A study on the standards in optical storage device industry

by

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Submitted to the Alfred P. Sloan School of Management and the School of Engineering in Partial Fulfillment of the Requirements for the Degree of

Master of Science in the Management of Technology

at the

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ABSTRACT

Standards have been a very important issue in many industries as the innovators of the standard technology have tremendous power in the industry. The standard holders are supposed to have the dominant market position and technology leadership for further generation of the product as well as direct royalty income from the intellectual property. However, other various forces are also included in the evolution of the market and the technology. This thesis deals with the issues related to the evolution of standards in the optical storage device industry and other forces leading the market competition.

Philips and Sony, the innovators of the CD technology, had taken the technology leadership of the industry for more than a decade. However, early followers such as Toshiba, Hitachi, and Panasonic took the leading position of the market, and competed with Philips and Sony for the standardization of DVD. The increased number of participants and the influence of complementors made the DVD standardization process much more complex. This trend will continue as current market leaders, who are late entrants, are added to the standard competition. This case shows that not only taking advantage from standardization but also proper market entry timing and continuous innovation is important for success in the optical storage market.

Thesis Supervisor: Michael A. Cusumano
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I. Introduction

I.1 Overview of thesis

Since digital technology has blurred the border of consumer electronics, communication, and computer industry, the importance of standards has been seriously considered in business strategy as well as in technology strategy. Standards provide the compatibility or interoperability to different hardware and software, and make it possible to share the data easily and conveniently. Once a new standard is accepted in the industry and the market, it helps the owner in leading in the market, or in guiding the development of the next generation of technology and in taking royalty income from intellectual property. Sometimes a standard brings critical results to a company’s business. Beta max and VHS standard competition brought Sony out of the business. Sony introduced its Beta max VCR earlier than JVC’s VHS VCR, but Sony failed to make it the dominant standard and finally dropped the format from the consumer market. However, many standards are determined by leading firms of the industry before the market launch of the products.

The standards for the optical storage device industry had been discussed among the leading firms of the industry before a product had been launched. However, as the standard competition becomes severer, the possibility of in market competition becomes higher, although in-market competition would be much riskier. Companies are willing to take risk because the benefit of owning a standard far exceeds the risk. They can make a stable revenue stream from proprietary assets, they can expect the dominant market share and technology leadership for the next generation of product. However, there are various forces
in the standardization process and new technology adoption in the market, and it might not happen exactly as expected.

In this thesis, I would like to review the history of optical storage devices by the standardization and the market evolution. The comparison of CD-ROM and DVD-ROM will show what kind of forces in the industry lead the competition. The discussion will focus on how standard setters tried to capture the values and how the other firms have been competing with them.

I.2 Optical storage device industry overview

The CD player was the first digital device in consumer electronics. Since Philips and Sony made CD standard in 1982, it became a base standard for various optical storage devices and titles. The market size of optical storage devices is now more than 50 billion dollars per year.

In 1984, Philips and Sony extended CD standard for data storage, and made the CD-ROM standard. The first application of the CD-ROM drive was large capacity read only storage for Mini computers and Workstations. After several technical standards were added to the CD-ROM standard, CD-ROM drives were starting to be adopted in Personal Computers in late 80's, but the volume was not large because of the price. As the PC industry accepted CD-ROM drives for multimedia PCs in the early 90's, the CD-ROM market has grown rapidly as the Personal Computer market has grown. By that time, early followers of CD-ROM standard such as NEC, Toshiba, Panasonic, and Hitachi shared the market with Sony and Philips. Other new firms such as Mitsumi, LG, and Samsung entered this market with a
low price design from the early to mid 90's, and they took the dominant market share in the
late 90's, while the speed of the drive became the major competition specification.

DVD standard had been prepared since 1993 by some of the early followers of the industry,
Panasonic, Hitachi and Toshiba. They were the market leaders at that time. They formed an
alliance to develop the next generation of CD standard. The original innovators of CD
technology, Philips and Sony, formed the other group immediately after the announcement
of the Toshiba group. These two groups competed with each other for being a standard
setter of DVD until they reached a compromised standard though the brokerage of IBM in
1995. DVD Video, DVD-ROM, DVD Audio, and DVD-RAM formats were included in the
compromised standard for format consistency and compatibility, though DVD Audio and
DVD-RAM technologies had not yet been developed in detail. Backward compatibility to
CD standard was also included in DVD standard.

DVD Video format started being accepted in the market recently making a new record of
adoption rate in consumer electronics industry history, but the DVD-ROM doesn't show
such an impressive result as yet.

Though a consortium named DVD Forum was formed after the settlement of DVD standard
for the discussion of a recordable DVD and the next generation of standards, several
companies announced that they would launch incompatible recordable DVD devices in mid
and late 2000. Following their announcement, consumers will have to choose from three
different kinds of incompatible Video Disc Recorders (VDR).
I.3 Suggested frame of reference

I.3.1 The effects of standards

Standards enhance the compatibility, or interoperability, generating greater values for users by making the network larger in a network driven market. Standards reduce the technology risk faced by consumers, so it accelerates the acceptance of a new technology. Standards reduce consumer lock-in by providing openness, so the competition moves from the early market for dominance to the later market for share increase. As standards reduce the room for differentiation, the competition becomes based more on price than on features. The owners of the proprietary assets of the standards have the control of the improvement of the standard thereafter. (Shapiro et al., 1999)

Some standards are tightly controlled by the owners of the standards. Usually it happens in a winner-take-all market like OS (Operating Systems). Even though the market is not like OS, generally the standard setter can enjoy the strongest position in the market and build their credibility to the industry and consumers. The patents of the technology related to standards are the most valuable proprietary assets. As these patents are impossible to design around, the company can make a very stable revenue stream with it as long as the standard is used.

I.3.2 Indirect network externalities

The usefulness of a technology product for an end-user often depends on the availability of complementary software products and services. The optical storage device is a typical example. A CD-ROM or DVD-ROM drive needs titles to play with. This phenomenon,
where the demand for hardware products is mediated by the supply of complementary software products, is called an indirect network externality. (Gupta et al., 1999) Indirect network externalities create a "chicken-egg problem", and result in a strategic interdependence between the actions of hardware manufacturers and the actions of software providers. Whenever a new standard is developed in the optical storage industry, this indirect network externality raises compatibility issues. Also, it influences the adoption rate of end-users. Standardization process becomes much more complex where there are strong indirect network externalities. The standards of optical storage devices have usually been led by device manufacturing companies; however, the active participation of software developers is becoming more common. Moreover, as the technology of optical storage devices is on the edge of consumer electronics and computers, a new standard should satisfy the requirements of a larger, more diverse group of players.

I.3.3 Dominant design and standard

The innovations, which lead to a new standard, change the industry, but other innovations also change the industry though the extent of the innovations depends on how tightly the standard is controlled by the standard owners.

Utterback(1996) proposed the concept of dominant design. The design which wins the allegiance of the marketplace, becomes the one that competitors and innovators must adhere to if they hope to command significant market following. The emergence of a dominant design is not necessarily predetermined, but is the result of the interplay between technical and market choices at any particular time. He described the dynamics of
innovation to two phases, the product innovation and the process innovation. He observed that the number of firms increased around the time when the dominant design appeared in many industries. The Dominant design concept is related to collateral assets, network externalities, industry regulations, and firms’ strategic maneuvering, which are closely related to standard establishment.

1.3.4 Pioneers, early followers, and late entrants

The pioneers tend to outperform the later entrants on average. (Lambkin, 1988) It depends on the dynamics of the specific industry. The first mover could have advantage of (1) Technology leadership, (2) Preemption of assets, and (3) Buyer switching costs. However, the late mover also could have the advantages of (1) Free-rider effects, (2) Resolution of technological or market uncertainty, (3) Easier adaptation to shift in technology or customer needs, and (4) Incumbent inertia. (Lieberman and Montgomery, 1988) Day and Freeman wrote the benefit of pioneering very similar to the first mover’s advantages. They referred to (1) Preemption of Competition, (2) Leadership Reputation, (3) Customer loyalty, (4) Proprietary Experience Effects, (5) Sustainable Lead on Technology as the advantages of pioneering, and warned the risk of early entry to (1) Premature Entry and “Burnout”, (2) Inability to maintain a lead and “Fadeout”. They modeled the timing of market entry using profit-making “window”.

A firm pioneering a new standard enjoys these same advantages and also faces these same risks. In some cases, a firm could take a strategy of a follower than of a leader. If the firm has less technological capability and/or inferior market position, it might be better to
become a supporter for the other prospective firm's proposal. This strategy can work if the market is not yet ready and if the standard doesn't confine the later innovation too much.

![Diagram of Profit-Making Window](image)

Figure I-1. Timing of Market Entry

Teece (1986) discussed about profiting from innovation using the concept of appropriability and complementary assets that are needed to succeed in the market. A regime of appropriability refers to the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation. The most important dimensions of such a regime are the nature of the technology, and the efficacy of legal mechanisms of protection. He explained that the distribution of profits between an innovator and followers could be caused by the dominant design. Though the innovator could capture the value from the product innovation with
major technological breakthrough, followers could capture the values from following process innovation in some cases. In almost every case, the successful commercialization of an innovation requires that the know-how in question be utilized in conjunction with other capabilities or assets. He argued that building the complementary assets is important as well as R&D to capture the value from innovation. Complementary assets also should be considered to establish the valuable standard for the firm.

I.4 Objective of thesis

This thesis will assess the standardization process and market evolution of the optical storage industry based upon the discussions about characteristics of a network driven market, innovations, and of capturing the value. This thesis will mainly compare the standardization processes of CD-ROM and DVD-ROM, and will try to understand the changes in the important factors between the two standards. The issues discussed in the thesis would help the forecasting result of on going standards issues, and would be helpful for the development of the technology strategy for not only standard setters but also standard followers.

Particularly, this thesis will address the following questions:

(1) How standard issues were raised in CD-ROM technology and DVD-ROM technology?

If any, what is the difference between the standardization process of CD-ROM and
DVD-ROM?

(2) Generally, standard owners can take the advantages of the strong market position, technology leadership, and revenue from proprietary assets. How did the owners of CD-ROM technology capture the value of the innovation (standard)? What did other companies do to compete with them?

What are the owners of DVD-ROM technology doing for capturing value?

(3) What might be the proper technology strategy on standards in this particular industry as a technology leader and a follower?
II. Evolution of standards in optical storage industry

Optical storage industry was began in 1982 when the first standard of CD (Compact Disc) was introduced as a cooperative result of Sony and Philips. Other CD family standards were developed based on this CD Audio standard. There are more than 10 kinds of CD formats so far, but the most successful standards are CD Audio and CD-ROM (Read Only Memory).

II.1 CD family standard

II.1.1 CD Audio standard

When Philips initiated the development of CD technology, one of the most important concerns was standardization. There were several alternative technologies developing, and Philips wanted to settle it to CD technology. Philips made an alliance with Sony for its error correction technology, and finally they succeeded to beat others in standard competition for the next generation of audio reproduction products. By the end of 1981, more than 30 companies signed the license agreement and other competitors withdrew their technologies.

The major technological differences between CD and previous technologies were optical signal pick-up, digital data manipulation, and large capacity. Optical signal pick-up provided virtually no degradation of the original data because there is no mechanical contact. Digital data manipulation enabled high quality audio sound with minor error
correction. CDs could hold up to 72 minutes of audio.

The standardization process of CDs was less competitive than of VCRs. However, as CD standard is an incompatible format with LP and CD is a prerecorded media, they had to consider all the issues related to the indirect network externalities. They had to be in CD pressing service business as well as CD player business. They had to promote CD format to music studios. Philips owned 50% of Polygram and used it to publish CD titles. They chose a mild royalty policy on proprietary assets for the promotion of CD standard. Instead of less royalty income, they built the complementary assets to capture the value from the innovation. After a few years' entry stage, CDs took off in the market, and became the dominant format for audio reproduction.

Figure II-1. U.S. Sales of Audio Software by Format (billions of dollars)

U.S. Sales of Audio Software by Format (billions of dollars)

Source: Inside the Recording Industry: A Statistical Overview, 1990
II.1.2 CD-ROM standard and initial market (1984 ~ 1991)

By 1984, the growth of the CD market was just moderate. Philips and Sony expanded CD standard to CD-ROM for computer storage. CD-ROM standard was developed to be compatible to CD standard, that is, CD-ROM drive could read CD Audio disc. Also CD-ROM titles could be produced with the same equipment for CD Audio disc. The difference between CD Audio and CD-ROM standard was in the logical formats. Missing data in audio doesn’t have much effect overall quality. However, missing data caused from disc defects would lead to total loss or crash of the computer file in data storage. CD-ROM standard has a stronger error correction system to prevent this kind of fatal error.

As CD technology is digital, it could be a natural evolution. Also, CD-ROM has several merits over hard disk or floppy disk. CD-ROM could provide enormous data capacity. A single CD-ROM disc could hold 650MB of digital data. This capacity is equivalent to 1,800 floppy diskettes (360k, 5.25 inch) or 250,000 pages of documents. Data encoded in a CD-ROM disc is virtually safe from crashing because the data is retrieved by optical pick-up. The first CD-ROM drive was like a player rather than a drive. Philips, Hitachi, and Sony were the first developers of the CD-ROM player.

However, there are obvious problems to solve. As it is a prerecorded media, there should be some contents to fill up the large capacity. There were several proposed usages for CD-ROM, mostly for electronic publishing such as encyclopedia and databases.

The first market was minicomputers. CD-ROM was used for database storage to reduce the expensive access time to a main frame. The market was not very large.

By 1988, there were about 15 manufacturers, 30 publishing companies, and 40 software
houses that were developing CD-ROM applications. However, as the initial cost to enter the CD-ROM business was still very high, there were only 100 to 200 general titles, which aimed at legal, medical, financial, library, and scientific markets up to 1988.

The price of CD-ROM drives also was the problem to overcome to enter the mass market. The average price of high-end CD-ROM drives was $1,200 and the average price of low-end CD-ROM drives was over $500 in 1988. The worldwide market was estimated to be 150,000 units and 69 million dollars in 1988.

By 1990, the CD-ROM market expanded to Workstations. CD-ROM was used for a delivery medium for large size software such as Operating systems and Computer Aided Design. The trial to develop the multimedia title was continued by software companies like Microsoft. Also the average price of CD-ROM drives dropped to around $300. The CD-ROM drive market grew to 133 million dollars 1990.

Major players in drive business were Philips, Hitachi, Sony, and Toshiba. They designed the CD-ROM drive differently from the CD player and put an emphasis on the reliability of data. Complex mechanism of caddy, circuits of discrete components, and expensive SCSI interface was the first dominant design for CD-ROM drives. As the demand for drives was not so big, there were few chances for economies of scale in manufacturing key components until the late 80's. As a result, it was a very luxurious device. On the contrary, the CD player was continuously innovated for lower cost without loss of data reliability.

By all means, CD-ROM drives were sold in this niche market until the early 90's though many companies expected the CD-ROM would become the standard for secondary storage.
II.1.3 Take-off of CD-ROM drive (1992~1999)

From the early 90's, the multimedia issue hit the PC industry though it was partially their strategy to enter the home market. The CD-ROM drive was perceived as a core device for multimedia applications. Multimedia PC level 1 guideline was announced by PC hardware and software companies. It was a platform guideline for software companies to develop multimedia software. It determined the direction of future PCs. A year after, they announced Multimedia PC level 2, which was on the same line with the previous guideline but with better specification.

Multimedia PCs changed the features of conventional PCs. It included a sound card, CD-ROM drive, and speakers. Now the PC became an entertainment device as well as a computing device. It changed the main market of CD-ROM drives from Workstations to PCs. It created a Multimedia upgrade kit market as well as before-market. Available CD-ROM titles were more than 500 by 1992. The CD-ROM drive market started to take off.

The possibility of mass market attracted many companies to enter this market. They were usually CD player manufacturers and/or other PC peripheral manufacturers. The Licensing fee was about 3% in 1993, which was a reasonable level for a new entrant, who has the basic technology for CD players and the ability to design the interface with the host PC. New entrants challenged the market with low cost designs. A small Japanese company, Mitsumi, was one of them. Mitsumi used to be in the floppy disk drive business, a business with low margins and tough competition. They could leverage manufacturing skills from floppy disk drives to CD-ROM drives. Mitsumi engineers changed the mechanism of the CD-ROM drive from caddy type to tray type, which was used in CD players, and the SCSI
interface to IDE interface. Caddy was used in CD-ROM drive for protection of Disc. Though the possibility of disc defects was increased in tray type, the manufacturing cost for the mechanism could be reduced a lot. IDE interface was the data bus format used in AT PC. With IDE interface, they could eliminate SCSI interface board though the transmission speed of data became slower. Mitsumi CD-ROM drives were supplied to sound card manufacturers for the Multimedia kits. Soon low cost design became a dominant design for PCs.

After the CD-ROM drive became a default device for PCs, the competition was focused on the improvement of the speed of CD-ROM drives.

Table II-1. CD-ROM drive Installed Units (000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1X</td>
<td>5,978</td>
<td>5,737</td>
<td>4,716</td>
<td>3,455</td>
<td>200</td>
</tr>
<tr>
<td>2X</td>
<td>7,147</td>
<td>13,914</td>
<td>15,737</td>
<td>17,833</td>
<td>11,881</td>
</tr>
<tr>
<td>3X/4X</td>
<td>93</td>
<td>9,833</td>
<td>35,768</td>
<td>46,363</td>
<td>46,874</td>
</tr>
<tr>
<td>6X</td>
<td>--</td>
<td>--</td>
<td>571</td>
<td>9,719</td>
<td>10,696</td>
</tr>
<tr>
<td>8X</td>
<td>--</td>
<td>--</td>
<td>86</td>
<td>19,292</td>
<td>31,310</td>
</tr>
<tr>
<td>10X/12X</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,512</td>
<td>17,073</td>
</tr>
<tr>
<td>16X</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>2,048</td>
<td>17,487</td>
</tr>
<tr>
<td>&gt;16X</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>24,015</td>
</tr>
<tr>
<td>DVD</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>662</td>
</tr>
<tr>
<td>Total</td>
<td>13,218</td>
<td>29,484</td>
<td>56,879</td>
<td>100,220</td>
<td>160,199</td>
</tr>
<tr>
<td>Growth</td>
<td>229%</td>
<td>123%</td>
<td>93%</td>
<td>76%</td>
<td>60%</td>
</tr>
</tbody>
</table>

The speed of CD-ROM drives almost doubled every year as in Table II-1. The CD-ROM drive market followed the typical characteristics of the computer market. After higher speed models came out to the market, the price of existing models dropped quickly. So, the fast development became a critical factor for success in the market. Also, the average OEM price of CD-ROM drives dropped to under $100 in 1995.

Early followers of CD-ROM standard took a dominant market share in 1996, but late entrants competed with them with aggressive pricing.

Table II-2. CD-ROM drive Market Share (1996)

<table>
<thead>
<tr>
<th>Company</th>
<th>Units</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panasonic</td>
<td>8,410K</td>
<td>18%</td>
</tr>
<tr>
<td>Mitsumi</td>
<td>6,890K</td>
<td>15%</td>
</tr>
<tr>
<td>Toshiba</td>
<td>6,250K</td>
<td>14%</td>
</tr>
<tr>
<td>Hitachi</td>
<td>4,400K</td>
<td>10%</td>
</tr>
<tr>
<td>NEC</td>
<td>4,500K</td>
<td>10%</td>
</tr>
<tr>
<td>LG Electronics</td>
<td>3,861K</td>
<td>9%</td>
</tr>
<tr>
<td>Sony</td>
<td>4,077K</td>
<td>8%</td>
</tr>
<tr>
<td>Teac</td>
<td>2,752K</td>
<td>6%</td>
</tr>
<tr>
<td>Others</td>
<td>4,495K</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>45,635K</td>
<td></td>
</tr>
</tbody>
</table>

Source: International Data Corporation (IDC) 1997

Late entrants were inferior to existing firms in terms of reputation and brand in after-market. But, as the built-in PC market overwhelmed the upgrade market and PC OEM became the
major market of CD-ROM drive from the mid 90’s, the difference between early followers and late entrants became smaller. This trend became severer as the market started to saturate. In 1999, LG Electronics from Korea took the largest share of the optical storage device market with its CD-ROM drive.

Table II-2. CD/DVD-ROM drives Market Share (1999)

<table>
<thead>
<tr>
<th>Company</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>LG Electronics</td>
<td>15%</td>
</tr>
<tr>
<td>Toshiba</td>
<td>13%</td>
</tr>
<tr>
<td>Panasonic</td>
<td>11%</td>
</tr>
<tr>
<td>TEAC</td>
<td>10%</td>
</tr>
<tr>
<td>Samsung</td>
<td>7%</td>
</tr>
<tr>
<td>Sony</td>
<td>6%</td>
</tr>
<tr>
<td>Acer</td>
<td>6%</td>
</tr>
<tr>
<td>Mitsumi</td>
<td>5%</td>
</tr>
<tr>
<td>Hitachi</td>
<td>5%</td>
</tr>
<tr>
<td>NEC</td>
<td>3%</td>
</tr>
<tr>
<td>Lite-On</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>15%</td>
</tr>
</tbody>
</table>

Source: International Data Corporation (IDC) 1999

As the difference between early followers and late entrants decreased, the leading companies in the market tried to move to the next generation of CD-ROM standard. It was DVD (Digital Versatile Disc) standard.
II.2 DVD Video and DVD-ROM standard

II.2.1 Two format groups

Two alliance groups were formed for the DVD standard. One group consisted of some early followers of the CD-ROM standard. They were Toshiba, Hitachi, Pioneer, and Panasonic (Toshiba Group). The Toshiba group formed in 1993. They co-developed a format known as Super Disc (SD) and developed their prototype in late 1993. The other group consisted of Philips and Sony, the original inventor of the CD-ROM standard. The Philips and Sony group developed its prototype following their Multimedia CD (MMCD) format in mid-1994.

As a successor format of CDs, both formats were developed considering entertainment use (Audio/Video) and computing use (DVD-ROM). SD format and MMCD format were not compatible not only in logical level but also in physical level though those formats are very similar in the end-users' viewpoint. Two groups respectively announced that they want their design to become accepted as the standard.

It is interesting that the Toshiba group took an action faster than the Sony and Philips group even though they were not the original standard setters for CDs. Also the Toshiba group had a stronger (or larger) alliance group than Sony and Philips. As backward compatibility with CDs was considered in both formats from the beginning, the Sony and Philips group should have had a better position than the Toshiba group by their historical heritage. But they did not. In truth, neither party had the power to determine the standard by themselves.
II.2.2 The standard setting process

Though both formats considered the home entertainment sector and the computing sector, there was a little difference in placing an emphasis on each sector. The Toshiba group conceived of the innovation as a way to play digital movies at home as a successor of VCRs. So, they successfully persuaded Time Warner, MCA and MGM/UA to join their supporting group. (By the way, Toshiba owns 5% equity in Time Warner and Panasonic fully owns MCA.) The Philips and Sony group conceived of the innovation as a replacement for CD-ROMs in computers. They targeted computer makers and software suppliers, but it was not very successful. They got partners in the entertainment sector, but both Polygram and Sony Pictures are 100% subsidiaries of Philips and Sony respectively. By 1995, the Toshiba group got more supporters mainly from consumer electronics, and Philips and Sony group mainly from the CD-ROM drive industry. Though there were trials to push through their formats by technological superiority, it was not clear which was better. Important players in entertainment sectors and computing sectors didn’t take a position to one group. They didn’t like standard battle in the market place. They worried that two incompatible standards would slow down the adoption of DVD. IBM took the role of brokerage in two parties. IBM and other companies gave pressure to both parties to settle a unified format.

Finally a compromised format was proposed to IBM and accepted in September 1995. It was bits and pieces from both formats, but important parts such as the basic structure of the disc and error correction code was adopted from the Toshiba group while the signal modulation method was adopted from the Philips/Sony group. This unified DVD standard
included DVD-ROM, DVD Audio, DVD-R (Recordable/once), and DVD-RAM (Rewritable) as well as DVD Video. However, some details in DVD Audio and Writable DVDs were not finalized and were to be discussed later.

II.2.3 Copy protection and regional code for movies

DVD is basically the same concept with CD except its capacity in user perspective. DVD Video can hold 135 minutes of digital movie encoded by MPEG-2 compression standard and 5.1 channel digital surround sound encoded by Dolby AC-3 standard in a single side. DVD-ROM can hold 4.7GB of digital data for an optical storage in single side.

This high performance raised a copy protection question for movie studios. They required strong encryption to prevent digital to digital copy. There was a conflict between movie studios and computer manufacturers on how strong it should be. Movie studios, of course, wanted the strongest encryption while computer manufacturer worried about the decryption burden on CPU. It seems to consider computing power more at first, but stronger protection later.

The other problem is regional code. The code system divides the world into 6 zones, and gives a code for DVD titles and Players. A title can be played on a player only if the regional code matches. It was required by major movie studios. They wanted to protect the current distribution scheme of the movies. Movies are viewed at the theater first and then by VCR and cable TV, finally on terrestrial TV. And this scheme is different from the region. They wanted to control the distribution scheme for DVD, too. Regional code was accepted for DVD Video from the beginning. However, they wanted to apply regional code
for DVD-ROM drives, in case the movies are played on a PC. DVD-ROM drive manufacturers don’t have to apply regional code for their drives if their drives don’t have a movie decoding function. However, in this case movie player software should have regional code and software decoding would give burden to CPU. DVD-ROM manufacturers started to apply regional code to DVD-ROM drives this year. That means they have to produce 6 types of DVD-ROM drives and promote them separately for the worldwide market.

II.2.4 DVD Forum

In December 1995, after the battle on DVD standard was settled, companies that were deeply involved in the DVD standard formed a consortium as an ad hoc group for DVD standard.

![Diagram of DVD Forum Organization](Source: www.dvdforum.org/struct.htm)
They opened it to other companies and organizations and made a working group under it for improvement of the DVD format. They also use the DVD Forum as an official information channel for DVD promotion. It seemed like they wanted to make an industry organization for further standards.

The Steering committee serves as the executive council of the DVD Forum, and approves all decisions relating to the fundamental structure or policy of the Forum. ‘The original members’ expanded steering committee members 10 to 17 companies in 1998 to wide spread the consortium’s influences.

Table II-3. DVD Steering Committee members

<table>
<thead>
<tr>
<th>Original Members</th>
<th>Additional Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi, Ltd.</td>
<td>IBM Corporation</td>
</tr>
<tr>
<td>Matsushita Electric Industrial Co. Ltd.</td>
<td>Industry Technology Research</td>
</tr>
<tr>
<td>Mitsubishi Electric Corporation</td>
<td>Institute of Taiwan</td>
</tr>
<tr>
<td>Philips Electronics N.V.</td>
<td>Intel Corporation</td>
</tr>
<tr>
<td>Pioneer Electronic Corporation</td>
<td>LG Electronics Inc.</td>
</tr>
<tr>
<td>Sony Corporation</td>
<td>NEC Corporation</td>
</tr>
<tr>
<td>Thomson Multimedia</td>
<td>Samsung Electronics Co., Ltd.</td>
</tr>
<tr>
<td>Time Warner Inc.</td>
<td>Sharp Corporation</td>
</tr>
<tr>
<td>Toshiba Corporation</td>
<td></td>
</tr>
<tr>
<td>Victor Company of Japan, Ltd.</td>
<td></td>
</tr>
</tbody>
</table>


In spite of efforts to make one standard within the DVD Forum, several formats have been discussed for DVD recordable standard outside the DVD Forum as well as inside the
Forum. Hitachi and Panasonic launched their DVD-RAM drives for the large capacity data recording market after discussion within the DVD Forum. But, three different formats are competing for the Video Disc Recorder (VDR) standard, and these three groups announced to launch the product in 2000 respectively.

There is another issue for the standard setters. Finalized DVD standard does not belong to a single company. As it was a compromised standard of two competing groups, patents related to DVD standard were also dispersed to several companies. It made the decision on licensing policy complex. They tried to make one association for collecting royalties, but they failed to reach an agreement among the patents holders. Finally they split into two groups, the Toshiba group and the Sony and Philips group. As DVD players and DVD-ROM drives should provide backward compatibility with CDs, the rights related to CD standard also belongs to the Sony and Philips group. Both groups also have different licensing policies on discs. The Toshiba group requires 7.5 cents per a disc and Philips group charges 5 cents for a disc. Licensees have to make a contract with both groups. This licensing fee is relatively high compared to the licensing fee for CD technology. If the licensee has to pay the other technologies not belonging to those groups, for example MPEG II or motor controlling technology, the fee becomes much higher than for the CD.
Table II-4. Licensor groups of DVD Patents

<table>
<thead>
<tr>
<th>Licensor Group</th>
<th>Technology</th>
<th>Royalty by Products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DVD Player</td>
</tr>
<tr>
<td>Panasonic</td>
<td>DVD Standard</td>
<td>*4% of Net Sales Price or Minimum $4</td>
</tr>
<tr>
<td>Toshiba</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hitachi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JVC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitsubishi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Warner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sony</td>
<td>CD Standard</td>
<td>**3.5% of Net Sales Price or Minimum $5</td>
</tr>
<tr>
<td>Philips</td>
<td>DVD Standard</td>
<td></td>
</tr>
<tr>
<td>Pioneer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Business Wire 10/20/97
**Excluding $2.5 of Royalty for Video CD compatible (Source: PR Newswire 2/17/99)
*** Other sources: Company estimated data

II.2.5 DVD in the market place

While these standard processes were going on, there were a lot of different market estimations from newspapers and magazines. When the copy protection was issued in 1996, some forecasts expected the ramp up of DVD-ROM would be faster than DVD Video. In the middle of optimistic and pessimistic estimates, DVD Video seems to be taking off from 1999. Table II-5 shows the sales of DVD players in the US market in 1997, 1998 and estimation of 1999 and further. Though the sales forecast was not met in 1997, 5% market penetration was achieved by 1999. It is one of the fastest adoption rates in consumer electronics history.
Table II-5. Estimation of Sales unit of DVD player

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimation of 1999* (000)</th>
<th>Estimation of 1996**</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>349</td>
<td>0.8m</td>
</tr>
<tr>
<td>1998</td>
<td>1,079</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>3,550</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>5,850</td>
<td>10.1m</td>
</tr>
<tr>
<td>2001</td>
<td>7,997</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>10,372</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>12,478</td>
<td>25.3m</td>
</tr>
</tbody>
</table>

*Source: Consumer Electronics Associations (1999–2003 is estimation)  
**Source: Paul Kagan Associates Inc. (Estimation)

Table II-6. Japan and US DVD title availability

<table>
<thead>
<tr>
<th>Year</th>
<th>Japan</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>1,200</td>
<td>2,500</td>
</tr>
<tr>
<td>1999</td>
<td>2,500</td>
<td>5,000</td>
</tr>
<tr>
<td>2000</td>
<td>5,000</td>
<td>9,500</td>
</tr>
</tbody>
</table>

Source: Buena Vista Home Entertainment

Also, available titles are increasing. It seems the number of available titles already exceeds critical mass. Rental service becomes popular. Major movie studios now usually publish new movies in DVD format as well as VHS tape. It looks like DVD Video is on the ramping up point of S-Curve.

However, DVD-ROM is different. At first, the DVD-ROM was expected to replace the CD-ROM drive rapidly. As the DVD-ROM drive can read CD-ROM discs, it can be comparable to high speed CD-ROM drives.

The price of the DVD-ROM drive was relatively high, average $298, in 1998. It was
usually sold as a DVD upgrade kit with an MPEG II decoder board. Unfortunately, the end-user market didn’t respond to DVD-ROM drives very positively.

A more than $100 price difference between a 20X~32X CD-ROM drive and a DVD-ROM drive made it hard to be adopted in below $1000 PCs in the OEM market. Major PC makers provide a DVD-ROM drive option only for high end PCs. Considering there were not enough DVD-ROM titles in the market, it was a natural result. However, the average price of DVD-ROM drives dropped to $215 in 1999, and major PC makers provided DVD-ROM drive options in mid range PCs. The shipments of DVD-ROM drives are estimated to be 5.4 million units in 1999 and they will exceed those of CD-ROM drives only after 2001.

Table II-7. Worldwide shipments of read-only drives, in units

<table>
<thead>
<tr>
<th>Year</th>
<th>CD-ROM</th>
<th>DVD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>74,580,900</td>
<td>1,199,000</td>
</tr>
<tr>
<td>1998e</td>
<td>82,237,500</td>
<td>4,365,000</td>
</tr>
<tr>
<td>1999e</td>
<td>87,295,000</td>
<td>13,120,000</td>
</tr>
<tr>
<td>2000e</td>
<td>76,573,000</td>
<td>37,320,000</td>
</tr>
<tr>
<td>2001e</td>
<td>46,053,000</td>
<td>79,727,000</td>
</tr>
</tbody>
</table>

Source: Disk/Trend, Mountain View, Calif. (1998) e = estimate

Not only low price high speed CD-ROM drives are competing with the DVD-ROM drive for the PC slot. DVD-ROM drives have to compete with CD-RW (ReWritable) drives in high-end PC options.

Philips and Sony improved the CD-R (Recordable but not erasable) format and finalized CD-RW standard in 1996. As the added value of CD-RW was clear to end-users, CD-RW
drives recorded impressive sales in 1997 and 1998. Though the portion of recordable drives would stay lower than that of read only drives, CD-RW drives attract more attention in the early stage market than DVD-ROM drives.

Table III-8. Worldwide Disc Drive Shipments (Million Units)

<table>
<thead>
<tr>
<th>Year</th>
<th>CD-ROM drive</th>
<th>CD-RW drives</th>
<th>DVD-ROM drives</th>
<th>Removable Hard Drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>73.2</td>
<td>2.6</td>
<td>--</td>
<td>0.9</td>
</tr>
<tr>
<td>1998</td>
<td>84.6</td>
<td>6.3</td>
<td>--</td>
<td>2.2</td>
</tr>
<tr>
<td>1999</td>
<td>91.4</td>
<td>15.7</td>
<td>9.8</td>
<td>2.5</td>
</tr>
<tr>
<td>2000</td>
<td>79.2</td>
<td>22.9</td>
<td>18.2</td>
<td>3.5</td>
</tr>
<tr>
<td>2001</td>
<td>62.1</td>
<td>28.4</td>
<td>38.4</td>
<td>4.2</td>
</tr>
<tr>
<td>2002</td>
<td>51.6</td>
<td>36.5</td>
<td>54.3</td>
<td>4.7</td>
</tr>
<tr>
<td>2003</td>
<td>40.1</td>
<td>44.6</td>
<td>75.2</td>
<td>4.3</td>
</tr>
<tr>
<td>2004</td>
<td>18.2</td>
<td>51.7</td>
<td>92.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Source: Computer Economics (1999)

So far, there are not many DVD-ROM titles in the market. Most of them are republished versions of multiple CD-ROM database titles except for a few games. It is very similar to late 80's of CD-ROM's. As the CD-ROM titles market is still growing, it is hard to expect to see various DVD-ROM titles within a few years. Some argued DVD-ROM drives should be installed in 40% or 50% of total PCs for software developers to move from CD-ROM titles to DVD-ROM titles except for in the case of a killer application.

The cost to publish a DVD-ROM title is still high compared to a CD-ROM title. It takes a
large amount of initial investment. The unit publishing cost of a DVD-ROM disc was estimated $2 in 1997 and $1.7 in 1999. Comparing to 50 cents per CD-ROM title, the most probable strategy for title manufacturers would be ‘wait and see’. Though the cost might drop very quickly as DVD Video becomes popular, it seems to take some time.

II.3 DVD Recordable standard

Though a basic agreement on a standard for recordable format was made in 1995, it is not unified yet. While the Panasonic, Hitachi and Toshiba group is sticking to DVD-RAM, Sony and Philips are proposing DVD+RW, and Pioneer is proposing DVD-RW for recordable formats. DVD-RAM and DVD-RW were discussed in the DVD Forum, but DVD+RW was dropped in the early stages of the discussion. These standards are somewhat different technically, but their user values do not seem so different.

DVD-RAM format went first. The first standard of DVD-RAM was finalized in 1997 through the DVD Forum. Its single-side capacity was 2.6GB. Panasonic and Hitachi launched their DVD-RAM drives for niche computing market in 1998. However, Sony and Philips didn’t withdraw the development of their 3.0GB DVD+RW standard. Also, Pioneer proposed DVD-RW with single-side capacity of 4.7GB to the DVD Forum for AV recording, and argued the importance of capacity compatibility with DVD-ROM. To cope with this argument, the DVD-RAM group upgraded DVD-RAM to 4.7GB through the DVD Forum, and finalized it in 1998. Panasonic and Hitachi are planning to launch their 4.7GB DVD-RAM drives for PCs in 2000. Sony and Philips also upgraded DVD+RW for
4.7GB single-side capacity. While DVD+RW was rejected already in the DVD Forum, Philips announced that they would launch VDR (Video Disc Recorder) in late 2000. Pioneer also announced they would launch VDR following the DVD-RW format in autumn 2000 though DVD-RW standard is not finalized in the DVD Forum yet.

Table II-9. DVD recorder formats and supporters

<table>
<thead>
<tr>
<th>Manufacturers with announced products</th>
<th>DVD-RAM</th>
<th>DVD-RW</th>
<th>DVD+RW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panasonic</td>
<td>Pioneer</td>
<td>Philips</td>
<td></td>
</tr>
<tr>
<td>Samsung</td>
<td>Zenith</td>
<td>Thomson</td>
<td></td>
</tr>
<tr>
<td>Supporting manufacturers</td>
<td>Toshiba</td>
<td>JVC</td>
<td>Ricoh</td>
</tr>
<tr>
<td>Hitachi</td>
<td>Sharp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hitachi Maxwell</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kenwood</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mitsubishi Chemical</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ricoh</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TDK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launch date(US)</td>
<td>Summer 2000</td>
<td>Autumn 2000</td>
<td>Q4 2000</td>
</tr>
</tbody>
</table>

Source: Screen Digest from industry sources (2000)

Although there might be a chance to reach a unified standard for DVD recordable, the possibility of the in-market standard war becomes very high.
III. Standards and major forces in the optical storage device market

CD standard was accepted with almost no resistance in the industry. This was partially because it was the result of cooperation of two giant consumer electronics companies, Philips and Sony, and because their technology was very advanced and technically the completion level was higher than other alternative technologies. The main issue was how they could make the adoption faster.

As there was about a three year gap between standardization of CD Audio and CD-ROM, they were discussed separately. The standardization processes were completely controlled by Philips and Sony. No other companies or industries participated in the standardization process. Philips and Sony were the first movers of the industry.

CD technology was a very radical innovation. Philips and Sony had to educate the consumers as to what is digital technology and what is optical technology. Though some parts of CD-ROM standard had been evolved by industry groups afterwards and became an ISO standard, the proprietary assets mainly belong to these two companies.

On the contrary, two groups developed the comparable technology separately for DVD, and it took more than a year to reach the compromised format. Even after that, they had to negotiate with movie studios for copy protection and regional code. There were several changes between 1985 when CD-ROM standard was made, and 1994 when DVD was.

III.1 The first mover advantage
III.1.1 CD-ROM standard

Philips and Sony were the first movers of CD technology. Then were they able to take the first mover's advantages? They surely had the technology leadership from R&D and patents since they made the standard of CD Audio in 1982. CD-ROM standard was the result of the successful CD Audio standard. Besides CD-ROM, Philips and Sony developed several other technical standards based on CD Audio technology. They had prepared various reserved areas in CD Audio standard for future format development. That provides the flexibility for development for various formats of the CD family (CD-ROM(1984), Photo CD, CD-I(1987), Video CD(1993), CD-R(1994), CD-RW(1996), etc.). Some of the formats include technologies that do not belong to Philips and Sony, but the standardization was totally controlled by Philips and Sony. For example, Video-CD format was developed in 1993. The most important new feature was that Video-CD contains digital video data compressed by MPEG 1 standard. Philips and Sony decided what technology Video-CD would take for data compression/decompression technology. Some formats were not led by Philips and Sony. Photo CD format was developed by Kodak, however, as it was based on CD format, it was developed under the approval of Philips and Sony. Philips and Sony have been the managers of all CD family formats with the technology leadership. Most of the patents related to original CD standard were expired, but they still keep the position of standard setter by managing the direction of the next generation technology. CD-RW, the most recent and the most prospective standard in the CD family, was also driven by Philips and Sony. By upgrading the CD technology in this way, they are keeping the technology leadership and creating royalty income for almost twenty years.
Their technology leadership in the optical storage device industry influenced the standardization of the next generation product, DVD. Even Philips and Sony were a little late in preparation of the next generation format than the Toshiba group, but they could use their leadership in CD technology to leverage in DVD standard competition. Though the competition ended up with compromising, which was actually a victory for the Toshiba group, the fact that the DVD player or DVD-ROM drive should have backward compatibility with CDs allowed Philips and Sony to still be in the technology leaders position.

However, it is hard to say that they were able to take advantage of technology leadership from a learning curve. Following the learning curve model, the unit production costs fall with cumulative output. This generates a sustainable cost advantage for the early entrant if learning can kept proprietary and the firm can maintain leadership in market share.

In the CD-ROM drive business, as in Table II-2 and II-3, Sony has been one of the major manufacturers, but Philips has not. Philips produced its CD-ROM drives until 1997, but had failed to take a large market share since 1992. One of the reasons is that Philips put higher priority on consumer markets than computer markets. While other competitors moved their focus from saturating the CD player market to the emerging CD-ROM drive market, Philips developed its CD-I player hoping to replace the CD player. The CD-I player was the first CD based, stand-alone, multimedia player hooked to a TV. Sony also took part in development of the format, but Sony didn’t produce a CD-I player. Philips tried to get allies, but no major CD player manufacturer joined. Philips produced software as well as hardware almost by itself. Despite desperate efforts on promotion, Philips failed to create a
positive feedback loop for its CD-I. When Philips was in the CD-I business, trying to make CD-I a new dominant design for consumer electronics, other competitors developed process technologies for CD-ROM drives. For example, Sony didn’t manufacture optical pick-up for CD-ROM drives in separate production lines until 1992. They collected optical pick-ups with good performance from CD pick-up lines, and sold them for CD-ROM drives. As the CD-ROM drive market started to grow, Sony built separate manufacturing lines for CD-ROM pick-ups. When the price of CD-ROM drives dropped drastically because of the new cheaper dominant design, Philips lost its first mover advantage rapidly.

Other sources of first mover’s advantage, preemption of scarce resources or switching cost of buyers didn’t work in the CD-ROM drive business. When the CD-ROM drive market started to ramp up in 90’s, there were lots of resources for CD player manufacturing which was able to change for CD-ROM drive manufacturing. By that time, CD-ROM drive market moved from the niche market for mini computers to the mass market for PCs. Philips and Sony had to compete with early followers like Panasonic, Toshiba, and Hitachi with the same position to different buyers.

The first mover disadvantages look dominant in CD-ROM drive industry. The CD-ROM drive market was a small niche until 1992, even more than 7 years after the standard was made. It is hard to say the difference between the first movers and early followers like Toshiba, Panasonic, and Hitachi. They were all in the same line for resolution of the initial market uncertainty and technological changes. Late entrants like Mitsumi and LG enjoyed free-ride effects by avoiding the entry into a prematuresd market. Late entrants could focus on the low price CD-ROM drives, which were the new dominant designs since 1993.
Philips and Sony could take the first mover advantage of technology leadership and collect royalty income as the standard setters, but they could not extend it to build a dominant position in the market. This was partially because of the timing of the market entry, and the transition from product technology to process technology.

**III.1.2 DVD-ROM Standard**

DVD technology is a discontinuous technology for CD, but it is also an extension of CD technology. The Toshiba group started earlier than the Philips-Sony group, but the difference was only 6 months. As the standard ended up with the partial success of both groups, they all could be the first movers of DVD technology. So there are too many first movers in DVD. So far, Panasonic and Sony are leading the DVD player market, and Toshiba is leading DVD-ROM drive market.

As in the CD-ROM drive case, these companies have the technology leadership in DVD technology with their R&D and patents. The Toshiba group has the dominant position in the DVD Forum. However, as DVD standard was a compromised one and there are too many owners of it, technology leadership is also dispersed to those companies. It would be much more difficult to manage new formats based on DVD technology than it has been to manage those which are based on CD standard. Current movements on DVD recordable standard shows that the standard battle would move from before market to in market.

These companies might be able to build brand credibility for DVD players. However, other possible first mover advantages such as preemption of resources or buyers' switching cost are not to be expected at this moment. The situation is worse in DVD-ROM drives than in
DVD players because it is a technology push without sign of market needs. Companies like LG and Samsung are late entrants to the CD-ROM drive market, but they are taking the largest market share now. Once the first movers such as Toshiba resolve the uncertainty of the DVD-ROM drive market, they will attack the market aggressively to see the free-ride effects using their relationship with buyers, PC makers.

III.2 Adoption of the market

III.2.1 The window opportunity of entry into the CD-ROM drive market

The development of the CD-ROM drive market shows the typical S-shape curve for installed base. However, it is noticeable that CD-ROM drives actually have served three different markets as time went by.

At first, it was adopted to the mini computer and workstation market. It was a niche market because it was used for special business purposes as well as because of the small volume. The benefit of network externality was also small. Until 1992, the major CD-ROM drive buyers were mini computer and workstation manufacturers. As the price of the host system was expensive, the price and brand name was not a very important factor for purchasing a CD-ROM drive.

The next market existed temporally in the early 90's. A CD-ROM drive was bundled with a sound card as a multimedia upgrade kit. Explosive growth of the CD-ROM market in this period was driven by end users. The price sensitivity and brand reputation acted as a major force for decisions on purchasing. Sound card manufacturers with good brand reputation
such as Creative Labs had great bargaining power over the CD-ROM drive manufacturers. They bundled CD-ROM drives produced by new entrants like LG and Mitsumi and used their brand name in marketing.

The third market is the PC manufacturer. As the value added by PC manufacturers is making it sure that the whole PC system works well without any compatibility problem, PC makers are sensitive to the reliability of CD-ROM drives as well as the price. At this moment, end-users don’t care much about who made the subsystem of their PC, but only for PC manufacturers. Table III-1 shows the characteristics of these three different markets.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Sensitivity</td>
<td>Low</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Brand Perception</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Reliability of the drive</td>
<td>Very high</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Supplier’s Capacity and Technology</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Supplier dependency</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Market growth rate</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

There was a window of opportunity for new entrants between 1992 and 1996. It was easier for new entrants to meet the compatibility requirements of an upgrade kit than of a PC because an upgrade kit was a subsystem of a PC. If a CD-ROM manufacturer could have
the economies of scale, then it could enter the largest market at the moment. New entrants aggressively attacked the multimedia kit market with low price design, which became a dominant design for PC application. The low price design was not a new technology. They just applied existing technologies, which were usually used in CD players, and changed the architecture of previously expensive CD-ROM drives.

Since then, the competition in the CD-ROM drive market focused on speed increasing technology. It was an incremental innovation, but it became a major competing specification of CD-ROM drives. It is still used as the notation of the grade for DVD-ROM drives as well as CD-ROM drives. The CD-ROM drive with basic speed (150KB/sec) and the CD-ROM drive of 32x have the exactly same concept except 32x drive can transmit data from the drive to the host PC faster. Even though more precise optical pick-up and faster signal processing power are required, the faster drive has the same architecture as the basic speed drive. Once the next speed model comes out to the market, the price of the old model drops rapidly and becomes under the marginal cost. Soon the old model fades away from the market. This pricing mechanism is very similar to other PC peripherals. Though there are technological limits in speed increases of optical storage devices, this mechanism had been ensuring reasonable profit for competitive manufactures up to 48x ensuring the competition remains on features.

Companies with a certain manufacturing capability and technology challenged the PC OEM market continuously. The market share was divided mainly to early followers and late entrants of the market in late 90’s.
III.2.2 The DVD-ROM drive market

As the DVD-ROM drive is the next generation of the CD-ROM drive and it has backward compatibility, there is no technical or functional resistance to substitute the CD-ROM drive to the DVD-ROM drive. However, PC manufacturers do not show very positive signs for adoption of DVD-ROM drives yet. So far, the majority of DVD-ROM drives have been sold in the upgrade kit market. Comparing to the market situation of CD-ROM drives in the early 90's, several forces which accelerated the adoption rate of CD-ROM drives do not exist in the current DVD-ROM drive market.

First, there is no concept change in PCs. When CD-ROM drives started to be adopted in PCs, multimedia was the most attractive issue. It created the upgrade demand to multimedia PCs with sound card, CD-ROM drive, and speakers. A compelling concept might be "movie PC" as in current DVD-ROM drive promotion, but it doesn't seem to appeal much.

Second, there was a new dominant design for CD-ROM drives when the multimedia PC was issued. Though it worked on rather the price of the CD-ROM drive than on the features, it accelerated the adoption of the market. Third, the life of feature competition would be much shorter than CD-ROM drive. The speed competition of CD-ROM drive started at 2x when the sales ramped up. However, the speed competition of DVD-ROM drive reached 10x already. Considering the speed of DVD-ROM is about 3 times faster than CD-ROM drive, it will not take long that the competition would move to price from speed increase.

As the price drops, it will replace the CD-ROM drive, but only a few companies, which have very competitive manufacturing skills would survive by that time.

DVD-ROM drives will replace CD-ROM drives in a few years, but the competition in the
market will be much tougher.

III.3 Complementors

III.3.1 Positive feedback loop of CD-ROM drives and titles
As the first CD-ROM drive was for business use, there were not many general titles. There were several data formats for different host computers. CD-ROM titles for this market were very different from the PC market.

While the installed base increased gradually for early adopters of the PC market, general CD-ROM titles for PCs started to be developed. Philips and Sony didn’t place as much effort on promotion of CD-ROM drives as they did on CD players. However, Microsoft embraced the CD-ROM in its early stage. Microsoft launched a device driver for CD-ROM drives connecting to PC’s DOS system in 1987 though the price of a CD-ROM drive was over $1,000. Bill Gates forecasted that every home would have personal computer with a CD-ROM drive and that the CD-ROM would be the core device for PC as a home information system. Microsoft continuously had supported CD-ROM standard holding the annual conference for CD-ROM development. Apple launched its CD-ROM drive attachable to Macintosh in 1988. Owing to computer industry’s efforts, the positive feedback loop of CD-ROM drive and titles started to work in the early 90’s. Also the cost for publishing CD-ROM titles became much cheaper as the publishing process is almost the same as CD Audio titles.

The eagerness of computer industry on CD-ROM was that they wanted to expand the
personal computer market from office to home. They needed new functions and media, which were able to attract home users to PCs. This independent, but positive relationship between CD-ROM drives and titles industry continued on, and led the speed increase of CD-ROM drives to enable faster data transmission for multimedia data.

**III.3.2 DVD-ROM titles**

The situation looks similar between DVD-ROM now and CD-ROM in 1989 in terms of title availability. DVD-ROM titles for general use are confined, for now, to encyclopedias and a few games. Though it is expected to be increasing gradually, there are two main obstacles to overcome for DVD-ROM titles to become popular. First, the publishing cost is not low enough. When CD-ROM titles were to come out, the cost of publishing a CD-ROM title was as low as that of a CD Audio title because publishers could work within the existing production technology of the CD Audio. However, DVD Video and DVD-ROM are both in the initial stage of marketing. The manufacturing technology has not developed enough yet. Second, more importantly, software firms are not as aggressive on DVD-ROM titles as they were on CD-ROM titles. They have a cheaper solution in CD-ROM, and the capacity of 640MB is still enough for most PC application software. Even in the case that software exceeds a CD-ROM's capacity, they usually prefer to create multiple CD-ROMs, considering the low installed base of DVD-ROM drives at this moment.

This situation will change as installed base of DVD-ROM drives increases, but it will not happen in short term unless an unexpected killer application appears.

It will take some time for adoption of DVD-ROM. However, the owners of DVD standard
will not be discouraged by the short term prospective. The DVD Video market has boosted up recently, and the owners fo DVD standard have strong market position. They can also expect as great a revenue stream from royalty income as Philips and Sony did with CD standard.

Toshiba is the most aggressive company in DVD-ROM drives marketing now. Toshiba is known to hold the weakest position in the royalty distribution among the licensing group. Toshiba is not strong in the consumer electronics market, either. Toshiba’s strategy seems that they are trying to build complementary assets in the DVD-ROM drive market faster than others do to take advantage of standard setting.

III.4 The number of players in standardization

Philips and Sony developed CD standard, and promoted it to the market by themselves. Taking the advantage of the first mover and the standard owner, they could expand it from audio format to data, video and recordable formats. They could manage the technology leadership in the CD field, and maintained the various formats consistent and compatible. As the optical storage device industry has been growing, the number of participants also increases. There are three groups in the industry. These are the standard owners, early followers such as Toshiba, Panasonic, and Hitachi, and the late entrants such as LG, Mitsumi, and Samsung.

The early followers group has the ability to innovate, but they could not participate in the continuing standardization process of CD formats. For example, Panasonic developed
alternative technology for CD-RW, and launched the product named PD (Phase change Disc) in the early 90's. As it was rewritable, obviously it was better than CD-R format at the time. However, it was not involved in the CD family group. PD has backward compatibility for CD-ROM, but discs written in PD format can not be read in CD-ROM drives. Philips and Sony made new CD standard, CD-RW, and provided the backward and forward compatibility for newly launched CD-ROM drives. Panasonic and other early followers formed an alliance for DVD based on PD technology.

Late entrants have the weakest position in technology leadership for the next generation, but they have the strongest position in the current market. They have large manufacturing capacity, and skills. Recently some of late entrants invested R&D for the next generation technologies, and joined standard activities.

The users of the standard in industry such as movie studios, software developers, and PC makers actively influence the standardization process for their interests also. DVD Forum was formed to coordinate among those players. The whole process of standardization became very slow and difficult by the change of negotiation style from individual to committee. It took more than 2 years to finalize the DVD-RAM standard after the basic agreement was made in 1995. Recent announcements of Pioneer and Philips about Video Disc Recordable shows the possibility that the cooperation in DVD Forum might not work anymore.

The increased number of participants in standardization influences licensing policy also. At first, the industry expected around 6% of royalty for one patent pool. However, Philips, Sony, and Pioneer were not satisfied with the share they would receive in the group, and
formed separate patents pool. As a result, licensees have to contract separately with both
groups. Also total royalty was raised up to 9% except royalties for other patents groups
such as MPEG, Dolby, and individual patent holders.

Higher royalty is a natural result of making up the shrinking share of individual companies.
This trend will deepen for the next generation standardization. The possibility of standard
war in the market also increases.
IV. Conclusion

Generally, Standard provides advantages in competition for the owners of related technology. However, to capture the value from the standard, there should be a continuous effort to maintain the initial advance.

The evolvement of the standards of optical storage devices is a good example of before-market standard competition. The first standard in the optical storage devices industry was CD Audio standard. CD Audio and CD-ROM standard themselves were accepted in industry and market without big troubles. The main reasons of easy adoption were that the technology itself was far advanced to alternative technologies and the standard owners, Philips and Sony, took a generous licensing policy. Philips and Sony held the technology leadership for following CD standards, and they could make royalty revenue for a long time. However, they were not very successful to keep the dominance in CD-ROM drive market share. Early followers like Panasonic, Toshiba, and Hitachi and late entrants like Mitsumi and LG took the larger market share with process innovations and proper market entry timing. Though leading the standardization with product innovation is very important to keep the technology leadership, but the succeeding process innovations are also important in this industry.

Early followers of the industry formed an alliance group for DVD standard, the next generation of CD standard. Philips and Sony allied again for competing with them, and DVD standard battle ended up with a compromised format. During the process, buyers groups and complementors groups pressed the standard competitors to include their
opinions in the standard. All DVD formats were discussed at the same time for the consideration of consistency and compatibility. But, different degree of technology development for each format and different market readiness were not properly reflected in the standardization process. An industry consortium, DVD Forum was composed of the companies related to DVD standard to coordinate the detail technology specification, but recordable DVD format is not unified yet, and a standard battle like Beta Max and VHS in the marketplace seems not to be avoidable. As the number of players in the industry increases and the number of related industries increase, the complexity of standardization also increases. This trend will deepen in the next generation standardization, therefore, managing consistency and compatibility of the formats based on DVD or the next generation will become more difficult. The Intel and Microsoft model in PC industry will be a good example of solving this kind of problem. Intel and Microsoft are involved in new standardization activities that would be adopted in PCs whether the technology is directly related in their business or not. They manage the consistency and compatibility of all technical standards related to PCs and prevents the possibility of their market being disturbed by new technology. Though there is no super hero like Intel or Microsoft in optical storage industry, involvement of a formal standard organization would be necessary, considering that the digital convergence between industries progresses.

Standardization process in this industry will become a market competence, and it will become a loser lost it all battle even though winner cannot take it all. To win the battle, the most important action would be making allies as many as possible and overwhelm the competitive devices in installed base in short term as in the Beta Max and VHS case. The
characteristic of optical storage device industry is that it is strongly influenced by complementors. The major complementors should be included in the allies. For the technology follower, it is important to get a better negotiation position. If the firm has a strong position in the current market, for example a large market share, large manufacturing capacity, and good customer relationships, use these assets in negotiation for better position in joining the allies. However, they have to invest in R&D for the next generation technology in the long run, otherwise they would stay in an inferior position because of increasing royalties for license.
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