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New Product Development and Evaluating Capabilities: The Case of the Material Industry

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Abstract: Effective new product development (NPD) is one of the most important processes firms should undertake in order to achieve a competitive advantage This paper will analyze the NPD process and explore organizational capabilities by presenting two case studies of the material industry. These analyses demonstrate that it is significant for material suppliers to evaluate not only material specifications but also the production process of their users and the performances of the users' products (system products). We call this "evaluating capabilities" and propose that knowledge beyond the business domain is necessary to achieve a competitive advantage.

Keywords: new product development (NPD), organizational capabilities, evaluating capabilities, material industry

1. NPD and evaluating capabilities

The purpose of this paper is to analyze the new product development (NPD) process and to explore organizational capabilities, especially "evaluating capabilities," which aid in achieving competitive advantage, and how to build them in the material industry.

NPD is one of the most important processes firms should undertake in order to achieve a competitive advantage. How does a firm develop a new product effectively? In addition, what types of organizational capabilities help achieve competitive advantage?

Research on NPD management began in the 1960s, where it focused on common factors for success in NPD projects across the manufacturing industry. It also focused on the NPD process and the

* This article is an English version of Tomita (2007) with certain modifications.

effective NPD patterns and organizational structures in certain industries, such as the automobile, electronics, or software industries, since the 1980s (Fujimoto, 1989; Fujimoto & Yasumoto, 2000; Kuwashima, 2002).

On the other hand, there has also been some empirical research on the organizational capabilities of the NPD process. For example, Henderson and Cockburn (1994) empirically analyzed the source of competitive advantage in the pharmaceutical industry. They analyzed five thousand NPD projects and revealed that it was a source of competitive advantage to build "architectural competence," which could combine or integrate "component competence," to solve a routine task problem.

Kusunoki, Nonaka, and Nagata (1995) empirically analyzed the organizational capabilities of Japanese firms. They indicated that organizational capabilities are consisted of three layers of knowledge. The lower layer consists of "local capabilities" that are based on the individual knowledge of the engineer. The middle layer consists of "architectural capabilities" that aid the engineer in designing the organization or implementing task partitioning based on "local capabilities." The higher layer consists of "process capabilities" that combine existing knowledge and translate it into new knowledge through interaction among the engineers. They concluded that the source of competitive advantage lay in the developing of "process capabilities."

Takeishi (2003) empirically analyzed effective supplier management in the automobile industry and discovered that it was effective for automobile manufacturers to build and evaluate organizational capabilities or the so-called "evaluating capabilities" of suppliers.

Evaluating capabilities are also important for suppliers such as component or material suppliers. Barnett (1990) empirically analyzed effective NPD in the material industry and discovered that it was effective for material suppliers to evaluate the users' production process or products in which materials are embedded, technologically.

This result is also consistent with our analysis of the chemical industry (Fujimoto, & Kuwashima, 2002; Fujimoto, Kuwashima, & Tomita 2000; Kuwashima & Fujimoto, 2001) wherein we empirically analyzed the success factors of NPD projects in the chemical industry. Successful projects had a higher average rate of technologically building evaluating capabilities than did failed projects.

Thus, previous research indicated that it was important for a firm to build their evaluating capabilities. However, there has been little in-depth discussion on this matter and about how a firm accumulates these capabilities. Therefore, this paper explores evaluating capabilities in detail and tries to determine how to build them in the NPD process in the material industry. We analyze the following two NPD cases: material for high refractive plastic glasses lenses, named "MR-6" and superabsorbent polymers for disposable diapers, named "AQUALIC CA."

2. Case study A: NPD of “MR-6”

2.1. Product

In 1987, Mitsui Chemicals Inc. launched “MR-6” into the market as a material for high refractive plastic glasses lenses (HRPGL). It was used not only locally but also in other countries because of its superior features such as high refraction, easiness of molding, and easiness of dyeing. It also contributed to the diffusion of the plastic glasses lenses market in Japan, US, and Europe. Mitsui Chemicals was a leader in its global market, and its share of MR series including “MR-6” constituted about 70% of the material market for HRPGL in 2004.

2.2. Background of the NPD

In 1982, Tokuyama Corp., the rival of Mitsui Chemicals, became a worldwide pioneer in the development of materials for HRPGL in collaboration with Seiko Epson Corp.—a lens manufacturer. However, the monopoly-supply contract between Tokuyama and Seiko Epson prevented other lens manufacturers from obtaining the material. Subsequently, other major lens manufacturers ordered the material for HRPGL from Mitsui Chemicals. In 1982, a researcher at the central research institute and an engineer in the development section of Mitsui Chemicals began to develop the lenses.

Theoretically, the introduction of benzene or halogen atoms, without fluorine or sulfur atoms, or the introduction of the atom of a heavy metal into the molecule structure of the material increases its refractive index. However, the heavy metal atom had a defect due to its high gravity. Therefore, most researchers tried three alternative approaches. Tokuyama achieved a refractive index of 1.595 by introducing benzene and the halogen atom (bromine) simultaneously.

Mitsui Chemicals also has experience in the development of materials for plastic glasses lenses (PGL) for developing fine chemicals since the late 1970s. However, they were developing material for HFPGL for the first time. The researcher and engineer tried to introduce benzene and a halogen atom but were unable to develop materials that would achieve the target performance for three years. They faced some resistance from the management board, but the research manager encouraged them to conduct further research and shouldered the responsibility for the result.

2.3. Material concept

In the meanwhile, a researcher at the Omuta factory tried to apply for the patent of the material for PGL. His research results revealed that the use of polyurethane in the formation of PGL was successful. Mitsui Chemicals had accumulated the technology of polyurethane since a long time. It was suitable for PGL because of its superior resistance against being crushed but was not sufficient to ensure the transparency and high refractive index of the PGLs. The researcher focused on these two points.

First, he improved the transparency by using non-yellowing monomers (isocyanate). Second, he increased the refractive index by introducing the sulfur atom, in other words, by using polythiol. Therefore, it was called “thiourethane material.”

The researcher at the central research institute and the engineer from the development section also focused on this concept and repeatedly created prototypes. As a result, they discovered that a combination of two types of monomers (Isocyanatomethyl benzene and Pentaerythritol tetrakis β-thio-propionate) was most suitable for HFPGL.

2.4. Market cultivation

In 1987, Mitsui Chemicals succeeded in developing the material for HRPGL. They named it “MR-6” and supplied prototypes to lens manufacturers. Some of them evaluated its high refractive index of 1.594 and decided to buy it because its balance among high refractive index, high abbe’s number (low chromatic aberration), and resistance to crushing was superior to the material provided by rival companies.

However, the users of “MR-6” faced several problems in their production process. It was molded by cast polymerization similar to the existing “CR-39” material, but their chemical characteristics were quite different from each other.

For example, some bubbles were generated inside the molded lens by including only a little water in the case of “MR-6,” but this did not pose a big problem in the case of “CR-39.” The liquid characteristic of “MR-6” was also changed before pouring it into the lens cast when combined with a polymerization catalyst. It was also difficult to remove the lens after polymerization because its adhesiveness to the cast was very strong.

Therefore, Mitsui Chemicals proposed a new cast polymerization system by drawing up evaluation contracts with each user. They accumulated cause-and-effect knowledge from “MR-6” to HRPGL by supplying prototypes to their users and obtaining their feedback data. They solved these problems in the following manner. First, they solved the bubbles generation problem by proposing a method wherein it would be unnecessary to include water. Second, they solved the liquid characteristic changing problem by using the catalyst with slower polymerization. Third, they solved the difficulty of removing the lens by adding a special mold release material. These solutions enabled the users to mass-produce HRPGL.

2.5. Market globalization

Mitsui Chemicals also planned to sell “MR-6” globally because of the lack of users in Japan, thereby increasing its competitiveness.

After one of the major users adopted “MR-6,” Mitsui immediately sold the product to other users and increased their domestic market share. They learned from their rival who was part of the monopoly-supply contract and did not increase the market share. They also succeeded in increasing their global market share

In 1991, they developed the “MR-7” with a higher refractive index of 1.67. Subsequently, in 1998, they developed "MR-8" with a higher abbe's number. They also got more than 200 patents. As a result, Mitsui Chemicals captured the top share of the global market for a while.

2.6. Building evaluating capabilities

The key factors for success of the MR series were product superiority itself, the development of a successive series of products, and a large number of patents. Besides, Mitsui Chemicals built evaluating capabilities in close communication with its users.

Initially, they did not have knowledge about the molding of lenses. Hence, they tried to accumulate cause-and-effect knowledge from the use of "MR-6" in lenses in the molding process of the users by drawing up an evaluation contract.

For example, they supplied prototypes to the users and obtained relevant feedback data. Often, engineers directly visited the users' factories and attempted to solve the problems. They also evaluated, in-house, not only the knowledge of the characteristics of "MR-6" but also the functions of the lens, such as optical uniformity and transparency. They learned the necessary conditions under which to precisely and efficiently mold the lens. As a result, they succeeded in developing the successive MR series and sustained their competitive advantage.

3. Case study B: NPD of "AQALIC CA"

3.1. Product

In 1983, Nippon Shokubai Co., Ltd. launched AQUALIC CA into the market as a superabsorbent polymer (SAP) product. AQUALIC CA is a type of powdered polymer that is a light cross-linked acrylic acid polymer. It was used not only locally but also in other countries because of its superior features such as free absorbency, high maintenance capacity, high complementarities, and low cost. Nippon Shokubai was one of the leading suppliers in its global market; its share was about 25% in 2004.

3.2. Background of the NPD

Nippon Shokubai began to develop a new material for sanitary napkins after an order from one of the major sanitary manufacturers in the late 1970s. However, they could not develop it because of a problem that had occurred at the mass production stage.

In 1978, they changed their development objective for disposable diapers. Three researchers who had tried to develop material for sanitary napkins also started to develop a new material.

In the initial stage of development, SAP was also used in a method wherein it was mixed with flocculent pulp in manufacturing disposable diapers. First, the manager proposed a method of immersing an acrylic acid monomer into the flocculent pulp by employing a special mixer. However, due to certain problems in the process, the method was not successful.

Subsequently, one of the three researchers discovered another method involving the polymerization of a monomer-water solution alone using a special mixer designed for different purposes; the process was successful. This was in 1980. This aqueous-solution polymerization method was an epoch-making manufacturing method that dramatically improved the productivity of SAP.

However, a problem in the absorption mechanism was soon detected. Specifically, the disposable diaper became wet and sticky at a single point subjected to the weight of the baby after it had absorbed urine, making proper absorption impossible. In order to ensure that the urine was absorbed properly, it was necessary to disperse the urine evenly throughout the diaper.

One of the researchers suggested making the surface of the gel particles “as hard as an eggshell”; moreover, he proposed a method of cross-linking the gel by adding a food additive to the polymerized particles. If the surface of the gel, which absorbed water, is solid, gaps between the gel particles are easily created making uniform dispersion easier. As a result, the surface was successfully cross-linked using this method, thereby considerably increasing its absorption capacity.

3.3. Chance and risk for a large contract

In 1983, Nippon Shokubai succeeded in developing a new SAP for disposable diapers, and they named it “AQALIC CA.” In the same year, an inquiry for 10,000 tons of SAP arrived from another major global sanitary product manufacturer. The production of 10,000 tons of SAP was extremely large for mass production in the functional polymers industry where an annual production of a mere 1,000 tons was considered large.

The researchers attempted to find a new manufacturing method to further improve productivity. They began to develop a continuous polymerization method using various approaches. Subsequently, one of the researchers suggested applying an automatic sushi-making robot technology and developed a prototype polymerization system, which turned out to be highly practical.

Nippon Shokubai shipped prototypes to their users for evaluation of the performance of AQUALIC CA produced by the continuous polymerization method and received approval with regard to the specifications of their user in February 1984. Subsequently, they contracted an agreement to deliver 10,000 tons of AQUALIC CA and began constructing a new production facility at the Himeji Plant.

However, their user requested Nippon Shokubai to increase the order by an additional 10,000 tons bringing the order to a total of 20,000 tons, 3 months later. A majority of the Nippon Shokubai directors opposed this request, insisting that the risks were too high. Finally, the president of Nippon Shokubai received the approval of the board and contracted the agreement for an additional 10,000 tons.

By then, the new facility at the Himeji Plant, which had a production capacity of 10,000 tons, was almost complete. Subsequently, they received a telex from their user reporting that they had detected a serious problem. The message stated that the performance of Nippon Shokubai's SAP was inferior to that of its rival products.

Nippon Shokubai faced the risk of losing their new 10,000-ton facility investment leaving the entire company in a difficult situation. The research manager immediately instructed his staff to improve the continuous polymerization method without any changes to the production facility. As a result, they discovered that the productivity could be improved by using the conventional batch-polymerization method.

The user repeatedly implemented a prototype test using babies as test subjects and this proved that AQUALIC CA was overwhelmingly superior in performance to the rival products.

3.4. Becoming a de facto standard

Since their user—the world's largest sanitary product manufacturer—had decided to use AQUALIC CA, major material suppliers throughout the world followed Nippon Shokubai's methods with regard to the use of acrylic acid as a raw material, the adoption of the aqueous solution polymerization method, and the surface cross-linking method. Thus, AQUALIC CA became the de facto standard in terms of both production and manufacture.

The production of AQUALIC CA has steadily increased in Japan since 1985. Production capacity grew at a rate of 10,000 tons annually until 1988. Subsequently, in 1990, Nippon Shokubai began production abroad. The global demand for SAP increased at an annual rate of more than 10%; Nippon Shokubai expanded its production capacity to meet this rising demand. The company boasts the world's largest production capacity, amounting to 320,000 tons, annually, from facilities that include a plant under construction in China and other plants in Japan, Europe, and the United States that are currently being expanded.

3.5. Building evaluating capabilities

As mentioned above, the production of AQUALIC CA increased with the growth in demand. The key factors for success were the product superiority itself and developing various production methods such as aqueous solution polymerization method and surface cross-linking method. Besides, Nippon Shokubai built evaluating capabilities that the company had developed ahead of its competitors.

The simplest evaluation method used for testing disposable diapers is the teabag method. In this method, a teabag is first emptied and is subsequently filled with the prototype polymer and immersed in water. Then, its weight is measured to determine its absorption strength. This method was first developed by Nippon Shokubai and is now widely used throughout the world.

The test of absorption strength under constant pressure is considered as most important for disposable diapers. A diaper is subjected to pressure when a baby is lying down; therefore, it should be able to properly absorb urine under such pressure. Further, the absorbed urine has to uniformly disperse throughout the diaper. Nippon Shokubai focused on such functions in the initial stages of development and developed the surface cross-linking technology well before diaper manufacturers requested for such specifications.

Using this pressure test, the analyses by Nippon Shokubai proved that the request by diaper manufacturers for faster absorption speed was, in fact, erroneous. The absorption speed was generally considered as “the faster, the better.” However, a polymer that hardens within a short period, if used in a diaper, will intensively absorb urine at only one point where the urine has directly seeped into the diapers. This decreases the life span of the diaper, even though the absorption speed increases. Nippon Shokubai learned through the tests that the polymer used in a diaper should gradually absorb and disperse the liquid throughout the diaper and facilitate the drying up of the absorbed liquid.

Later, Nippon Shokubai came across another myth concerning absorption capacity, which was represented by claims such as “absorbs 1,000 times its volume.” A polymer is generally considered better if a larger amount of liquid can be absorbed by a smaller quantity of polymer. However, after absorbing the liquid, a polymer with high absorption capacity will swell and the liquid will become gel-like, similar to tofu. This gel-block problem prevents further liquid from being absorbed into the diaper. For this reason, Nippon Shokubai reduced the absorption capacity to only 300–400 times its volume.

Even if the specifications provided for the polymer are met, it does not necessarily guarantee that the performance of the diapers will be satisfactory. Since diapers are used over extended periods, they need to repeatedly absorb urine instead of only once. Specifications generally define values that apply to momentary use; however, it is also necessary to collect evaluation data pertaining to long-term use.

Subsequently, Nippon Shokubai developed and improved its SAP by understanding the potential needs of babies with respect to disposable diapers; moreover, it offered these new features and improvements to disposable diaper manufacturers while building their evaluating capabilities by collecting feedback data.

This suggests the importance of such perspectives as an end-user oriented approach (Tomita & Fujimoto, 2005) or “customers of customers” strategy (Kuwashima, 2003), which takes into consideration the hierarchical nature of customer relationships. Specifically, in developing its products, Nippon Shokubai, a SAP supplier, not only had to attend to the requests from diaper manufacturers—its immediate customers—but also had to consider the performance of the diapers that were actually used by babies—the end-users of the diapers.

4. Discussion

This section discusses the evaluating capabilities in detail. Case study A showed that one of the key success factors for developing "MR-6" was increasing the yield in the lens molding process. Mitsui Chemicals tried to build evaluating capabilities by supplying prototypes and obtaining feedback data. This logic is consistent with the fact that it is important for material suppliers to evaluate the production process of the user's product in which the material is embedded (Barnett, 1990).

Case study B showed that the key success factors for developing AQUALIC CA included not only the high performance of the product, but also the increasing performance of disposable diapers under pressure when used by babies, by understanding the requirements of SAP in advance. Nippon Shokubai tried to develop their evaluating capabilities by supplying prototypes and obtaining feedback data. This logic is consistent with the fact that it is important for material suppliers to evaluate the performance of the user's product in which the material is embedded (Barnett, 1990).

These two cases imply that since users do not build sufficient evaluating capabilities to appropriately evaluate and use raw materials embodying a novel technology, material suppliers have to build evaluating capabilities by maintaining close communication with their users from the early stages of NPD in order to gain a competitive advantage. These cases should prove to be valuable in helping material suppliers implement effective NPD management.

In other words, they require the knowledge and expertise beyond their business domain. Brusoni and Prencipe (2001) indicated that a firm, without integrating the total system of a product, could not succeed in the NPD of an aircraft engine, for example. They further insisted that a firm also required to accumulate technological knowledge beyond its business domain.

It could be also helpful to consider adequate division of labor between suppliers and system product manufacturers. New system products development requires both component knowledge and architectural knowledge, which integrates multicomponents or equipments (Henderson and Clark, 1990).

Generally speaking, component suppliers have component knowledge, while system manufacturers have architectural knowledge. However, if innovative technology is required for system product innovation like in the case of the auto industry, broader and deeper knowledge is required for components innovation (Takeishi, 2003). Therefore, component suppliers also have to build evaluating capabilities in close communication with their users from the early stages of NPD.

As mentioned above, both the case studies involved NPDs by the follower firms, but their technologies were innovative enough for the suppliers and system manufacturers. Therefore, both parties required knowledge beyond their products or business domain. As a result, there was close communication between them.

This logic implies that it could be effective for suppliers to build their evaluating capabilities and accumulate knowledge beyond the business domain in the early stage of innovative NPDs. For example, supplying prototypes and obtaining feedback data. They also sustain their competitive advantage by improving their product performance or developing the following products based on the evaluating capabilities

It could also be important for the system manufacturers to differentiate between their new products through close contact with the suppliers and by building their evaluating capabilities from the early stages of NPD.

5. Conclusion

This paper focused on organizational capabilities, especially the evaluating capabilities in the NPD process in the material industry and discussed them in detail. It also focused on how to build these capabilities by presenting two case studies.

Case study A showed that one of the key success factors was to evaluate the production process of the user's product in which the material was embedded. Case study B showed that one of the key success factors was to evaluate the performance of the user's product in which the material was embedded. This implies that knowledge beyond the business domain was indeed necessary to achieve competitive advantage.

It should be a valuable aid for industrial goods suppliers not as materials, but also as components, equipments to implement effective NPD management.

This paper also clarified the dynamic process of evaluating capabilities in the form of two case studies, since there had been little discussion earlier.

Of course, this paper analyzed only two cases, therefore, our conclusion was limited to generalize the cause-and-effect relationships between the competitive advantage and evaluating capabilities of a firm. We should try to empirically analyze evaluating capabilities in detail as organizational capabilities and explore the relationships with competitive advantage by collecting quantitative data.

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