論文の内容の要旨

# Abstract

**Title: Architectural Attribute of Component and Transaction Pattern Choice**
（部品のアーキテクチャ的特性と取引パターンの選択）

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This thesis attempts to explore the conditions under which the transaction patterns of components design are strategically chosen during product development. We mainly examine the assembled products with relatively high complexity such as automobile and motorcycle. Especially within the setting of transaction dyads, we try to tackle that why diverse patterns still exist between a fixed pair of assembler and supplier.

The transaction patterns under the spotlight here refer to (1) Drawing supplied (DS) system (貸与図方式), (2) Drawing entrusted (DE) system (委託図方式), (3) Drawing approved (DA) system (承認図方式) and (4) Purchased parts system（市販品方式）. Such classification is made by previous studies on product development in the automobile industry (Asanuma, 1988; Clark and Fujimoto, 1991; Fujimoto, 1997).

**Figure 1 Taxonomy of Transaction Patterns**

| Ownership of Design Drawings: Supplier / Assembler | Assembler | Supplier |
|---|---|---|
| | | Purchased Parts & Design-approved (DA) System |
| | Design-supplied (DS) System | Design-entrusted (DE) System |

Detail Design Task Fulfillment

As Figure 1 shows, the choice of transaction patterns can be regarded as the

make-or-buy decision of component's detail design. Because detail design is essentially a trial-and-error process and is crucial to determine product's cost and quality (Pahl and Beitz, 1984; Ulrich and Eppinger, 1995), managing the division of labor across firm's boundaries has remarkable strategic meaning to product development management (Womack et al. 1990; Clark and Fujimoto, 1991; Nishiguchi, 1994).

Within the dyadic transaction setting, the explaining power of the factors such as asset specificity, inter-firm relationship, and relational skill (Asanuma, 1989) is not enough to explain the observed diverse patterns. Therefore, we introduce the perspective of product architecture to explore additional conditions underlying the strategic choice of transaction patterns. Product architecture is "the scheme by which the function of a product is allocated to physical components and by which the components interact" (Ulrich, 1995). Consisting with the steps of engineering design methodology, the concept of product architecture contains three elements: (1) the arrangement of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components. Accordingly, in this paper, the architectural attributes of components are specified in terms of the degree of the inter-component functional and structural interdependence.

We propose that transaction patterns as alternative coordination mechanisms should be aligned with the architectural attributes of components. When the inter-component functional and structural interdependence is low, the merits of design outsourcing and the high-powered incentive to suppliers can be realized without less coordination costs. On the other hand, when there are high degrees of functional and structural interdependence, the measurement and monitoring costs of identifying design responsibilities and the adjustment costs during design changes will favor the centralized coordination. The Drawing-supplied

system is likely to be chosen.

Two field studies are carried out. One is on the transactions between Toyota and one of its suppliers in Japan. We adopted the method of hypothesis testing and statistically examined whether architectural attributes of different auto parts influenced the transaction pattern choices. Functional integrity and internal complexity were two significant results, which partially supported our propositions.

The other field study is done on the motorcycle industry of China. We found that even the same component, frame or cowling parts for example, is transacted under different patterns within a transaction dyad. As the case unfolded, we saw that the different patterns for transacting the same component stemmed from the different ways of imitating the same focal model during the reverse engineering-based product development. In the case of assembler-led top-down reverse engineering, the drawing-supplied system was chosen because the integral architectural of the focal model calls for close coordination. But when suppliers can imitate the focal model's component independently and exert the bottom-up efforts of localized integration --- coordination of the physical interfaces in the neighborhood around its main products to facilitate assembly, the so-called architectural transformation took place during which the specific design of the focal model's components was changed to the relatively standardized, or quasi-open one. The motivation of suppliers to carry out such localized integration is to acquire higher margin in the transaction similar to the drawing-approved system, and further to achieve open transactions via purchased parts system with more assemblers.

Although the natures of product development in Toyota and in the Chinese motorcycle assemblers are different, by exploiting the apparatus from the engineering design methodology (Pahl and Beitz, 1984), we can treat the different development processes as

the contrasting cases. While new product development in the Japanese auto industry is a forward engineering process starting from functional requirements and then followed by a mapping procedure to the physical auto parts, the imitating activities in the Chinese motorcycle industry are a reverse engineering-based process beginning with the decomposition of focal model's physical structure and then followed by an exploration of the functioning mechanism behind.

The results from two empirical studies imply different industrial dynamics from the matching of architectural attributes of components and transaction patterns choice. The function-oriented approach adopted by Toyota implies the sophisticated system design capabilities of the company. While encouraging suppliers to participate actively into the early stage of development, Toyota retains the evaluation capabilities based on the knowledge of functional structure and chooses the transaction patterns according to the optimal functional design of the automobile system.

By contrast, the matching of quasi-open attribute of motorcycle components and purchasing parts system in the Chinese motorcycle industry creates paradoxically phenomenon. As the entry barrier became lower due to the easy procurement and assembly of the focal model's components, the industry and the low-end market has expanded at an astonishing speed. Nevertheless, rare production differentiation made price war inevitable. The industry then has been driven into a vicious circle in which the motivations of exploring the functional structure of the focal model and creating original products are severely impaired. We call this phenomenon the technological lock-in because firms get stuck in the middle way of the reverse engineering process.

Therefore, this paper shows that the architectural attributes and transaction pattern choice are two endogenous variables complemented with each other calling for strategic

coordination. The interactions between the design decisions on the component's architectural attributes and the choice of transaction patterns can lead to multiple paths that both continuous improvement and lock-in are possible.

The originality and contributions of this study are:

(1) Explicit focus on design outsourcing by looking at the generation and ownership of detail design drawings;

(2) Using the dyadic setting to highlight the architectural attributes while controlling other explaining variables during explaining the transaction patterns choice;

(3) Approaching the architectural issue by examining the interrelationship between functional and structural elements on the basis of engineering design methodology;

(4) Illustrating the dynamics generated from the complementarity of design and procurement strategies; and

(5) Incorporating the analysis of the reverse engineering oriented process which is rarely found in the previous studies. It is believed to shed some new light on the study of the dynamics of catch-up activities in developing countries.

In the future study, we want to use not only function-form diagram, but also some more tractable apparatus such as function-form matrix to make rigorous quantitative studies. The research subjects will also be expanded from the integral one such as automobile and motorcycle to the products with a variety of design attributes.