Journal of Theoretical and Applied Information Technology
15th December 2012. Vol.46 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SOCIAL NETWORK ANALYSIS OF RECYCLING PRODUCTION CHAIN: THE CASE OF GUIGANG EIP

[1] LING TANG, [2] Jian L, [3]XIAOFENG SUN

[1] Environmental protection research institute of light industry, Beijing, 100012, China
[2] Environmental protection research institute of light industry, Beijing, 100012, China
[3]Environmental protection research institute of light industry, Beijing, 100012, China
E-mail: [1]tangl122@163.com, [2]lijian@gmail.com [3]kalaxf@126.com

ABSTRACT

Within the rapid industrialization, the noticeable environmental problems are prominent in the world. The eco-industrial park (EIP) is a new form of industrial organization. This article used the social network analysis (Social Network Analysis, SNA) to analyze the structure of the recycling production chain in Guigang (China), proving useful in the analysis of the structural characteristics of the network and the different actors play. An index system including density of a network, clustering coefficient, average path length, centrality and core-periphery structure is established to measure the structural features. This paper concludes that, SNA provides a comprehensive approach and analytical framework to understand the structural elements of recycling production chain, and the analysis can help to clarify some light structural elements conditioning the operation of the network and a different actor to play the role..

Keywords: *Social Network Analysis; Recycling Production Chain; Eco-Industrial Park*

1. INTRODUCTION

1.1 Eco-industrial park (EIP)

The eco-industrial park (EIP) is a new industrial organization form. Some developed countries, such as Kalundborg, Denmark [1], Puerto Rico, USA [2], Netherlands [3], United Kingdom [4], Kwinana and Gladstone, Australia [5] and Guigang, China [6], started to plan the construction of ecological industrial demonstration zone in the early 1970s. How to build the recycling production chain is the core of EIPs, and it becomes the necessary way for many countries to a sustainable industry development.

But most of the contributions focus on the engineering and technical feasibility of the exchanges [7] and there is still only limited understanding of the social structure of these networks. We argue that social network analysis provides a framework for the understanding of the social aspects of EIPs, offering insights to the structure and interaction of agents within EIPs.

1.2 Social Network Analysis (SNA)

Social Network Analysis (SNA) is a structural analysis method. It involved in the data analysis, the network structure determining and the experience summarizing, whose object can be individuals, businesses, independent organizations or groups. So it is effective to analyze the organizational structure and network structure of the eco-industrial park.

Social Network Theory provides an theoretical and methodological framework for advancing the understanding of the social aspects surrounding networks and can shed some light on issues such as the role of the different members in the network, the processes of information transfer and material exchange negotiation, trust building and alliance formation. The potential to apply SNA to EIPs has been explored elsewhere [8].

Section 2 presents the data sources and methodology, and the study mainly used Pajek and UCINET to analyze the data. In section 3, we propose the Guigang EIP as the case study which including organization structure, network structure and Structure characteristics. Section 4 gives a conclusion to the whole paper, and we should pay attention to the stability of the SNA in pursuing better environmental and economic performance, as this may provide the basis for a better understanding of the adaptation capacity of the network and its ability of innovation..

2. DATA SOURCES AND METHODOLOGY

2.1 Data Sources

The main data of Guigang EIP including: A site-visit to Guigang, face-to-face interviews; the examination and analysis of secondary sources.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2.2 Methodology

We use excel to process the basic data and use Pajek and UCINET which are the common used software in Social Network to analyze the data. An index system including nodal degree, density of a network, clustering coefficient, average path length, centrality and core-periphery:

1) Density of a network

The density of a network is the proportion of possible lines that are actually present in the graph [9]. It is the ratio of the number of lines present L, to the maximum possible. The density of a network, which we denote by D, is calculated as Eq. 1:

$$D = \frac{L}{n(n-1)/2} = \frac{2L}{n(n-1)} \quad (1)$$

Table 1 Equations Of Centrality

	Degree	Betweenness	Closeness
Equations	$C_i^D = \frac{k_i}{N-1} = \frac{\sum_{j\in G} a_{ij}}{N-1}$	$C_i^B = \frac{\sum_{j<k\in G} n_{jk}(i)/n_{jk}}{(N-1)(N-2)}$	$C_i^C = (L_i)^{-1} = \frac{N-1}{\sum_{j\in G} d_{ij}}$

Table 2 The Main Structural Characteristics Of Guigang EIP

	Node	Number of ties	Density of a network	Clustering coefficient	Average path length
Guigang EIP	10	22	0.2444	0	2.133

Table 3 Centrality Measure Scores By Actors

		Degree	Betweenness	Closeness
sugar refinery		66.667	79.167	75.000
alcohol plant		22.222	9.722	50.000
cement mill		22.222	8.333	50.000
fertilizer plant		22.222	1.389	37.500
alkali recovery		22.222	2.778	40.909
paper mill		11.111	0.000	37.500
pulp plant		11.111	30.556	56.250
power station		33.333	0.000	45.000
fish farm		11.111	0.000	45.000
agricultural eco-farm		22.222	9.722	50.000
overall	Mean	24.444	14.167	48.716
	Std Dev	15.556	23.371	10.453

2) Clustering coefficient

Clustering coefficient Ci is a measure of degree to which nodes in a graph tend to cluster together. ki is the number of neighbors of a vertex, is calculated as Eq. 2. In real-world networks, this likelihood tends to be greater than the average probability of a tie randomly established between two nodes [10].

$$C_i = \frac{E_i}{k_i(k_i-1)/2} \quad 2)$$

3) Average path length

Flament [11] defines the average length of a path in a valued graph as equal to the sum of the values of the lines included in the path which is showed in Eq. 3

$$L = \frac{\sum_{i\geq j} d_{ij}}{n(n+1)/2} \quad (3)$$

4) Centrality

We used the three most commonly adopted measures of point centrality which defined by Freeman [12]: the degree centrality CD, the betweenness centrality CB, and the closeness centrality CC (Table 1).

5) Core-periphery

The notion of a core-periphery structure was formalized in social networks by Borgatti and Everett in 1999 [13], who proposed algorithms for detecting both discrete and continuous versions of core-periphery structure in weighted, undirected graphs.

3. THE CASE STUDY

3.1 Organization structure

Guigang EIP is established in 1954, it operates the largest sugar refinery in China, as well as

Journal of Theoretical and Applied Information Technology
15th December 2012. Vol.46 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

several other enterprises such as a pulp plant, a paper plant, an alcohol plant, a cement mill and a fertilizer plant. So far, two main supply chains were formed among the Guigang EIP, the alcohol chain and the paper chain [14]. These are depicted in Figure 1.

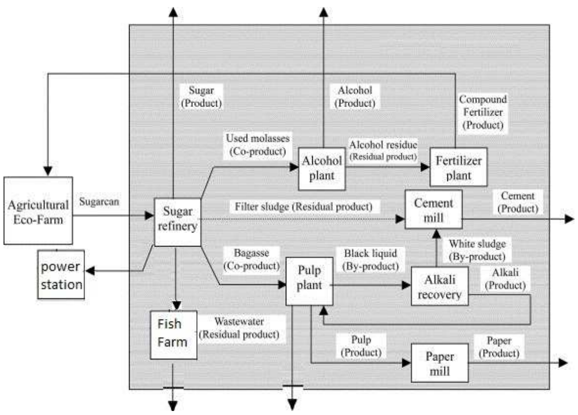


Figure1: Industrial Components Of Guigang EIP (Extended From [14])

3.2 Network structure

Figure 2 shows the Network structure of Guigang EIPP. The graph, as a representation of the structure of the network, already sheds some light upon its properties, offering some approximation to the idea of centrality and density.

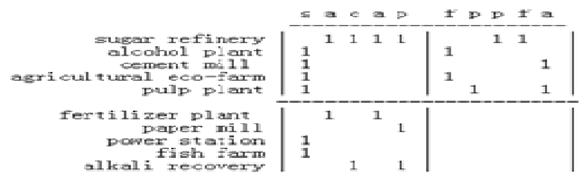
3.3 Structure characteristics

The main structural characteristics of the network have been analyzed for the whole network. General results of the analysis are summarized in Table 2.

In general terms, guigang network has 10 nodes and 22 numbers of ties. Also, and partly as a consequence of the small size of the network, it shows a rather low average path length (2.133) and high density of a network (0.2444). Clustering coefficient is 0 that means guigang network has a high degree of aggregation.

Guigang network has a higher closeness centrality (48.716), that means it have shorter distances to other nodes. While it shown a lower betweenness centrality (14.167), that means it have less pass information and connect nodes. More relevant analysis of these measures for each of the network nodes showed in Table 3, allowing a better understanding of the role played by the different actors in the network. In general, as it was expected, actors at the core of the network have higher centrality scores. The analysis of the centrality measures point to only one key player of the networks: Sugar refinery. Sugar refinery achieves the highest scores of all measures of centrality (degree centrality 66.667; betweenness centrality 79.167; closeness centrality 75.000).

The network has a clearly differentiated core and periphery (figure3). As already mentioned, guigang EIP is a small network, made up by only one core node, actors are more likely to be connected. The analysis of the core periphery structure of the network defines one core/periphery memberships: Sugar refinery.



	s	a	c	a	p	f	p	p	f	a
sugar refinery		1	1	1	1			1	1	
alcohol plant	1					1				
cement mill	1									1
agricultural eco-farm	1					1				
pulp plant	1						1			1
fertilizer plant		1		1						
paper mill					1					
power station	1									
fish farm	1									
alkali recovery			1		1					

Figure3: The Core/Periphery Matrix

4. CONCLUSIONS AND DISCUSSIONS

4.1 Conclusions

Some main conclusions of the SNA are summarized here.

As a result of the small size of the network, guigang EIP has a rather low average path length and high density of a network which indicates short paths and high density between companies. This facilitates exchanges and reduces the transactions costs associated with them.

While it has a core player of the networks which achieves the highest scores of all measures of centrality: Sugar refinery. It is important not only for the number of direct connections they hold with other members of the network, but also for their capacity to connect other nodes, and therefore, to ensure the cohesion of the network. Hence, the disconnection of this node will cause an important disturbance to the operation of the network, which could lead to defragmentation.

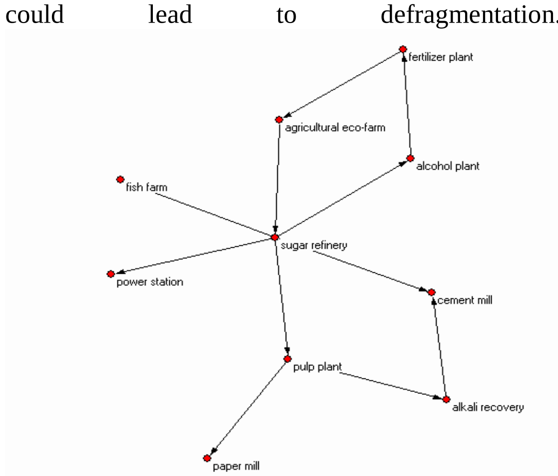


Figure2: Network Structure Of Guigang EIP

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

And the network has a clearly differentiated core and periphery. The core is dense and well-articulated, favoring the interaction between the members. This morphology favors the rapid dissemination of ideas and information over the network and therefore, offers the basis for the identification of new opportunities among member companies. The periphery, however, is not well structured. Linkages among members located at the periphery have not been found and they do not seem to play a role as local bridges, connecting the network to other networks or potential members.

4.2 Discussions

Analysis of case studies shows that the SNA provides a comprehensive approach and analytical framework, in order to understand the structural elements of Guigang EIP. The impact of of Guigang network and network morphology, reached the understanding of the organizational model of the expected results of assessment, which is critical. In addition, the analysis can help to clarify some light structural elements conditioning the operation of the network and a different actor to play the role. These elements are extremely important areas, still lack the required framework, in order to take the direction of policy actions.

From a complex systems perspective , sustainability in SNA encompass the retention of creative and adaptive capacities which allows subsystems to innovate, grow, and interact in ways that enhance overall system health and function. Thus, we should pay attention to the stability of the SNA in pursuing better environmental and economic performance. And the future research is the investigation of the connection between knowledge matrix and the material networks, as this may provide the basis for a better understanding of the adaptation capacity of the network and its ability of innovation.

REFRENCES:

[1] N. B. Jacobsen, "Industrial symbiosis in Kalundborg, Denmark – a quantitative assessment of economic and environmental aspects", *Journal of Industrial Ecology*, Vol.10, No. 1–2, 2006, pp. 239–255.

[2] M. Chertow, D. Lombardi, "Quantifying economic and environmental benefits of co-located firms", *Environmental Science Technology*. Vol.39, No.17, 2005, pp. 6535–6541.

[3] L. Baas, F. Boons, "The introduction and dissemination of the industrial symbiosis projects in the Rotterdam harbor and industry complex", *International Journal of Environmental Technology Management*, Vol. 7, No.5–6, 2007, pp. 551–577.

[4] M. Mirata, "Experiences from early stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges", *Journal of Cleaner Production*, Vol.12 No.8–10, 2004, pp. 967–983.

[5] D. V. Beers, G. Corder, A. Bossilkov, R. van Berkel, "Industrial symbiosis in the Australian minerals industry: the cases of Kwinana and Gladstone", *Journal of Industrial Ecology*, Vol. 11, No.1, 2007, pp. 55–72.

[6] Q. Zhu, E. Lowe, Y. Wei, D. Barnes, "Industrial symbiosis in China: a case study of the Guitang group", *Journal of Industrial Ecology.*, Vol. 11, No.1, 2007, pp. 31–42.

[7] M. Chertow, R. T. Lombardi, "Quantifying Economic and Environmental Benefits of Co-located Firms", *Environmental Science & Technology*, Vol. 39, No. 17, 2005, pp. 6535-6541.

[8] T. Domenech, M. Davies, "The social aspects of industrial symbiosis: The application of social network analysis to industrial symbiosis networks", *Progress in Industrial Ecology, an International Journal*, Vol. 6, No.1, 2009, 68-99.

[9] J. Scott, Social network analysis: A handbook, London: Sage Publications. 2000.

[10] PP. W. Holland, S. Leinhardt, "Transitivity in structural models of small groups", *Comparative Group Studies.* Vol. 2, 1971, pp. 107-124.

[11] C. Flament, Applications of Graph Theory to Group Structure. Englewood Cliffs, NJ: Prentice-Hall 1963.

[12] C. Freeman, Centrality in social networks: I. Conceptual clarification. *Social Networks*, 1979, pp. 215-239.

[13] S. P Borgatti, M. G. Everett, Social Networks 21, 1999, pp.375–395.

[14] Q Zhu, P. C. Raymond, "Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group", *Journal of Cleaner Production*, Vol. 12, 2004, pp. 1025–1035.