A Case Study on Micro Social Network Structure of Building Industrialization: Based on Structural Hole Theory

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ABSTRACT

The industrial chain of building industrialization (BI) has been forming in China during the latest three decades development, which gradually presents a trend of networking. However, the enterprises' implementations of building industrialization are far from satisfactory. Both practitioners and managers hold the same confusions: Who is controlling effective information resources by occupying critical path in BI network? Who decides the flow direction of materials resources in the network? To solve these doubts, this paper makes an analysis of building industrialization micro social network based on the structural hole theory. A typical industrialized construction project in Shenzhen (China) was selected for the empirical study. Firstly, a questionnaire survey is conducted to collect authentic data and Ucinet is used to delve structural holes by four indicators named effective size, efficiency, constraint and hierarchy. Secondly, the roles and function of stakeholders would be re-explained by the theory of brokerage roles. The outcomes of social network analysis indicate that developer is the information hinge of this BI project due to its largest value of effective size as well as lowest constraint. From the perspective of resource control, contractor and component supplier also occupy critical structural holes and play important roles in building industrialization network. But to some extent, the network of BI in China is not optimized. Thus, enterprises should try to adopt some reasonable accretive measures according to the market condition and self-position.

KEYWORDS

building industrialization; structural hole; brokerage role

1. INTRODUCTION

The Central Economic Working Conference pointed out that miniaturization, intellectualization and professionalization will be the new features of industrial organization in the trend of "new normal" economic development (Cao, 2014). Construction industry is resource-intensive, crude and labor-intensive, which is imperative to be reformed. Building industrialization(BI) is exactly an effective way to solve those problems of construction industry. Industrialization in construction is not a new phenomenon(Research, 1966), and the emerging industrialization follows an international trend. It is further recognized as a key vehicle for driving the improvement of productivity and efficiency within construction industries, accompanying with transporting work from construction site to factory (Gibb, 1999). In the past twenty years, the evolution of industrial organization has experienced profound changes, while the increasing investment of capital and knowledge made its organization structure appears networked and vertical integrated trend. However, the development of BI market lags far behind this rapid growth networked trend. BI has not yet to be extensively used in mainland China compared with developed countries(Goodier & Gibb, 2005). Nowadays, industrialized techniques are applied in only a few enterprises in China, like Vanke and Broad Group. The fundamental reason of this phenomenon is that enterprises haven't recognized the detailed characters of BI network structure, they are not clear about precise self-position and hardly to seize the opportunity for development. There are many factors hinder the generalization of BI, for example, lack of confidence and global understanding are considered as critical reasons (Mao, Shen, Pan, & Ye, 2013; Ou, 2006). Thus, it would be the top priority to plan and build Chinese BI network reasonably, which could help industrialized participants find respective structure positions accurately and help managers optimize the allocation of resources and dispatch management to promote the update and transition of construction industry.

The development of social network analysis(SNA) is the outcome of structure and systematization in contemporary science. Pryke and Pearson (2006) tried to apply SNA to the project management of construction industry alliance. In addition, the classical theory of SNA, namely, structural hole, was widely used in many subjects to analyze structures of different networks, such as human intelligence network, innovative network, social capital network and virtual learning network, etc(Hu, 2005; W. Jiang, 2008; liang, Ge, & Chen, 2010; Sheng & Fan, 2009; Xie & Feng, 2010). However, there is still a gap of whole network analysis of BI project from the perspective of SNA.

Based on the previous research, this article uses a case study combined with structural hole theory and brokerage theory to analyze the characters of BI microstructure:

(1) Four indexes, namely, effective size, efficiency, constraint and hierarchy, will be used to quantify structural holes;

(2) The roles and function of stakeholders will be re-explained by assorting thought of the theory of brokerage;

(3) General analysis of the network structure of BI project.

Building industrialization, a new mode of construction, has general characters of traditional industrial organization, as well as the unique structure due to its special manufacturing technique and process. Therefore, conducting a research and discussion of BI

project's microstructure and having a clear grasp of stakeholders' structural position and developing potential is quite necessary. Theoretically, it would promote the marketization of BI and could effectively guide enterprises' implementation of BI project management.

2. METHODS

SNA is used to describe and measure the relationships among different subjects or those tangible/intangible relationships, like information and resource(Burt, Minor, & Alba, 1983). The key point of SNA is to form a network structure to represent all various and complicated relationships, then illustrate the significance of individual action and social structure. Nowadays, SNA is widely applied in the area of sociology, medicine, pedagogy even construction industry(Chinowsky, Diekmann, & Galotti, 2008), while limited research use it to analyze whole network of industrialization projects. In this study, the major tool of SNA is Ucinet, which has the function of measuring index and visualizing social network's structure(Liu, 2012).

2.1 DESCRIPTION

Hill City Project is, located in Shenzhen (China), sponsored by Vanke, which can be considered as a typical BI project in Shenzhen. Industrialized technologies adopted in this project are: precast concrete, aluminum shuttering, climbing scaffold, light-weight partition board and light-gage steel joist. Prefabricated rate of it is approximately 20% (according to the volume calculation of building).

Field data are collected in three steps: Firstly, the list of related participants is preliminarily identified based on the literature review; Secondly, items in the preliminary list will be refined and revised, then contact information of representative of each participant will be obtained by the interview of 8 developer engineers of this project; Finally, data of interactive evaluation will be collected from other participants by questionnaire survey. From November 28, 2014 to December 20, 2014, the research team has made an onsite questionnaire survey towards targets who are representative of participants. The response rate of it is 92%. Participants contact each other by three kinds of medium: information, capital and material. For each medium, the strength of connection can be measured by two-value(1-contact; 0-un-contact). The evaluation between participants is two-way and asymmetrical evaluation.

2.2 STRUCTURAL HOLES MEASUREMENT

The concept of structural hole theory is fairly important in economic sociology and organizational sociology. Structural hole, a kind of non-redundancy relationship, which represents weak links among each groups in social network. The individuals or organizations who occupy the structural holes could obtain more resources and own greater competitive advantages.

In general, there are two types of calculation indexes of structural holes: structure holes index proposed by Burt(Burt, 2009), and the betweenness of centrality index. The former is discussed in this study, including four indicators: effective size, efficiency, constraint and hierarchy.

Through interview and questionnaire survey, 31 participants are identified in this project. preliminarily data were processed to 1-mode matrix after bidirectional asymmetrical evaluation,

as showed in Fig 1.

	P	D	L	E	F	Q	F	S	D	A	D	L	S	W	C	C	D	H	L	B	L	C	E	C	D	L	S	I	H	R	P
Planning Department	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Development and Reform Commission	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land and Resource Administration Bureau	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental Protection Agency	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0
Fire Department	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
QC Department	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
Financial Institution	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Scientific Institution	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Developer	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1
Architecture Designer	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	0	1	0	1	1
Decoration Designer	0	0	0	1	1	1	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	1	1
Landscape Design	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	1
Steel Supplier	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0
Wood Supplier	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0
Cement Supplier	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0
Concrete Supplier	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0	1	1	0	0	0
Decorative Materials Supplier	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1	1	1
Heat Insulating Material Supplier	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	0	1	1
Landscape Product Supplier	0	0	0	1	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1
Building Subassembly Supplier	0	0	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	0	0	1	0	0	1	0	0	1	1	0	0	1
Logistics Company	0	0	0	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	1	0	1	0	1	0	1	1	1	1	1	0	0	1
Construction Machinery Supplier	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	1	1	0	0	0
Electromechanical Equipment Suppliers	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	0	0	0
Contractor	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	1	1	1	1	0	0	0
Decoration Contractor	0	0	0	1	1	1	1	0	1	1	1	1	0	0	1	0	1	1	0	0	1	1	0	1	0	1	1	1	0	1	0	0
Landscape Contractor	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	1	1	0	1	1	0	1	1	0	0	0
Supervisor	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Insurance Company	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0
Housing Sales Agent	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Resident	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1
Property Management Company	0	0	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	0	1	0

Fig. 1 The 1-mode binary matrix

Then structure hole indexes are measured following the routine "Network - Ego networks - Structural Holes" in Ucinet6.0.

Structural Hole Measures

	EffSize	Efficie	Constra	Hierarc	Indirec
Planning Department	1.000	0.250	0.350	0.051	0.159
Development and Reform Commission	1.000	0.250	0.350	0.051	0.159
Land and Resource Administration Bureau	1.000	0.500	0.549	0.000	0.048
Environmental Protection Agency	9.433	0.555	0.150	0.026	0.564
Fire Department	3.806	0.346	0.198	0.050	0.426
QC Department	8.500	0.500	0.163	0.078	0.570
Financial Institution	9.333	0.549	0.154	0.079	0.521
Scientific Institution	6.179	0.562	0.176	0.071	0.335
Developer	17.781	0.635	0.138	0.069	0.853
Architecture Designer	11.230	0.591	0.157	0.077	0.632
Decoration Designer	6.630	0.442	0.180	0.042	0.592
Landscape Design	9.129	0.537	0.173	0.068	0.637
Steel Supplier	3.800	0.422	0.201	0.045	0.308
Wood Supplier	3.800	0.422	0.201	0.045	0.308
Cement Supplier	4.132	0.344	0.201	0.033	0.519
Concrete Supplier	3.853	0.385	0.207	0.039	0.403
Decorative Materials Supplier	5.529	0.503	0.181	0.053	0.365
Heat Insulating Material Supplier	5.853	0.488	0.172	0.059	0.380
Landscape Product Supplier	6.469	0.539	0.171	0.058	0.382
Building Subassembly Supplier	10.433	0.549	0.166	0.072	0.675
Logistics Company	12.424	0.565	0.161	0.057	0.795
Construction Machinery Supplier	4.912	0.447	0.204	0.056	0.444
Electromechanical Equipment Suppliers	3.682	0.460	0.240	0.085	0.323
Contractor	12.600	0.548	0.154	0.035	0.825
Decoration Contractor	9.722	0.512	0.156	0.021	0.692
Landscape?Contractor	7.726	0.454	0.165	0.024	0.643
Supervisor	14.038	0.610	0.142	0.058	0.718
Insurance Company	11.061	0.651	0.142	0.045	0.505
Housing Sales Agent	3.000	0.429	0.245	0.009	0.304
Resident	2.833	0.405	0.266	0.031	0.342
Property Management Company	7.571	0.541	0.177	0.063	0.507

Fig. 2 The result of structural holes indexes

As showed in Fig. 2, developer has the maximum effective size, which indicates that developer is in the core position of the whole network, and has the lowest restriction. Insurance company has the highest efficiency followed by developer. In addition, efficiencies of architectural designer, contractor, building subassembly supplier and logistic company are also stand at relatively high level. These members have larger impacts than other stakeholders in this network. Furthermore, developer has minimum constraint, and values of architecture designer, contractor, building subassembly supplier and logistic company are relatively small as well. It is indicated that these members occupy most structural holes to become the potential opinion leaders in this network. On the contrary, land and resource administration bureau has

the maximum constraint, meaning that land and resource administration bureau is in the edge position. Electromechanical equipment supplier has the maximum hierarchy followed by financial institution and QC department. And these subjects with high hierarchy are in the edge zone. Since most participants in this project have insurance business with insurance company, it has the maximum efficiency although it is a participant from other industry.

Above all, developer is in the core position in the whole network of building industrialization. It has the highest degree of freedom and influences the flow direction of information and resources. With large effective size and low constraint, contractor, architecture designer and building subassembly supplier have low redundancy when they connect with other participants.

2.3 BROKER

Broker was defined as the actor who obtains information and resources from one actor and deliver those to another(Burt, 2009; Gould & Fernandez, 1989). Gould and Fernandez (1989) held the view that broker can be divided into five types according to the social role it plays: Coordinator, Consultant, Gatekeeper, Representative and Liaison. Classification of aforementioned five brokers depend on which block are actors belong to. In this study, Block Models would be adopted to divide blocks.

(1) Block Model analysis

Block model is a research method of network location model that can be used to make descriptive algebra analysis of social roles. It rearranges the nodes in the raw matrix by cluster analysis, and then, we can get an equivalent matrix structurally(Liu, 2009). Participants in the BI project are divided into eight groups according to convergent correlation, as shown in Fig. 3:

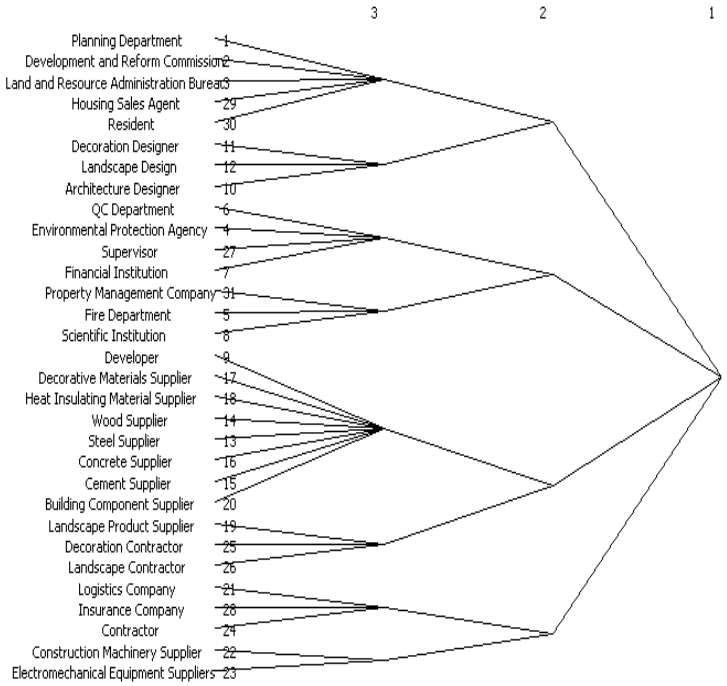

Fig. 3 Tree-diagram of subgroup distribution of participants in BI project

Block model analysis results reveals that the density of the whole network of BI project is 0.3796. Numbers bigger than 0.3796 are replaced by 1 in density matrix of subgroup, otherwise, they changed to be 0. And then an image matrix of relevant participants' network was obtained.

(2) Brokerage roles analysis

Brokerage roles analysis of participants in BI project can be conducted by importing the image matrix into Ucinet according to the subgroup distribution, and its first line data named "ROW1" is partition vector.

Number of classes: 8

Un-normalized Brokerage Scores

		1 Coordinat	2 Gatekeepe	3 Represent	4 Consultan	5 Liaison	6 Total
1	Planning Department	0	0	0	0	0	0
2	Development and Reform Commission	0	0	0	0	0	0
3	Land and Resource Administration Bureau	0	0	0	0	0	0
29	Housing Sales Agent	0	3	3	0	8	14
30	Resident	0	2	2	1	5	10
11	Decoration Designer	0	2	2	13	47	64
12	Landscape Design	0	4	4	21	85	114
10	Architecture Designer	0	8	10	27	136	181
6	QC Department	0	0	0	1	39	40
4	Environmental Protection Agency	0	0	0	38	78	116
27	Supervisor	1	4	12	39	152	208
7	Financial Institution	0	0	0	7	41	48
31	Property Management Company	0	0	0	3	48	51
5	Fire Department	0	0	0	0	16	16
8	Scientific Institution	0	0	0	1	20	21
9	Developer	1	95	10	33	195	334
17	Decorative Materials Supplier	0	0	0	5	24	29
18	Heat Insulating Material Supplier	0	0	1	4	17	22
14	Wood Supplier	0	0	0	5	9	14
13	Steel Supplier	0	0	0	5	9	14
16	Concrete Supplier	0	0	0	5	9	14
15	Cement Supplier	0	2	4	5	9	20
20	Building Component Supplier	18	18	16	5	33	90
19	Landscape Product Supplier	0	0	2	2	21	25
25	Decoration Contractor	0	4	4	20	119	147
26	Landscape Contractor	2	10	6	12	62	92
21	Logistics Company	0	1	7	32	79	119
28	Insurance Company	1	3	9	39	107	159
24	Contractor	0	7	13	39	153	212
22	Construction Machinery Supplier	0	3	4	2	11	20
23	Electromechanical Equipment Suppliers	0	0	1	1	4	6

Fig. 4 Brokerage roles index of participants in BI project

The results of brokerage roles analysis in Fig. 4 clearly show that building subassembly supplier plays the role of coordinator frequently. So it plays an important role in the subgroup and has advantages of information-obtaining, especially among material suppliers. From the results of numerical analysis, it is obvious that developer plays an important role as the gatekeeper while it imposes direct effect on communication by making a choice or controlling external information. As a representative, building subassembly supplier controls the threshold of external coordination, since it determines each material supplier in the subgroup such as steel supplier, wood supplier, cement supplier, concrete supplier, etc. Besides, supervisor and insurance company act as consultant in the network. They both have little effect on communicating in their own subgroups but play main role among subgroups. As a liaison, developer possesses the ability to manipulate the circulation of information. Hill City is a turnkey project, so contractor has contractual relationships with most onsite stakeholders, and plays a critical role amongst them(Li, 2014). That's the reason why calculation result reveals that contractor also act as a liaison only behind developer.

3. DISCUSSION

Combining the results of structural hole and brokerage role, it is noted that there are some innate rules of this BI project's network structure:

(1) From the perspective of information communication, there's no doubt that developer is the information hinge of BI project owing to its maximum effective size as well as lowest constraint. Nevertheless, developer doesn't have the highest efficiency, which shows that there are some redundant links exist between developers and other subjects. The roles of Liaison and Gatekeeper determine that developer is like the information window of subgroup, so it has the responsibility for external communication and coordination. Besides, it is also the Coordinator of the internal information flow. Governmental departments and financing institution are located at relative edge position in this network.

(2) From the perspective of resource control, although the developer lies in the center of this project, the characters of this turnkey project determined that the contractor and component supplier decides the source and whereabouts of materials to a large extent. Considering the social circumstance, architectural designer is actually the mainly occupant of structural holes, while it decided the usage of relevant resource from source. In addition, the control action of indirect controller (logistics company) cannot be ignored in BI project.

4. CONCLUSION

With the increasingly serious environment issues, industrialization has become an inevitable trend of Chinese construction industry, and it is particularly important to organize the implementation of BI project efficiently. This article analyzes structural hole and brokerage roles based on SNA, which reflectes some laws and issues of BI implementation in China from the microstructure level. It is Ucinet that calculated the structural hole indexes to quantize the restricted degree of each stakeholder during the information exchange in this network and the impact one exerts on others(X. Jiang, 2012). Finally, by the attributive classification of brokerage roles, authoritative subjects and isolates were identified.

In a sense, this study would help subsequent researchers to find out bottleneck of information-sharing in BI network, then some improvement measures would be adopted to enhance the efficiency of BI projects' implementation. The revelations we could get from this study is that the organization of BI in China is still in the transition peroid from conventional mode to industrialized mode, and there is still not the best match of roles and foundation in the inner of network organization. The aim of BI project management is forming a structurally stable community with rich structure holes. To achieve this, all stakeholders from different social groups should play the roles of their own. This study was conducted based on the case study, but BI projects in different countries and under different social background may have different characteristics.

REFERENCE

Burt, R. S. (2009). *Structural holes: The social structure of competition*: Harvard university press.

Burt, R. S., Minor, M. J., & Alba, R. D. (1983). *Applied network analysis: A methodological introduction*: Sage Publications Beverly Hills, CA.

Cao, Z. (2014). The new normal, new luminescent spot and new direction-Interpretation of 2014 Central Economic Working Conference *Policy Research & Exploration*(12), 4-9.

Chinowsky, P., Diekmann, J., & Galotti, V. (2008). Social network model of construction. *Journal of Construction Engineering and Management*, *134*(10), 804-812.

Gibb, A. G. (1999). *Off-site fabrication: prefabrication, pre-assembly and modularisation*: John Wiley & Sons.

Goodier, C. I., & Gibb, A. G. (2005). Barriers and opportunities for offsite in the UK.

Gould, R. V., & Fernandez, R. M. (1989). Structures of mediation: A formal approach to brokerage in transaction networks. *Sociological methodology*, 89-126.

Hu, R. (2005). *A study on the Struetural Holes Theory —Based Egocentric Human Intelligence Network Analysis System (In Chinese)*. Southwestern Normal University. Available from Cnki

Jiang, W. (2008). Influence mechanism of entrepreneurial social capital- from the perspective of Structural Hole Theory (In Chinese). *Journal of Nanjing Agricultural University(Social Sciences Edition)*(02), 21-28.

Jiang, X. (2012). ResearchonTacitKnowledge Sharing inOrganizationalSocialNetworksfrom the Perspective ofStructuralHoles (In Chinese). *Information and Documentation Services*(01), 32-36.

Li, Y. (2014). *Study on communication behavior of virtual learning community based on social network analysis (In Chinese)*

Qufu Normal University. Available from Cnki

liang, D., Ge, Y., & Chen, Y. (2010). Prospect for a study on the application of the structuralhole theory to social capital of TMT(In Chinese). *East China Economic Management*(04), 97-99.

Liu, J. (2009). *Handouts of whole network analysis (In Chinese)*: Gezhi press.

Mao, C., Shen, Q., Pan, W., & Ye, K. (2013). Major Barriers to Off-Site Construction: The Developers' Perspective in China. *Journal of Management in Engineering*, 130801050844006. doi: 10.1061/(asce)me.1943-5479.0000246

Ou, Y. (2006). *Study on the restricting factors of the development of housing industrialization and their countermeasures of China*. Hohai University. Available from Cnki

Pryke, S., & Pearson, S. (2006). Project governance: case studies on financial incentives. *Building Research & Information, 34*(6), 534-545.

Research, I. C. f. B. (1966). *Towards Industrialised Building: Proceedings of the Third CIB Congress, Copenhagen, 1965* (Vol. 3): Elsevier Publishing Company.

Sheng, Y., & Fan, D. (2009). Structural holes classification theory and its application in innovation network (In Chinese). *Studies in Science of Science*(09), 1407-1411.

Xie, Y., & Feng, R. (2010). Structural holes: Study on behaviors of information collection of virtual learning community (In Chinese). *Software Guide*(08), 19-21.