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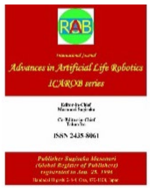

Research Article

# Measuring the Entire Degree Centrality in Mazda's Yokokai Keiretsu: A Parts-Importance Weighted Model

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ABSTRACT

As a most important index in calculating network interrelationships, there are many definitions and more than 400 different centrality dimensions, such as degree, and betweenness, among many others, have been developed. All centrality indexes are calculated using the number of connection lines, and its position in a given network. In the automotive industry, interrelationships among partner firms are tied within a typical systemic network known as keiretsu. As it is widely known that different partners play different roles in assembly line, it is crucial to measure the centrality of transaction network in the keiretsu.. Thus, the relative importance of each partner in a connection line in a transaction network should be measured based upon the pivotal nature of each part, which has never been proposed. This paper contributes and advances our knowledge to the literature by proposing a new parts-importance weighted centrality model.



## 1. Introduction

It is widely acknowledged that the success the automotive industry in Japan enjoys is structured with member-partners belonging tie a network known as keiretsu. After bubble economy collapsed in the beginning of the 1990s, Toyota and Mazda continued to maintain its keiretsu network with their parts suppliers, although the keiretsu of Nissan and Honda have been dismantled. The corporate strategy of in any given network, all companies engage in transactions where business activities are reciprocal. Thus, to identify the *de facto* leader, or principal influencing member in a given network it is necessary to calculate its position. Thus, to evaluate the structure of a whole network is a crucial issue for discovering rational interfirm relationship and forming effective business strategy. Based on technical connections and development of any automotive assembly system, a novel 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, the relevant literature on networks is reviewed. Section 3 introduces the models and measurement including network diameter, degree centrality, entire centrality of degree, and the new method referred to as the parts-importance weighted centrality model. Section 4 describes the findings and discusses the managerial implications. The conclusions including limitations and future directions of this research are proffered in Section 5

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## 2. Background

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]. In essence, network analysis is a research method that expresses the interrelations among various members within a network consisting of points and lines and explores their structural features. For instance, within social networks, it is possible to calculate the centrality of the network by identifying influential individuals. In a similar vein, it is possible to do the same within interfirm networks within industries using business-to-business transaction data. Based on the definition, more than 400 different centrality such as degree, and betweenness, among many others, have been developed. In sum, 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 parts suppliers in Keiretsu while other parts are procured from the open market using arms-length transactional—instead of relational—approaches. In other words, the former refers to keiretsu trading, and the latter is known as market trading. A phenomenon called "the keiretsu loosening" has occurred where the percentage of market trading increased [2]. This dynamic change occured due to the loosening of technical connections and ties among parts suppliers and automotive manufacturers [3].

Because different components command different importance levels in an assembly line, it is crucial to measure the centrality of transaction network in the keiretsu. Thus, the importance of each connected line in a transaction network should be measured based upon the importance of the parts. Hence, 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 in this research endeavor.

## 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. That means the degree centrality of each node is highly valued for more interrelationships between members in a network. The degree centrality of each node is formulated by Nieminen's formula as denoted below [5].

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

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 $p_k$;

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].

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

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* refers to 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 an extensive review of the literature [7], [8],

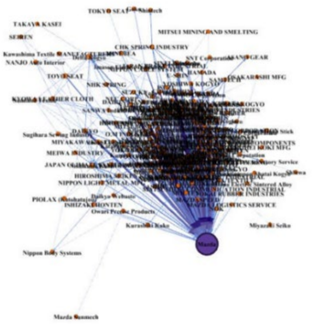

Figure 1. Entire degree centrality and network diameter.

[9], [10], [11]. Parts classification and their relative weights are shown as in Table1.

Engine parts—widely referred to the "heart of automobiles" are of the utmost importance because they are the power source for automobiles. Comparatively, powertrain-related parts are given less importance to the engine parts because they transmit the driving force of the engine to the tires and determine the specification of the vehicles. Moreover, automobiles cannot turn or stop without parts, such as the suspension systems, 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 also different. In addition, an internal combustion engine assists in the production of energy, which produces power, whereas the oil pump supplies lubricating oil, and the water pump 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 well-known "Gephi", a free open-source software, the visualization of the diameter, and the degree centrality of each node in Yokokai is illustrated in Figure1.

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. As depicted by the color of the line connecting each node, the heavier the weight of the edge, the darker the blue holds.

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 |

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 that started with the loosening of Keiretsu, may have had a strong influence on Mazda's cost reduction. Based on this speculation, we compared the changes in the overall degree centrality and Mazda's cost rate. Based on the results reported in Figure 2, it can be seen that Mazda's stand-alone cost ratio has

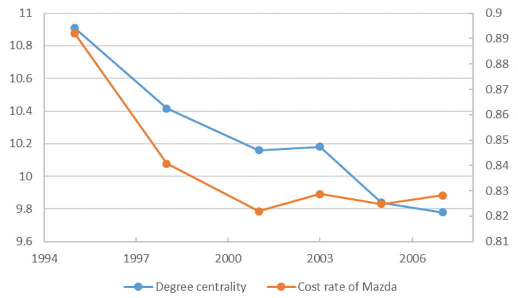


Figure 2. Time series changes in Mazda Group's entire centrality and Mazda's cost rate.

declined as the overall degree centrality declines over the years. Evidently, 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 expansion 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 was proposed. Using this model, the relationships among scale of market trading, diameter of the network Yokokai, and the production cost of the core firm in Yokokai was been examined. To test the validity of this model, data drawn from Toyota and other auto makers should be tested. In addition, only 6 fiscal years' data drawn from Yokokai is not sufficient. Thus, more longitudinal data set should be gathered and tested before firm conclusions are made.

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