# Modular Manufacturing Architecture in Automobile Production

**George Ming-Hong Lai***, Associate Professor
Department of Business Administration, Taichung Institute of Technology
No. 129, Sanmin Rd., Sec. 3, Taichung, Taiwan, R.O.C.
E-mail: gm.lai@msa.hinet.net
*Corresponding author

**Eun-Teak Oh**. Assistant Professor
Department of Applied Japanese, Yu-Da College of Business
No. 168, Shiuefu Rd., Tan-Wen Tsuen, Chao-Chiso Shiang, Miao-Li Hsien
Taiwan, R.O.C.
E-mail: etoh@ydu.edu.tw

**Ren-Jye Liu**, Professor
Department of Industrial Engineering and Enterprise Information, Tunghai University,
Box 985, Tunghai University, Taiwan R.O.C.
E-mail: liurj@ie.thu.edu.tw

**Abstract**

This study represents a first attempt at using manufacturing architecture to explain different paths of modularization. Its objective is to explore how and why South Korean automakers and Taiwanese automakers use modular manufacturing architectures to catch up with front runners in Japan, U.S.A., and Europe. Theoretical framework is based on a classification of production architecture into four types of manufacturing architecture. After case study research and analysis, the results suggest that modular manufacturing architecture can be practiced in different forms and in different conditions to combine the advantages of standardization and flexibility. For synergy effect, Kia Motor in South Korea has adopted modular product architecture with modular products within the same integral inter-firm organization. To learn from brand-name automakers, China Motor in Taiwan has adopted modular organization architecture with integral products in different modular inter-firm organizations.

**Keywords** - Modular manufacturing architecture; product module; organization module; automobile; case study

## 1. Introduction

Modular manufacturing architecture is the adoption of unit standardization or substitution principles to create modular components and activities that can help to assemble a wide range of end products to meet specific customer needs (Ulrich, 1995; Baldwin and Clark, 1997; Tu et al., 2004). Such a manufacturing architecture can help firms in introducing new products faster, because it can upgrade individual subsystems without having to rearrange the entire system. Its strategic potentials have been discovered by many leading researchers and manufacturers as they seek to use modular architectures to produce customized, low-priced products with better than average functionality and reliability (Sanchez, 2000; Schilling, 2000; Fujimoto, 2002). Application of modular manufacturing architecture in the production system is an effective strategy which enables firms to mix and match best-of-breed components or suppliers to give every customer exactly what he or she wants for meeting today's escalating market demands (Baldwin and Clark, 2000).

With the adoption of modular architecture platforms, manufacturers can gain competitive advantages by outsourcing or by assembling a wide variety of standardized modules to significantly reduce uncertainty and complexity, cut product development time, and lower overall costs (O'Grady, 1999; Schilling, 2000). Manufacturers can also break down of the original inter-firm organization and regroup it thereafter with more capable new members as a new organization to meet new customer demands. Such a practice can reduce the total cost of the system by fostering competition from multiple suppliers of parts.

Based on well established interfaces which are defined in this study as the connecting elements in facilitating the development of an effective manufacturing system, modular manufacturing architecture consists of modular product architecture and modular organization architecture, both of which can create specific forms of strategic flexibility (Fujimoto et al., 2001; Schilling and Steensma, 2001; Dahmus et al., 2002). Modular product architecture contains interfaces between components to allow the free substitution of some range of component variations on one or both sides of the interfaces. Modular organization architecture contains interfaces between organizational arrangements or activities that define how the organizational arrangement or activity components interact in the manufacturing system (Sanchez, 2004). To gain its benefits and avoid its potential damages, modular manufacturing architecture requires disciplined re-use of standard common components or arrangements and articulated usage of variation components or activities to secure low cost production and intended variation for each market segment with flexibility and quick response.

The concept of modular manufacturing architecture can also apply to supply chain management with not only the modularization of product system but also the modularization of organization system (Doran. 2003). Specialized module suppliers providing modularized and up-gradable modules often serve as organization modules of an inter-organization supplier network for a product family of final products. In an integral organization network, final assemblers or module producers connect only to other component makers in a closed network. The component makers often supply only to one specific final assembler or one module producer. In a modular organization network, final assemblers or module producers received components from multiple

component makers in an open network. The component makers also supply to multiple final assemblers or multiple module producers.

Fujimoto (2004) points out that different countries and regions have different types of strengths in terms of organizational capabilities. The products that fit the particular strengths of each country or region are more likely to survive there. This is the idea of "comparative advantage in architecture." Companies in the United States have traditionally tended to excel in the ability to sketch out business models in advance, create industry standards, and flexibly assemble human, physical, and financial resources to match their immediate requirements. U.S. companies' power of conceptualization is most effective when applied to modular products, especially the Silicon Valley type of knowledge-intensive modular products. In comparison, Fujimoto (2004) considers that Japan is most effective in integral manufacturing architecture. He points out that Japan has numerous companies excelling at integral architecture products which rely on delicate mutual adjustment of part designs, tight liaison between development and production, and close communication with suppliers and other business partners. In addition, integral manufacturing architecture can prevent the erosion of market power and architectural control. Automobile companies in Japan such as Toyota and Honda are front runners in such type of production system.

Automakers in South Korea and Taiwan are late starters trying to copy Japan's success in the competitive automobile market. However, inspiring to catch up with the front-running automakers and constrained by fragile supplier base and deficient technical capability, automakers in South Korea and Taiwan have adopted two distinctively different modular manufacturing architectures in the modularization process (Chung, 2001; Zho, 2001). To be able to adapt quickly to customer demands and to pursue economy of scale benefit, automakers in these two countries rely on the ability of modularity to increase flexibility in assembly by using modular architecture in new models. The purpose of this article is to elaborate how and why they use modular manufacturing architectures of their own in stead of following the Japanese model of integral manufacturing architecture.

## 2. Theoretical background

The concept of manufacturing architecture is commanding increasing attention from researchers and practitioners in the field of production technology and innovation because of its capability to combine the advantages of standardization and flexibility. Ueda (2001) and Fujimoto (2002) have articulated this line of thinking with the success of Toyota Production System and regard architecture as a successful manufacturing strategy for effectively organizing complex products and processes. However, Fujimoto (2004) argues that fully integral architecture is the field where Japanese automakers have been able to maintain their competitive advantages, because the delicate mutual adjustment of part designs, the tight liaison between development and production, and the close communication with suppliers and other business partners can only function well in a fully integral architecture.

## 2.1 Modularization of front-running automakers

Noticing the importance of modular architecture, front-running automakers have carefully developed modular strategies in response. For the U.S. and the European automobile industries, modular strategies are carried out by established part suppliers, which develop and produce entire modules according to the demands of final assembly automakers (Marx, 1998; Salerno, 2001). The final assembly automakers maintain their control of the production system through establishment of proprietary interface, selection of supplier, setting of purchasing price, emphasis on quality control, and approval of module design. In comparison, Japanese final assembly automakers prefer to design and produce new module in house or by collaborative first tier keiretsu business group members (Nishikuchi, 1994; Lai, 1999).

Ueda (2001) and Fujimoto (2004) both point out that integral architecture is the field in which Japanese automakers have been able to maintain their competitive strength. They advocate that automobile production is expected to continue to be mainly an integrative industry for the foreseeable future. Japanese automakers' lead is likely to continue for some time to come. Only limited modularization in parts modification and systemized interface is necessary. In comparison, automakers in U.S.A. /Europe are more supportive of modularization (Suzik, 1999; Doran, 2003). The existence of big part/module suppliers supplying for multiple final assembly automakers allows for specialization and economy of scale in module design and production. However, there remain some skeptics for full embrace of modularization (Fleming and Sorenson, 2001; Ketchen and Hult, 2002). Modularization of front-runner automakers in U.S.A. /Europe and Japan is shown and sorted out at Table 1.

【Take in Table 1 here】

## 2.2 Modularization of late-starting automakers in South Korea and Taiwan

As late-starters, automakers in South Korea and Taiwan are interested in using modular strategies to catch up with front runners in Japan, U.S., and Europe. Constrained by restless labor union, inadequate R&D capability of part suppliers, and unstable supply of high quality components, automakers in South Korea and Taiwan have to start with where their competitive advantages are and renovate where they have competitive disadvantages. Because of contextual differences, modular strategies of automakers in these two countries are pursued with different paths.

Chung (2001) and Zho (2001) point out that product module is where South Korean automakers' competitive advantages are. With strong R&D and production capability, South Korean automakers have begun the process of modularization. However, labor unrest, preservation of core competence, and inadequate R&D capability of most parts suppliers are restraining the development of modularization in full scale. In contrast, Liu and Brookfield (2000) and Yung (2003) indicate that organization module is where most Taiwanese firms' competitive advantages are. Strong industrial cluster and organization networks in computer industry and machine tool

industry and their successes in the world market provide good examples for Taiwanese automakers to follow suit. However, technical dependence on Japanese automakers and part suppliers is denying the development of modularization in full scale.

## 2.3 Product Module & Organization Module

Product module is defined in this study as the specification of standardized interfaces among physical components with their mapping functional elements in assembling a wide range of end products to meet specific customer needs (Ulrich, 1995). Based on well established interfaces, module can be taken off or added into the original architecture. Successfully implemented, modular products with open and internationally accepted industrial standards can lower entry barriers caused by patents and proprietary know-how and consequently lower transaction costs of the products. Integral products with closed and patented industrial standards, on the other hands, can raise transaction cost due to limited competition.

Organizational module is defined in this study as the specification of standardized interfaces among inter-firm arrangements and activities in assembling a wide range of end products to meet specific customer needs (Sanchez and Mahoney, 1996). Through standardized organization interfaces, the pursuit for added value can be achieved by effective collecting and grouping of organization modules. The core concept of such an inter-firm system is based on a collaborative relationship, which allows each organization module to concentrate on its core competence before grouping them together as a functional network. Successfully implemented, organization modularity can coordinate manufacturing operations, share complementary resources, and motivate organizational learning. Under modular organization architecture, collaborating firms can all benefit from resource expansion and reduced manufacturing time and cost (Dess et al., 1995; Dahmus et al., 2001).

## 2.4 Theoretical Framework

To illustrate how and why South Korean automakers and Taiwanese automakers adopt the modular manufacturing architecture in stead of the Japanese model of integral architecture, a classification of manufacturing architecture is necessary. As illustrated in Table 2, product architecture can be dichotomously classified into modular product architecture and integral product architecture. Organization architecture can be dichotomously classified into modular organization architecture and integral organization architecture. Four types of manufacturing related architectures – fully integral architecture, modular product architecture, modular organization architecture, and fully modular architecture – can be derived to form the base of our theoretical framework.

【Take in Table 2 here】

Fully integral architecture is most effective when the manufacturing process needs delicate mutual adjustment

of part designs, tight liaison between development and production, and close communication with suppliers and other business partners. In addition, fully integral architecture is most effective in preventing the erosion of market power and control of technology and know-how. Fully modular architecture is most effective when the outsourcing or assembling process relies on a wide variety of standardized modules to significantly reduce uncertainty and complexity, cut product development time, and lower overall costs. Modular product architecture is most effective when the manufacturing process aims to benefit from specialization and economy of scale. Modular organization architecture is most effective when the manufacturing process needs to function smoothly and profitably without the opportunity cost of being "locked in" to a single brand-name automaker for technical supports. The foci of this study are in modular product architecture represented by Korean automakers, and modular organization architecture represented by Taiwanese automakers.

## 3. Method and Data Collection

The case study below was developed based on interviews and various sources of archival data. The interviews were with key informants, general managers or other important figures with relevant experience or knowledge. Additionally, secondary data included database, corporate website, newspapers, magazines, and research reports. Kia Motor in South Korea and China Motor in Taiwan were selected as the target automakers in the two countries based on their market strength and their leading positions in both countries. The interviews with Kia Motor were conducted in Korean language in year 2002 and year 2003, and the interviews with China Motor (Taiwan) were conducted in Chinese language in year 2003. Public documents and publications are also used to supplement the data from the interviews following the rule of relying on multiple source of evidence.

Manufacturing arrangements and activities related to modular product architecture and modular organization architecture are major foci of our case study. Four major manufacturing arrangements and activities of these two cases are studied: Activities and arrangements of modularization in these two automakers. Form of subassembly, outsourcing and parts delivery. Roll sharing between final assembler and module/part makers. Development of modular manufacturing architecture from the view point of the entire production system.

## 4. Case Study

By selecting Kia Motor in South Korea and China Motor in Taiwan as our cases, we intend to study how these two leading final assembly automakers in each country pursue their own modular manufacturing architectures. Kia Motor as well as other automakers in South Korea is oriented toward global market with mass production. In the mean time, China Motor as well as other automakers in Taiwan is oriented toward niche market with customized production. It is an interesting contrast worthy of study. The profiles of these two automakers are shown in Table 3.

【Take in Table 3 here】

4.1 Kia Motor of South Korea

Kia Motor is currently South Korea's second largest automaker and its oldest. It had received capital investment and technical support from Mazda Motor of Japan before Hyundai Motor took over Kia in 1998. Following the development of modular architecture, Kia Motor is trying for higher level of product modularization. It intends to increase the percentage of standard parts in each new model. Activities and arrangements of modularization at Kia Motor are shown in Table 4. Since year 2000, Kia Motor has been promoting the product part of modular manufacturing architecture successively with other core members in the same integral business group (Chaebol), which centers on Hyundai Motor, Kia Motor, and Hyundai Mobis. Hyundai Mobis is responsible for supplying more and more product modules to Kia Motor and Hyundai Motor, which together control seventy percent of South Korean domestic market in addition to their growing international sales. Currently, cockpit module and sub-frame module are produced and managed mainly by Hyundai Mobis. Specialization and economy of scale can be secured under such arrangements, which can facilitate quality improvement and cost reduction.

【Take in Table 4 here】

There is no need to change the existing production lines for the sake of modularization. Because of product modularization, increasing number of tire and front end module makers are settling around the neighborhood of Whasung yard, where Kia Motor is located. However, as the product part of modular manufacturing architecture continues to progress, the tension with the aggressive labor union increases. Such a development has become an enormous constraint for outsourcing of subassembly modules. The organization part of modular manufacturing architecture is therefore difficult to implement.

Main instrument board is a good example to show such a development in the product part of modular manufacturing architecture. Assembly of main instrument board for the year 2002 model was shifted from former collaborative part suppliers to Hyundai Mobis. These main instrument boards are then delivered to Kia's Whasung yard as cockpit modules. Because of such arrangements, management of subassembly parts was shifted from Kia to Hyundai Mobis. The same pattern can be seen on sub-frame assembly. Table 5 shows sharing of control activity about subassembly module - cockpit module and sub-frame module. Parts makers, once directly traded with Kia Motor, are obliged to deliver to Hyundai Mobis. Thus, they are becoming second tier makers from the position of Kia Motor as the final assembly automaker. In a sense, Kia Motor has shifted part of design, production and purchase functions to Hyundai Mobis. Hyundai Mobis, in the process, has also merged or taken control of some former module related makers. Without a doubt, Hyundai Mobis has emerged to be an important module supplier in the integral Hyundai-Kia motor group.

【Take in Table 5 here】

4.2 China Motor (Taiwan)

China Motors (Taiwan) has indicated that it does not consider developing or outsourcing product modules for its new models a top priority. Both China Motors (Taiwan) and its first tier suppliers have formed alliances with Mitsubishi Motor and its related Japanese first tier suppliers. Such a closed supply system helps to produce the final assembled automobiles of China Motors (Taiwan) as integral products. The organization module part of modular manufacturing architecture is currently the major focus of China Motors (Taiwan). Activities and arrangements of modularization at China Motor are shown in Table 6. China Motors (Taiwan) has a close relationship with Mitsubishi Motor of Japan, from which new auto models were introduced. Alliance with Mitsubishi Motor is so critical that they are going to promote the product module part of modular manufacturing architecture together with the expectation of further extension on such an alliance.

【Take in Table 6 here】

As a final assembler, China Motor (Taiwan) tries to safe-guard its core technology in final assembling from part makers. On the subassembly line at the yard, there is no spot where works are relied on or assigned to outside part makers. Wage difference is small between workers of China Motor (Taiwan) and workers of auto-part makers in Taiwan or in China. There is no incentive to subcontract job in the yard. Since there is no large Taiwanese auto module maker, China Motor (Taiwan) has not outsourced its instrument panel module, cockpit module and other modules. Among the purchased parts, instrument panel is probably the easiest to become a module. However, instrument panel includes various parts made by different professional works. There is no auto-part maker in Taiwan large enough and capable of integrating these various parts together as one module (see Table 7).

【Take in Table 7 here】

Manufacturing and marketing under the Mitsubishi brand-name, China Motor (Taiwan) has carved out a market niche in mainland China. Its fifty-fifty joint venture subsidiary, Soueast Motor, is located in the Fujian province, People’s Republic of China. In this fast growing Chinese auto market, business cars and passenger cars are now being produced with the collaboration of some 30 Taiwanese auto-part makers, forming a cluster production group, which settled in the same industrial park. Soueast Motor’s auto production is increasing yearly, which earns handsome profits for China Motor. It is estimated that the number of cars sold by Soueast Motor will soon exceed China Motor’s own domestic sales of 100,000 cars yearly.

Such a success had attracted Daimler Chrysler to enter a joint venture with China Motor (Taiwan) at the end of year 2003 to produce and market small Benz passenger cars in China. It is vital for China Motor to maintaining good working relationships with Mitsubishi Motor, Daimler Chrysler and other brand-name automakers, with its Chinese partners such as Soueast Motor, and with the collaborating Taiwanese parts makers. For future

development of China Motor, the organization module part of modular manufacturing architecture is more important than the product module part of modular manufacturing architecture.

Another loosely-structured production cluster of auto-part members has been formed to support the joint venture of China Motor (Taiwan) with Daimler Chrysler in China, but with some changes of key suppliers in the process. Most Taiwanese auto-part makers are small compared to their U.S., European, or Japanese counterparts and they are willing to produce customerized parts if the orders are large enough for them to enjoy the benefit of economy of scale. As long as China Motor (Taiwan) can guarantee continuous flow the large orders, it is not difficult for China Motor (Taiwan) to form another modular organization for another integral automobile production other than that for Mitsubishi Motor. Interviewees of China Motor (Taiwan) indicate that it is easier for China Motor (Taiwan) to implement the organization part of modular manufacturing architecture in its Soueast Motor operation in mainland China, because of the opportunities created by the huge Chinese market, which no brand-name automaker can afford to ignore.

## 5. Findings

As presented in our cases above, South Korean and Taiwanese automakers have adopted two different paths of modular manufacturing architecture. South Korean automakers are pursuing modularization with the architecture of modular products within the same integral inter-firm organization, whereas Taiwanese automakers are pursuing modularization with the architecture of multiple integral products with modular inter-firm organizations. The comparison is shown in Table 8.

【Take in Table 8 here】

Four distinct patterns can be generalized from the modularization process of South Korean automakers. Firstly, the drive for product modularization is pursued in accordance with development of new models to reduce organizational resistance. Secondly, parts of the management responsibilities and burdens have been transferred from final assembly automakers to large-scale part supplier in the same Chaebol business group in the process of modularization. Thirdly, a new collaborative network with second tier and third tier part suppliers has been formed centering on Hyundai Mobis. Fourthly, Chaebol Facilitation can be considered as the core competence of South Korean automakers in successful implementing of modularization.

Four distinct patterns can be generalized from the modularization process of Taiwanese automakers. Firstly, the drive for product modularization has not been pursued by Taiwanese automakers as zealously as leading automakers in Europe and the U.S. Secondly, management responsibilities and burdens have firmly rested on final assembly automakers and foreign technical supporters. Thirdly, a new collaborative network with first tier part suppliers has been formed to collaborate with the new brand-name automaker, Daimler Chrysler. Fourthly, ability to collaborate with multiple brand-name automakers can be considered as the core competence of Taiwanese

automakers in successful implementing of modularization.

## 6. Discussion

After presenting how they use different modular manufacturing architectures of their own, we find it imperative to discuss why South Korean automakers and Taiwanese automakers have chosen modular product architecture and modular organization architecture as their best strategies in implementing modularization process. The reasons are as follows:

For South Korean automakers, synergy effect obtained by integrating technology and resources of the Chaebol business group is what they rely on to compete with other automakers in the global market. In addition to the benefit of specialization and economy of scale with the adoption of modular product architecture, outsourcing product modules from part makers in the same Chaebol business group can significantly reduce uncertainty and complexity, cut product development time, and lower overall costs without the erosion of market power and control of technology and know-how. The creation of a European-styled super supplier on top of the original collaborative network is an attempt to solve the problems of fragile auto-part supplier base and restless owner-labor dispute in the modularization process. Since this super supplier of product modules, Hyundai Mobis, is in the same Chaebol business group with Kia Motor and Hyundai Motor, delicate mutual adjustment of part designs, tight liaison between development and production, and close communication of key partners can all be realized.

For Taiwanese automakers, ability to collaborate with and learn from multiple brand-name automakers is what they rely on to compete in their niche markets. In addition to the benefit of functioning smoothly and profitably without the opportunity cost of being “locked in” to a single brand-name automaker for technical supports, establishing collaborative networks with disciplined re-use of standard common component suppliers and articulated usage of variation components suppliers can secure low cost production and required variation for different brand-name automakers with flexibility and standardization. The creation of modular organizations for multiple integral products is an attempt to solve the problem of relying on only one technology supporter as well as the problem of uncontrollable and unspecialized small auto-part suppliers in the modularization process. The opportunities created by the growing Chinese auto market benefit China Motor (Taiwan), other Taiwanese automakers and key Taiwanese auto-part suppliers by giving them a second or maybe a third chance to be more specialized and sophisticated in their chosen area of niche markets.

## 7. Conclusion and Implication

This study represents a first attempt at using manufacturing architecture to explain different paths of modularization. Following the rule of relying on multiple source of evidence, we carry out this research based on interviews and various sources of archival data. The units of analysis are manufacturing arrangements and

activities related to modularization, which are practiced by two East Asian late-starters in automobile production.

Contrary to the new model of fully integral architecture advocated by many Japanese scholars, This study discovers that modular manufacturing architecture is what these two East Asian late-starters rely on to catch up with the front-runners in automobile production. South Korean automakers are pursuing modularization with the architecture of modular products within the same integral inter-firm organization. Taiwanese automakers are pursuing modularization with the architecture of multiple integral products in different modular inter-firm organizations. The success of these two late-starters reveals that modular manufacturing architecture can be practiced in different forms and in different conditions to combine the advantages of standardization and flexibility.

In this paper, owing to the geographical restriction and difficulty in data collection, we focused our effort only on automakers in South Korea and Taiwan. Different paths of modular manufacturing architecture may appear in different countries. For instance, fully modular architecture for automobile production may be a possible path for Chinese automakers. Chinese firms have already demonstrated that they can successfully manage fully modular architecture in the production of related products such as bicycle and motorcycle. Chinese firms are now world-class low cost producers of bicycle and motorcycle. “Will automobile be the next?” is an interesting extension of our study as some data of our study have indicated such a possibility.

**References**


Baldwin, C. Y., and Clark, K. B. (1997), “Managing in an age of modularity”, *Harvard Business Review*, Vol.75 No. 5, pp. 84-93.

Baldwin, C. Y. and Clark, K. B. (2000), *Design Rules: The Power of Modularity*, Boston: MIT Press.

Chung, M. K. (2001),”The expanding buyer-supplier partnership for product and process technology development in the Korean automobile industry”, *International Journal of Automotive Technology and Management*, Vol. 1 No.2/3, pp. 347-357.

Dahmus, J. B., Gonzalez-Zugasti, J. P. and Otto, K. N. (2001), “Modular product architecture”, *Design Study*, Vol. 22, pp. 409-24.

Dess, G. G., Rasheed, A., McLaunghlin, K. J. and Priem, R. L. (1995), “The new corporate architecture”, *The Academy of Management Executive*, Vol. 9, pp: 7-20.

Doran, D. (2003), “Supply chain implications of modularity,” *International Journal of Operations and Production Management*, Vol.23. No. 3, pp. 316-26.

Fleming, L., and Sorenson, O. (2001), “The dangers of modularity”, *Harvard Business Review*, Vol. 79 No. 6, pp: 94-102.

Fujimoto, T., Takeishi, A. and Aoshima, Y. (2001), *Business Architecture: The Design of Product, Organization, and Process strategies* (in Japanese), Yuhikaku Press, Tokyo.

Fujimoto, T. (2002), “Japanese type of supply system and modularization: the case of automobile industry”, In

Aoki, Y. and Andou, M. (eds.), Modularization: The Essence of New Industry Architecture (in Japanese), Toyo Economic Report, Tokyo, pp. 69-78.

Fujimoto, T. (2004), "A twenty-first-century strategy for Japanese manufacturing", *Japan Echo*, Vol. 31 No.1, pp. 20-25.

Galvin, P., and Morkel, A. (2001), "The effect of product modularity on industry structure: the case of the world bicycle industry", *Industry and Innovation*, Vol. 8 No.1, pp. 31-47.

Ketchen, D. J., and Hult, G.. T. M. (2002), "To be modular or not? some answers to the question", *Academy of Management Executive*, Vol. 16 No. 2, pp.166-68.

Lai, G. M. (1999), "Knowing who you are doing business with in Japan: a managerial view of keiretsu and keiretsu business groups", *Journal of World Business*, Vol. 34 No. 4, pp. 423 –48.

Liu, R. J., and Brookfield, J. (2000), "Stars, rings, and tiers: Organizational networks and their dynamics in Taiwan's machine tool industry", *Long Range Planning*, Vol. 33, pp. 322-48.

Marx, R., Zilbovicious, M. and Salerno, M. (1997), "The modular consortium in a new VW truck plant in Brazil: New forms of assembler and supplier relationship", *Integrated Manufacturing System*, Vol. 8 No. 5, pp. 292-98.

Nishikuchi, T. (1994), Strategic Industrial Sourcing: The Japanese Advantage, Oxford University Press, New York.

O'Grady, P. (1999), The Age of Modularity: Using the New World of Modular Products to Revolutionize your Corporation, Adams and Steele Publishers, New York.

Oh, E. (2000), "Korean production system and its different types: the case of automobile industry", *Industrial Management Review*, Vol. 5, pp. 62-76.

Pires, S. (1998), "Managerial implications of the modular consortium model in a Brazilian automotive plant", *International Journal of Operations and Production Management*, Vol. 18 No. 3, pp. 221-32.

Salerno, M. S. (2001), "The characteristics and the role of modularity in the automobile industry", *International Journal of Automotive Technology and Management*, Vol. 1 No. 1, pp. 92-107.

Sanchez, R., and Mahoney, J. T. (1996), "Modularity, flexibility and knowledge management in production and organization design", *Strategic Management Journal*, Vol. 17, pp. 63-76.

Sanchez, R. (2000), "Modular architecture, knowledge assets and organization learning: New management processes for product creation", *International Journal of Technology Management*, Vol. 19 No. 6, pp. 610-29.

Sanchez, R. (2004), "Creating modular platforms for strategic flexibility", *Design Management Review*, Vol. 15 No.1, pp. 58-67.

Schilling, M. A. (2000), "Toward a general modular systems theory and its application to interfirm product modularity", *Academy of Management Review*, Vol. 25 No. 2, pp. 312-34.

Schilling, M. A., and Steensma, H. K. (2001), "The use of modular organizational forms: an industry-level analysis", *Academy of Management Journal*, Vol. 44 No. 6, pp. 1149-68.

Suzik, H. A. (1999), "GM announces modularity project", *Quality*, Vol. 38 No. 5, p. 14.

Tu, Q., Vonderembse, A. and Ragu-Nathan, T. S. (2004), "Measuring modularity based manufacturing practices

and their impacts on mass customization capability: a customer-driven perspective", *Decision Sciences*, Vol. 35 No. 2, pp. 147-168.

Ueda, H. (2001), "Modularization and supply of automobile industry", *Economics Review* (in Japanese), Vol. 41 No. 5, pp. 40-60.

Ulrich, K. (1995), "The role of product architecture in the manufacturing firm", *Research Policy*, Vol. 24 No. 3, pp. 419-440.

Yung, I. S. (2003), "The cluster of vertical disintegration by network and quick procurement of components", *Hitotsubashi Business Review* (in Japanese), Vol. 51 No. 2, pp. 56-83.

Zho, H. (2001), "The changes of supplier collaboration network caused by modularity", *Economy and Society* (in Korean), Vol. 50, pp. 186-213.

**Table 1**. Modularization of U.S.A. /Europe and Japan

| Item | Support for modularization | Characteristics of modularization | Control of future modularization |
|---|---|---|---|
| U.S.A. /Europe | Growing support from large-scale parts suppliers with strong R&D capability | 1. Functional & physical grouping of parts<br>2. Outsourcing from multiple suppliers | Shared by final assembly automakers and part suppliers |
| Japan | Moderate support from final assembly automakers and 1st tier keiretsu suppliers | 1. Functional grouping of parts<br>2. Physical subassembly in self-owned yard | All by final assembly automakers |

**Table 2**. Classification of manufacturing architecture

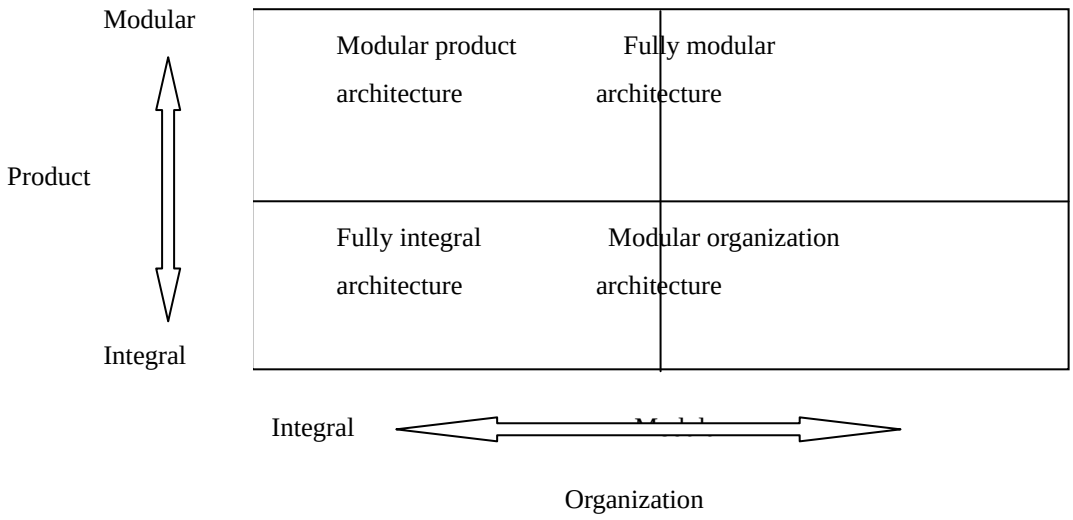

**Table 3**. Outline of the two representative automobile assemblers (2004)

| Automaker | Kia Motor Whasung yard | China Motor Yang-Mei yard |
|---|---|---|
| Nationality | South Korea | Taiwan |
| Established | 1944 | 1969 |
| Capital investment & technical support | Hyundai Motor group | Yulon Motor group and Mitsubishi Motor of Japan |
| No. of autos sold in 2002 | Domestic 252,000 Export 760,000 | Domestic 96,624<br>OEM Export 7,700 |
| Employees | 32,000 | 3,001 |
| Production capacity | 2 million, including 500,000 by Whasung yard | 198,000 including 120,000 by Yang-Mei yard |
| Auto type | 6 types (self-developed) | 6 types (From alliance with Mitsubishi Motor, Japan) |
| Production line | Toward exclusive line | Mixed line |
| Domestic market share | 23% (2nd in South Korea) | Passenger car 28.16% (2nd in Taiwan)<br>Business car 33.6%<br>(Top in Taiwan) |
| Labor union | Aggressive | Cooperative |

**Table 4**. Activity and arrangement of modularization at Kia Motor

| Management / Part & module | Activity and arrangement | | | | | Model types & beginning year of application |
|---|---|---|---|---|---|---|
| | Selection of suppliers | Approval & quality control | Setting of parts/module price | Assembly | Supply chain management | |
| Parts: | | | | | | All models |
| Sub-frame | Kia | Kia | Kia | Kia | Kia | 1997 |
| Door | Kia | Kia | Kia | Kia | Kia | 1997, 2002 |
| Engine | Kia | Kia | Kia | Kia | Kia | 1997, 2002 |
| Instrument panel (purchased) | Kia | Kia | Kia | Supplier | Supplier | All models 1997 |
| Seat (purchased) | Kia | Kia | Supplier | Supplier | Supplier | All models 1997, 2002 |
| Cockpit module (Hyundai Mobis) | Hyundai Mobis | Hyundai Mobis (with Kia) | Hyundai Mobis ( with Kia) | Hyundai Mobis | Hyundai Mobis | Sorento 2002 |
| Sub-frame module (Hyundai Mobis) | Hyundai Mobis | Hyundai Mobis ( with Kia) | Hyundai Mobis ( with Kia) | Hyundai Mobis | Hyundai Mobis | Sorento, Opirus 2002 |

**Table 5**. Main subassemblies of Kia Motor Whasung yard

| Parts | Main subassembly composing parts | Final assembler | Delivery form | Major supplier |
|---|---|---|---|---|
| Door | Molded material<br>Basic material: speaker, lamp, etc. | Kia Press<br>Kia's own door teams | Delivered to subassembly line in the yard | Kia Motor & Hyundai Motor |
| Instrument panel | Meter board and attached parts<br>Plastic parts<br>Air condition module | Hyundai Mobis for cockpit module | Delivered to sub-assembler in industrial park. | Hyundai Mobis |
| Sub-frame | Front chassis<br>Rear chassis | Hyundai Mobis | Same as above | Hyundai Mobis |
| Seat | Seat<br>Seat and periphery parts | Outside makers (made outside of the yard) | Delivered to outside makers nearby | Big 1st tier supplier A, B |
| Engine | Machined<br>Unit-assembled | Kia engine dept. Kia assembly dept. | Synchronized delivery | Kia Motor |

**Table 6**. Activity and arrangement of modularization at China Motor (Taiwan)

| Management / Part & Module | Activity and arrangement | | | | | Model types & beginning year of application |
|---|---|---|---|---|---|---|
| | Selection of suppliers | Approval & quality control | Setting of parts/module price | Assembly | Supply chain management | |
| Parts: | | | | | | |
| Sub-frame (yard made) | China Motor & Mitsubishi | China Motor & Mitsubishi | China Motor | China Motor | China Motor | Mitsubishi model |
| Door (yard made) | China Motor & Mitsubishi | China Motor & Mitsubishi | China Motor | China Motor | China Motor | Mitsubishi model |
| Engine (purchased) | China Motor & Mitsubishi | Mitsubishi | China Motor & Mitsubishi | Supplier | Supplier | None |
| Instrument panel (purchased) | China Motor & Mitsubishi | China Motor & Mitsubishi | Supplier & China Motor | Supplier | Supplier | Mitsubishi model |
| Seat (purchased) | China Motor & Mitsubishi | China Motor & Mitsubishi | Supplier | Supplier | Supplier | Mitsubishi model |
| Cockpit module | None | None | None | None | None | None |
| Sub-frame module | None | None | None | None | None | None |

Savrin New Galant Virage Lancer

**Table 7**. Main subassemblies at China Motor (Taiwan) Yang-Mei yard

| Parts | Main subassembly composing parts | Final assembler | Delivery form | Related maker |
|---|---|---|---|---|
| Door | Molded material<br>Basic material & speaker, lamp etc. | China Motor press line<br>China Motor doorless line | Delivered to subassembly line in the yard | China Motor (Taiwan) |
| Instrument panel | Meter board and attached parts Plastic parts Air condition parts | Different part makers for different auto types | Delivered to sub assembler near by | Small 1st tier supplier A, B, C |
| Sub frame | Front sub frame<br>Rear sub frame | Yard made for passenger car purchased for business car | To subassembly line in the yard (delivery by order) | Small 1st tier supplier D |
| Seat | Seat<br>Seat and attached parts | Outside maker | To sub assembler near by | Small 1st tier supplier E |
| Engine | Machined parts completed units | Mitsubishi Motor and Xin-Zhu Yard | To major assembly line in Yang-Mei yard | Mitsubishi & China Motor Engine Dept. |

**Table8**. Comparison of modularization by South Korean and Taiwanese automakers

| Country<br>Element | South Korea | Taiwan |
|---|---|---|
| Product architecture | Modular product | Multiple integral products |
| Organization architecture | Integral organization | Modular organization |
| Major driving force | Large-scale part supplier in the same Chaebol business group | Final assembler & foreign technical supporters |
| Core competence | Gaining synergy effect by using Chaebol as facilitator for group success | Ability to collaborate with and learn from multiple brand-name automakers |