Measuring the entire degree centrality in Yokokai

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Abstract

Centrality is one of the most important indexes in network calculation. Based on the definition, more than 400 different centrality such as degree, betweenness have been developed. All centrality indexes are calculated using the number of connection line, and its position in a given network. In automotive industry, keiretsu is considered as one of typical networks. It is crucial to measure the centrality of transaction network in the keiretsu. It is widely well-known that different parts play different roles in assembly line. Thus, the importance of each connect line in a transaction network should be measured based upon the importance of the parts. A new parts-importance weighted centrality model is proposed in this paper.

Keywords: Keiretsu loosening, Degree centrality, Entire degree centrality, Diameter, Production cost rate.

1. Introduction

It is widely well known that keiretsu is considered as one of the successful factors in automotive industry. After bubble economy collapsed in the beginning of 90s, Toyota and Mazda continue to maintain its keiretsu network with their parts suppliers while most of the keiretsu in car makers such as Nissan and Honda have been dismantled. In a given network, all companies develop their business activities as part of corporate strategy. Thus, to calculate their position in a given network, and evaluate the structure of a whole network is becoming crucial issue for discovering rational interfirm relationship and forming effective business strategy. Based on technical connections and development of car assembly system, a new method to calculate the centrality, one of the indexes of network structure, called parts-importance weighted centrality model is proposed in this paper.

This paper is structured as follows: In Section 2, a plethora of typical literature of network research are reviewed. Section 3 introduced models and measurement including network diameter, degree centrality, entire centrality of degree, and a new method called parts-importance weighted centrality model. Section 4 show the results and discussed the managerial implication. The conclusions including limitations and future directions of this research are proffered in Section 5.

2. Background

Network analysis is a research method that expresses various objects as a network consisting of points and lines and explores their structural features. Network analysis has been used in the humanities and social sciences such as sociology, anthropology, and psychology that deal with human relationships and relationships between groups, as well as mathematics called graph theory and engineering fields such as information science and operations research [1]. There are social networks that calculate the centrality of the network to identify influential people, and interfirm networks that classify industries from business-to-business transaction data. Based on the definition, more than 400 different centrality such as degree, betweenness have been developed. All centrality indexes are calculated using the number of connection line, and its position in a given network.

Basically, most of the parts for assembly line is purchased from its part suppliers in Keiretsu while other parts are traded from market. The former is called keiretsu trading, and the latter is called market trading. A phenomenon called "the keiretsu loosening" had occurred when the percentage of market trading increased [2]. A great change happened due to technical connections, and the ties between parts suppliers and car maker [3].

It is crucial to measure the centrality of transaction network in the keiretsu. It is widely well-known that different parts play different roles in assembly line. Thus, the importance of each connect line in a transaction network should be measured based upon the importance of the parts. In this study, the centrality of Mazda's transaction relationships is calculated and evaluated based on graph theory. Furthermore, an original evaluation model has been developed using parts-importance weights and the effectiveness of the model is examined.

3. Models and Measurement

3.1. *Network Diameter*

The maximum distance from one vertex to another is called eccentricity. The maximum number of eccentricities of the vertices included in the graph is called the diameter of the network [4].

3.2. Degree Centrality

The value of degree centrality is high if the number of edges connected to other nodes is more. It means that the degree centrality of each node is highly valued for more relationships in a network. The degree centrality of each node is formulated by Nieminen's as below [5].

$$C_D(p_k) = \sum_{i=1}^{n} a(p_i - p_k). (1)$$

where

$a(p_i, p_k)$ = w if and only if p_i and p_k are connected by a line with weight w

= 0 otherwise;

$C_D(p_k)$ ……the degree centrality of the vertex p_k;

Table 1. Parts Classification and Weights.

Parts Classification	Edge Weight	Example
Engine (block parts, valve system, fuel system)	10	Engine block and crankshaft, etc.
Engine auxiliary equipment (intake, exhaust, lubrication, cooling)	9	Oil pump, etc.
Engine electrical components	8	Alternator, and spark plug, etc.
Powertrain related parts	7	Torque converter, and transmission parts
Brake related parts	6	Brake system
Suspension and steering related parts	5	Power steering system
Body exterior	4	Wipers, bumpers, and door mirrors
Electrical parts (including air conditioner)	3	Airbags, door locks, relays, and sensors
Interior parts	2	Upholstery, dash insulator, and handle
others	1	Oil seals, air pipes

n ……the number of vertices included in a network.

3.3. Entire Centrality of Degree

Entire centrality refers to the centrality index of the entire network and was proposed by Freeman [6].

The entire centrality of degree is a centrality index for calculating the degree centrality of the whole network based on the degree centrality of each node in the network obtained by equation (2). The entire centrality of degree is formulated as follows [6].

$$C_D = \frac{\sum_{i=1}^{n}[C_D(p^*) - C_D(p_i)]}{n^2 - 3n + 2}. \quad (2)$$

In equation (2), $C_D(p_i)$ indicates the degree centrality of each node existing in the network, and $C_D(p^*)$ indicates that the degree centrality of each node in the network is the maximum. In addition, n is the number of nodes.

3.4. Parts-importance weighted centrality model

In consideration of importance of parts based technological view, the evaluation standard of parts is designed, and ten categories of parts with different importance are divided based on interview results of experts, and a plethora of literature [7-12]. Parts classification and their weight are shown as in Table1.

Engine parts are of the utmost importance because they are the power source for automobiles, also known as the "heart of automobiles." The powertrain-related parts are less important parts compared with that of the engine parts because they transmit the driving force of the engine to the tires and determine the specification of the vehicles. Moreover, the car cannot turn or stop without these parts such as suspension, and brakes. Thus, these parts were evaluated and determined based on their technical importance. Furthermore, the engine body requires technology for casting and cutting, but the electrical components are the control devices for the fuel supply system, the ignition system for gasoline engines, and wiring technology such as wiring and circuits. The quality of the technical capabilities required is different. In addition, when the engine is considered as an internal combustion engine, it assists in the production of energy-producing parts such as the engine that produces power, the oil pump for supplying lubricating oil, and the water pump that cools the engine. Therefore, the engine-related parts are divided into three stages including engine body, engine accessories, and engine electrical components. Finally, based on technical importance, the weight of 10 different categories is proposed in this paper.

4. Analysis and Discussion

4.1. Entire degree centrality and network diameter

Using the free open-source software "Gephi", the visualization of the diameter, and the degree centrality of each node in Yokokai is illustrated as Figure1.

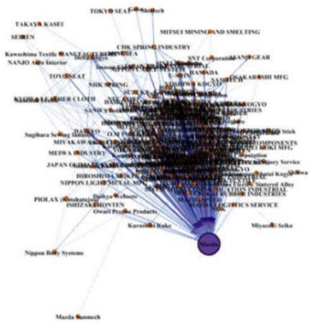

Figure 1. Entire degree centrality and network diameter.

Using an algorithm called ForceAtras2 in "Gephi", the network is visualized by reflecting the height of degree centrality and the weight of edge. In Figure 1, the higher the degree centrality value of each node, the darker the blue color, and the larger the size of the node circle is displayed. Even in the color of the line connecting each node, the heavier the weight of the edge, the darker the blue holds.

Figure 1 shows that the parts supply network of Mazda's cooperative organization "Yokokai" was affected by the loosening of the Keiretsu, the scale of the network expanded, and the overall degree centrality decreased holds. Thus, loosening of Keiretsu has led to the multi-centralization of technology networks, and the influence of the technology sharing among companies and the modularization of parts can be considered.

4.2. Mazda and entire degree centrality

To observe how the multi-centralization of the network due to the decrease in overall degree centrality affected Mazda, we compared Mazda's sales performance with overall degree centrality.

Since the affiliated transactions are premised on long-term transactions between car makers and parts suppliers, the parts suppliers were not exposed to competition. However, it is speculated that market principles have been introduced into the trading of parts and price competition among parts suppliers has started with Keiretsu loosening, which may have strong impacts on Mazda's cost reduction. Based on the speculation, we compared the changes in the overall degree centrality and Mazda's cost rate. The result is shown in Fig. 2.

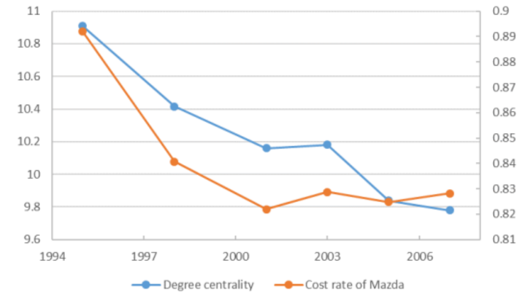

Figure 2. Time series changes in Mazda Group's entire centrality and Mazda's cost rate.

From Figure 2, it can be seen that Mazda's stand-alone cost ratio has declined as the overall degree centrality declines over the years. It was derived that the size of the parts supply network became wider and more centralized as the loosening of the affiliates progressed, thus the market trading of parts increased, the size of Yokokai expanded holds. This hypothesis is considered as the cause that make Mazda's cost rate down.

5. Conclusion

In this paper, a new parts-importance weighted centrality model is proposed. Using this model, the relations among scale of market trading, diameter of the network Yokokai, and the production cost of the core firm in Yokokai has been examined. Obviously, not only Mazda group, but also Toyota and other cars makers should be tested using this new model. In addition, only 6 fiscal years' data drawn from Yokokai is not enough. Much more data set should be gathered for our conclusion.

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