An Investigation about the Influence of the Conversion into Electric Vehicle on Automotive Industry in Tokai Area, Japan

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Abstract—Automobile industry has been facing a major innovation of electric vehicle (EV). Many automobile companies launched and are launching new project of EV. The shift to EV means not only an appearance of new car but also the major change of the architecture of a car from closed-and-integral one to open-and-modular one. Based on the status quo in automobile industry, we will investigate suppliers whose technology seem to be suited only to gasoline vehicle (GV), not be suited to EV and make it clear how they reconstruct their existing relationship. Through our investigation we will lead our conclusion.

I. INTRODUCTION

The architecture of a car has been closed and integral one. And Japanese automobile industries have led the world market with the practice of ‘Kaizen’ and ‘Keiretsu,’ the unique relationship with components suppliers. In general, ‘Keiretsu’ means continuous and good relationship in transaction. However, in automobile industry, it means closer relationship than good one.

On the other hand, automobile industry has been facing a major innovation of electric vehicle (EV). Many automobile companies launched and are launching new project of EV. The shift to EV means not only an appearance of new car but also the major change of the architecture of a car from closed-and-integral one to open-and-modular one.

‘Toyota Keiretsu’ has two aspects. The one is Toyota’s inter-firm relationship with suppliers, and the shift to open and modular architecture cause changes of production and procurement from a worldwide standpoint.

Supplier companies, therefore, have to adapt to Toyota’s change and improve their technology and skill of EV. The other aspect is the relationship among suppliers. They organize a supplier group named ‘Kyouhoukai’ and ‘Eihoukai’ to exchange information about market and/or technology from each other. At the same time they compete for order from Toyota. Therefore, the shift to EV is expected to cause new kind of cooperation and competition among the global suppliers within the out of ‘Keiretsu’ members.

Based on the status quo in automobile industry, we will investigate suppliers whose technology seem to be suited only to gasoline vehicle (GV), not be suited to EV and make it clear how they reconstruct their existing relationship. Do they make it tight or loose, or construct a new relationship? Through our investigation we will lead our conclusion.

II. THE FEATURES OF KEIRETSU IN PAST PAPERS

To understand structure of Japanese automobile industry, ‘keiretsu’, a set of companies with interlocking business relationships and shareholdings is an important key word. The aim of this section is to discuss some features of keiretsu in past papers of management theory.

The first feature of keiretsu is the power balance between assemblers (which manufacture the final product) and supplier
(which manufacture components) in Japanese automobile industry. Here, suppliers are considered to be subordinate to assemblers. And it is main point how to change the balance between them to make supplier more independent from assemblers. This is a classical viewpoint in management theory.

In a high-growth period of Japanese economy, many scholars discussed that some suppliers in Toyota group would be independent from assembler, and suppliers were supposed to have a different role from assembler so that some suppliers in Toyota group would be more competitive. For example, ‘Kyohoukai’ is an association of suppliers of parts, and ‘Eihoukai’ is an association of suppliers of distribution and equipment.

The second point of keiretsu is a long and continuous relationship between assemblers and suppliers as a whole system. Asanuma insists that assemblers protect suppliers, and promote the growth of suppliers from the start-up period [1]. And he points out that suppliers learn the relation-specific skill from assemblers, and this long and continuous relationship between them have brought about competitive advantage.

For example, the systems of supplying parts are grouped into approved drawing system, provided drawing system, and supplier proprietary parts system. And with suppliers from provided drawing system and approved drawing system, assemblers develop product. Therefore assemblers and suppliers have constructed long and continuous relationship.

The third point is an international competitive advantage of Japanese automobile industry. Clark and Fujimoto insist that Japanese automobile assemblers have been achieving shorter lead-time of products than that of Western assemblers in spite of lower rate of common parts [2]. Therefore Japanese assemblers can develop products using new suppliers’ parts in shorter time than Western assemblers.

As the cause of these Japanese automobile’s competitive advantage, Clark and Fujimoto point out that assemblers order a set of related work to suppliers at a time [2]. And as the cause of Japanese automobiles’ competitive advantage they point out that well-known suppliers compete for order for same parts severely. As a result, keiretsu implements have been able to achieve cost down and quality improvement. The above is general features of keiretsu in past papers of management theory.

### III. CHANGE OF MONOZUKURI INDUSTRIAL STRUCTURE BY SHIFT FROM GV TO EV

Along with a worldwide eco-boom, eco cars (ecologically-friendly cars) are marked, and development of them is expected in near future. There are various kinds of eco cars as shown in the Table I. It is thought that hybrid vehicle (HV),

**Table I** Typology of EV

<table>
<thead>
<tr>
<th>Kind of Economic Vehicle</th>
<th>Energy Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline Vehicle (GV)</td>
<td>Fuel-efficient Car</td>
</tr>
<tr>
<td></td>
<td>Clean Diesel Vehicle</td>
</tr>
<tr>
<td>Hybrid Vehicle (HV)</td>
<td>Hybrid Vehicle (HV)</td>
</tr>
<tr>
<td>Electric Vehicle (EV)</td>
<td>Plug-in Hybrid Vehicle (PHV)</td>
</tr>
<tr>
<td></td>
<td>Fuel Cell Vehicle (FCV)</td>
</tr>
<tr>
<td></td>
<td>Electric Vehicle (EV)</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

**Table II** Differences between EV and GV

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Component</th>
<th>Assemble</th>
<th>Main Component</th>
<th>Maker of Main Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>Simple</td>
<td>Module</td>
<td>Simple</td>
<td>Battery</td>
<td>Electronics (Chemical) makers</td>
</tr>
<tr>
<td></td>
<td>Flexible</td>
<td>Independence</td>
<td></td>
<td>Motor</td>
<td></td>
</tr>
<tr>
<td>GV</td>
<td>Complicated</td>
<td>Mutual</td>
<td>High-Tech</td>
<td>Engine</td>
<td>Automobile (Mechatronics, Machine)maker</td>
</tr>
<tr>
<td></td>
<td>Difficult</td>
<td>dependence</td>
<td>Complicated</td>
<td>Transmission</td>
<td></td>
</tr>
</tbody>
</table>
plug-in hybrid vehicle (PHV), fuel cell vehicle, and EV will get higher share of automobile in near future. Especially EV will get large share because of the fossil fuel shortage. EV had been already sold by Mitsubishi Electric Corporation and Fuji Heavy Industries Ltd. in 2009, and this year is called 'First year of EV'.

EV has good points as follows against GV: 10 percents of the components of GV; possibility of modularization of components; large of free space in car: ease of car design; good for the ecology (zero emission); better of energy effectiveness; and cover of requirement of luxury automobile (acceleration performance, stability, mobility, tranquility, and reactivity)

It will be possible to assemble components as a module, because components of EV have little dependency relations. Then EV is easier to product than GV technically. Consequently new assemblers of EV will appear from companies excluding in automobile industries.

Also new design automobiles will appear. Then main components of EV are battery and motor, and main technologies of EV move to Electronics (Chemical) maker. (See Table II).

As EVs are developed and produced in place of GVs, the following points are thought as a change in the automobile 'Monozukuri' structure.

- New mega suppliers of EV components break into automobile industry
- Unnecessary suppliers for EV components appear
- Number of suppliers comes down by decrease of components
- New assemblers (electric power companies, electronics makers, toy makers, and IT ventures) break into automobile industry
- The spread of the smart grid is promoted
- Infrastructure technology of smart grid and battery charge station will be developed

Tokai area in Japan is central area which has some automobile assemblers (including TOYOTA), and automobile 'Monozukuri' industry. Then shift from GV to EV will change 'Monozukuri' industrial structure. Correspondence method against EV gives impacts the Tokai 'Monozukuri' industry. Therefore in the Tokai area, approach to take the initiative in EV is discussed in various fields.

Also the problem of the EV is given as follows.
- Moving distance is short. (Battery capacity is small)
- Battery charging time is long. (Capability of battery boot charge is low)
- Price of EV is expensive
- Infrastructure of battery charge is not structured

IV. INFLUENCE OF SPREAD OF EV ON AUTOMOBILE INDUSTRY

GV consists of mechanical components such as engine, transmission, gear, and driveshaft, and they have a complex interdependence and connected complicatedly.

On the other hand, in case of EV, main parts are connected via cables, so there is more flexibility in arrangement. Less complexity in interdependence among components promotes modularity in architecture. In modular architecture, the rule of design is determined in advance and each part is supposed to do one function. An example of product based modular architecture is desk-top PC. In turn, modular architecture promotes openness where design rule is shared and standardized in the whole industry from closed modularity where they are limited within one company.

In the automobile industry, separation of production process, lower entry barrier, value-added through integrated process, innovations, and appearance of platform leadership, are being promoted under the shift toward modularity (see Fig.1).

On the other hand, a main source of Japanese manufacturing industry is close relationship between assembler and components supplier and the ability adjustment and harmonization on components. In Japanese automobile industry, automobile makers share the information on 30,000 of components and adjust them with Keiretsu companies throughout long process of production, and this has lead to cost reduction and quality improvement, and therefore competitive advantage.

As noted above, in the process of production of EV, horizontal disintegration like desk-top PC industry will be the mainstream, so traditional way will suffer from the integrated way. Besides, the

- Separation of production process
- Lower entry barrier
- Lower value-added through integrated process
- Innovations
- Appearance of platform leadership

Fig.1. Effects of Modularizaion.
number of components will decrease dramatically compared with a gasoline car.

V. INFLUENCE OF SPREAD OF EV ON KEIRETSU SYSTEM

Japan Automobile Manufacturers Association, Inc. (JAMA) announces Japan’s domestic shipments of automobile parts in “Trend Investigation of Automobile Parts Shipments” every year. Fig. 2 shows Japan’s domestic shipments of automobile parts from 1999 fiscal year to 2008 fiscal year. In this figure, the shipments of automobile parts such as (1) engine parts, (2) electrical device and electronic parts, (3) electrical and electronic parts as illumination or meter, (4) drive, transmission and control device parts, (5) suspension and break device parts, (6) body parts, (7) supplies and (8) parts relate to information were respectively shown. According to this figure, the total shipments of automobile parts had increased year by year to 2007 fiscal year, and decrease with Riemann Shock in 2008 fiscal year.

Next, we analyzed how much shipments will decrease if all GVs are replaced by EVs. In the analysis, 2002 fiscal year is chosen. As shown in Table III, some parts being used for GVs will be unnecessary for the EVs were also chosen. As Fig. 3 shows the result, and total shipments decrease 23%. It seems that Keiretsu companies similarly decrease. Under the shift toward modularity, the separation of production process and lower entry barrier will further damage to sustainability of the Keiretsu companies.

Chesbrough described that Industrial Ecosystem will take the place of Keiretsu system [3]. Companies within Keiretsu can't win to Open Innovation. Companies with no capital relations should cooperate mutually, and produce products and businesses based

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Table III  Unnecessary parts of GV for EV

<table>
<thead>
<tr>
<th>Engine parts</th>
<th>Electrical device and electronic parts</th>
<th>Drive, transmission and control device parts</th>
<th>Body parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>All parts</td>
<td>• Starter</td>
<td>• Crutch cover</td>
<td>• Fuel tank</td>
</tr>
<tr>
<td></td>
<td>• Alternator</td>
<td>• Crutch disk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Distributer</td>
<td>• Crutch phasing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ignition coil</td>
<td>• Manual transmission</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Spark plug</td>
<td>• Transmission Parts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Glow plug</td>
<td>• Oil seal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Engine control unit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. Japan’s domestic shipments of automobile parts.
VI. CONCLUSION POSSIBILITY OF STRUCTURAL CHANGE IN AUTOMOBILE INDUSTRY OF TOKAI AREA

In this section, we make it clear how the ‘Keiretsu’ relationship reconstructs their existing relationship, along with the development of EV. Will the relationship make itself tight or loose, or construct a new relationship?

In automobile industry, it is very difficult for one company to take a long vertical integrated form of organization from planning to marketing, because a variety of works and skills are necessary to be gathered. In Tokai area in Japan especially, ‘Keiretsu’ companies have contributed to the development of automobile industry. A relationship called ‘Keiretsu’ has a characteristic of closed relationship, where management resources such as information, materials and component, money, skill, and personal relationship, get together, to achieve high level of performance. So we can say that ‘Keiretsu’ behaves like a single, big, and closed company.

If architectures of some components are made open near future, we don’t think that ‘Keiretsu’ relationship become loose one immediately. Followings are the reasons.

1. ‘Keiretsu’ relationship has achieved quick delivery. Since group companies share the information about production plan. Moreover, they are located in on region, Tokai area.
2. It has decreased procurement cost drastically and contributed to global low cost competition. Interchange of personnel within ‘Keiretsu’ companies realized shared information about cost and profit.
3. It has contributed to the protection of technical information. This is mainly because of one of characteristics of Japanese people; criminal behavior makes it difficult to find another job.

The forces breaking off ‘Keiretsu’ relationship are following:
A. Political pressure; it might bring about international problems such as trade conflicts.
B. Local production; it makes local procurement to achieve quick delivery.
C. Avoidance of foreign exchange risk; local production and sales needs transaction based on local currency.
D. Employment of local people; management and control of local people will change the transaction relationship.

However if components of EV are open, keiretsu collapses quickly. So we might have supposed that the Keiretsu would survive under the conditions showing below,

1. In order to keep the delivery schedule, the common parts which have less-important technical information such as the basic construction frame of the body might be
produced in the oversea factories and special modules which have higher technical secrets would be produced and assembled in Keiretsu factories. As the composition of the EV is much simpler than that of GV, the design works of mapping the modules might be free.

2. The top company such as the TOYOTA would pay by its domestic currency to the Keiretsu companies in order to cover the risk of the exchange.

3. The Patent technology in the Keiretsu companies should be protected by the top company.

4. The foreign company should respect the local culture and employ local people at higher position without the colonial policy.

5. The Japanese should be able to communicate with the local language or English at the meeting.

6. The Keiretsu companies should tune up the quality of the parts after getting the information of the differences how to treat the vehicles between the other countries.

If all the conditions showing above may be met enough, the Keiretsu in Japan would be much closer and stiffened.

REFERENCES

