community, increasing the efficiency of community operation and management, enhancing community value, and then promoting the sustainable development of the community and the city. By the end of 2022, the total number of smart communities


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in China has exceeded 500,000. China's smart community construction has made great achievements, but the development situations vary from places to places, and the regional differences are still big. There are problems such as single construction subject[3], shortage of operating talents and lack of trust in targeted clients[4]. On one hand, it is due to lack of social participation mechanism. On the other hand, it is due to high cost of enterprise participation. Not only are enterprises less involved in the construction of smart communities, but community residents don't spend enough time to participate either because of their busy work[5].

## 2 RESEARCH OVERVIEW

At present the research on the construction of smart communities mainly focuses on technology application and construction model. Foreign research focuses on the relationship between smart communities and smart cities, the service of smart communities to residents and the application of communication technology to smart communities. Applying communication technology to smart communities can enhance residents' participation and simplify the way that residents obtain information[6], hence providing better services for residents. It does have some risks. However, the application of new network technology can minimize the problem of data uploading[7] and reduce the risk[8]. Smart communities can generally provide convenient, fast, comfortable, and safe services for residents, and improve government efficiencies, thereby benefiting all participants[9]. The domestic research on the construction of smart community mainly focuses on two parts: first, the macro concept research, which analyzes the value and logic problems in the construction of smart community[10], or predicts the future development trend of smart community[11]; Second, from a practical point of view, based on the experience of smart communities in Beijing, Shanghai, Shenzhen, Hangzhou and other cities[12], it analyzes the main components of smart community construction and summarizes the results at the levels of provinces, cities, districts and streets[13]. In the study of stakeholders in smart communities, it is not difficult to find that the current model of building smart communities in China is still led mainly by the government. There are also studies on the operation system of smart communities[14] and the responsibilities of stakeholders and analysis of the performance evaluation results of smart communities from the perspective of stakeholders[15], but there are few studies on the synergy between stakeholders. In fact, in the practice of building a smart community, there are only a few participants, mainly because the interests of all stakeholders are not well coordinated.

To study the constraints of the cooperation among stakeholders in the smart community, this paper uses the evolutionary game method to study the cooperative relationship among stakeholders in the smart community construction and discover the main factors that prevent the corporation among all stakeholders. This paper offers some ideas on how to solve problems in the construction of smart communities, setting strategies for the construction of smart communities in the region, and provides analysis and references for the construction of smart communities in other countries.

# 3 THE GAME MECHANISM IN THE CONSTRUCTION OF SMART COMMUNITIES

There are many stakeholders involved in the whole life cycle of constructing a smart community. Main stakeholders are government, real estate service providers, community residents, property owners, technology providers and service providers. Key members are connected while performing different functions through property management, service, payment, provision of information and other businesses, forming a community of interests in building smart communities. Conflicts of interest among the stakeholders involved are often manifested between short-term interests and long-term interests. In this paper, the stakeholders involved in the construction of smart community are divided into three categories based on participation methods: supervisors (represented by the government), service providers (technology providers, hereinafter referred to as service providers) and residents (beneficiaries of smart community construction).

## 3.1 Analysis of the Game Relationship Between Government and Service Providers

Government needs to pay the greatest attention to improve people's happiness. The construction of smart community can greatly enhance people's life satisfaction and happiness. Therefore, the government makes policies and procedures to encourage the construction of smart communities. Although the construction of smart community can bring economic and social benefits to the government and increase its credibility, the government's economic incentives payout will put pressure on taxpayers. The more the incentives, the greater the pressure. At the same time, as enterprises, service providers pursue the goal of maximizing benefits. Moreover, in the early stage of participating in the construction of smart communities, service providers expect to get certain incentives from the government, because the market hasn’t opened up due to lack of acceptance from the society. Therefore, the government's incentive policy and the economic benefits of service providers have become the focus of the interest game between the two.

## 3.2 Analysis of the Game Relationship Between Government and Residents

Compared with traditional communities, smart communities have higher quality and more efficient management and control. More importantly, they can provide better living experience for residents. However, because residents don’t have deep understanding of the smart community, they are still used to the traditional community management. Plus they are very sensitive to the extra expenses required for the construction of smart communities, which reduce their enthusiasm for participating in the construction of smart communities. Residents' failure to actively participate in the construction of smart communities leads to an imbalance between supply and de-

mand, resulting to many social risks for the government. Therefore, the government needs to strengthen policy propaganda, give residents some preferential benefits, raise residents' awareness of smart communities, and guide residents to actively participate in the construction of smart communities. Therefore, how to balance the perception differences in smart communities between residents and the government will be the focus of the game between the two.

### 3.3 Analysis of the Game Relationship Between Service Providers and Residents

Service providers are stakeholders in the market economy. Their decisions are not only influenced by enterprise value orientation, but also limited by government policies and residents' needs. Compared with regular communities, the information collected from residents is more and needs to be properly preserved, so smart communities have higher requirements on technology and management. Therefore, they need to invest more resources in construction, which means that service providers need to invest more in technology upgrading and software development. In order to guarantee the profitability, while answering government's call, service providers tend to expect government subsidies, and they raise the prices of products and services. Residents are the main users of smart communities. For residents, although the residential effect of smart community has great advantages, the increased construction cost and the risk of information leakage make them tend to be conservative. Therefore, the focus of the game between residents and service providers is the cost and benefit.

## 4 ESTABLISHMENT AND ANALYSIS OF EVOLUTIONARY GAME MODEL

### 4.1 Model Assumptions

In the process of promoting the construction of smart communities, the main stakeholders involved are service providers, residents and the government. According to Maslow's hierarchy of needs, residents tend to live in a safe and convenient environment. Residents participating in the construction of smart communities can improve their living environment and get preferential services from service providers, but they are very sensitive to the extra expenses. The decision-making of enterprises always aims at profit, and enterprises can get government subsidies and increase market share by actively participating in the construction of smart communities. In order to satisfy people's pursuit of a better life and improve residents' quality of life, government promotes the construction of smart communities. In the process, it also gives financial incentives and makes certain policies to service providers and residents. In the game process, the information of the three parties in the game is not completely symmetrical, and they are all bounded rational subjects. And the decision-making of the game subjects is to maximize their own interests, and finally seek the best strategy in the evolution of the three-way game behavior.

In the tripartite game, the behavior strategies of the players can be divided into the following categories. Assume that the set of behaviors that the government can choose is $M_1$ = {supervised $K_1$ but not supervised $K_2$}, and the corresponding probabilities are X and 1-X; Assume that the decision set of the service provider is $M_2$ = {actively cooperating $M_1$ but not actively cooperating $M_2$}, and the corresponding probabilities are y and 1-y; Suppose that the policy set that residents can choose is M3 = {supporting $N_1$ but not $N_2$}, and the corresponding probabilities are Z and 1-z respectively.

### 4.2 Game Model Construction

The government can choose to supervise or not to supervise two behavior strategies. When the government chooses "supervision", it will give service providers a certain subsidy, so as to encourage service providers to actively participate in the construction of smart communities; At the same time, encouraging enterprises to participate in the construction of smart communities will bring social benefits to the government as J; When the government adopts the incentive strategy, the reward given by the higher authorities and the promotion of credibility among citizens are K; The expenditure of manpower, material resources and financial resources when the government adopts the regulatory strategy is F. When the government chooses "no supervision", it will lead to a decline in credibility, resulting in a loss of D. Service providers can choose two behavioral strategies: active cooperation and non-active cooperation. When the service provider chooses "active cooperation", the income that the service provider can get from actively participating in the construction of smart community is R1, and the cost of equipment and technology that the service provider needs to provide at this time is C1. When the service provider chooses "no active cooperation", the service provider only provides necessary equipment services for social needs, plus certain basic services for ordinary communities. In this case, the service provider gains R2 and pays C2. Residents can choose to support or not support two behavioral strategies. When residents choose to “support” the construction of smart communities, they need to spend R1, and they can enjoy certain preferential services provided by service providers as B. At the same time, the benefits of improving the community environment and improving the security are U, but there is also a certain risk of information leakage as I. When residents choose "no support", it will bring certain social risks as L, the benefits of residents' living experience in building ordinary communities as S, and the cost they need to spend as R2.

### 4.3 Establishment of Tripartite Game Payment Matrix

According to the above hypothesis, there are eight kinds of tripartite game combinations of government, service providers and residents, in which K1 is supervision and K2 is not supervision; M1 is active cooperation, M2 is not active cooperation; N1 is supported, N2 is not supported, as shown in Table 1.

### 4.4 Replication Dynamic Equation of the Game Subject.

When the government adopts the regulatory strategy, the expected income is: $V_{11} = z(F-K)(y-1) - y(A+F-J-K)$; When the government adopts the strategy of non-supervision, the expected income is: $V_{12} = y(z-1)(D-J+L) - yz(D-J)$; Therefore, the average income of the government is: $V_1 = Jy - Fx - Dy + Kx - Ly - Axy + Dxy + Lyz$.

**Table 1.** Construct a tripartite game payment matrix

| Strategy combination | Government | Service provider | Resident |
|---|---|---|---|
| （$K_1$，$M_1$，$N_1$） | $K+J-A-F$ | $R_2 - C_2 + R_1 - C_1 + A - B$ | $S+U+B-I-R_1-R_2$ |
| （$K_1$，$M_1$，$N_2$） | $K+J-A-L-F$ | $-C_2-C_1+A$ | 0 |
| （$K_1$，$M_2$，$N_1$） | $K-F$ | $R_2-C_2$ | $S-R_2$ |
| （$K_1$，$M_2$，$N_2$） | $K-F$ | $-C_2$ | 0 |
| （$K_2$，$M_1$，$N_1$） | $J-D$ | $R_2-C_2+R_1-C_1-B$ | $S+U+B-I-R_2-R_1$ |
| （$K_2$，$M_1$，$N_2$） | $J-L-D$ | $-C_2-C_1$ | 0 |
| （$K_2$，$M_2$，$N_1$） | 0 | $R_2-C_1$ | $S-R_2$ |
| （$K_2$，$M_2$，$N_2$） | 0 | $-C_2$ | 0 |

The expected benefits of active cooperation strategy are: $V_{21} = x(z-1)(C_2 - A + C_1) + z(x-1)(B + C_1 + C_2 - R_1 - R_2) + xz(A - B - C_1 - C_2 + R_1 + R_2) - (x-1)(z-1)(C_1 + C_2)$. The expected benefits of the service provider's passive strategy are: $V_{22} = z(C_2 - R_2)(x-1) - C_2(x-1)(z-1) - xz(C_2 - R_2) + C_2x(z-1)$; Therefore, the average income of service providers is: $V_2 = R_2z - C_1y - C_2 + Axy - Byz + R_1yz$. The expected benefits of residents adopting the support strategy are: $V_{31} = x(R_2 - S)(y-1) + (B - I - R_2 - R_1 + S + U) - (R_1 - S)(x-1)(y-1)$; The expected income of residents who adopt non-support strategy is: $V_{32} = 0$; The average income of residents is: $V_3 = -z(R_2 - S - By + Iy + R_1y - Uy)$.

**Analysis of the game strategy selection of government's stable evolution.**The replication dynamic equation of government subject is:

$$F(x) = \frac{dx}{dy} = (V_{11} - V_1)x(1-x) = (F - K + Ay - Dy)x(x-1)$$

**Analysis on the choice of service providers' stable evolution game strategy.**The replication dynamic equation of the service provider is:

$$F(y) = \frac{dy}{dt} = (V_{21} - V_2)y(1-y) = (C_1 - Ax + Bz - R_1z)y(y-1)$$

**Analysis of strategy selection of residents' stable evolution game.**The replication dynamic equation of resident subject is:

$$F(z) = \frac{dz}{dt} = (V_{31} - V_3)z(1-z) = (R_2 - S - By + Iy + R_1y - Uy)z(z-1)$$

# 5 ABILITY ANALYSIS OF SYSTEM EVOLUTION

The analysis of the evolutionary game behavior of the government, service providers and residents can be described by the replication dynamic equation of the decision-making behavior strategy choice of the government, service providers and residents solved above.

$$F(x) = \frac{dx}{dt} = x(x-1)(F-K+Ay-Dy) = 0$$

$$F(y) = \frac{dy}{dt} = y(y-1)(C_1-Ax+Bz-R_1z) = 0$$

$$F(z) = \frac{dz}{dt} = z(z-1)(R_2-S-By+Iy+R_1y-Uy) = 0$$

The above three equations can solve the evolutionary equilibrium solution of the three-party game system, with a total of 12 solutions. They are: $E_1\left[0, \frac{R2-S}{B-I-R1+U}, -C1/(B-R1)\right]$, $E_2[0,0,0]$, $E_3[0,1,0]$, $E_4[0,0,1]$, $E_5[0,1,1]$, $E_6\left[1, \frac{R2-S}{B-I-R1+U}, (A-C1)/(B-R1)\right]$, $E_7[1,0,0]$, $E_8[1,1,0]$, $E_9[1,0,1]$, $E_{10}[1,1,1]$, $E_{11}\left[\frac{C1}{A}, -\frac{F-K}{A-D}, 0\right]$, $E_{12}\left[\frac{B+C1-R1}{A}, -\frac{F-K}{A-D}, 1\right]$.

According to the evolutionary game theory, the equilibrium point that satisfies that all eigenvalues of Jacobian matrix are non-positive is the evolutionary stability point of the system. Among the 12 solutions obtained above, there are 8 pure strategic solutions and 4 impure strategic solutions. Therefore, only the equilibrium points $E_2 \sim E_5$ and $E_7 \sim E_{10}$ need to be considered. When y=0, that is, service providers do not actively participate in the construction of smart communities. In fact, under the influence of the government's policy of promoting the construction of smart communities, service providers can't give up the opportunity to expand the market, so $E_7$ and $E_9$ are not considered, and only need to determine whether $E_2$, $E_3$, $E_4$, $E_5$, $E_8$ and $E_{10}$ are evolutionary stable points. According to the replication dynamic equations of three subjects, the Jacobian matrix is constructed as left:

$$T(J) = \begin{bmatrix} \frac{dF(x)}{dx} & \frac{dF(x)}{dy} & \frac{dF(x)}{dz} \\ \frac{dF(y)}{dx} & \frac{dF(y)}{dy} & \frac{dF(y)}{dz} \\ \frac{dF(z)}{dx} & \frac{dF(z)}{dy} & \frac{dF(z)}{dz} \end{bmatrix}$$

$$= \begin{bmatrix} (2x-1)(F-K+Ay-Dy) & x(x-1)(A-D) & 0 \\ -Ay(y-1) & (2y-1)(C_1-Ax+Bz-R_1z) & y(B-R_1)(y-1) \\ 0 & -z(z-1)(B-I-R_1+U) & (2z-1)(R_2-S-By+Iy+R_1y-Uy) \end{bmatrix}$$

Substitute the above six equilibrium points into the Jacobian matrix, calculate the eigenvalues by software, and determine the asymptotic stability of the equilibrium points by looking at the signs of the eigenvalues. The eigenvalues corresponding to the six equilibrium points are shown in Table 2.

The eigenvalues of equilibrium point $E_2$ [0,0,0] substituted into Jacobian matrix all satisfy negative Lyapunov stability conditions, so it is an evolutionary stability strategy. The equilibrium point $E_3$ [0,1,0] is substituted into the eigenvalue $\lambda_1 = C_2 > 0$ of Jacobian matrix, which does not satisfy the stability condition of Lyapunov, so $E_3$ is an unstable point. The eigenvalues of equilibrium points $E_4$ [0,0,1], $E_5$ [0,1,1] and $E_8$ [1,1,0] are all positive and negative, so these three points are not evolutionary stable strategies. The equilibrium point $E_8$ [1,1,1] satisfies $\lambda_1$= A-D+F-K < 0, $\lambda_2$ = B-A+$C_1$-$R_1$ < 0 and $\lambda_3$ = I-B+$R_1$+$R_2$-S-U < 0, so the equilibrium point $E_{10}$ [1,1,1] is evolutionarily stable.

**Table 2.** eigenvalues corresponding to the six equilibrium points

| Equilibrium point | Eigenvalue1 | Eigenvalue2 | Eigenvalue3 | Asymptotic Stability |
|---|---|---|---|---|
| $E_2$[0,0,0] | $K - F$ | $S - R_1$ | $-C_1$ | Stable Point |
| $E_3$[0,1,0] | $C_1$ | $D - A - F + K$ | $B - I - R_2 - R_1 + S + U$ | Instability Point |
| $E_4$[0,0,1] | $K - F$ | $R_2 - S$ | $R_1 - C_1 - B$ | Saddle Point |
| $E_5$[0,1,1] | $B + C_1 - R_1$ | $D - A - F + K$ | $I - B + R_1 + R_2 - S - U$ | Saddle Point |
| $E_8$[1,1,0] | $C_1 - A$ | $A - D + F - K$ | $B - I - R_2 - R_1 + S + U$ | Saddle Point |
| $E_{10}$[1,1,1] | $A - D + F - K$ | $B - A + C_1 - R_1$ | $I - B + R_1 + R_2 - S - U$ | Stable Point |

Based on the above evolutionary game stability strategy, the three-way game equilibrium point E8[1,1,1] participating in the construction of intelligent community is combined with the mathematical logic relationship provided by the three-way evolutionary game, and on this basis, the system dynamics model of the three-way game is constructed by using Vensim software. The model contains 3 flow bit variables, 3 flow rate variables, 14 external variables and 6 intermediate variables. Each variable is determined by the replicated dynamic equation in the evolutionary game.(see Fig. 1.)

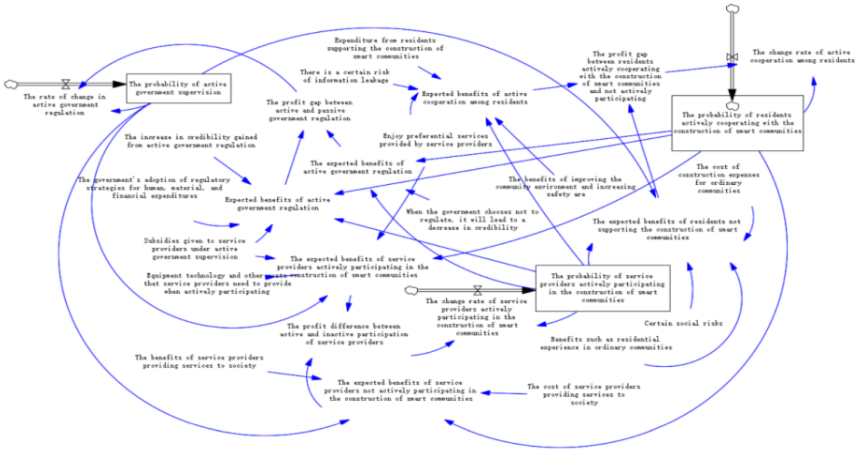


**Fig. 1.** SD Simulation Model of Evolutionary Game System

According to the system dynamics model, when A=3, B=2, U=3, I=2, the system will naturally reach the evolutionarily stable state E8(1,1,1). The tripartite game evolution path can be obtained.(see Fig. 2.)

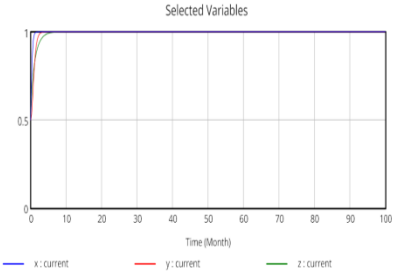


**Fig. 2.** Evolutionary path

# 6 GAME RESULT ANALYSIS

The above shows that the three-way evolutionary game system of smart community construction will realize two evolutionary stable States. These two evolutionary stability strategies are E2 [0,0,0] and E10 [1,1,1] .

**The evolutionary stability strategy is $E_2$ [0,0,0]** , which does not conform to the current market law of promoting smart community construction. In order to satisfy people's pursuit of a better life, the government has actively promoted the construction of smart communities and introduced a series of preferential policies to encourage service providers to actively participate in expanding the market. At this time, with the favorable policies and preferential services, residents will participate. Therefore, this strategy is only feasible in theory, but it is not the best strategy for policy promotion to participate in building smart communities at present.

**The evolutionary stability strategy is $E_{10}$ [1,1,1]**, which is in line with the current policy of promoting the construction of smart communities. The cooperation of the three parties in the game promotes the construction of smart communities. Among them, the government plays an obvious leading role and make policies to encourage service providers and residents actively participate in the construction of smart communities; At the same time, service providers and residents also actively participate in the construction of smart communities to promote the game to reach a stable state. Therefore, this strategy is the best stable strategy for building a smart community.

# 7 CONCLUSIONS AND SUGGESTIONS

## 7.1 Suggestions

**Government**

First, we should strengthen the government's dominant position in the process of building smart communities. Especially in the early stage of construction, when service providers take a wait-and-see attitude, government incentives are particularly

important. High government subsidies can effectively improve the participation enthusiasm of service providers. However, blindly subsidizing incentives will greatly increase the financial burden of the government, so it cannot be maintained for a long time. Therefore, it is difficult to achieve a long-term evolutionary balance. In view of this, government needs to maintain a balance between incentives and subsidies, and it is suggested to strengthen the marketing of smart communities to enhance the public's awareness of smart communities, thus increasing market demand for smart communities. In addition, the enthusiasm of local governments may slack off in the long-term practice, and the encouragement and support of higher level of authorities is an important driving force to encourage local governments to participate in the construction of smart communities. Therefore, the central government can incorporate the construction of smart communities into the work evaluation system. Evaluate the policies and procedures established by local governments for building smart communities. Give rewards according to the results, thus promoting the enthusiasm of local governments to support the construction of smart communities.

**Service providers**

As a service provider of smart community, it should actively respond to the government's incentive policy to promote the construction of smart community and take responsibilities accordingly.Social responsibility: Improve the technology skills, pay attention to protect residents' privacy, make safety commitments, and at the same time, reduce the incremental cost of building smart communities as much as possible, so as to maximize their own benefits. In addition, the incremental income of smart community construction will encourage service providers to participate in smart community construction, but it will have a negative impact on residents' willingness to participate. Therefore, in the early stage of smart community construction, service providers should give certain preferential services to residents who participate in smart community construction while getting financial incentives from the government to increase the enthusiasm of residents to support smart community construction.

**Residents**

As the users and beneficiaries of smart communities, residents should have a deep understanding of smart communities and respond positively to the government's relevant policy propaganda, establish a scientific understanding and actively participate in the construction of smart communities while getting the preferential services provided by service providers; At the same time, smart community not only can provide residents with a safe and comfortable living environment, but also accelerate the construction of a harmonious society, which is of great significance to the sustainable development of society. Therefore, residents should take their responsibilities, actively respond to the construction of smart communities and participate in the construction of smart communities.

### 7.2 Conclusion

In this study, the core stakeholders of smart community construction are selected, and the theoretical analysis of the system evolution equilibrium state is carried out by constructing the evolutionary game model of smart community construction with three game subjects. Finally, the following conclusions are drawn: Firstly, By constructing the tripartite evolutionary game model between government, service providers and residents and analyzing the evolutionary stability game strategy, the optimal evolutionary stability strategy for building smart communities is ; Secondly, The government gives some preferential treatment to service providers in the construction of smart communities, and the service providers provide some preferential services to residents, which can improve the enthusiasm of residents, thus maximizing the synergy of the three players in the game and jointly promoting the construction of smart communities.

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