Research on the Identification of the Key Elements of Mega Project System

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Abstract

The social attribute of mega project, the complexity of stakeholders and the arduousness of management objectively require managers to identify the key elements of the system from the perspective of social networks. This research constructs a social network structure of mega project to study the centrality of social networks of mega project system with social network analysis (SNA). With Local centrality, Closeness centrality and Betweenness centrality, the key index of elements is established and these elements are reordered according to the importance. This paper makes an empirical analysis in which the key elements of Chongqing Metro Line 6 project are defined with UCINET. The results are expected to simplify the structure of social networks with the key elements identified, and it can improve the management efficiency to achieve the expected management goals more effectively.

Keywords: Mega Project; Key Elements; Social Network Analysis

1 Introduction

Mega project refers to the oversize project that will have a significant and lasting impact on the regional economy, the national economy, even the global economy, and the implementation of which needs breakthroughs in core technologies, resource integration and organization of a huge team [1]. Mega project often takes more time and resources to complete, involving in more stakeholders. It has great influence on economy, social, culture and natural environment. The implementation of the project contains large amounts of material operation activities, also a wealth of organizational cooperation and coordination [2]. Therefore, mega project has a typical social nature, and it is more difficult to manage than traditional project. And it is not rare that the budget of mega project breaches 50% or 100%. In addition, the income deficit also makes many large engineering construction project get into trouble. The project influence on region and environment is different from the promise at the beginning of the project. Therefor mega projects need more scientific and efficient management to avoid risk, so as to achieve project goals [3-4].

Considering the above background, this paper analyzes the relationships among various stakeholders in a complex mega project system by SNA theories and methods from the perspective of social network, identifies a few key stakeholders, simplifies the system scale, optimizes organizational structure, improves resource efficiency and management efficiency [5], also solves the main aspects of the main contradiction to improve management efficiency and achieve management goals more effectively.

2 Research method

The social network is composed of actors and the relationships between actors. The core foundation of the theory is the relationships between actors rather than the properties of the actors themselves. Social networks analysis method is an analyzing tool extending from the theory of social network, combined with the achievements of econometrics, mathematics, social psychology, balance theory, graph theory, social comparison theory, etc. And it also develops weak tie [6], strong tie [7], and the structural hole theory [8], etc. This analysis tool can be applied to organizational theory and organizational behaviour etc. SNA is featured by connecting macro level with micro level data, and it can analyses the network data of inter-organization and organization at the same time with a single architecture [9].

According to the SNA theory, the social network structure of mega project system is constituted by the relationships among the nodes.

(1) Node: Any stakeholder in mega project system, which means the main elements as for the mega project system, including natural person man, legal person or organization.

(2) Relationships: Contractual relationship, interest relationship, right and obligation relationship, information exchange relationship, and matter and energy exchange relationship, etc.

In a complex social network, it helps to seek the few key elements that we pay more attention to nodes which is in the center of the network. Questions about what kinds of rights individuals or organizations have in their social

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networks or where the central status of them is, they are centrality analysis, and it is one of the many issues discussed in the early [10]. There are following kinds of indicators of centrality analysis:

(1) Local centrality: $C_{AD}(i)$ represents local centrality of node i. It represents the number of nodes which have direct relationships with node i.

$$C_{AD}(i)=\frac{\sum_{i-1}^{n}(\max C_{AD}-C_{AD}(i))}{\max\left[\sum_{i-1}^{n}(\max C_{AD}-C_{AD}(i))\right]} \quad (1)$$

(2) Closeness centrality: C_{APi}^{-1} represents closeness centrality of node i. It represents the sum of shortest distances between node i and all other nodes in the structure of network. The distance between any two adjacent nodes is one.

$$C_{APi}^{-1}=\sum_{j=1}^{n}d_{ij} \quad (2)$$

In the above formula, d_{ij} is the shortest distance between node i and j. Closeness centrality is also called approach centrality. As for the directivity of relationships, if the relationship is that node i positively points to the other node, this kind of closeness centrality is called out-Closeness, on the contrary, it is called in-Closeness.

(3) Betweenness centrality: It represents the ability that node i is in the shortest geodesic between j and k. It can be described with $b_{jk}(i)$ and C_{ABi}.

$$b_{jk}(i)=g_{jk}(i)/g_{jk} \quad (3)$$

In the above formula, $b_{jk}(i)$represents a proportion that node i is in the shortest geodesics between node j and k,g_{jk} represents the number of all the shortest geodesics between node j and k,$g_{jk}(i)$ represents the number of all the above shortest geodesics that pass node i.

$$C_{ABi}=\sum_{j}^{n}\sum_{k}^{n}b_{jk}(i) \quad (j\neq k\neq i,\ j<k) \quad (4)$$

In the above formula, represents the sum of b_{jk} between any two different nodes.

3 Social network structure of mega project

Mega project system is essentially a complicated relationship network among a series of stakeholders, any stakeholder's behaviors and their results will not only be affected by network structure, but also affect the system itself. Social network analysis (SNA) is an important theoretical method and a tool for research on network structure of mega project system. The theory offers a theoretical foundation for bringing mega project's organizational activities into social networks and inspecting [11].

According to SNA theory, Local centrality represents the ability that a node is located on the center of local network. If the local centrality of a certain node is bigger than others, it is more likely to be at the center of the local scope, which brings more power, thus the node's influence on the whole network cannot be ignored, deserving that administrators attach importance to it and it may become the key element.

Closeness centrality represents the ability that a node is located on the center of whole network. While if closeness centrality of a certain node is bigger than others, it is far apart from the whole network system, it is relatively independent, and it may go out of control of other actors. On the contrary, if it is smaller than others, it is more likely to be at the center of the structure, and it should become the key element.

Betweenness centrality represents the ability to that a node control others to exchange information. It is more capable to influence part of the lines and even the whole network if its betweenness centrality is bigger than others, and it should be the key element certainly.

These show that, the key element should be the one whose Betweenness centrality and Local centrality are bigger than others, while whose closeness centrality is smaller than others, representing its higher control ability to other's information exchange, which is at the center of the local scope, even the whole network system.

4 Identification of the key elements of mega project system

4.1 BASIC HYPOTHESIS

(1) In-centrality and out-centrality are components of Closeness centrality, and they are just reflect relation of different direction, playing the same role. Therefore the weights of each one is assumed to be 1/2, and Closeness centrality is assigned the arithmetic average of them.

(2) Three indicators, Local centrality, Closeness centrality and Betweenness centrality reflect the key degree of nodes from different angles, and the Index value of which is one of ways to measure the key degree of nodes. For Local centrality, Closeness centrality and Betweenness centrality playing the same role essentially, the weight of each one influencing the key degree of elements are assumed 1/3. The key index of elements are assigned the arithmetic average of these three indicators.

4.2 INDEX NORMALIZATION

All kinds of indexes respectively describe and measure the elements importance from different angles, In order to eliminate the differences between the data of different dimensions, these indexes need to be normalized. Among these different attribute indexes, some indexes reflect importance of elements, and the bigger the index value, the more importance of elements, such as Local centrality and Betweenness centrality called Benefit index. Others reflect unimportance of elements, and the bigger the index value, the more unimportance of elements, such as Closeness centrality called Cost index [12]. The method of normalizing Benefit index and Cost index is different, while they are all in [0, 1], and bigger is better, thus solving

the problem of differences between the indexes, meanwhile making these different indexes having comparability.

Benefit index (Local centrality and Betweenness centrality): The formula of normalization is as follow (5) and (6):

$$C'_{AD}(i) = \frac{C_{AD}(i) - \min\{C_{AD}(i)\}}{\max\{C_{AD}(i)\} - \min\{C_{AD}(i)\}} \quad (5)$$

$$C'_{ABi} = \frac{C_{ABi} - \min\{C_{ABi}\}}{\max\{C_{ABi}\} - \min\{C_{ABi}\}} \quad (6)$$

Cost index (Closeness centrality): The formula of normalization is as follow (7):

$$C^{-1\prime}_{APi} = \frac{\max\{C^{-1}_{APi}\} - C^{-1}_{APi}}{\max\{C^{-1}_{APi}\} - \min\{C^{-1}_{APi}\}} \quad (7)$$

4.3 KEY INDEX OF ELEMENTS

The key degree of nodes are determined comprehensively by the weighted average of the index value of three indicators, Local centrality, Closeness centrality and Betweenness centrality. Key index of elements are established to reflect the key degree of elements, and the formula of Key index of elements K_i is as follow (8):

$$K_i = \frac{C'_{AD}(i) + C^{-1\prime}_{APi} + C'_{ABi}}{3} \quad (8)$$

According to the results, the value of K_i is between zero and one, and bigger the value is, more important the element will be. Obviously, it should be the focus of our management objects. Managers can select elements ranking on the front according to their preferences as key elements.

5 Case study

Chongqing Metro Line 6 project which lasts four years is 61km, it runs through five main cities, and links three core business districts. It is an important backbone line from southeast to northwest of Chongqing. The total investment is 13.4 billion, it took the lead to adopting American TBM tunnelling machine. The stakeholders mainly refer to Municipal Government, Chongqing Metro Group Corporation Limited, CIECC Engineering Construction Project Management Corporation, China State Construction Engineering Corporation, the leading group of Supervision Consortium, the leading group of Construction Union, and some other 23 ones. Whether in the circuit layout, the scale of investment, technology, or stakeholders, its complexity is unprecedented. The social network diagram of the project is shown in FIGURE 1 [13].

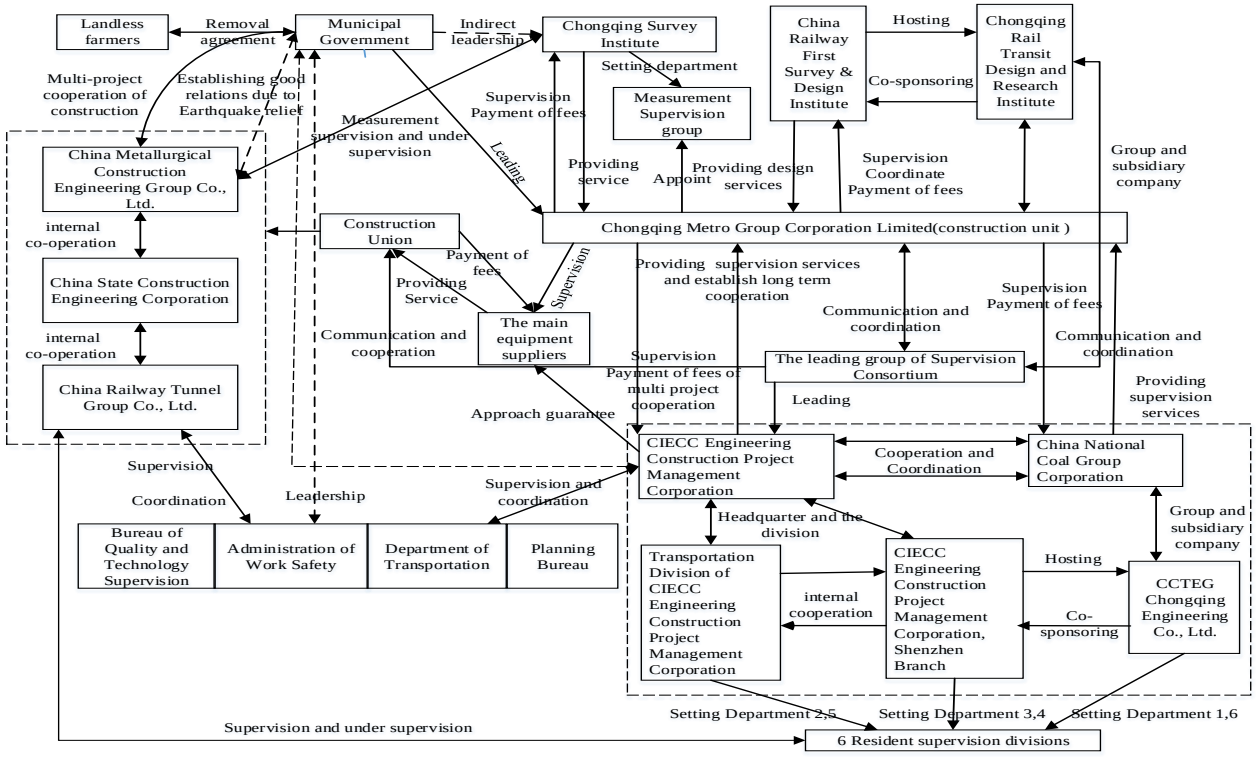

FIGURE 1 The social network diagram of Chongqing Metro Line 6 project

5.1 NETWORK ANALYSIS

The relationships between each two nodes can be classified into three types, which respectively are the relationship of Information exchange, Material exchange and energy Exchange. According to the above social network as shown in the Figure 1, an Adjacency Matrix for the 23 stakeholders is built: All nodes are distributed in rows and columns, forming a 23×23 matrix. Dominating by the nodes in rows, if the node in Row i has social relations

with the node in Column j, the value of Row i and Column j is 1, and can be accumulated if there are kinds of relationships. If a node has no relationship with another one, the value will be 0. According to formula (1), (2), (3), (4), Putting Adjacency Matrix into software UCINET, the results is shown as TABLE 1.

5.2 KEY INDEX OF ELEMENTS AND RECORDATION

According to the above formula (5), (6), (7), (8), the results of normalization and reordering are shown in TABLE 2.

According to the above results, Managers can determine the key elements of the mega project. However, different managers have different preferences, so, the final result may be different. In this case, the top six nodes are Chongqing Metro Group Corporation Limited, CIECC Engineering Construction Project Management Corporation, Municipal Government, The leading group of Construction Union, The leading group of Supervision Consortium and China State Construction Engineering Corporation, their results are higher than others significantly, so, we choose these 6 ones as the key elements.

According to final key elements, we can simplify the social network structure, the result is shown as FIGURE 2. Compared to earlier, the structure is simpler, also the relationship is clearer. These effects will become more obvious as the project become larger and larger under the limited human, material and financial resources.

We manage the system simplified easier, and it contributes to managers' macroeconomic policy-making and overall control, improves management efficiency and achieves management goals more effectively.

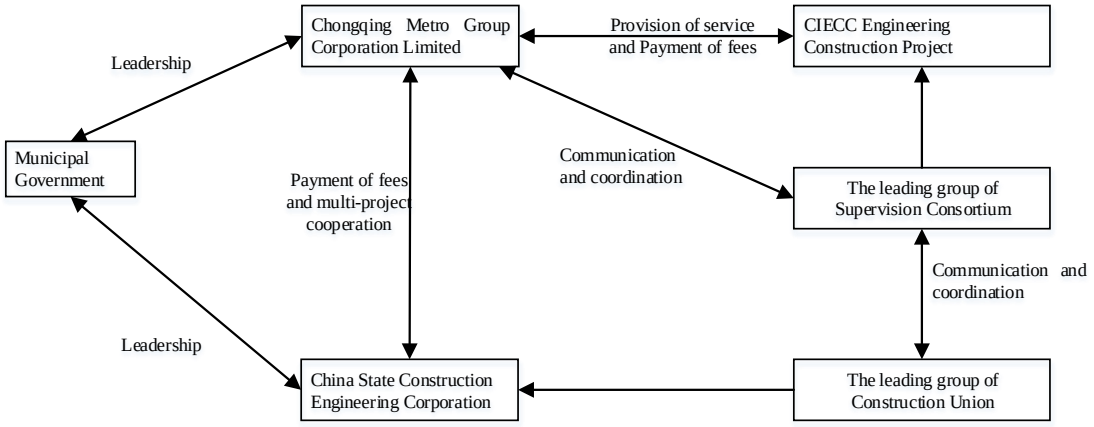

FIGURE 2 Simplified social network structure of Chongqing Metro Line 6 project

TABLE 1 Results of SNA by UCINET

	C_{AD}	C_{ABi}	C_{APi}^{-1}	
			In-Closeness	**Out-Closeness**
Municipal Government	8	118.3333	47	39
Chongqing Metro Group Corporation Limited	12	157.1615	34	32
China Railway First Survey & Design Institute	4	0.0000	47	48
Chongqing Rail Transit Design and Research Institute	4	0.0000	47	48
CIECC Engineering Construction Project Management Corporation	12	101.1712	33	42
CIECC Engineering Construction Project Management Corporation, Shenzhen Branch	5	13.4231	50	52
Transportation Division of CIECC Engineering Construction Project Management Corporation	5	20.0481	50	49
China National Coal Group Corporation	4	19.1955	40	45
CCTEG Chongqing Engineering Co., Ltd.	5	16.2789	55	48
6 Resident supervision divisions	3	1.6667	66	57
Measurement Supervision group	2	0.0000	41	41
The leading group of Supervision Consortium	7	35.7167	35	44
China State Construction Engineering Corporation	7	56.4250	38	50
China Railway Tunnel Group Co., Ltd.	5	6.8583	38	50
China Metallurgical Construction Engineering Group Co., Ltd.	5	4.7583	46	47
The leading group of Construction Union	9	56.0000	42	43
Chongqing Survey Institute	9	24.4827	41	67
The main equipment suppliers	3	6.5833	65	54
Planning Bureau	3	1.9744	65	54
Bureau of Quality and Technology Supervision	3	1.9744	65	54
Administration of Work Safety	3	1.9744	65	54
Department of Transportation	3	1.9744	67	59
Landless farmers	1	0.0000	47	39

TABLE 2 Results of normalization and reordering

	$C_{AD}(i)$	C_{ABi}	C_{APi}^{-1}	K_i	Reorder
Municipal Government	0.6364	0.7529	0.6667	0.6853	3
Chongqing Metro Group Corporation Limited	1.0000	1.0000	1.0000	1.0000	1
China Railway First Survey & Design Institute	0.2727	0.0000	0.5167	0.2631	15
Chongqing Rail Transit Design and Research Institute	0.2727	0.0000	0.5167	0.2631	15
CIECC Engineering Construction Project Management Corporation	1.0000	0.6437	0.8500	0.8312	2
CIECC Engineering Construction Project Management Corporation, Shenzhen Branch	0.3636	0.0854	0.4000	0.2830	13
Transportation Division of CIECC Engineering Construction Project	0.3636	0.1276	0.4500	0.3137	11
China National Coal Group Corporation	0.2727	0.1221	0.6833	0.3594	8
CCTEG Chongqing Engineering Co., Ltd.	0.3636	0.1036	0.3833	0.2835	12
6 resident supervision divisions	0.1818	0.0106	0.0500	0.0808	22
Measurement Supervision group	0.0909	0.0000	0.7333	0.2747	14
The leading group of Supervision Consortium	0.5455	0.2273	0.7833	0.5187	5
China State Construction Engineering Corporation	0.5455	0.3590	0.6333	0.5126	6
China Railway Tunnel Group Co., Ltd.	0.3636	0.0436	0.6333	0.3469	9
China Metallurgical Construction Engineering Group Co., Ltd.	0.3636	0.0303	0.5500	0.3146	10
The leading group of Construction Union	0.7273	0.3563	0.6833	0.5890	4
Chongqing Survey Institute	0.7273	0.1558	0.3000	0.3944	7
The main equipment suppliers	0.1818	0.0419	0.1167	0.1135	18
Planning Bureau	0.1818	0.0126	0.1167	0.1037	19
Bureau of Quality and Technology Supervision	0.1818	0.0126	0.1167	0.1037	19
Administration of Work Safety	0.1818	0.0126	0.1167	0.1037	19
Department of Transportation	0.1818	0.0126	0.0000	0.0648	23
Landless farmers	0.0000	0.0000	0.6667	0.2222	17

6 Conclusions

The complexity of mega project management needs managers to find the key elements to grasp the overall situation, the social nature of mega project also provides possibility of the SNA method application. It helps managers to clarify the comprehensive relationship among stakeholders, identify key elements effectively, and simplify social network structure, so as to increase efficiency of management, and achieve the management objective in better way. However, the final key elements selected may be different due to diverse preferences of multiple managers, mentioning how should we select the final key element in accordance with various preferences, it is further study.

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