Strategic management of a large-scale technology development: The case of the Korean telecommunications industry

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Abstract

This paper deals with dynamic patterns of the longitudinal technology development and strategic changes in the Korean telecommunications equipment industry, focusing on a case of the large-scale technology development project that is known as the TDX project. The ultimate purpose of this paper is to find underlying principles in successfully managing large-scale projects or programs which involve collaborative efforts of public and private sectors in the context of developing countries. For this purpose, this paper takes a system-analytic approach to the innovation process and strategic changes. From the process perspective, it explains dynamics of the technology development process of a Korean telecommunications industry and its strategic changes along three development stages: initiation, early, and late internalization stages. From the strategy perspective, some underlying principles behind the successful technology development process are identified: the focused-and-phased, the buy-for-make, and the harmonized collaboration-and-competition approaches. Finally, implications for researchers and policy makers are discussed.

Keywords: Technology strategy; Technology development process; Case study; Telecommunications industry

1. Introduction

A nation's competitiveness depends upon the effective management of innovations in its industries (Porter, 1990). In a world of increasingly global compe-
tition, most industrialized countries select their strategic industries and support them to achieve technological leadership in the international market and to build technological capabilities in the selected industries, through large-scale projects that involve collaborative efforts of public and private sectors (Soete, 1991). Developing countries must also focus their scarce resources on appropriately selected industries and technologies to attain national competitive advantage and to survive in the global competition. However, most developing countries are facing difficulties in developing technological capabilities because of fierce global competition and weak infrastructure, as well as the lack of resources. Considering the pending milieu of developing countries, they need different strategic approaches from those of advanced countries in initiating and supporting large-scale projects as the strategic means.

Although there is some literature on the accumulation of technological capabilities in developing countries, strategies to achieve industrial growth and technological self-reliance have not been dealt with sufficiently. In this paper we address the following questions:

(a) How can developing countries build up technological capabilities in high technology areas?
(b) How can they formulate and implement their technology strategies in spite of the various obstacles and difficulties faced by developing countries?

To answer these questions, this paper investigates the technology development process in the Korean telecommunications industry and analyzes the strategic decisions that led the large-scale project in the industry.

For this research, relevant information was obtained through unstructured interviews with decision makers and project leaders of public research institutes and private firms. In addition, various historical records and related documents were reviewed to confirm our research findings and to reduce undue subjectivity. Because research in this area is not structured yet, our research findings are based on an in-depth case analysis with qualitative analysis of large-scale projects. To reduce subjectivity, a system-analytic approach was taken, which provides important implications for managing large-scale projects initiated and supported by governments in developing countries.

This study attempts to examine changes in technology strategy along the technology development process at industry level. This paper first reviews the previous literature and describes the conceptual model in Section 2. Section 3 describes a case of the major innovation project in a high technology industry in Korea and shows how the industry has accumulated technological capabilities through the succeeding development stages. The discussion in Section 4 following the case presentation will reflect upon the dynamics of the technology strategy and technology development process. Finally we will discuss some lessons for policy makers trying to formulate and implement national strategies and policies for technology development.
2. Technology development process and strategy

2.1. Technology development process: The perspective

There have been some studies on the technology development process or industry life cycles (Utterback and Abernathy, 1975; Lall, 1980; Moore and Tushman, 1982; Lee et al., 1988; Porter, 1990). Among them, Lee et al. (1988) describe the dynamic patterns of technology development in developing countries with a global perspective, along three development stages such as initiation, internalization, and generation. The characteristics of each stage are summarized in Table 1.

Although this model is hypothetical, it explains how and why developing countries develop their technologies through the linkages with developed countries, by changing modes and contents of technology acquisition depending on the technology development stages. Government's technology policy and socio-cultural characteristics are also considered in this model. Lee et al.'s (1988) model will be used as a conceptual framework for the empirical analysis in this paper.

Although several stage models imply that there are different strategic requirements for success at different stages of industry life-cycles (Smith and Cooper, 1988; Spital and Bickford, 1992), most of them cannot fully explain the underlying principles of the technology development in developing countries. Therefore, we adopt the evolutionary process perspective on technology strategy (Burgelman and Rosenbloom, 1989; Burgelman, 1988) to analyze the dynamics of strategy and technological capabilities shown in the technology development process. This model focuses on three main constructs; capabilities, strategy, and experience. Within this perspective, “capabilities give strategy its force; strategy enacted creates experience that modifies capabilities” (Burgelman and Rosenbloom, 1989, p. 19). This approach not only provides a useful framework for explaining dynamic behavior over time but also stimulates us to search distinctive strategies and appropriate mechanisms for increasing technological capabilities. However, it requires more research efforts to find out how to formulate technology strategy and how to develop distinctive technological capabilities. This study examines the dynamics of the strategy and other contextual issues such as technological capabilities in the Korean telecommunications equipment industry based on this perspective.

2.2. Technology strategy: The elements

In spite of the growing body of literature on technology strategy, less is known about how to effectively formulate or implement a technology strategy (Weiss and Birnbaum, 1989; Adler, 1989). This is because the discipline of “management of technological innovation” or “management of technology” is still in its academic infancy (Chiang, 1990). Reviewing the broad literature on technology strategy, Adler (1989) emphasizes the need for a re-conceptualization of technology strategy. To do this and provide managers with needed guidance in their
Table 1
The characteristics of the technology development stages in developing countries

<table>
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<tr>
<th>Characteristics</th>
<th>Stages</th>
<th>Generation</th>
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<td></td>
<td>Initiation</td>
<td>Internalization</td>
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<td></td>
<td>Early</td>
<td>Late</td>
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<tr>
<td>Major activities</td>
<td>Simple production of adopted technology</td>
<td>Modification/improvement of existing products</td>
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<tr>
<td>Level of transferred technology&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Mature technology (Specific)</td>
<td>Mature technology (Specific)</td>
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<tr>
<td>Acquired technological elements</td>
<td>Operations technology</td>
<td>Operations technology</td>
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<tr>
<td>Major source of technology</td>
<td>External</td>
<td>External/internal</td>
</tr>
<tr>
<td>Internal dependency</td>
<td>Very low</td>
<td>Medium</td>
</tr>
<tr>
<td>Degree of design technology</td>
<td>None</td>
<td>Low level</td>
</tr>
<tr>
<td>Focus of efforts</td>
<td>Stable production</td>
<td>Product development</td>
</tr>
<tr>
<td>Key actors in technology development&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Domestic engineers</td>
<td>Domestic engineers</td>
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<td>TA/JV</td>
<td>TA/JV</td>
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<sup>a</sup> Corresponding Utterback and Abernathy's (1975) stages are represented in parentheses.

<sup>b</sup> TA (technical agreement) and JV (joint venture) imply the active roles of foreign engineers.

Source: Adapted from Lee et al. (1988).

formulation of technology strategy, the most basic categories and terminology should be satisfactorily determined (Adler, 1989; Chiang, 1990; Pavitt, 1990). Also in-depth case studies and system-analytic approaches that highlight strategic issues are required (Adler, 1989; Lee et al., 1988).

There can be two viewpoints on the elements of technology strategy: content and process approaches. Several studies focus on the content of technology strategy. Maidique and Frevola (1988) provide one concept of technology strategy, and suggest its seven decision areas: technology selection, embodiment, level of competence, sources of technology, level of investment, competitive timing, and...
organization and policies. Horwitch (1988) asserts that large, modern technology-intensive corporations are making decisions of technology strategy along three dimensions: competitive strategy, domain, and structure. Among these dimensions, structure, organization and policies are related with the implementation of strategy and are at least conceptually distinct from the content of strategy (Spital and Bickford, 1992). Meanwhile, Burgelman and Rosenbloom (1989) frame the substance of technology strategy around four dimensions: competitive positioning, technology and the value chain, the scope of technology strategy, and the depth of technology strategy. Investigating empirically the relationships between technology strategy, business strategy, environment, and performance, Spital and Bickford (1992) propose five dimensions of technology strategy at the business unit level: technology selection or portfolio, level or depth of competence, breadth or scope of competence, sources of technological capability, and level of investment.

This content approach clarifies the important decision areas in order to formulate and implement technology strategy. However, the content approach is criticized that it neglects the context and the process of technology strategy formulation and implementation (Pavitt, 1990).

On the other hand, some researchers view the elements of technology strategy based on the process approach: Ford (1988) suggests three elements of technology strategy—technology acquisition, technology management, and technology exploitation—and provides general guidelines for developing technology strategies. Granstrand and Sjolander (1989) present a model and case studies that conceptualize various technology strategies based on the notion of a technology base. They distinguish between technology acquisition (or sourcing) strategies for building up the technology base and technology exploitation strategies for exploiting it, though they do not provide the guidelines for selecting the appropriate strategies.

In this paper, we try to integrate these two approaches based on the process approach to analyze the important decisions and processes as well as the context of strategy formulation and implementation. Minimizing the overlaps and duplication between concepts (Chrisman et al., 1988), we derive the critical dimensions from the most important decisions and activities during the technological innovation process. We suggest that technology strategy consists of the decisions and activities centering around three elements:

(a) Technology selection: Which technologies should be selected?
(b) Technology acquisition: How to acquire required technologies?
(c) Technology implementation: How to accelerate the technology development more efficiently?

These three elements are closely interrelated and must be consistent with each other in order to be an effective strategy. Important decisions of each element will clarify the concepts and their interrelationships.

First, "technology selection" includes the choice of technology development areas and goals, and the choice of needed technologies to attain these goals. This strategic element is related with the specialization in a few strategic areas and the
domain of technology development. The more dynamic the competition, the more focused the technology development must be (Spital and Bickford, 1992). Especially, in less-developed countries that have scarce resources, the selection of appropriate technologies is important and not simple. Moreover, technological appropriateness is a dynamic concept, and depends to a large extent on the purpose of having the technology, for example, competitive advantage in the international market (Sharif, 1986).

Second, "technology acquisition" includes the choice of technology acquisition sources and methods. This element is related to competitive timing. The more fierce the competitions, the more external sources of technology are needed (Ford and Farmer, 1986; Quinn et al., 1990). This trend also requires some 'make-or-buy' decisions as to which activities should be carried out within or outside an organization. However, more important is the integration of internal technology and external technology (Sen and Rubenstein, 1990; Ford, 1988; Sharif, 1986). Therefore, 'make-and-buy' or 'buy-for-make' decisions are crucial to competitive advantage, though these decisions are mostly determined on different units of analysis.

Third, "technology implementation" includes the choice of the modes of collaboration, technology transfer and diffusion during the cooperative innovation process. This element is to obtain organizational synergy and is increasingly important in the light of the current trend towards strategic alliances and cooperative research and development (R&D) to develop advanced technologies. Such alliances demand the strong cooperation of its participants, and sometimes require fierce competition between them. This element emphasizes the organizational policies and mechanisms to fully utilize the acquired technologies and to accelerate the technology development more efficiently.

The strategic decisions on these elements of technology strategy during a major innovation process will be analyzed in Section 4.

3. Technology development process in the Korean telecommunications industry

During the last decade, the Korean telecommunications equipment industry has grown from a simple assembly operation to the indigenous development of advanced technologies. It has especially developed and commercialized the state-of-the-art digital switching systems called the TDX (Time Division Exchange) series switches, by a joint project of government agencies and industrial firms. Recently, the industry has started exporting TDX switches to other developing countries, though on a limited scale.

The world public switch market has been dominated by a few major firms such as Northern Telecom, Alcatel, AT&T, and Ericsson, who compete fiercely based on their strong technological capabilities. In the midst of this world-wide competition and cooperation among the telecommunications giants for more global market shares and advanced technologies, industries in Korea, India, and Brazil are now producing their own digital switches for local and export markets. Ac-
According to the forecasts of the Datapro Research Group (1991), as these switches are more appropriate to the needs of the developing countries and will be less expensive to manufacture, market, and support, they will be new competitors in the world market.

It is interesting to examine how the Korean telecommunications industry could achieve such growth that requires a high level of technology and huge capital investments.

Backgrounds.

In 1977, the Korean government initiated an ambitious program to revolutionize its telecommunications sector which lagged behind in spite of the rapid growth in a few selected industries. Though the demand for telecommunications services had exploded due to the economic growth, the telecommunications industry could not supply enough facilities and services because of the lack of technological and managerial competence. The unfilled telephone subscription demand in 1977 reached about 200,000 lines, about 12.8 percent of the 1,537 thousand telephone subscribers of that year. The situation for the following year was expected to be even worse. The backlog for telephones became a serious social problem that had to be settled quickly. Moreover, the insufficient telecommunications services restrained the economic growth. Therefore, the Korean government decided to initiate a program to accomplish several objectives at once. The major objectives of the program were:

(a) the expansion and modernization of the telecommunications infrastructure,
(b) the strengthening of the telecommunications equipment industry, and
(c) the internal development of digital switching systems.

Performance of the program.

Because of the ambitious program and the government’s massive investment, the telecommunications infrastructure of Korea has improved very rapidly. The number of telephone lines has increased from 1.2 million lines in 1975 to 15.3 million lines in 1990. The chronic excess demand for telephones decreased after the peak year of 1979, when it had reached 620 thousand lines, and eventually disappeared in 1987. Along with the growth in the number of lines, the telecommunications infrastructure has been modernized. The proportion of electronic switching systems rose from 0.7 percent in 1980 to 87.6 percent in 1990. The ratio of digital switches went up from 3.9 percent in 1985 to 35.7 percent in 1990. This modernization of the network has enabled, upgraded, and enhanced telecommunications services.

Meanwhile, the industrial electronics industry including telecommunications equipment was at a primitive stage until the beginning of the program in the late 1970s. As a result of the program, telecommunications equipment production in 1989 reached about 2.4 billion dollars with an average annual growth rate of 26.4 percent during 1981–1989. The export of telecommunications equipments has also grown remarkably based on the export policies of the Korean government.

To analyze the technology development process of the Korean switching equip-
ment, an in-depth case study on the development project of the TDX-series switches was carried out. According to Lee et al.'s (1988) model, the switching equipment industry in Korea has not reached the generation stage yet in spite of the development of the large-capacity TDX-10 switches. Therefore, we have classified the technology development process of the Korean switching equipment industry into three stages: initiation, early internalization, and late internalization. A more detailed description of each stage will follow.


When the first analog switch in the world, No. 1 ESS of AT&T was installed in 1965, the global competition to develop competitive switches was started. Especially, since Alcatel developed the first digital switch in 1970, AT&T and Ericsson had started to commercialize digital switches from the mid 1970s. At that time, telecommunications services in Korea were provided by the Ministry of Communications (MOC). Its bureaucratic management and operation of the telecommunications networks had led to the serious backlog of telephone subscriptions (Kim and Lee, 1991). Besides, the rapid development of telecommunications technology had made the MOC reluctant to supply switching systems. Meanwhile, the local manufacturers of the electromechanical switches held the MOC back from purchasing the more advanced foreign electronic switches. In spite of their low production capacity, these manufacturers insisted on supplying inefficient switches with a nice-looking plan to develop analog electronic switches on their own.

However, as the telephone backlog became a serious social problem, the Korean government decided to import foreign switches and technologies in 1976, with the Economic Planning Board in charge of the Economic Development Plan taking this decision-making initiative.

In order to set up the program, the Korean government established the Telecommunications Development Task Forces (TDTF) within the MOC. The role of the TDTF was to formulate the telecommunications policies concerning the introduction of foreign switching systems and the expansion and modernization of the telecommunications infrastructure. When it introduced foreign switches, the government emphasized the importance of technology import in order to develop the domestic telecommunications industry. Because analog switching technology was at a mature stage in a very competitive international market, it could be obtained easily. To develop digital switches and support the negotiations for purchasing analog switches, the Electronics and Telecommunications Research Institute (ETRI) was established in 1977. At the same time, the Korea Telecommunications Company (KTC) was founded by the government to import technologies and produce analog switches.

The TDTF selected the M10CN switch of BTM, a Belgian subsidiary of ITT. Though KTC did start to produce M10CN switches with the help of BTM, KTC's production capacity could not meet the soaring demand. In addition, BTM's request for a price rise forced the TDTF to search elsewhere. In 1979, the MOC
determined to purchase No. 1A switches of Western Electric, a subsidiary of AT&T, and handed over KTC to the Samsung Group. The Lucky Goldstar Group and AT&T entered into a technical agreement and established the joint venture, the Goldstar Semiconductor Co. (GSS). In those days, the Korean government preferred the technical agreement to the joint venture believing that the technical agreement would be more advantageous in developing advanced technologies based on imported technologies.

At first, KTC and GSS purchased analog switches on a turn-key base. However, they had agreed with their partners that the proportion from local production should grow through the transfer of technologies. Because electronic switches consist of millions of components, the buildup of the components industry such as the semiconductor was the key factor for success of the program. So semiconductor and other component technologies were transferred from abroad, setting up the base of related microelectronics industries.

In 1978, ETRI started a preliminary study on the digital switching systems. In a few years, ETRI designed their structure and developed a series of prototypes. However, because of a lack of technology, funds and engineers, ETRI could only develop a basic call-processing function. ETRI, however, came to understand the structure of digital switches and gained confidence in its technological capability.


During the fifth Economic Development Plan period, 1982–1986, the Korean telecommunications sector underwent an extensive reform. As a part of the Plan, the MOC initiated two ambitious policies—the Immediate Telephone Installation System and the Widening and Automation (Kim and Lee, 1991). The former was to reduce the telephone demand backlog by supplying switches on a larger scale. The latter was to reduce the gap between urban and rural areas in telecommunications services by widening local call zones and automating switches. With a motto of “One Household, One Telephone”, these became the backbone of telecommunications policies of the 1980s and contributed greatly to expand and modernize the telecommunications networks.

To accomplish these policies and provide efficient telecommunications services, the MOC decided to relegate the operation to Korea Telecom (KT) which was founded anew by the government at the end of 1981. The MOC organized the Telecommunications Policy Bureau to formulate a policy, enlarged the TDTF by supplementing its members, and set up the Time Division Exchange Development Steering Committee within the TDTF. The TDTF, a temporary organization by 1988, changed its focus from importing switches and technologies to developing indigenous technologies.

On the basis of these policies and institutional changes, the MOC decided to develop digital switches as a National Project. The main points of the MOC's plan to develop digital switches were:

(1) the phased development from small- to medium-capacity switches,
(2) the collaborative development of ETRI, KT and manufacturers,
(3) the recruit of competent engineers, especially from abroad, and
(4) the investment of about 3.7 million dollars and 1,350 total man–years.

The MOC had thought that early outputs could be installed in rural areas, but
it became necessary to modernize rural telephone networks that were falling be-
hind. Considering the outputs of digital switches development in ETRI and the
uncertainty of developing up-to-date technologies, the MOC decided to purchase
foreign digital switches for rural areas. As a result of the selection process, Ori-
ental Precision Co. of Korea and Ericsson of Sweden established a joint venture,
Oriental Telecommunications Co. (OTELCO).

At that time, KTC and GSS, the manufacturers of analog switches, asked the
MOC to import digital switches and technologies. Importing large-capacity digi-
tal switches would harm its indigenous development because of the reduced local
demand. On the basis of the cost/benefit analysis of the technology import, the
Korean government decided to pursue two strategies concurrently—the indige-
nous development in ETRI and the import of technology by KTC and GSS. KTC
and GSS came to technical agreements for importing digital technologies with
ITT and AT&T.

Meanwhile, KT and ETRI also had to import necessary technologies for indig-
enous development. KT purchased toll switches from Ericsson, and formed a
technical agreement in 1982. Many engineers of ETRI were trained at Ericsson.
Most transferred technologies were engineering in nature such as network design,
software design and project management and became the base for indigenous
development.

In 1982, the developed prototype in ETRI was named the TDX (Time Divi-
sion Exchange) at the opening ceremony. Thereafter, the succeedingly developed
digital switches in ETRI were called the TDX-series.

To speed up the development process of the TDX switches, huge organiza-
tional changes were made in ETRI and KT. ETRI organized the TDX Develop-
ment Division to develop digital switches. KT established the Digital Switches
Program Office (the Project Development Center at present) whose responsibil-
ity was to manage the overall project that included planning, controlling, and
providing funds.

In 1982, about 20 engineers from manufacturing firms were sent to ETRI for
technical training and cooperative development. They worked as members of de-
vancement teams and served as liaisons for the transfer of technology. When ETRI
developed the TDX-1 switch in 1984, the TDTF decided to transfer the technol-
ogy from ETRI to manufacturing firms.

Technology transfer was performed by transferring technical documents, and
providing technical training and support for the design, production, and opera-
tion of the TDX-1. With the help of ETRI, manufacturers could produce and
install the TDX-1 systems at four sites for field trial. Despite their good switching
capabilities, several problems were found in their reliability and functions. After
many disputes on their performance, KT and the MOC decided to upgrade and
supply the TDX-1 on a large scale. While solving the technical problems, ETRI
improved the functions of the TDX-1. By the transfer of ETRI’s improved tech-
Table 2
Technology development stages of the Korean telecommunications industry

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<tr>
<td>Directions of technology development</td>
<td>- Expansion of telecom networks (purchase of foreign switches)</td>
<td>- Technology transfer from abroad</td>
</tr>
<tr>
<td></td>
<td>- Promotion of technology transfer from abroad</td>
<td>- Indigenous R&amp;D in ETRI</td>
</tr>
<tr>
<td></td>
<td>- Pre-development in ETRI</td>
<td>- Technology transfer from ETRI to firms</td>
</tr>
<tr>
<td>Major activities</td>
<td>- Technology import and pre-development</td>
<td>- Rural exchange development</td>
</tr>
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<td></td>
<td>Procurement and technical licensing agreements of analog switches</td>
<td>Technical agreement of digital switching technologies</td>
</tr>
<tr>
<td>Major outputs</td>
<td>- Development of prototypes</td>
<td>- Development of production model switches (TDX-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Development of small-scale digital switches (TDX-1A)</td>
</tr>
<tr>
<td>Imported technologies</td>
<td>- Analog switching technology</td>
<td>- Digital switching technology</td>
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<tr>
<td>Methods of technology import</td>
<td>- Technical contract agreement (ITT)</td>
<td>- Technical contract agreement (ITT, AT&amp;T)</td>
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<td></td>
<td>- Joint venture Technical agreement (AT&amp;T)</td>
<td>- Joint venture/Technical agreement (Ericsson)</td>
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<tr>
<td>Acquired technology elements</td>
<td>Operations technology</td>
<td>Parts/process-related technology</td>
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<tr>
<td>Major sources of technology</td>
<td>Outside</td>
<td>Outside/inside</td>
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<tr>
<td>Internal dependency</td>
<td>Low</td>
<td>Medium</td>
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<tr>
<td>Level of design technology</td>
<td>Low</td>
<td>Medium</td>
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</tbody>
</table>
Notes: (1) The selection of the electromechanical EMD switch of Siemens
(2) The rejection of the proposals for importing crossbar switches
(3) The introduction of analog switches and the start of R&D on digital ones
(4) The introduction of digital switching technology and the full-fledged R&D on the TDX
(5) The collaborative development of the upgraded versions of the TDX, the TDX-1B and the TDX-10
(6) The thin lines represent the development stage and the thick lines represent the commercialization stage in the international market of the public switches.

Fig. 1. The technology development process of the Korean telecommunications industry.

3.3. The late internalization stage (1987–present)

During the sixth Economic Development Plan period, 1987–1991, the TDX development program was carried out in two directions (Kyong, 1989). The first
was to upgrade and improve the TDX-1A switch. The second was to develop a large-capacity switch, the TDX-10.

Because of its limited capacity for subscription and call processing, the TDX-1A was not appropriate for urban areas. KT could not wait long until ETRI and the manufacturers developed the TDX-10 because of the soaring demand from urban areas. After discussions with the manufacturers, KT decided to develop the TDX-1B switch by expanding the processing capacity of the TDX-1A and adding several various features. With KT's guidance, the four manufacturers agreed to share their tasks and exchange their technologies with each other. From 1986 to 1988, they had developed the TDX-1B. With the support of ETRI, they commercialized the TDX-1B competitively in 1989 and have exported the TDX-1B switches to other developing countries since 1990. According to Seo (1990), the development of the TDX-1B not only promoted the technological self-reliance of manufacturers but reduced ETRI's burden of developing the TDX-10 switches.

The main objective of the technology development project at this stage was to develop and commercialize the large-capacity TDX-10 switch. The development of the TDX-10 started as a full-fledged cooperative project by KT, ETRI, manufacturers and universities based on a collaborative development agreement between ETRI and the manufacturers. KT identified their requirements as a user of the TDX-10 and coordinated the overall development process. ETRI performed the overall system design and project management, and developed the common features like development tools. Manufacturers created the subsystems through task sharing and partially competed to develop important parts. To shorten the time for commercializing the TDX-10, the manufacturers developed the ordinary telephone switching functions by 1990. In addition, they created some fundamental features of ISDN (Integrated Services Digital Network) that will guide the direction of technology development and the future of the telecommunications infrastructure. With their excellent functions and quality, the TDX-10 switches competed well with switches imported from abroad.

The characteristics of each technology development stage are summarized in Table 2, and the process of developing the TDX-series switches and acquiring technological capabilities is outlined in Fig. 1.

4. The adaptive and dynamic changes of technology strategy

If technology strategy is a capabilities development vector, then it is through projects that it operates (Adler, 1989, p. 75). However, the project management literature is so occupied with the tactical aspects that it has some difficulties in drawing strategic lessons (Adler, 1989). In this section, we focus on the strategic factors that have strongly affected the progress of the TDX development project and analyze the dynamics of technology strategy in managing a large-scale technology development project.

The strategic factors that have led the development process of the TDX-series
switches can be analyzed according to three major elements of technology strategy: the selection, the acquisition, and the implementation of technology. Looking at the technology development process of TDX switches, we believe that the following three approaches have strongly guided the process: (1) the focused-and-phased approach, (2) the buy-for-make approach, and (3) the collaboration-and-competition approach. As shown in Table 3, these correspond with the technology strategy elements we suggested.

These approaches are very closely interrelated with each other, but we describe them separately for analytical purposes.

### 4.1. Technology selection

Korea has taken the focused-and-phased approach in the development process. After the pre-development period of the late 1970s, the government selected digital switching equipment industry as a strategic sector to promote the electronics industry. It concentrated its resources on developing marketable switches and started with a full-fledged and well-prepared technology plan. The government
based its phases and goals on the evaluation results of the technological capabilities and the potential for product commercialization. The focus of the plan changed as more technology was accumulated. The development project evolved from a small-capacity switch for rural areas, the TDX-1A, and the TDX-1B, for urban areas, to the TDX-10, a large-capacity switch for metropolitan areas. This phased development and dynamic adaptation have helped Korea to build its technological capabilities. In sum, by selecting technologies appropriate to its scarce resources and weak capabilities (Sharif, 1986) and following the life-cycle of "focused and controlled growth" (Horwitch, 1979), the government could have led the entire large-scale technology development project. Some typical strategic issues related to technology selection are:

(1) The selection of strategic sectors

National support policies for strategic industries are now worldwide (Soete, 1991; OECD, 1989). In the early 1980s, the Korean government selected three sectors—semiconductors, computers, and electronic switching systems—as the strategic industries for reviving the economy and building an information society. Among them, the switching system is the core of a nation's telecommunications infrastructure and requires a high level of technical expertise in semiconductors, computers and communications. Therefore, its development can have enormous spill-over effects on the overall telecommunications industry and technological capabilities of Korea. Moreover, there was a large local demand resulting from rapid economic development. The government and industry fully understood the importance of developing switches although they were not so confident of the success. For developing countries to fully utilize their scarce resources and capabilities and acquire the critical mass for developing advanced technologies, it is essential that they carefully evaluate the value of technologies and their capabilities focusing on the sector with the largest benefits.

(2) Technological leapfrogging

Because of the rapid development of telecommunications technologies, developing countries have an excellent opportunity to 'leapfrog' over less-efficient technologies and modernize their networks with fewer expenses than ever (Mody and Sherman, 1990). When the Korean government initiated a telecommunications development policy in the early 1960s, it selected the EMD switches of Siemens to be installed nationwide. However, that decision was regarded as an inappropriate one because it was made based on the political considerations of chaebols, business conglomerates in Korea, rather than technical considerations. From the early 1970s, there were severe disputes over the new switching systems to be introduced in Korea. Many firms requested the government's approval for the import of technology of cross-bar switches. However, the government compared the characteristics of various existing electromechanical switches with those of cross-bar systems and rejected the requests. The cross-bar technology was not superior to the existing electromechanical technology in terms of performance and was expected to be eventually replaced with electronic switching technolo-
gies. As a result, Korea could leapfrog from electromechanical to electronic switches by skipping cross-bar technology that now hinders many countries replacing their infrastructure because of its remained life.

4.2. Technology acquisition

Korea has taken the buy-for-make approach. From the beginning, the government clarified this strategy to acquire needed technologies. The equipment industry imported technologies and products from developed countries, while at the same time ETRI continued to develop its own technologies through in-house R&D. Although the initial plans were to develop 'digital' switches indigenously based on imported analog switching technologies, Korea had to import the technologies for lack of technological capability to develop these digital switches. Fortunately, the technologies developed from in-house R&D have helped Korea select and internalize key and essential technologies for import, for example, components such as semiconductors and systems engineering techniques. The appropriate utilization of foreign technologies balanced with the internal development of key technologies has greatly helped Korea in its technology development. In short, it was a pragmatic strategy to "make some and buy some" (Sharif, 1986) technology for the Korean telecommunications industry. Typical strategic issues related to technology acquisition are:

(1) **In-house development versus technology import (make-or-buy)**

In the early stage of technology development in the 1970s, there were severe disputes on the technology development methods for electronic switches. The MOC, suffering from the serious backlog of telephones, insisted that analog switches be introduced from abroad as soon as possible. On the opposite side, the manufacturers of electromechanical switches insisted on the in-house development of analog switches to delay the introduction of foreign switches and maintain their oligopolistic profits. Also many scientists in the universities opposed the introduction of foreign switches, because they were eager to achieve indigenous development in that area. Motivated by the good-looking excuse of in-house development, the late President Park ordered domestic engineers to develop analog switches, and thus a plan for the indigenous development was prepared. However, the EPB held back the plan because it was so urgent to expand the telecommunications infrastructure for economic development and there were considerable uncertainties about the outcomes of the analog switches development project. In 1976, the government finally decided to develop digital switches and import analog switches simultaneously.

(2) **Buy-for-make**

When the Korean government decided to both import analog switches and develop digital systems in the mid 1970s, the worldwide competition to develop digital switches was expanding. Developing countries could take advantage of their monopolistic purchasing powers and the fierce competition among inter-
national telecommunications equipment suppliers and acquire the needed technologies (Hobday and Baba, 1990). When the Korean government selected its foreign suppliers of analog switches, it emphasized the likelihood of technology import and indigenous technology development as the primary consideration. However, the more accumulated the technological capabilities, the less dependent the Korean industry became on foreign technologies. In the late internalization stage, the manufacturers and ETRI could focus on the 'make' of digital switches themselves. In sum, the parallel pursuit of technology import and in-house development in the early stages was a practical alternative for developing countries. Korea's make-and-buy strategy has shortened the time for effective technological accumulation.

4.3. Technology implementation

Korea has taken the harmonized collaboration-and-competition approach. Collaboration and competition are the critical elements of strategic decision making in the information technology sector (Molina, 1990). Especially for developing countries to fully utilize their scarce resources and to spread the risks between participants, collaborative development is an important technology strategy. The introduction of competition among participants speeds up the collaborative development process and improves the quality of outputs.

During Korea's development of the TDX-series switches, the modes of collaboration and competition have varied according to the accumulation of technology. Moreover, the roles of participants have also changed. The strategic issues related to technology implementation are:

(1) The modes of harmonized collaboration and competition

The methods of collaborative R&D have changed according to the accumulation of technology. When ETRI was developing the TDX-1, about twenty engineers from the manufacturing firms were sent to ETRI for technical training and collaboration. After the manufacturers installed the TDX-1A with the support of ETRI, they decided to share the tasks of developing the TDX-1B. ETRI provided the necessary technical support and evaluated the performance of the participants. In developing the TDX-10, KT, ETRI and the manufacturers formed a cooperative R&D system. The manufacturers not only shared the development tasks according to their specialized areas, but also sent their engineers to ETRI for the joint development of generic technologies. These changes of collaboration modes were possible due to the technological accumulation of the manufacturers.

During the development of the TDX-10, the manufacturers competed against each other to develop some key technologies for a competitive advantage. Competition between manufacturers means parallel development that might seem somewhat like the duplication of resources to the policy makers of developing countries. However, it can shorten the time for developing competitive technologies and upgrade the quality of the outputs of the in-house development if it goes well. In order to motivate the competition, KT and ETRI have evaluated the
performances and technological capabilities of manufacturers since they developed the TDX-1B. The proportion of purchase from each firm was set as the reward, on the basis of the evaluation. It is also similar for the TDX-10. As a result, a fierce competition to develop more advanced technologies was brought about, and several negative effects have appeared. For example, the manufacturers became reluctant to share the information gained by each firm and to encourage their excellent engineers to participate in the joint project. Therefore, collaboration and competition must be balanced according to the accumulation of technological capabilities.

(2) The roles of participants

In this collaborative R&D project, each participant has its own role that is evolving with the accumulation of technical experience. KT has managed the whole project very effectively since 1982. KT has coordinated the project by controlling the progress, resolving conflicts between participants, providing ETRI with funds and users' requirements, and confirming the quality of the outputs. The development of the TDX-series switches can be called a user-dominated innovation. The consistent participation of KT from the research stage to the installation and operation stage brought about the success of TDX development.

ETRI has developed and transferred digital switching technologies to selected manufacturers. In addition, ETRI has provided technical services for them, and successfully formalized and implemented project management methodologies. From the early stage, it was required to get suitable project management techniques for the Korean engineers of ETRI and collaborating organizations. Though ETRI had learned the required techniques from Ericsson, it could not apply them directly to Korean engineers because of the cultural differences between Europe and Korea. As a result, ETRI has developed its own project management methods. The formalization of these methods has helped the participants to communicate effectively with each other and to accomplish their tasks efficiently. Recently, ETRI has moved to develop more advanced switches.

During the initiation stage, the switching equipment industry has manufactured switches with imported production technologies. It has internalized and accumulated the transferred technologies from foreign suppliers and ETRI. As a result, it can develop the important functions of TDX-switches and create the essential design technologies for system development.

The government's support and policy-making function played a very important role, especially in the early stage of the project. While the Economic Planning Board led the preparation of development plans in the initiation stage, the MOC played a leading role in planning the TDX development in the early internalization stage of the 1980s. When the manufacturers were not confident in their ability to commercialize the TDX-series switches, the MOC decided to develop indigenous switches to induce the manufacturers to participate in collaborative development. In the early 1980s, the President had a strong desire for technological development and self-reliance. During the early stage of the TDX develop-
ment, his concern about the progress of the project strongly influenced the direction and speed of the project and contributed to building the supportive environment for in-house development. In addition, the Korean government separated policy making from network operation in its pursuit of consistent technology development. However, in the late internalization stage, governmental support was changed from direction and control to the encouragement of technological advancement through the informational and symbolic leadership similar to the situation in Japan (Porter, 1990). The government's role in the technology development process must be changed according to technological accumulation, managerial competence and environmental conditions.

5. Conclusion and implications

This paper has focused on process, strategy, and their contingent relationships based on the case analysis of a successful large-scale technology development (TDX) in the Korean telecommunications industry. As the analytic framework of the study, this paper adopted the global-perspective model of technology development process (Lee et al., 1988) and the evolutionary process perspective of technology strategy (Burgelman and Rosenbloom, 1989).

First of all, this paper has described the process of longitudinal technology development and capability accumulation along stages. Three stages of technology development, including the initiation, the early and late internalization, show distinctively different behaviors and patterns that were highly influenced by the government policies and active learning efforts of participants, as shown in Table 2. It is notable that the levels of transferred technologies, the channels of technology acquisition, and the roles of indigenous efforts are different according to development stages. These dynamic patterns are also found in other successful Korean industries (Hyun and Lee, 1989) and are directed to the achievement of technological self-reliance.

Secondly, this paper tried to find some underlying principles in managing the large-scale technology development project and in achieving successful technology development of the Korean telecommunications industry from appropriate formulation and implementation of technology strategies. In the TDX case, technology strategies have been implemented corresponding to the level of technological capabilities and potentials. More specifically, technology strategy was classified into three dimensions: technology selection, technology acquisition, and technology implementation. Furthermore, three underlying principles were identified: the focused-and-phased, the buy-for-make, and the harmonized collaboration-and-competition approaches. These principles or approaches are correspondent to three dimensions of technology strategy respectively, and involve several strategic decisions that made the TDX development project very successful, as shown in Table 3.

In the early stage of the development, everybody doubted the success of the TDX. However, the Korean telecommunications industry did its best to accumulate technological capabilities systematically and to develop indigenous
switches based on the government's leadership and support. Especially, planned manpower training abroad, appropriate utilization of foreign technologies in addition to indigenous R&D, and harmonized and dynamic role plays among participants are very important ingredients for successful indigenous development of the TDX.

Although the TDX development case is not directly applicable to other situations, the experience of the Korean telecommunications equipment industry and the underlying principles acquired from the case can provide some strategic lessons and implications for developing countries that are planning for industrial growth and technological self-reliance. Especially, the adaptive and dynamic changes of technology strategy contingent to technological accumulation and environmental conditions are very important in managing large R&D programs.

Because these conclusions are based on a single case study, however, it cannot be necessarily generalized to other situations. Moreover, the global environment surrounding a nation's technological development changes so rapidly. Global competition prevents developing countries from acquiring advanced technologies in the same way that Korea pursued the TDX development. For example, because of technological protectionism, developing countries are finding it more difficult to import technologies. The technological development policy through procurement or market protection is no longer generally applicable. Branscomb (1992) contends that it is important to find out "what kind of government policies and programs make sense in the new competitive environment". Therefore, more case studies, especially comparative case studies across countries, industries or technologies, and further theoretical frameworks would be very helpful in understanding the nature and underlying principles of the technology development processes in developing countries and in formulating proper technology strategy and policies.

References


Spital, F.C. and Bickford, D.C., 1992. Successful competitive and technology strategies in dynamic