International Journal of Information Management 32 (2012) 479–488

Contents lists available at SciVerse ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt

Product architecture, organizational capabilities and IT integration for competitive advantage

YoungWon Park[a], Takahiro Fujimoto[b], Paul Hong[c,*]

[a] Waseda Institute for Advanced Study, Waseda University, Japan, 1-6-1 Nishi Waseda, Shinjuku-ku, Tokyo 169-8050, Japan
[b] Graduate School of Economics, Faculty of Economics, The University of Tokyo, Japan, Kojima Hall 5F, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[c] Information Operations and Technology Management, College of Business and Innovation, University of Toledo, Toledo, OH 43606, USA

ARTICLE INFO

Article history:
Available online 12 January 2012

Keywords:
Organizational capabilities
Product architecture
CAD Usage
Information integration
IT system effectiveness
Japanese and Korean Electronic Manufacturers

ABSTRACT

Increasingly, firms recognize the strategic implications of front-end product design for improving total cost effectiveness. Computer-aided design (CAD) is becoming firms' competitive weapon beyond its traditional function as a product design tool. Yet, it is unclear how the full potential of IT system, particularly the usage patterns of 3D CAD system, may be realized through organizational capabilities. This paper presents a model of IT system configurations and CAD usage patterns. Next, a typology of IT system configurations is presented based on (1) the degree of CAD integration between assembly makers and suppliers and (2) the structure of product design information (i.e., product architecture). The product architecture of four electronic firms illustrates that information integration through organizational capabilities is more important than IT investment itself. The findings suggest that a Korean firm accomplishes a greater level of IT integration compared to the other two Japanese firms and thus attain better market performance. This study offers valuable insight on effective IT integration strategy for competitive advantage in the global market.

1. Introduction

Many IT researchers have focused their attention on the IT's enabling roles of business processes, IT's impact on organizational outcomes, and IT's contribution in creation of business opportunities (Davenport, 2000). Even after years of massive investment on building IT system infrastructure, many Japanese firms have not reaped the benefits in terms of desirable economic and financial outcomes (Park, 2004). Eighty percent of total costs of products is determined between concept design and production stage (Bae, 2003). Increasingly, the strategic attention of many firms is moving toward exploring IT effectiveness in the context of product architecture and organizational capabilities (Fujimoto, 2006a). 3D Computer-aided design (CAD) in particular is no longer a mere product design tool. Instead, it is becoming a strategic core competence (Fujimoto, 2006a; Ku, 2003; Takeda, 2000; Tan & Vonderembse, 2006).

An examination of the usage patterns of CAD system in Japanese auto industry and electronic industry shows noticeable differences. Major Japanese automakers have implemented integrated product development that reflects the high level of dependence among component parts suppliers (Clark & Fujimoto, 1991). Many auto-suppliers commonly use the same CAD systems of their original manufacturers. On the other hand, consumer electronic product manufacturers adopt modular product development because the level of dependence among their component parts suppliers is relatively low. The majority (e.g., 70% or more) of electronic suppliers use diverse CAD systems as they see fit. Since new product development processes reflect the interactions between assembly makers and suppliers, the above differences suggest quite distinct patterns of IT system usage in the two industries. Therefore, an effective IT implementation requires strategic fit with the firm's product architecture and corresponding innovative organizational processes. Otherwise, the potential value of IT remains buried deep within the organizational system.

2. Product architecture and 3D CAD system

2.1. Structure of product architecture

In general, product-process architecture is "the overall mapping to envision and identify product functions and distributes them through common elements, essential processes and critical interfaces through which vital information and value creation opportunities are shared and realized" (Fujimoto, 2003). In other words, product architecture is the sum of the basic concepts that

* Corresponding author. Tel.: +1 419 530 2054; fax: +1 419 530 2290.
E-mail addresses: ywparkjp@gmail.com (Y. Park), fujimoto@e.u-tokyo.ac.jp (T. Fujimoto), Paul.Hong@Utoledo.edu (P. Hong).

0268-4012/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijinfomgt.2011.12.002

link together all core components of a product. The choice of architecture determines the essential rules on (1) how to realize desirable functions of the product, (2) how to divide them into different components, and (3) how to design the interfaces among the component parts (Fujimoto, 2003).

Fig. 1 shows how global electronic firms construct their product architectural strategy. Business processes include product development-commercialization-support that involves diverse functions and require the integrative link between vital functional architectures (i.e., product architecture, production architecture and marketing-logistics-service architecture). Such business architectures build on organizational architecture that reflects organizational, learning and innovational capabilities. IT tool, 3D CAD in particular, represents technological capability. Technology matters but strategy governs the use of technology. An effective business strategy requires a keen insight of top management. Such vital insight requires new business models that define the essential nature of problems and provides a clear sense of direction. This study, through the theoretical model and case illustrations, might be useful for electronic firms that are in serious search for better business models for their global competitive advantages.

Major classifications of product architecture are – modular or integral, open or closed (Baldwin & Clark, 2000; Fine, 1998; Fujimoto, 2003; Ulrich, 1995). Fujimoto (2003) used two parameters for classification purpose. The first one is modular-integral axis. Modular architecture refers to 1:1 relationship between function and module. Each component is self-sufficient and highly independent with little need for interactions. The issues of interfaces are simple and therefore easy to resolve. Integral architecture refers to products that are highly related between functional groups and component parts. Automobile is a typical example. Functions such as noise and vibration are important for the comfortable feeling for a ride. For such desirable functions, many component parts work together as a total system and display the effect. The relationships between functions and components are not one on one but many to many. Designers of each module must closely interact to work out all the details.

It is worthy to mention two types of product architecture here. Closed-integral type fits to products such as automobile, luxury motorcycles, TV game software and high-end copiers. Closed-modular type is about mainframe computers (e.g., IBM System 360), standardized machine tools and Lego (block toy). Open-modular type displays the product characteristics of bicycle and desktop PC. In case of Mobile PC, however, its architectural characteristics may be different depending upon the layers and positions in the product-component hierarchy. For an example, Intel microprocessor in a PC is open to other component parts but its content is not divisible as open-module. A battery in typical American cars (as an automobile functional part) shows open-modular characteristics with its interfaces standardized across the auto firms. Auto-suspension, on the other hand, is interdependent and its interfaces are complex.

A product as a whole may be combined with different architecture types. According to Fujimoto (2003), a certain product may not be classified as either modular-integral or open-closed. In general, product function and product process structure might be explained in hierarchical manner. Modular-integral classification in this model merely shows two extremes of product functions and structures for our analysis purpose. Nobeoka, Ito, and Morita (2006) also classifies modular characteristics of electro-digital products within the wide range between closed-integral to open-modular. In this paper, we use the modular/integral and open/closed classifications by Fujimoto (2003) and Nobeoka et al. (2006).

2.2. Relationships between CAD and product architecture

2.2.1. CAD usage and impact on organization in new product development

To further explore the relationships between product architecture and CAD, we now consider 3D (three-dimensional) CAD usage and its impact on characteristics of product development organizations. 2D (two-dimensional) CAD mostly focuses on efficiency of internal design activities. Digitalization of product information has partly been realized in 2D CAD. On the other hand, 3D CAD with the function of solid modeling has the capacity to visualize images of physical products in a realistic way. As a result, introduction of 3D CAD system caused fundamental changes in product development processes, development task definitions and designer skill requirements (Adler, 1989; Baba & Nobeoka, 1998; Aoshima, Nobeoka, & Takeda, 2001). Many Japanese firms have used 2D CAD simply for replacing design drawings with electronic design data without changing their product development processes. As numbers of engineers who can read complex design drawing decrease, they started to rapidly introduce 3D CAD systems. However, 3D CAD usage has not yet impacted changes in internal design activities, choices of process technology and analytical methods (Aoshima et al., 2001). Tan and Vonderembse (2006), on the other hand, analyzed the integrative effects on marketing, design and manufacturing by the use of 3D CAD system. 3D CAD also simplifies the information transfer process in new product development (Aoshima et al., 2001).

3D image definition allows each development group to change database on the common database (Aoshima et al., 2001). With 3D CAD use, it is possible for sharing information cross-functionally among engineering, marketing, and manufacturing (Koufteros, Vonderembse, & Doll, 2001). As design information

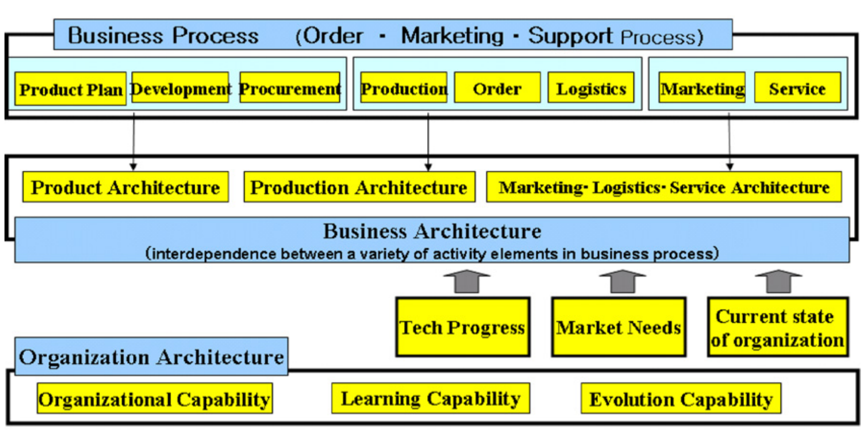

Fig. 1. Architecture strategy.