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Standards, dominant designs and preferential acquisition of complementary assets through slight information advantages

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Abstract

This paper discusses how firms can use slight information advantages to obtain preferential access to complementary assets and create multi-level dominant designs. It does this by using an analysis of several cellular phone industries and the literature on standards and dominant designs. In the most prominent case, the leading Japanese cellular service provider (NTT DoCoMo) offered preferential information about the "open" Japanese digital phone standard in return for preferential access to the lightest phones from four phone suppliers. These four phone suppliers used the preferential access to this information to obtain preferential cooperation from parts suppliers and to make better design tradeoffs between parts than the other phone suppliers. These superior design tradeoffs enabled the DoCoMo suppliers to create various dominant designs within the Personal Digital Cellular (PDC) standard. The creation of these dominant designs forced other phone and part manufacturers to change their design strategies and copy the designs used by the DoCoMo phone and part suppliers. The result is that DoCoMo and its four phone suppliers have substantially reversed the slides in their market shares. By comparing this case with several other cellular phone industries in which different modes of competition exist, the paper discusses how market conditions determine the way in which standards and dominant designs emerge.

Keywords: Multi-level dominant designs; Preferential acquisition of complementary assets; Industry standard

1. Introduction

It is widely recognized that innovating firms can make above-average profits when their technology or products become an industry standard. Unfortunately, firms must often open their technology or product specifications in order to have them adopted as an industry standard. And since the opening of the technology can destroy their initial competitive advantage, many innovators attempt to create a competitive advantage in complementary assets.

Access to these specialized assets often has a greater affect on the success of firms than the early development of the technology, particularly in regimes of weak appropriability, which is a common situation. However, it is often difficult for the innovators to obtain preferential access to the best holders of complementary assets. Integration is not always possible and suppliers typically want to sell to all possible customers. Further, the suppliers may not be interested in making substantial irreversible investments at an early stage in the technology's development. Finally, the

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suppliers may take the lion's share of the profits if the complementary asset is a bottleneck (Teece, 1986).

This paper discusses how firms can use slight information advantages to obtain preferential access to complementary assets and create multi-level dominant designs. Although the literature on industrial standards typically represents a standard as a high-level interface specification for the product in question, literature on a similar concept, dominant design describes a more complex process of technology innovation. Following the emergence of a dominant design, problem solving moves into more detailed levels in the design hierarchy (Clark, 1985; Nelson and Winter, 1982). It can be said that this movement of problem solving to consecutively more detailed levels in the design hierarchy means that the dominant design is also expanding into more detailed levels of the design hierarchy.

Both the innovator and the holders of the complementary assets can reap the benefits from creating multi-level dominant designs. The innovator can receive preferential access to the complementary assets in return for preferential information and guarantees of heavy investments. But it must prevent the holders of the complementary assets from co-opting the profits by maintaining control over at least one technological aspect of the complementary assets. The holders of the complementary assets can benefit in this partnership particularly if their products also become a dominant design. This strategy has implications for both the dominant design literature where firm strategy is not typically emphasized (e.g. see Utterback, 1994) and current theories on tight customer–supplier relations where high co-asset specificity is recommended (Liker et al., 1996).

This paper uses a case from the cellular phone industry to describe the concept of dominant designs within standards. NTT DoCoMo, the largest provider of cellular phone services in Japan received preferential access to the lightest phones from four phone suppliers (Matsushita, NEC, Mitsubishi, Fujitsu) in exchange for preferential information about the Japanese digital phone standard (Personal Digital Cellular, PDC). NTT DoCoMo's four phone suppliers used the preferential access to this information to obtain preferential cooperation from parts suppliers and to make better design tradeoffs between parts than the other phone suppliers. These superior design tradeoffs enabled the DoCoMo suppliers to create the dominant design within the PDC standard. The DoCoMo suppliers were able to create this dominant design in spite of the fact that DoCoMo did not obtain more than 50% of the digital subscribers until almost 2 years after the new entrants had started their digital service.

The creation of the dominant design by the DoCoMo suppliers forced other phone and part manufacturers to change their design strategies and copy the designs used by the DoCoMo phone and part suppliers. This put the non-DoCoMo suppliers at a distinct disadvantage in terms of the severe weight competition that existed and has continued to exist in the Japanese market. The non-DoCoMo suppliers had much heavier phones than the DoCoMo-suppliers until 1998; 4 years after competition in digital handsets began.

The result is that DoCoMo and its four phone suppliers have substantially reversed the slides in their market shares in spite of the increasing number of competitors. In particular, DoCoMo has managed to obtain the majority of the profits by requiring its four phone suppliers to use one part of DoCoMo's technology in their phones (thus making it more difficult to sell to other carriers) and by promoting competition among them. Further, the superior brand image created by DoCoMo enabled it to continue obtaining more than 50% of the subscribers even after losing its weight advantage in 1998.

This paper first discusses previous research on technological innovation, industrial standards, dominant designs, and customer–supplier relationships. Second, it presents the pre-innovation situation in Japan's cellular phone market. Third, it describes DoCoMo's strategy and the response by its competitors. Fourth, it presents the results of these strategies and fifth it discusses why similar competitive situations have not arisen in other cellular phone industries both in Japan (Japan's Personal HandyPhone System (PHS) industry) and elsewhere (e.g. Europe's Global System Mobile (GSM) market). Sixth, it discusses the implications of this paper for the theory of dominant designs and supplier relations.

2. Background

It is generally recognized that technological change is accelerating and within this accelerated rate of technological change, the importance of technological discontinuities is increasing. Thus, the issue of how to recognize and adapt to these technological discontinuities is an increasingly important managerial challenge. In many of the information and telecommunication industries, firms must deal with a continuous stream of technological discontinuities (Anderson and Tushman, 1990; Christensen and Rosenbloom, 1995; Shapiro and Varian, 1999).

Technological discontinuities cause a period of ferment in which alternative product forms compete for dominance due to the large amount of market and technological uncertainty that exist following a technological discontinuity. Thus, innovation is relatively rapid and production processes are highly flexible and labor intensive. Eventually, however, the process of experimentation between the firm and the users of the product leads to the appearance of a standard or dominant design where standardized parts, software, and manufacturing equipment appear; these lead to both cost reductions and further increases in performance. Further, the appearance of a standard or dominant design also causes the competition to change from product or service performance to the effective use of complementary assets such as marketing, distribution, competitive manufacturing, and after-sales support. Thus, the firms that are successful in the pre-dominant design phase often fail once a standard or dominant design emerges unless they develop the appropriate complementary assets (Abernathy and Utterback, 1978; Abernathy and Clark, 1985; Anderson and Tushman, 1990; Christensen and Rosenbloom, 1995; Teece, 1986; Tushman and Anderson, 1986; Utterback, 1994).

The existing literature is not very clear on the differences between standards and dominant designs. Both concepts are similar in that they both reflect an established design or product/service concept. This similarity has become even more pronounced as the concept of de facto standards has been applied to a wider range of products and services. Historically, industrial standards have been thought of as formal documents that specify a technical approach to a specific interface; these documents were historically created in government–industry committees (Shapiro and Varian, 1999; Funk and Methe, 2001). However, the term is now often used where there is not a formal document that specifies the standard; specific foods, beverages, and fast food services are sometimes referred to as standards (Shapiro and Varian, 1999; Asaba, 1995).

In the existing literature, the major difference between standards and dominant designs is the way in which they emerge. In the industrial standard's literature, firm behavior and network externalities have a strong effect on which design becomes an industrial standard through the so-called bandwagon effect. Since the number of users has a direct effect on the value of the product, market share becomes a measure of quality and a rising market share increases the product's charm. Thus, the acquisition of an early installed base and the opening the standard in order to acquire an early installed base are accepted strategies for making your product or technology an industrial standard (Rofles, 1974; Oren and Smith, 1981; Farrell and Saloner, 1985; Katz and Shapiro, 1985; Asaba, 1995; Shapiro and Varian, 1999).

The dominant design literature is much less clear on how dominant designs emerge and how firms can make their products or technology a dominant design. The literature generally argues that technical factors play a more important role than network externalities and openness. This suggests that firms compete solely in terms of technology and the competition between alternative product forms is determined by technical factors and economies of scale (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Henderson and Clark, 1990; Utterback, 1994).

An exception is Thompson's (1954) article on the automobile industry where the largest firms used their economies of scale to influence inter-firm standardization activities. Small auto and part makers pushed for the standardization of materials like steel grades, simple parts like nut and bolt designs, and sub-assemblies like carburetors so they could obtain economies of scale. While large automakers also pushed for the standardization of materials and simple parts, they had sufficient volumes to make proprietary carburetors. By the 1930s, the standardization activities only emphasized materials and simple parts and the standards for more complex parts and subassemblies had disappeared.[1]

This paper defines standards as interface standards and dominant designs as product architecture and technical solutions. For example, the critical mobile phone standard is an air-interface standard because

[1] I am indebted to an anonymous reviewer for the reference and insights to the Thompson paper.

it defines the interface between mobile phones and base stations. Both phones and base stations can have dominant designs but they must work with the air-interface standards. Computers and other products often have standards that define the interface between hardware and software. For example, the operating system software defines the interface between the computer's hardware (e.g. a microprocessor in a PC) and application software while it can be said that dominant designs exist both in the microprocessor and application software.

This paper shows how firm behavior does determine the emergence of a dominant design and in doing so extends Clark's work on design hierarchies. Within the process of competition between alternative product forms, the logic of problem solving and the formation of concepts that underlie choice in the marketplace impose a hierarchical structure on the evolution of technology (Nelson and Winter, 1982; Clark, 1985). Thus, it can be said that alternative product forms compete at consecutively more detailed levels as a dominant design emerges at the previous level in the design hierarchy. And as the dominant design spreads to more detailed levels, problem solving becomes more interdependent and incremental. These incremental improvements enhance and extend the underlying technology and thus reinforce the existence of the dominant design at the higher levels in the design hierarchy.

As the dominant design spreads to more detailed levels in the design, it is likely that the design of interest will involves multiple levels of suppliers, i.e. complementary assets. Most discussions of dominant designs do not involve suppliers and complementary assets in spite of their recognized importance in the technology management literature. As mentioned earlier, access to complementary assets often determines the competitive outcome once a dominant design emerges. In most cases, contracting is considered the more appropriate strategy (Teece, 1986) due to the large investments and time that are required to create these complementary assets (Teece, 1986; Saxenian, 1994). However, there are several problems with contracting:

(1) suppliers may not be interested in taking a large risk so the innovator has to make the contract beneficial to the supplier;
(2) the suppliers may become competitors;
(3) the suppliers may take the lion's share of the profits particularly if the complementary assets are a bottleneck; and
(4) the imitators may have equal or preferential access to holders of complementary assets.

One solution to problems 2, 3 and 4 is to create the type of customer–supplier relationship that exist in the Japanese automobile and subsequently to some extent in the US automobile firms and firms in Silicon Valley. These firms make significant partner-specific investments that lead to high switching costs for both parties (Itami and Itami, 1984). The problem with this approach is that it requires a high investment by both parties (problem one) and it may not guarantee success for the participants.

An alternative, yet similar approach is to jointly create a multi-level dominant design. As the jointly developed product becomes a dominant design, by definition other firms use the product thus making it easier for large and risky partner-specific investments to be recovered. This solves the first problem. The second and third problems require firms to maintain control over certain aspects of the technology.

The fourth problem is more problematic. When firms open their technology in order to have it adopted as a standard they retain early mover advantages. By creating a dominant design at a detailed level in the design hierarchy, the innovator and the holders of the complementary assets are able to further delay the imitator's access to the preferential complementary assets. And in the current era of rapid technological change, a few years can often be enough time to establish a sufficient financial and brand image advantage and use this advantage to prepare for the next technological discontinuity.

3. The setting and research methodology

Between 1993 and 1997, the author gathered data, and tested and revised theories numerous times using the case study approach (Eisenhardt, 1989; Yin, 1989). The initial research focused on management of the phone development process and how firms could reduce development times and costs and improve product quality. Seventeen interviews were carried out with five Japanese cellular phone producers in 1993 and

1994 (Funk, 1997). During this time period, the author recognized the importance of industrial standards to competition in the cellular phone industry and thus broadened the research goals. In 1996, 1997 and 1998, the author interviewed two carriers and seven new phone suppliers for a total of 63 interviews. Many of these cellular phone producers are also producers of key parts. In 1999, two of the leading independent part suppliers were also interviewed. Between 1996 and 1998, the interviews focused on the movement of market shares in the mobile phone and service industries. In particular, the issue of how NTT DoCoMo and its four phone suppliers able to reverse the slides in their market shares and come to dominate the Japanese cellular service and phone markets was addressed.

4. Pre-innovation situation

In the early 1990s, NTT DoCoMo's (it was spun off from NTT in 1992) share of the Japanese cellular phone market was steadily decreasing due to the success of the Cellular Group who competed with NTT DoCoMo in several regions of Japan. Unlike the third mobile service provider (IDO), that operated in the regions not covered by the Cellular Group, the Cellular Group had adopted an open foreign standard (TACS) that is far superior to NTT DoCoMo's analog standard. In particular, the large installed base of this standard in the US and elsewhere[2] enabled the Cellular Group to offer handsets that were far superior to NTT DoCoMo's handsets. These competitive differences enabled the Cellular Group to obtain more than 60% of the new subscribers in its regions while IDO was only able to obtain about 35% of the new subscribers in its regions between the start of their services (in 1989) and 1993. Further, the Cellular Group was also able to obtain a much higher return on sales than both NTT and IDO (see Table 1).

Table 1
Financial performance of Japanese carriers

Carrier	After-tax return on sales in fiscal 1994 (%)
NTT DoCoMo	1.8
IDO	−32
Cellular Group	11.6

Further, the decline in NTT DoCoMo's share was expected to and did continue for several years due to the Cellular Group's superior technology and the entry of two new carriers. Two new carriers (Tsuka Cellular and Digital Phone) started digital services in Tokyo, Kansai, Kyushu, and Tokai in mid-1994. This additional competition caused NTT DoCoMo's share of subscribers to reach a minimum of 48% in March 1996 (Telecommunications, 1990–1999).

NTT DoCoMo's phone suppliers (Matsushita, NEC, Fujitsu, Mitsubishi) were also concerned with the success of the TACS standard. Since NTT DoCoMo did not allow them to sell TACS phones to the Cellular Group, the success of the Cellular Group meant that their shares were also dropping. In addition, it was widely believed that the shares of the NTT suppliers would continue to drop with the liberalization of the phone market (the rental system was eliminated) in April 1994 and with the entry of the new carriers who were planning to buy phones from a number of suppliers[3] in 1994. In reality, their shares did drop to between 47 and 53% between 1994 and 1997.

5. DoCoMo's new strategy

NTT DoCoMo realized that it needed to provide better handsets than the Cellular Group and the other carriers. Further, it realized that it needed a more subtle strategy than it had used in analog technology since Japan's MPT required NTT to publish the specifications of its digital system, called PDC in return for the adoption of the system as a national standard. While the MPT did not formally require carriers to use PDC, the frequency bands it allocated for the carriers made it very difficult for them to adopt foreign standards like GSM.

[2] TACS is a modified version of AMPS (initially adopted by the US), which had more than 80% and now has more than 90% of the world's analog subscribers.

[3] In particular, it was believed that Sanyo, Sharp, and Sony would dominate the cellular phone market just as they had come to dominate the cordless phone market after it was liberalized in 1985.

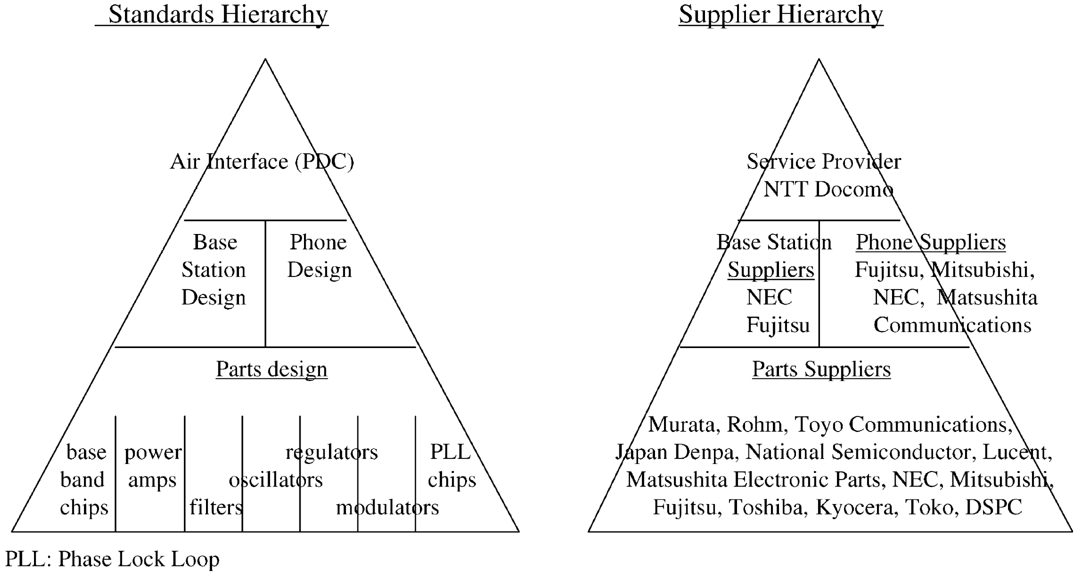

Fig. 1. Standards and supplier hierarchy.

NTT DoCoMo used its information advantages in the PDC standard to obtain preferential access to handsets from Matsushita, Mitsubishi, Fujitsu, and NEC. NTT had originally developed the PDC standard and when NTT DoCoMo was spun off from NTT in 1992 (NTT is still NTT DoCoMo's largest investor), most of the engineers who had been developing PDC were sent to NTT DoCoMo. NTT DoCoMo's phone suppliers informally agreed that they would delay the sale of their handsets to other carriers until 6 months after NTT DoCoMo had received them in return for preferential access to information about the PDC standard.[4]

This effect of this strategy on the evolution of dominant designs in the Japanese mobile phone market can be described in terms of the relationship between the hierarchy both in standards and suppliers (i.e. complementary assets), which is illustrated in Fig. 1. Like other mobile digital standards that are based on Time Division Multiple Access (TDMA), the PDC air-interface standard defines the way in which the frequency spectrum is divided into radio channels and how callers are allocated to time positions in each radio channel. Since the phones and base stations must match these specifications, the definition of the air-interface standard has a strong effect on the hierarchical nature of the base station and mobile phone designs. For example, during a call, circuits in mobile phones, such as filters and amplifiers modify the voice analog signals before the signals are converted into a digital format using base band chips and transmitted to another mobile phone via base stations. Circuits in the receiving mobile phone merely carry out the opposite set of operations.

The primary participation by NTT DoCoMo, NEC, and its three other phone suppliers meant that information about the PDC standards including early test results[5] was primarily shared between NTT DoCoMo

[4] Further, NTT DoCoMo's sole development of the PDC standard also meant that it has been the source of most updates to the PDC standard. And each time it proposes an update to the PDC standard, NTT DoCoMo and its phone suppliers do not release the details of the changes until the revised standard has been officially accepted by Japan's standard setting body, the Association for Radio Industry Business.

[5] Further, there were subtle differences between each generation of NEC base stations thus requiring all handsets to be tested with each generation of NEC base stations. This provided additional advantages to the DoCoMo suppliers.

and its four phone suppliers. This information was essential to solving various problems that always occur with new technologies. For example, the most important design tradeoff involved power amplifiers, filters, and base band chips, which were mentioned above. Power amplifiers are critical because they have a very strong effect on a phone's power consumption through their connection with the voltages used in base band chips. And if the power consumption can be reduced, smaller and thus lighter batteries can be used in the phone. The DoCoMo suppliers used their preferential information from the test results to make better design tradeoffs between these three types of parts. In particular Matsushita and to a lesser extent NEC was able to produce far superior base band chips than either Toshiba (a non-DoCoMo supplier) or DSPC, an independent supplier of chips to the other non-DoCoMo suppliers.

The literature on supplier management suggests that one of the largest problems with "contracting" as opposed to "integrating" is that suppliers may take the lion's share of the profits particularly if the complementary assets are a bottleneck. NTT DoCoMo realized this was a potential problem and thus has used its control of PDC related information and its high share to require its handset suppliers to use some of its technology in their phones. DoCoMo created the basic call functions for the phones using about 70 of the 500 engineers it had assigned to the PDC standard. DoCoMo requires its four phone suppliers to use this technology in their phones and charges them a licensing fee (about 3.5% of the sales) when they do sell the phones to other carriers. And the proceeds from the sale of these handsets to other carriers easily cover the cost of the 70 engineers that DoCoMo had assigned to the PDC handsets.

6. The strategies of the other carriers

The other four carriers including the two carriers that started service in 1994 (Digital Phone and Tsuka Cellular) pursued very aggressive strategies. In fact, they all set lower charges, paid higher activation commissions to retail outlets for acquiring new subscribers, and utilized new distribution channels more than NTT DoCoMo. They set charges that were about 5% lower, activation commissions that were two to four times higher, and utilized discount stores more than NTT DoCoMo. The two new carriers also expanded their digital coverage faster than the existing carriers including NTT DoCoMo.

Table 2
The main phone suppliers for each carrier in 1995 and 1996

Carrier	Phone suppliers
NTT DoCoMo	Matsushita, Mitsubishi, NEC, and Fujitsu
Cellular Group	Kyocera, Toshiba, Hitachi, and Sanyo
IDO	Denso, Kyocera, and Hitachi
Digital Phone	Denso, and Kenwood
Tsuka Cellular	Sony

The weakness of the other carriers was in handsets. The non-DoCoMo carriers initially assumed that the openness of the PDC standard and the large number of handset suppliers would enable good handsets to be available. Further, as they realized that this was not the case, they attempted to copy DoCoMo's strategy. Carriers and handset suppliers increased the closeness of their collaboration in order to create handsets only for their subscribers (See Table 2).

However, this merely accelerated the very phenomena that they were attempting to counteract. By restricting their number of phone suppliers, they reduced the amount of choice available to their customers, a major error in an industry where network effects play a strong role (Shapiro and Varian, 1999). Further, their policies not only reduced customer choice, they reduced the influence of their phone suppliers on the path of the design hierarchy. Since dominant designs are at least partly determined by installed base, the move towards specific suppliers made it more likely that designs from the DoCoMo suppliers would be the sources of the dominant designs.

7. DoCoMo's four phone suppliers develop lighter phones

DoCoMo's four phone suppliers used their preferential access to information about the PDC standard to obtain preferential cooperation from parts suppliers and to make better design tradeoffs between parts than the other phone suppliers. There are more than 100 suppliers of discrete components in Japan of which most firms deal regularly with about half of these suppliers.[6] All of the phone suppliers (both DoCoMo and non-DoCoMo suppliers) work with various part suppliers to develop new generations of discrete components. In particular, during the early years of PDC, part suppliers developed a wide variety of custom components for each phone supplier. These development projects contain non-disclosure agreements where the part suppliers agree not to disclose the contents of the development project or sell the component to other phone suppliers for a given time period—it was typically 6 months in the mid-1990s.

The preferential information that the DoCoMo suppliers obtained from NTT DoCoMo enabled them to obtain more cooperation from the part suppliers and to make better design tradeoffs with respect to weight and size. Weight, size, and battery times (talk and stand-by time) are the most important factors driving the consumer selection of phones in Japan. Further, the manufacturer's handset prices are less important than in Europe and the US due to the high activation commissions that were mentioned above. These high activation commissions caused the subsidized-price of most handsets to drop below ¥10,000 by early 1996 and remain at this level. These high activation commissions and the similar battery times offered by suppliers caused a single market segment to emerge where weight was the key buying factor. In fact, manufacturers with a large weight disadvantage (e.g. 50 g) could not give their phones away for free in the late 1990s.

As shown in Fig. 2, the weight advantages held by the DoCoMo suppliers changed considerably between 1994 and 1998. While in 1994, two DoCoMo suppliers, Matsushita and Mitsubishi offered far lighter phones than the other manufacturers; these differences had largely disappeared by late 1998. This change in the weight advantages of the DoCoMo suppliers appears even larger when one considers that the DoCoMo suppliers were slow to release phones that contained lithium ion batteries.[7]

The late adoption of the lithium ion battery by Matsushita, NEC and to a lesser extent Fujitsu concealed their true design advantages in non-battery parts of the phone in 1994 and 1995 and the fact that these advantages have slowly declined since 1995. Further, NEC's emphasis on folding phones, which are fundamentally heavier than regular phones, also concealed its true design advantage. The change in the true design capability of the DoCoMo suppliers can be estimated by subtracting between 20 and 30 g from all phones that did not contain lithium ion batteries and between 30 and 40 g from folding phones.[8] This assumes that all of the firms adopted a lithium ion battery at the same time and they all produced regular, non-folding phones.

Fig. 3 shows how the DoCoMo suppliers' imputed weight advantage has dropped considerably since between 1994 and 1998. First, Matsushita and NEC had far lighter phones than the non-DoCoMo suppliers did until the end of 1997 while Mitsubishi's phones were also much lighter than the non-DoCoMo suppliers were until the end of 1996. Second, Fujitsu's phones were for the most part in the top five through 1997.[9] Third, the difference between the heaviest and lightest phones of the eight leading suppliers dropped from 68% in April 1995 to 25% by late-1998.

[6] In the cases where the part suppliers are in a firm that also produces cellular phones (which is very common), the divisions are different and almost completely independent. The cellular phone divisions are not required to use the parts that are made by their discrete component divisions and the discrete component divisions are not required to sell exclusively to the cellular phone divisions.

[7] Matsushita (first released in late 1996), NEC (first released in early 1996), and Fujitsu (first released in late 1996) were the last three firms to release phones that contained lithium ion batteries. Other firms such as Kyocera, Toshiba, Kenwood, and Sony released phones that contained lithium ion batteries in some cases more than 2 years before Matsushita first released a phone containing a lithium ion battery. Matsushita and to a lesser extent NEC were late adopters primarily due to their concerns about the higher cost of lithium ion batteries and in particular how their adoption of the lithium ion battery might cause prices to rise dramatically. Further, NEC, Fujitsu, and Matsushita were also influenced by DoCoMo's concerns about the safety of lithium ion batteries (there were some early cases of batteries exploding).

[8] Matsushita claims that the adoption of the lithium ion battery saved 30 g in 1996 and the performance of the lithium ion battery has improved faster than the performance of the previous generation of batteries (nickel-hydride). Therefore, 20, 25, and 30 g are subtracted from all phones that did not contain a lithium-ion battery in 1994, 95, and 96, respectively. Similarly, the NEC folding phone (105 g) weighed 25 g or was about 35% heavier than its regular counterpart (85 g) in 1998. Therefore, 40, 40, 35, 30, and 25 g are subtracted from folding phones that were released in 1994, 1995, 1996, 1997, and 1998, respectively.

[9] The phone that was released in late 1996 by Fujitsu appears to have become heavier since Fujitsu increased the talk time of this phone substantially while it simultaneously adopted the lithium ion battery (thus 30 g was subtracted from the phone released in October 1995).

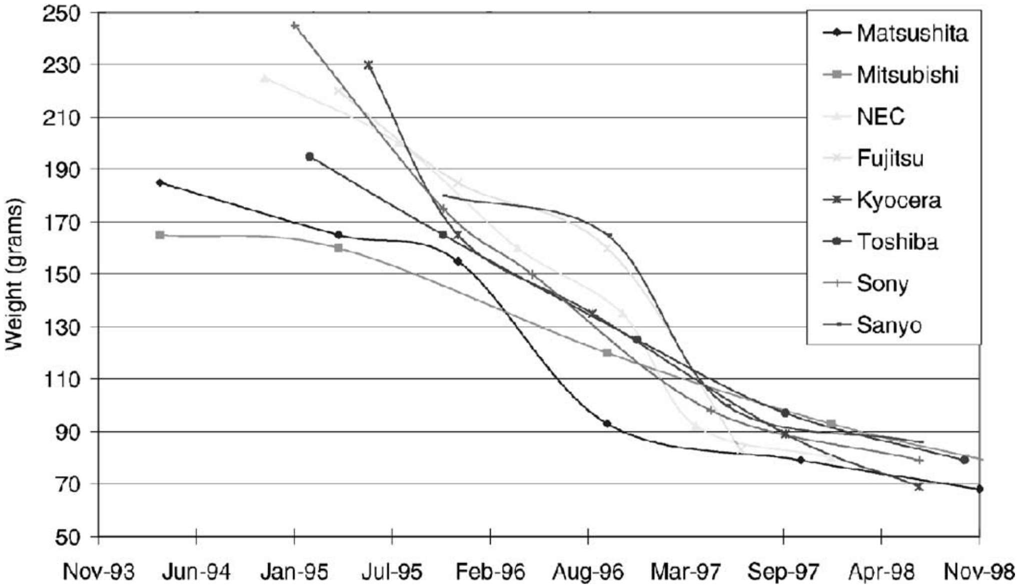

Fig. 2. Weights (grams) of Japanese digital mobile phones.

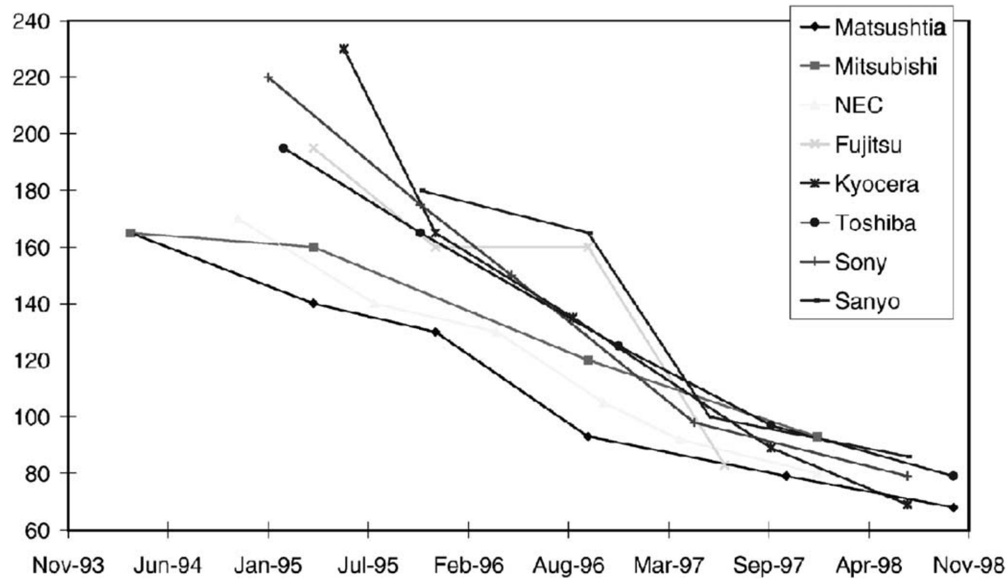

Fig. 3. "Imputed" weight of Japanese digital mobile phones.

8. Dominant designs and the declining weight advantage

The reason for the existence of and decline in the weight advantages of the DoCoMo suppliers highlights this paper's contribution to the dominant design literature. In the current literature, the emergence of a dominant design causes the emergence of standard parts, manufacturing equipment, and higher production volumes, which in turn cause competition to change from technology to complementary assets. It is for this reason that innovators often lose their initial advantage.

This paper argues that NTT DoCoMo was able to use its information advantages in the PDC standard to obtain preferential access to phones. And as described earlier, its four phone suppliers were able to receive more cooperation from discrete component suppliers and they were able to make better design tradeoffs than the non-DoCoMo suppliers due to the preferential information they received from DoCoMo about the PDC standard. This forced the non-DoCoMo phone suppliers to change their design strategies and copy the DoCoMo designs in 1995 and 1996. This required them to move back up the design hierarchy and modify their design architectures, a task that is not easy to do as research on dominant designs/standards (Thompson, 1954) and architectural innovations (Henderson and Clark, 1990) has shown.

In particular, Matsushita's design became the dominant design at most levels in the phone design and other phone suppliers were forced to copy its design in order to obtain access to the best parts. This trend was strengthened by the emphasis on weight and size in the Japanese market and the importance of functional integration in electronics to obtain lighter phones. For example, the non-DoCoMo phone suppliers were forced to reassess the design tradeoff between power amplifiers, filters, and base band chips, which took time and caused some of their design experience to be become less relevant.

Discrete component and IC suppliers who were not supplying DoCoMo suppliers were also forced to make their parts match the DoCoMo dominant design in order to sell components. For example, most of the non-DoCoMo suppliers switched to DoCoMo parts (i.e. parts that were made by firms supplying DoCoMo phone manufacturers) in base band chips (Matsushita and NEC), low noise regulators (Toko), temperature control exchange oscillator (TCXO) parts (Toyo Communications and Japan Denpa), filters (Murata), modulators and Phase Lock Loop (PLL) integrated circuits.[10]

Nevertheless, as the dominant design became defined at very detailed levels in the phone and sufficient information about this dominant design and the PDC standard in general diffused throughout the industry, the differences between phone and between discrete component suppliers began to disappear. Further, consistent with the dominant design literature, the emergence of a dominant design lead to increasing volumes of digital phones[11] and the emergence of standard parts. Whereas in 1994, most parts where produced on special production lines, by 1997, the discrete component suppliers wanted to produce all parts on the same high-volume production line on thus dramatically increased the price differential between the standard high-volume and custom low-volume parts. Further, when phone suppliers still demanded custom-developed parts, they were willing to accept a shorter delay (from 6 to 3 months) in selling parts to other phone suppliers in order to receive price discounts in the parts. The result was that by 1997 most phone suppliers were using the same parts, which caused the weight differences between phone suppliers to disappear.

9. The rising shares of DoCoMo and its four phone suppliers

As shown in Fig. 4, DoCoMo's share of new subscribers did not begin rising until the second half of 1996. The other carriers were able to obtain relatively high shares until that time due to their lower charges, their faster utilization of discount stores to obtain subscribers, and their higher activation commissions. Further, as shown in Table 3, DoCoMo did not obtain more than 50% of the total digital subscribers until March 1996, which was almost 2 years after the new

[10] Toko was the only supplier of the best low noise regulator until the end of 1996. Toyo Communications (the top supplier) and Japan Denpa Industries (second leading supplier) were the only suppliers for the best TCXO parts until 1997. Murata, which is the world's leading supplier of filters with a share of more than 50%, produced far smaller and lighter filters than its competitors until 1997. Several firms produced PLLs (National Semiconductor, NEC, Matsushita, and Fujitsu) and modulators (Lucent, NEC, and Matsushita).

[11] The production of phones increased from about 3 million in 1994 too more than 20 million in 1998. For digital phones, the percentage increase is even larger. In 1994, about 35% of the phones were digital phones while in 1998 more than 90% of the phones were digital phones. Thus, there was about a 20-fold increase in the production of digital phones between 1994 and 1998.

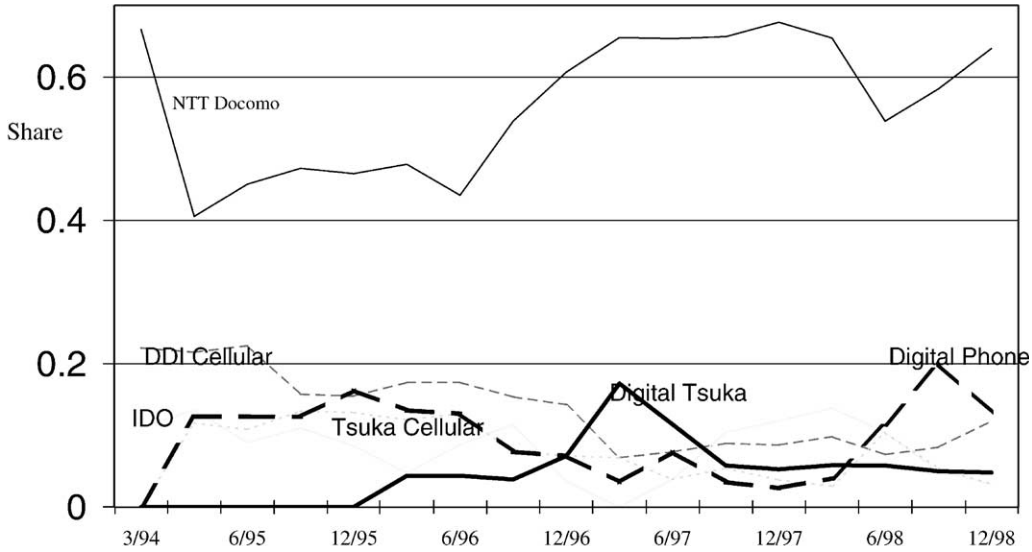

Fig. 4. Fraction of total subscribers obtained in previous period by each carrier.

Table 3
Number (millions) of cumulative digital subscribers by carrier

Carrier	March 1995	October 1995	March 1996
NTT DoCoMo	0.45	1.1	2.8
Digital Phone	0.28	0.58	1.1
Tsuka Cellular	0.27	0.55	1.0
IDO	0	0	0.2
Cellular Group	0.05	0.1	0.4
Total	1.04	2.24	5.5

entrants had started their digital service. Thus, the creation of de facto standards by the DoCoMo suppliers cannot be explained by installed base.

The superior phones available from NTT DoCoMo caused its share and the shares of its phone suppliers to increase dramatically beginning in late 1996 for two reasons. First, the other carriers reduced their activation commissions in 1996 in response to their rising cancellation rates,[12] which had risen partly due to the superior phones available from NTT DoCoMo.[13] Second, Matsushita introduced the first sub-100 g phone in October 1996, which was more than 40 g lighter than the smallest non-DoCoMo phone when it was released. Subsequently, NEC and Fujitsu released even smaller phones in the summer of 1997 followed by a Matsushita's second sub-100 g phone in October 1997. DoCoMo's share of all (both analog and digital) new subscribers rose dramatically following the introduction of Matsushita's first sub-100 g phone. On a monthly basis, DoCoMo's share of new subscribers rose from 48% in August 1996 to over 60% in October and it stayed over 60% throughout 1997 and most of 1998 (Telecommunications, 1990–1999).

Matsushita, NEC, and Fujitsu also benefited from their early release of sub-100 g phones. As shown in Fig. 5, Matsushita's share rose from 21 to 32%, NEC's share rose from 9 to 16%, and Fujitsu's share rose from 8 to 11% between 1996 and 1997. Thus, the total share of the cellular phone market held by the DoCoMo suppliers increased from 52 to 68% between 1996 and 1997 after being 72% in 1993. In other words, in spite

[12] NTT DoCoMo had about one-third the cancellation rates as the other carriers in 1996.

[13] Although the higher cancellation rates of the non-DoCoMo carriers were also partly due to their weaker coverage than DoCoMo, an equivalent reason was the superior handsets from DoCoMo. Many subscribers changed to DoCoMo in order to obtain these superior handsets. And because the retail outlets lose their commissions when subscribers cancel a subscription within 6 months of making it, the retail outlets do not want to sell phones that might result in early cancellations. Thus, the rising cancellation rates for the other carriers increased the chances that a retail outlet would recommend DoCoMo phones in spite of DoCoMo's lower activation commissions.

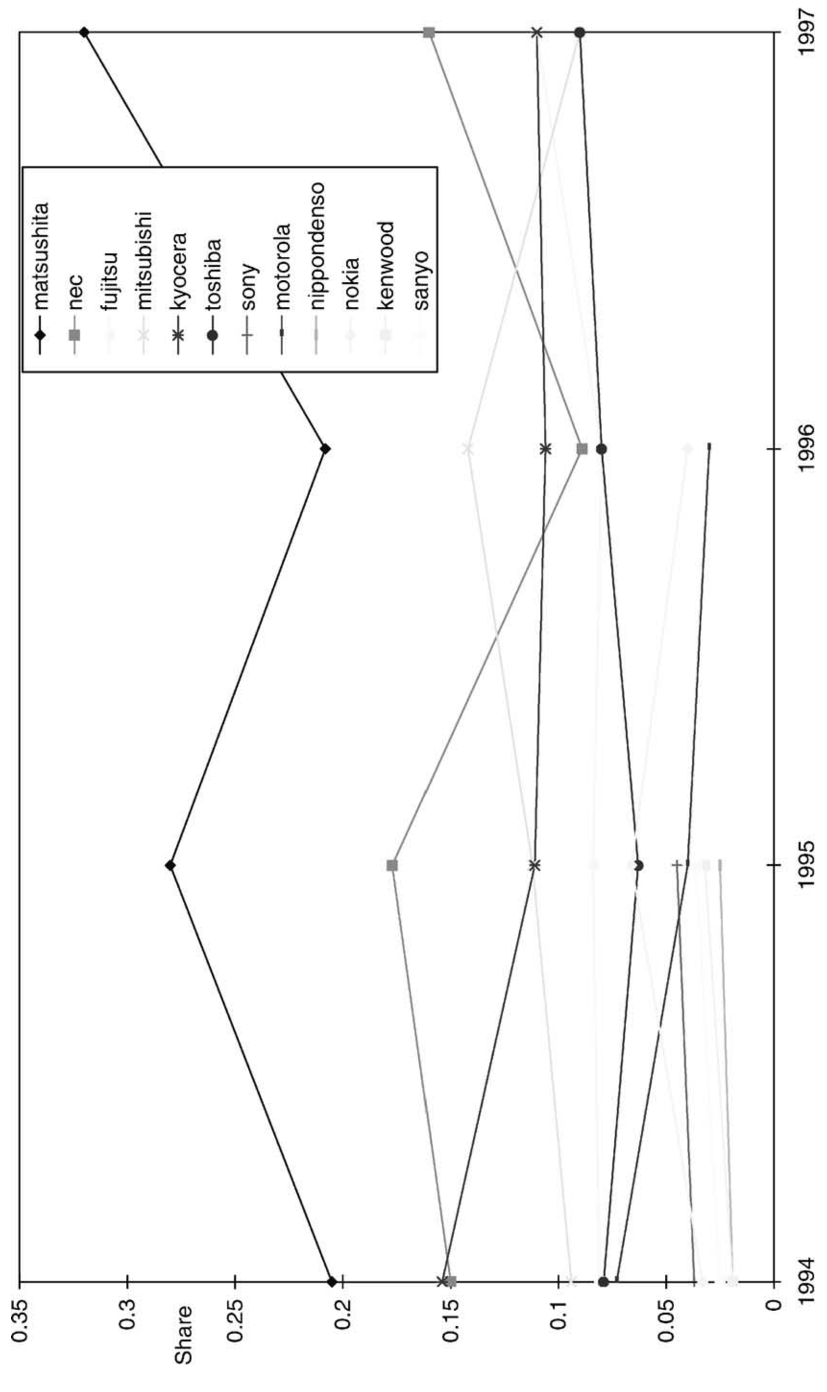

Fig. 5. Mobile phone market shares in Japan.

of the dramatic increase in competition between 1993 and 1996, their shares had almost returned to the levels that they were at before digital service was started in 1994. This increase in shares was due to both the increase of DoCoMo's share and their sale of phones to other carriers.

This total domination of the market by DoCoMo and its four phone suppliers caused the Cellular Group and IDO to decide in the spring of 1997 to start services based on cdmaOne and later merge. This system would be the third and fourth cellular system for the Cellular Group and IDO, respectively. These two carriers believed that they could not compete with DoCoMo due to the differences in handset capability. The Cellular Group and IDO achieved a nationwide service in April 1999. Ironically, Kyocera released the smallest PDC phone in July 1998 just as its subsidiary Kansai Cellular started cdmaOne services. In other words, just as it was starting services based on cdmaOne, the original reason for starting these services disappeared.

Nevertheless, the strong brand image created with NTT DoCoMo's lighter phones and its new mobile Internet service (i-mode) has enabled it to continue its domination of the Japanese cellular phone market. One reason it was able to promote a proprietary mobile Internet service in the Japanese market was its high share, which came from its strategy in the PDC standard. Further, although much of its success from mid-2000 can be attributed to i-mode (Funk, 2001a), the high brand image created by its lighter phones enabled it obtain more than 50% of the new subscribers even after its weight advantage disappeared in mid-1998; it is likely that its high share would have continued for several years even without i-mode (see Table 4).

10. A comparison with other digital phone markets

The strategy created by NTT DoCoMo and its phone suppliers has not been used in other "open" standards

Table 4
Financial performance of Japanese carriers

Carrier	After-tax return on sales in fiscal 1997 (%)
NTT DoCoMo	11.9
IDO	−11.3
Cellular Group	6.3

like AMPS in the US, NMT in Scandinavia, GSM in Europe, and PHS in Japan. There are two reasons for this. First, a single carrier was not able to obtain an advantage in these standards since they were created in a more open standard setting process. In AMPS, the US Federal Communications Commission (FCC) created an open standard based on proposals from various manufacturers. In NMT and GSM, the national carriers and various manufacturers while in PHS the manufacturers created an open standard (Funk, 1998; Funk and Methe, 2001; Funk, 2001b).

Second, there was and still are a wider variety of market needs and strategies used in the US and European markets than in the Japanese PDC market. For example, although weight and size are also important in both the US and European markets, many consumers place more value on other factors such as aesthetic design, user-interface, or price than weight and size. Thus, manufacturers have used a wider variety of strategies to compete in the US and European markets.

One result is that a dominant design has not become defined in the US and European phones to the level at which it has become defined in the Japanese PDC phones. There is much wider variety of technological solutions in the US and European markets due to the greater the level of heterogeneity in market needs and firm strategies. Interestingly, this is in spite of the greater detail in the US and European standards[14] which suggests that there may not be a strong relationship between the level of detail in the standard and the depth to which the dominant design spreads. Instead, in this case, the depth appears to depend on the level of heterogeneity in market needs and firm strategies.

One question is whether different strategies by the non-DoCoMo carriers could have lead to different outcomes. As implied earlier, they would probably have been more successful if they had cooperated with each other and the manufacturers to develop phones that are compatible with all carriers. This would have reduced the chances that the designs used by the DoCoMo suppliers; in particular Matsushita's design would become a dominant design at a fairly detailed level in the phone.

An example of how a different standard setting process and firm responses lead to a different outcome in

[14] For example, the GSM standard includes specifications for the interface between base stations and switching equipment.

the Japanese market can be found in Japan's Personal HandyPhone System. Three carriers have offered services since late 1995 in PHS, which uses a much different technology than Japanese PDC.[15] Nevertheless, because there are many similar attributes of the PHS and PDC markets, it would be expected that a situation similar to that described here for the PDC standard would also emerge. PHS is also a Japanese standard, services were started shortly after services based on PDC were started, and many suppliers collaborate closely with a single carrier. In particular, NTT carried out the original development work on the standard and DoCoMo's handset suppliers also initially delayed the sale of their PHS phones to the other two carriers. Further, Fujitsu was replaced by a much stronger consumer electronics producer, Sharp. Thus, one would expect that NTT's partially owned subsidiary NTT Personal (it was subsequently acquired by NTT DoCoMo) and its suppliers would have been able to create a very similar strategy to that created by NTT DoCoMo and it phone suppliers in the PDC market.

However, the critical difference between PHS and PDC is that Japan's MPT and the manufacturers were responsible for the creation of and modifications to the PHS standard. The MPT opened the standard to all interested Japanese firms in 1993 (it was not opened to foreign firms until early 1996) and no one firm controls the standard setting process. Further, many firms pushed for a well-defined standard in order to reduce phone and part costs. For example, the major manufacturers of TCXO parts (a type of crystal oscillator) defined standard packaging and other aspects of these parts in order to avoid the large amount of custom development that occurred in the PDC market. These manufacturers were forced to incur heavy development costs in PDC and they wanted to avoid this burden in PHS.

The result of this more open standard is that NTT Personal's four suppliers were not able to create a large initial weight advantage in PHS phones as they were able to do in PDC phones. Sharp was able to develop the first sub-100 g phone by convincing part suppliers to develop very light and small discrete components for it; Sharp argued that it would place a great deal of emphasis on PHS and thus warranted the preferential cooperation. However, its temporary advantage (and temporary high market share) quickly disappeared as all of the PHS phone suppliers began focusing on the development of small and light phones and similar discrete components became available from all of the part suppliers. As shown in Table 5, by mid-1996, the smallest phones were available from Toshiba, and Sanyo. By 1998, Matsushita's and Sharp's phones were the only phones produced by an NTT Personal supplier that were in the top eight lightest phones. As the DoCoMo suppliers had originally worried when the PDC standard was being created, new firms like Sanyo, Denso, Kenwood, and Casio have become major suppliers of PHS handsets. The main four NTT Personal suppliers had less than 25% of the PHS handset market in 1997.

There are also a greater variety of firm strategies in the PHS market than in the PDC market. This prevented a dominant design in the PHS phone from spreading to the levels to which it reached in the Japanese PDC phones in spite of the greater detail in the PHS than in the PDC standards. The carrier with the largest share in the PHS market, DDI Pocket has succeeded by introducing higher power base station and thus expanding coverage faster than its two competitors. Simultaneously, the major owner of DDI Pocket, Kyocera has acquired the highest share in the PHS handset market through its ownership of DDI Pocket and its introduction of phones that have better voice quality and newer features than the competitors. As shown in Table 5, this is in spite of the fact that Kyocera did not have the lightest phones. By using a strategy that is different from the weight-centered strategy of DoCoMo in PDC and NTT Personal in

Table 5
Ranking of PHS phones in terms of weight

Firm	Mid-1996 (g)	Spring 1998 (g)
Toshiba	81	73
Sanyo	88	68
Matsushita	89	72
Sharp	91	77
NEC	94	
Mitsubishi	95	

[15] PHS is a low-cost version of second generation digital systems. It uses small, low-power and low-cost base stations that cover a very narrow area and whose signals have trouble penetrating buildings. The narrow coverage area makes it difficult to transfer calls from phones that are travelling at high speeds (>30 mph). Thus, they have been mostly considered applicable to densely populated areas in Asia.

PHS, Kyocera and DDI Pocket's other suppliers have been able to compete on factors other than weight. Further, the heterogeneity in the strategies used by the carriers and manufacturers prevented a dominant design in the PHS phone from spreading to the levels to which it reached in the Japanese PDC phones.

11. Discussion

This paper makes five theoretical contributions. First, this paper shows that firms can influence the emergence of dominant designs. While the literature on dominant designs emphasizes the emergence of these designs through a natural process of experimentation between the firm and the users of the product, NTT DoCoMo and its suppliers heavily influenced the resulting dominant design through their information advantages. DoCoMo's phone suppliers used their greater knowledge of the PDC standard to make better design tradeoffs. This forced the other phone suppliers to change their design strategies and copy the Matsushita designs in order to obtain the best parts. Part manufacturers who were not supplying NTT DoCoMo's phone manufacturers were required to make similar changes.

Second, installed base does not appear to play the same role in the determination of dominant designs (at least in this case) as it does in standards. The literature on network effects emphasizes installed base and how "tipping" occurs when one technology obtains more than 50% of the market. Of course, network effects do not play the same role here that they play in the creation of standards and this is one reason why the dominant design literature emphasizes natural selection as opposed to firm strategy in the choice of a dominant design. Nevertheless, it is quite interesting that in a case where a firm does heavily influence the emergence of a dominant design, it has done so without having a share that was far larger than 50%. On the other hand, NTT DoCoMo did have the largest share in the market when it was implementing its strategy and without this large share, it would probably have been hard to implement the strategy.

Third, the creation of a dominant design provided NTT DoCoMo and its suppliers with a strong advantage over the other carriers and phone suppliers. The shares of NTT DoCoMo and its phone suppliers rose substantially through their development of lighter phones. As for profits, NTT DoCoMo's return on sales had exceeded the Cellular Group by fiscal 1996 and this trend has become more pronounced since then. NTT DoCoMo's largest phone supplier Matsushita also experienced the same phenomena of rising profits until folding phones became the dominant design (see below).

Of course, it should be emphasized that the advantage incurred by NTT DoCoMo and its suppliers is a temporary phenomena, which is consistent with the dominant design literature. In the dominant design literature, early mover advantages often disappear once a dominant design emerges. NTT DoCoMo's strategy may have merely extended the time in which it and its suppliers could benefit from their early mover advantages. NTT DoCoMo's suppliers had lighter phones from 1994 to 1998 and it appears that the resulting improved brand images of NTT DoCoMo and perhaps its suppliers have enabled them to maintain their profitability for several years after that. Interestingly, NTT DoCoMo's strong brand image helped it to create i-mode while the change in dominant design brought about by i-mode has caused Matsushita's share and profits to plunge and NEC's to rise. Folding phones were a disadvantage when competition revolved around weight but are now an advantage when competition revolves around display size.

This suggests that this strategy is particularly useful in industries with rapid technological change like the information and telecommunications industries. It is not uncommon for these industries to see new generations of technology every 5–10 years. With such rapid technological change, a temporary 3–5-year competitive advantage combined with the increased brand image that often accompanies such a competitive advantage may enable a firm or an alliance of firms to last until the next technological change.

Fourth, this paper has identified some of the conditions that are necessary to use the "multi-level dominant design" strategy. It appears as if it would be difficult to use the strategy in a market that values diversity. A diverse set of customer needs often prevents dominant designs from appearing. Weight has played an important role in the Japanese cellular phone (but not PHS) market and this facilitated the emergence of a dominant design since the main method of reducing phone weight was greater integration of electronic functions on smaller pieces of silicon.

An information advantage is also necessary to implement this strategy. Often times the most important aspects of a standard are not included in the documents but instead are written “between the lines”. When standards are created in open forums alternatives are debated and thus reasons why certain technical solutions are better than others become apparent. When the standard is determined in a closed forum, the outsiders do not know why certain technical solutions are better than others and thus must find out themselves, which can often be a time consuming process.

It is unclear whether the sufficient information advantages can be created in cases where standards do not play a role. Clearly, first mover advantages include some form of information advantage. If firms use these information advantages to create an advantage in complementary assets particular those that involve suppliers, it is quite possible that the firm can utilize first mover advantages over a longer period of time.

It is possible that this has occurred many times before but has not been noticed by managerial researchers. Looking back 50 years, we often interpret a firm’s short period of competitive advantage as an “unsustainable” competitive advantage. In 5–10 years, NTT DoCoMo’s current success may be viewed in a similar way just as the tables have quickly turned on Matsushita. In an age of many technological discontinuities, it is necessary to implement appropriate responses to each and every one of them and even a few failures may be lethal.

Fifth, the existing supplier literature emphasizes tight customer–supplier relations where high co-asset specificity is recommended (Liker et al., 1996). The analysis described in this paper suggests that the issue is somewhat more complex than this. At an information level, the relationship between NTT DoCoMo and its suppliers has high co-asset specificity since there is an intense amount of information exchanges between the firms. However, at a physical level, the successful creation of dominant designs by NTT DoCoMo’s phone suppliers has resulted in low co-asset specificity and thus low investment risk. This is clearly an attractive outcome for NTT DoCoMo and its phone suppliers. NTT DoCoMo has maintained control over the suppliers by requiring them to use some of NTT DoCoMo’s technology and charging them a licensing fee when they sell phones to other carriers.

On the other hand, the other carriers attempted to copy DoCoMo strategy in terms of information exchanges, i.e. high co-asset specificity. But this strategy merely accelerated the phenomena they were trying to counteract since it reduced the influence of the non-DoCoMo phone suppliers on the path of the design hierarchy. This was clearly a mistake and highlights the risks associated with attempting to create your own multi-level dominant design when the firms do not have information advantages or sufficient market share. Thus, the tradeoff between high and low co-asset specificity may need to be revised for the cases where standards play an important role.

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