



# Analysis on Cooperation Relationship of Poverty Alleviation Organizations in Sichuan Province Based on Link Prediction

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**Abstract.** Poverty eradication is the common ideal of mankind. Currently, as COVID-19 continues to rage around the world, the cause of poverty reduction faces greater challenges. Poverty reduction requires the involvement of multiple parties, and the challenging nature of it determines the complexity of participation in poverty reduction cooperation. In this paper, the link prediction method is used to calculate the path similarity in the network and use the Katz index to predict the connection possibility between unknown links in the poverty alleviation network. Take Sichuan Province as a case to analyze and put forward cooperation suggestions. The results show that in the entire network, all anti-poverty organizations recommend cooperation with one of the government departments, local schools, state-owned enterprises and high quality schools. Among them, government departments and local schools are the most recommended organizations. After the overall victory in the fight against poverty, the governance of relative poverty still requires continuous attention. Through our research, we hope to contribute to a better construction of a new poverty reduction system under the new poverty model.

**Keywords:** Network analysis · Link prediction · Poverty alleviation

## 1 Introduction

As COVID-19 continues to spread worldwide, it poses a huge challenge to reducing poverty. Affected by the epidemic, it is estimated that more than 140 million people worldwide will be plunged into extreme poverty, swallowing the poverty reduction achievements of the poorest countries in the past few year [6]. Poverty is a chronic global disease, eradicating poverty is a global problem [22]. However, through large-scale efforts, China's rural poor population has been greatly

reduced, the living standards of the poor have been greatly improved, and the overall regional poverty reduction has achieved remarkable results. According to China's current poverty line, 770 million rural residents have been lifted out of poverty in the past 40 years of reform and opening up. Since the 18th National Congress of the Communist Party of China in 2012, China has launched a tough battle for targeted poverty alleviation. After eight years of hard work, China has achieved the goal of poverty alleviation by the end of 2020. Nearly 99 million rural poor people, 832 poor counties and 128,000 poor villages have been lifted out of poverty. China's poverty reduction achievements make it the first developing country to achieve the poverty reduction goals of *United Nations 2030 Agenda for Sustainable Development* 10 years ahead of schedule [21]. The poverty rate has dropped from 10.20% to 0%, some data are shown in Fig. 1 and Fig. 2. The poverty reduction path explored in China's poverty reduction practice and the anti-poverty theory with Chinese characteristics have expanded the human anti-poverty thinking, explored a new path for human poverty reduction, and made great contributions to the global poverty mitigation cause [17]. After completing the poverty reduction task in 2020 as planned, the relative poverty in China will persist for a long time [19]. To adapt to the new situation, after 2020, the focus of China's poverty reduction will shift from centralized governance of extreme poverty to the conventional governance of relative poverty [16].

Poverty alleviation requires the involvement of organizations from all backgrounds, stressing the need to give full effect to government and society. Text [12] found that social organizations play an important role in the process of poverty reduction. Through policy orientation and encouragement, numerous social organizations have participated in the assistance, improving the effectiveness of poverty reduction. At the same time, the cooperation network formed by social organizations in the process of cooperation in poverty reduction supports the development of. For poverty in coastal areas, text [2] proposed that future poverty alleviation strategies need to consider the development of small and medium-sized enterprises based on social networks, and provide them with policy solutions based on the creativity of network resources, they also believe that the synergistic effect of these network resources will become a powerful force in poverty alleviation in coastal areas. Text [14] took the poor village Sealshui in China as an example to study the development process, characteristics and operating mechanism of the village's poverty reduction integrated network, describes how it successfully meets the challenges of rural tourism poverty alleviation through the integration of tourism and extended industries, he found that the integrated network provides more income channels for the poor and effectively reducing poverty. Domestic and foreign research on poverty alleviation cooperation networks mainly focuses on the efficiency and quality of the construction of cooperation networks for poverty reduction, and the structural characteristics and operating mechanisms of the entire network, as well as the impact of the establishment of the network on the performance of the organization, few articles have studied the potential cooperation relationship between various nodes of the poverty alleviation cooperation network.

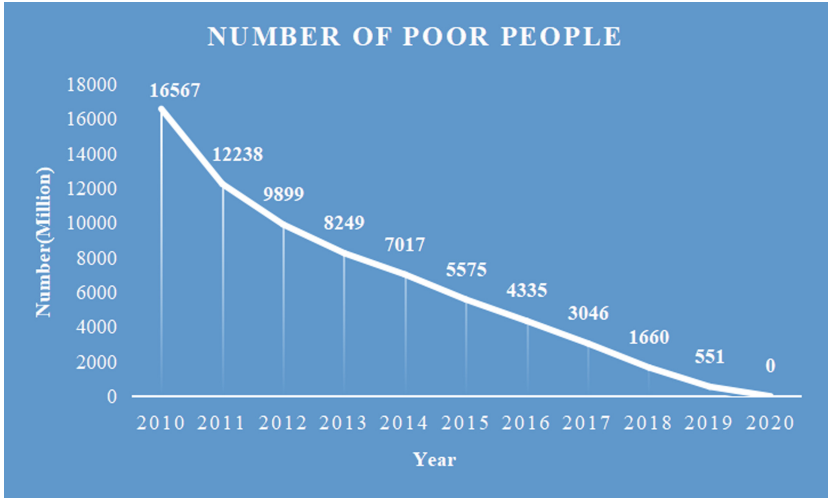


Fig. 1. Number of poor people in China

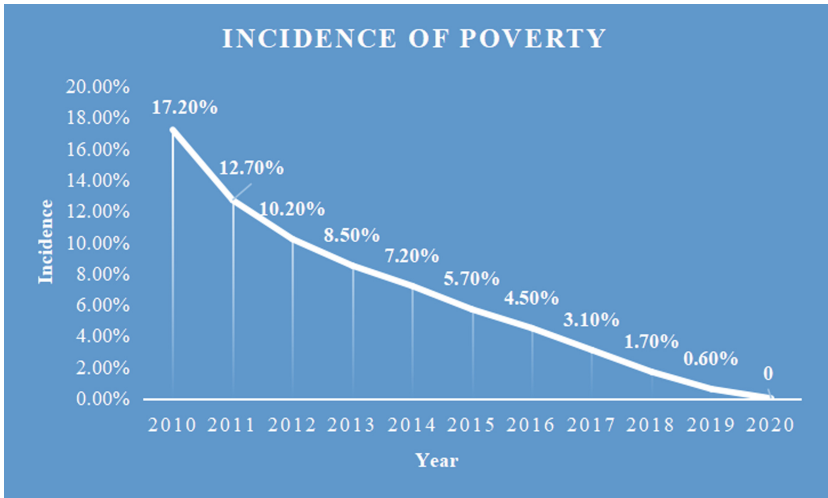


Fig. 2. Incidence of poverty in China **Data resource:** China Statistical Yearbook (2021) [3]

The nodes of the social cooperation network are the individuals or organizations involved in the cooperation, which is the first type of network that has received attention. The current method for social cooperation networks is mainly link prediction [9]. Link prediction refers to the use of known network nodes and structure as well as other information to predict the likelihood of future connections between two nodes that have not yet formed an edge [4]. Typically, the most basic network parameters are nodes and edges. Using social networks as

an example, nodes are generally used to represent users, and connected edges are used to represent the dynamic relationship between them. The collection of connected edges constitutes the interaction between users as well as the relationship between time and space [18]. The cooperation network of poverty alleviation organizations can be regarded as a social network centered on poverty alleviation organizations, in which poverty alleviation organizations are nodes in the network, and the cooperative relations between organizations are the edges. In the cooperation network of the anti-poverty organization, the network structure indicates the position of the organization in the network. If two organizations are in a similar environment, this means they are more likely to have links and have a greater possibility of cooperation in the future. Thus, the structure of the network provides an opportunity to discover potential partnerships of poverty alleviation organizations.

Traditional methods of link prediction are based on the Markov chains or machine learning, which takes into account the attributes of nodes [15]. But these methods cannot be applied in many cases as these attributes are hard to obtain. For example, user information in many cooperative networks is confidential, and user attributes are hard to distinguish, which means that the universality of these methods is not too high. Another method is the maximum probability estimation based on the network structure, but the computational complexity is relatively high. Compared with the above two methods, through experiments in multiple actual networks, text [10] found that the similarity-based method can obtain a good prediction effect, and the calculation process is comparatively simple.

Based on the previous discussion, this paper inspired the method of link prediction to predict and recommend the cooperation relationship in the poverty alleviation cooperation network. The rest of this study is arranged as follows: In Sect. 2, we will introduce the specific methods of this article. Section 3 conducted a case study in Sichuan and made predictions. Finally, conclusions, limitations and outlook in Sect. 4.

## 2 Methodology

### 2.1 Method of Link Prediction

In research on link prediction, using similarity for prediction is the simplest and most empirical method. Text [5] pointed out that similarity predictors of network topology are divided into two types: path-based and node-based. Text [7] used a series of social network snapshots to determine the possibility of new interactions among future members, a link prediction method based on the structural proximity of nodes was developed, which demonstrating its effectiveness and practicality. Text [20] used papers published in 59 journals in the field of graphic information from 2001 to 2011 as the research object, compared the predicted effects of various indicators in link prediction, the experimental results showed that among the prediction indicators based on the topology, the Katz indicator predicted the best. In this regard, this research will build an algorithm

based on path similarity calculations, use the Katz index to calculate the similarity between nodes to predict the potential cooperation relationships in the cooperation network of poverty mitigation organizations.

## 2.2 Model

Define  $G(V, E)$  as an undirected network,  $V$  as a set of nodes,  $E$  as a set of edges. The total number of nodes in the network is  $N$ , the number of edges is  $M$ . It is easy to know that the network has a total  $N \times (N - 1)/2$  node pairs, which is the complete set  $U$  [1]. For a method of link prediction, each pair of unconnected node pairs  $(x, y) (\in U/E)$  is assigned a score value  $S_{xy}$ . The higher the score value, the greater the probability of connecting the edges.

In path-based link prediction, the Common Neighbor index (CN) is most commonly used, that is, if two nodes have many common neighbor nodes, then the two nodes are similar, that is to say they are more inclined to connect edges [13]. It is defined by the Formula (1):

$$S_{xy} = |\tau(x) \cap \tau(y)| \quad (1)$$

In this formula, for a node  $x$  in the network, define its neighbor as  $\tau(x)$ . The advantage of CN is the low computational complexity, but the information used by CN is very limited, so the prediction accuracy of it is not very high in some cases. Therefore, text [8] considered the third-order path of the network on the basis of common neighbors, proposed the Local Path index (LP). Its definition is shown in the Formula (2):

$$S = A^2 + \alpha A^3 \quad (2)$$

where  $A$  is the adjacency matrix of the network,  $A^3$  represents the number of paths between nodes with a length of 3, and  $\alpha$  is an adjustable parameter used to control the third-order path. LP can also be extended from low-level to high-level, so the Katz index that considers all paths of the network is obtained. The Katz index considers the number of all paths, assigning a larger weight value to nodes between short paths, and assigning a smaller weight value to node pairs between long paths [11]. Its definition is represented in the Formula (3):

$$S = \alpha A + \alpha A^2 + \alpha A^3 + \dots \quad (3)$$

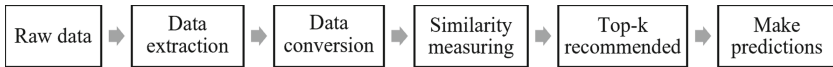
Among them,  $\alpha \in (0, 1)$  is the weight attenuation factor, which is used to adjust the influence of long-distance paths on the similarity. When the number of network nodes is large, the Katz coefficient is difficult to calculate in a finite time, but when  $\alpha$  is less than the reciprocal of the maximum eigenvalue of the adjacency matrix  $A$ ,  $S$  can converge, and the expression form after  $S$  convergence is as follows:

$$S = (I - \alpha A)^{-1} - I \quad (4)$$

where  $I$  is the identity matrix, whose diagonal elements are all 1 and all other elements are 0.

### 2.3 Process of Link Prediction

The program is implemented by Python, and the steps are shown in the Fig. 3.



**Fig. 3.** Flowchart of link prediction

To sum up, the Katz method calculates the similarity scores among various organizations based on the network of poverty alleviation cooperative organizations, then we rank the probability of cooperation according to the similarity score, finally predict the cooperation relationship based on ranking results. Specific steps are as follows:

- (1) Extract the raw data to obtain the required information, construct the cooperation matrix of poverty alleviation organizations, and save the matrix in Excel format.
- (2) Use Python to convert the cooperation matrix from Excel format to Edgelist format, then build a network adjacency matrix.
- (3) Based on the network adjacency matrix, the Katz index is used to calculate the path similarity in the network. The higher the result of the calculation, the more similar the environment the nodes are in, and the greater the possibility of edge connections between nodes.
- (4) Depending on the results of the similarity calculation, we use the recommended top-k method (take  $k=3$ ) to obtain the three most recommended cooperative institutions for each organization.
- (5) Classify cooperation organizations for poverty reduction and obtain cooperative institutions recommended by various organizations.

## 3 Case Study

In this section, the link prediction algorithm above is used to predict the potential cooperative relationship of poverty alleviation organizations.

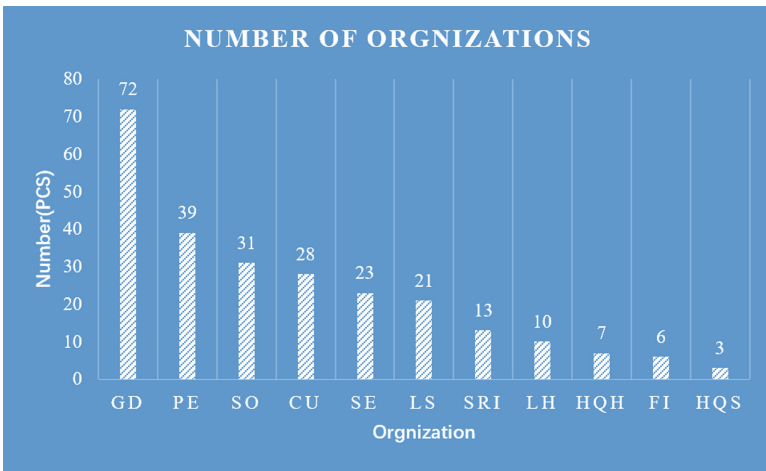
### 3.1 Data Collection

Sichuan, located in southwestern China, is one of the provinces most affected by poverty alleviation in China and the main battlefield for poverty reduction in China. The basic conditions of Sichuan are large population, weak foundations, and underdeveloped, the problem of imbalanced and inadequate development is even more prominent. At the end of 2013, Sichuan counted 6.25 million people living in poverty, or 7% of China. Mainly distributed in the areas of the North West Sichuan Plateau, the Qinba Mountains, the Wumeng Mountains and the Daliangshan Yi District. Poverty has obvious characteristics of “large amount, wide area, deep degree”, and there are many factors restricting development. Despite the difficulties, Sichuan still won the fight against poverty as scheduled in 2020, and handed in answers to the satisfaction of the people. In recent years, Sichuan has regarded poverty alleviation as the biggest political responsibility, the biggest livelihood project, and the biggest development opportunity. Under the province’s current standards, 6.25 million registered poor populations were lifted out of poverty, 88 impoverished counties were all removed, 11501 poor villages all withdrew, eliminating the absolute poverty that has existed of thousands of years. The fight against absolute poverty and regional poverty has been won to the full.

Our data comes from the paired-up assistance poverty alleviation exhibition conducted by the government departments of Sichuan Province, which collectively reflects the poverty alleviation effect of 379 provincial departments (128 government departments, 124 colleges and universities, 44 hospitals, 61 state-owned enterprises, and 22 financial institutions) poverty alleviation effect from 2015 to 2020. The data summarizes 71 advanced cases of provincial-level paired-up assistance poverty alleviation units, with a total of 253 nodes (including 71 designated poverty alleviation units and 182 cooperative organizations). We classified and summarized the poverty alleviation actions of 71 provincial units, and added them to the cooperative network of poverty alleviation organizations. That is, the cooperation network of poverty alleviation organizations in Sichuan includes nodes: government departments, state-owned enterprises, private enterprises, colleges and universities, high quality schools, local schools, high quality hospitals, local hospitals, scientific research institutions, financial institutions and social organizations. Nodes and their abbreviations in the network are displayed in Table 1 below, their statistics are shown in Fig. 4 below.

**Table 1.** Nodes of the network

Nodes	Abbreviations
Government departments	GD
State-owned enterprises	SE
Private enterprises	PE
Colleges and universities	CU
High quality schools	HQS
Local schools	LS
High quality hospitals	HQH
Scientific research institutions	SRI
Financial institutions	FI
Social organizations	SO



**Fig. 4.** Number of poverty alleviation cooperative organizations

### 3.2 Results and Analysis

Table 2 and Table 3 shows the results of the cooperation recommendation based on the link prediction by paired-up assistance poverty alleviation units in Sichuan Province. Table 2 indicates the number of recommended collaborations per organization. The larger the number, the more times of recommended cooperation, the greater opportunity for cooperation. Table 3 shows the most recommended cooperative units of each organization.



**Table 2.** Number of collaborations with recommended organizations

	GD	SE	PE	CU	HQS	LS	HQH	LH	SRI	FI	SO
GD	0	13	4	9	0	1	13	0	3	1	8
SE	31	0	1	0	1	3	1	0	0	0	1
PE	8	0	0	1	0	11	0	1	5	0	4
CU	31	2	5	0	0	2	2	0	1	1	3
HQS	0	1	0	0	0	1	0	1	0	0	0
LS	6	2	4	3	1	0	0	0	0	1	1
HQH	10	0	0	2	0	3	0	0	0	0	0
LH	2	1	1	0	1	4	0	0	0	0	2
SRI	5	0	2	0	0	6	0	0	0	0	1
FI	5	0	0	1	0	2	0	0	0	0	2
SO	5	1	1	2	0	11	1	1	1	1	0

From Table 2 we can get the result of link prediction. Taking government departments as an example, it is recommended to cooperate with state-owned enterprises, private enterprises, colleges and universities, local schools, high quality hospitals, scientific research institutions, financial institutions and social organizations, which shows that government departments play an extremely important role in the cooperative relationship network. Among them, the number of recommended cooperation between government departments and state-owned enterprises, high quality hospitals, colleges and universities and social organizations is higher, indicating that there is a greater possibility of cooperation between them. Government departments should consider their cooperation in the process of poverty alleviation.

**Table 3.** Top 1 recommended organization

Poverty alleviation organization	Top 1 recommendation
GD	SE, HQH
SE	GD
PE	LS
CU	GD
HQS	SE, LS
LS	GD
HQH	GD
LH	LS
SRI	LS
FI	GD
SO	LS

From Table 3, we can obtain the preferred cooperative institution recommended by each poverty alleviation organization which is the organization that recommends the most cooperation. Among them, state-owned enterprises, colleges and universities, local schools, high quality hospitals and financial institutions give priority to recommend cooperation with government departments; Private enterprises, high quality schools, local hospitals, scientific research institutions and social organizations give priority to recommend cooperation with local schools; Government departments and high quality schools give priority to recommend cooperation with state-owned enterprises; Government departments give priority to recommending cooperation with high-quality hospitals. Among them, government departments and local schools recommend 5 times for cooperation, state-owned enterprises 2 times, and high-quality schools once. This shows that when most organizations cooperate in poverty alleviation, government departments and local schools recommend the most cooperation. This is because, on the one hand, from an institutional perspective, China's poverty alleviation is a "government-led" model, so there will be more cooperation with government departments, this is a poverty alleviation that fits China's national conditions. On the other hand, it can be seen that Sichuan attaches great importance to poverty alleviation through education. Education is the fundamental way to ending the intergenerational transmission of poverty.

## 4 Conclusions and Future Prospect

Getting rid of poverty is not the end, but the starting point for a new life. China had eliminated extreme poverty, but relative poverty is still long-standing. Therefore, we must sum up valuable experience in the process of poverty alleviation, and strive to inspire the smooth progress of rural revitalization and the governance of relative poverty. In the context of the fight against poverty in China, a large number of relevant enterprises and third-party organizations have been actively involved in the work of poverty mitigation. Therefore, exploring the cooperative model and cooperative relationship between multiple entities is of great help to consolidate the effectiveness of poverty alleviation and understand the profound connotation of poverty reduction policies. This paper adopts the method of link prediction, combined with the poverty alleviation cases of the paired-up assistance organizations in Sichuan to predict the possibility of connection of unknown links in the network and make cooperative recommendations. The results show that in the entire cooperation network, all organizations recommend to cooperate with government departments, local schools, state-owned enterprises, and high-quality schools. Among them, government departments and local schools are the most recommended organizations. This has certain enlightenment for the cooperation of poverty alleviation organizations under the new form of rural revitalization.

From the above conclusions, it can be seen that government departments and schools play an extremely important role in the poverty alleviation cooperation network. On the one hand, major livelihood projects such as poverty alleviation

and rural revitalization are inseparable from the leading role of the government. Only when the government has a good grasp of the policy direction, actively guides the implementation of policies in provinces, districts, counties and towns, and calls on social organizations to participate, can poverty alleviation become a cause that the whole society pays attention to and participates in. On the other hand, education is an important means for the poor to get rid of intergenerational poverty. Poverty alleviation must first rely on education to help. Thus, in the process of poverty alleviation, special attention must be paid to cooperation with schools. China's poverty alleviation has achieved complete success, achieved world-renowned achievements, and accumulated rich experience in poverty alleviation, which has had a profound impact on the world's poverty alleviation. Therefore, we also hope that the experience in poverty alleviation and cooperation summarized in this paper can also be used for reference by other countries.

The disadvantage of this paper is that the data are derived from cases. Due to the high specificity of the case data, the types of paired-up assistance units included are not complete. Among them, financial institutions and hospitals have less poverty alleviation case data, resulting in inaccurate descriptions of the network. At the same time, the poverty alleviation network is changing dynamically, and the relationship of the poverty alleviation organization's cooperation network will also change at different stages of the process. The above is only a static study, but it cannot reveal the dynamic evolution of the actual relationship data. After 2020, when China has completed the arduous task of poverty alleviation, how to achieve stable poverty alleviation and prevent the poor from returning to poverty still needs continuous attention. The direction of future research may be the evolution of the network in different stages of poverty alleviation.

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