

The Historical Development of Technological Capabilities in Korean Steel Industry: The Case of POSCO*

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Introduction

Korean capitalism continued to develop through the compressed industrialization from the 1960s to the 1990s. Studies on the industrialization of Korea have focused on the role of the government, large corporations, and labor, gradually concerning themes such as technological development. Studies on technological development have emphasized the concept of technological capabilities, and are summed up by Park Woohee and Bae Yongho's *Korea's Technological Development* (1996), Kim Linsu's *Imitation to Innovation* (1997), and Lee Keun, et al.'s *Technological Capabilities and Competitiveness of Korean Industries* (1997).¹ Based on these achievements, recent studies have attempted to redefine the stages and types of development of technological capabilities in Korea. For instance, Kim Linsu re-composed technological development stages into duplicative imitation, creative imitation, and innovation, and Lee Keun and Lim Chaisung categorized the types of technological catch-up into path-following catch-up, stage-skipping catch-up and path-creating catch-up.²

* Received 16 June 2011; revised 20 July 2011; accepted 20 August 2011. This paper is prepared for the request of editor of The Korean Journal for the History of Science, and based on Song Sungsoo, "Historical Perspectives on the Development of Technological Capabilities: A Case Study on POSCO", *Journal of Technology Innovation* 10-1 (2002), 174-200 [송성수, "기술능력 발전의 시기별 특성: 포항제철 사례연구", 『기술혁신연구』]. I partially revised and updated the previous paper.

¹ Park Woohee and Bae Yongho, *Korea's Technological Development* (Kyungmoonsa, 1996) [박우희, 배용호, 『한국의 기술발전』]; Kim Linsu, *Imitation to Innovation: The Dynamics of Korea's Technological Learning* (Boston, MA: Harvard Business School Press, 1997); Lee Keun, et al., *Technological Capabilities and Competitiveness of Korean Industries* (Kyungmoonsa, 1997) [이근 외, 『한국산업의 기술능력과 경쟁력』].

² Kim Linsu, "Building Technological Capability for Industrialization: Analytical Frameworks and Korea's Experience," *Industrial and Corporate Change* 8-1 (1999), 111-136; Lee Keun and Lim Chaisung, "Technological Regimes, Catching-up and Leapfrogging: Findings from the

These research achievements have contributed greatly to understanding the development of technological capabilities in Korea, but are deemed to have the following problems. First, existing studies on the development of technological capabilities generally focus on the logical completion of theories, but do not pay sufficient attention to exploring historical facts. Second, previous studies have analyzed the development of technological capabilities of many industries, but major industries that contributed to Korean industrialization including the iron and steel industry have not been sufficiently explored, and even where research has been carried out, the study does not span the entire timeframe of the industry. Third, most of the existing studies are only able to briefly describe the process of technological development, and analyze its success factors, therefore, with a few exceptions aside, what momentum technological capabilities were developed and what features technological activities had during each period is still left in the black box.

Based on the awareness of such problems, this paper seeks to examine the historical development process of technological capabilities in the Korean iron and steel industry through the case of Pohang Iron and Steel Company. Established as a public enterprise in 1968, Pohang Iron and Steel Company (포항제철) grew by leaps and bounds, with the construction of the Pohang Steelworks (포항제철소) in the 1970s and Gwangyang Steelworks (광양제철소) in the 1980s. The company was completely privatized in 2000 and renamed as POSCO in 2002. In terms of output, POSCO was the world's third largest steelmaker from 1990 to 1992, and the second from 1993 to 1997. In 1998, 1999, and 2001, the company made the very top of the list. Since 2002, POSCO has fallen back in the rankings as the world's 4th or 5th largest steelmaker as a result of merges between large steel producers in Europe and Japan.

Unit: 1,000 tons, %

Year	1970	1975	1980	1985	1990	1995	2000	2005
Production capacity (POSCO)	504 (-)	2,534 (1,234)	8,558 (5,903)	13,539 (9,284)	23,125 (16,223)	36,772 (23,428)	43,107 (27,735)	47,812 (31,420)
Share of global steel industry	0.1	0.4	1.2	1.9	3.0	4.9	5.1	4.2
Share of GDP	0.4	1.1	1.5	1.9	1.9	2.0	1.7	2.5

Table 1. Development of the Korean Steel Industry (From 1970 to 2005) [Source: Bank of Korea Iron and Steel Association]

Technological development of POSCO has been studied by Byun Hyungyun, Park Woohee, Alice H. Amsden, Anthony P. D'Costa, and Sung Jowhan.³ Studies by Byun, Park and Amsden examined several features evinced in the course of POSCO's technological development, but are limited to the 1970s. D'Costa and Sung used the notions of "structural competitiveness" and "reverse exploitation strategy" respectively and analyzed technological achievements of POSCO, but did not give sufficient description on the process of the technological development. In contrast to these studies, this paper seeks to explain and analyze features of POSCO's technological activities considering the entire timeframe from the 1970s to the 1990s, and thus contribute to finding out the whole mechanism in the development of technological capabilities.

To this end, this paper explored historical facts through POSCO's company history, newspapers, memoirs and essays, in addition to existing literature. In particular, I carried out in-depth interviews with major actors who had been deeply involved in technological activities at POSCO. This paper reconstructs the stages of technological development into technological acquisition in the 1970s, technological catch-up in the 1980s, and technological creation since the 1990s. During interviews, I confirmed that the major actors held notions of acquisition, catch-up and creation for each period. Hence, these notions are deemed to be based on "following the actors", as referred to widely in sociology of science and technology.⁴

Technological Acquisition Started by Overseas Training

In the 1970s, overseas training was main route through which POSCO acquired technologies necessary for constructing and operating steel mills. This is well evinced in POSCO's official record: "The successful construction of factories and normal operations were made possible thanks to the results of overseas training."⁵

³ Byun Hyungyun, "Technological Accumulation in Korea's Steel Industry: A Case Study on POSCO," *Economic Journal* 19-2 (1980), 124-136 [변형윤, "한국철강공업의 기술축적: 포항제철을 중심으로", 『경제논집』]; Alice H. Amsden, *Asia's Next Giant: South Korea and Late Industrialization* (New York: Oxford University Press, 1989), pp. 291-318; Anthony P. D'Costa, "State, Steel and Strength: Structural Competitiveness and Development in South Korea," *Journal of Development Studies* 31-1 (1994), 44-81; Park Woohee and Bae Yongho, *Korea's Technological Development*, pp. 161-197; Sung Jowhan, "A Study on the Process of Technological Development in the Korean Steel Industry: POSCO's Reverse Exploitation Strategy" (Ph. D. Dissertation, Kookmin University, 1999) [성조환, "한국 철강산업의 기술개발 과정에 관한 연구: 포항 제철의 역할용 전략"].

⁴ Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987); Wiebe E. Bijker, "The Social Construction of Fluorescent Lighting, or How an Artifact Was Invented in Its Diffusion," Wiebe E. Bijker and John Law (eds.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (Cambridge, MA: MIT Press, 1992), pp. 75-105.

⁵ POSCO, *POSCO in 7 Years: Construction Records of Integrated Steel Mill* (1975), p. 526 [포항 제철, 『포항제철 7년사: 일관제철소 건설기록』].

Technologies that existed in the domestic steel industry at the time were limited to operating small-scale equipment in certain specific processes, so POSCO had to depend on advanced countries in order to acquire technologies necessary for operating large-scale comprehensive steel mills.

POSCO selected overseas training candidates two-fold, and the in-house training, which the candidates had to undergo prior to being sent abroad, included education on some basic knowledge of the steel industry, as well as etiquettes and attitudes to be aware of in a foreign working environment. Final candidates were organized into respective teams, assigned specific purposes of overseas training, and were given intensive education on their core tasks.⁶ Moreover, before relevant staff left for their respective overseas training institutes, POSCO gave a mindset education which was designed to instill in them the importance of their current jobs for the nation, and even instructed them to thoroughly learn technologies on a man-to-man basis, regardless of official contracts or schedules.⁷

POSCO sent trainees mostly to Japan Group (JG) comprised of Nippon Steel Company (NSC, 新日本鐵鋼) and Nippon Kokan (NKK, 日本鋼管), and Japan at that time was positively cooperative in transferring technologies to POSCO. For instance, Kim Gihong (김기홍), who received training in the Muroran (室蘭) steel mill in 1969, recollected: “Eminent personnel from the Japanese steel industry gave lectures”, and “thanks to the characteristics of the Japanese people, such as precision and kindness, I could grasp the various concepts of the steel industry in just three months.”⁸ Likewise, Hong Sangbok (홍상복), who as supervisor in the steelmaking department received training in NKK in 1972, recollected: “The company, competing with its elder brother-like NSC, was more eager to teach trainees, and provide whatever data trainees requested.”⁹

POSCO’s trainees actively participated in the overseas training programs with great enthusiasm. They jotted down lectures in detail, incessantly asked questions to lecturers, and memorized what they could not understand in belief that it would be of great use someday.¹⁰ Also, the trainees collected and copied whatever was deemed would be helpful for the operation of steel mills. In this regard, one of technological staffs at JG recollected: “they (trainees) appeared to have been ordered by their company to bring as much data as possible, or they applied a formula whereby their training performance was evaluated by the thickness of the data they brought home.”¹¹ Moreover, POSCO trainees complemented their know-

⁶ POSCO. *POSCO in 7 Years*. pp. 527-531.

⁷ Park Taejoon. *New Kind of Separate Family* (POSCO, 1987). p. 238 [박태준, 『신종이산가족: 華甲문집』]. Park Taejoon was president of POSCO from 1968 to 1993. For the biography of Park Taejoon, see Seo K. K., *The Steel King: The Story of T. J. Park* (New York: Simon & Schuster, 1997).

⁸ Lee Ho (ed.), *Chorus of Bewitched People: POSCO in 30 Years* (Hansong, 1998), pp. 264-265 [이호, 『신들린 사람들의 합창: 포항제철 30년 이야기』].

⁹ My Interview with Hong Sangbok (2000. 11. 23).

¹⁰ Lee Ho (ed.), *Chorus of Bewitched People*, p. 159.

¹¹ Toshihiko Ariga, et al., *Memoirs of POSCO’s Construction: A Record of Technological Coop-*

ledge through personal relations with JG engineers. For instance, Kim Jongjin (김종진), who led the trainees in hot rolling process at the early stage of POSCO, recollected: “our team approached Japanese engineers with all means available including treating them to dinner with drinks ... When design drawings were spotted, we were quick in slipping them into pockets or tried to memorize them as much as possible, even though we were quite drunk.”¹²

POSCO intended to maximize the benefits of education and training program by systematically managing and utilizing the overseas trainees. Trainees were required to report before and after the overseas training, and trainees dispatched for over two months must make intermediate reports twice a month. Also, trainees were assigned to their professional fields, and worked mandatorily for POSCO for two years after the program. More importantly, POSCO included gathering of training data and providing in-house training in the overseas trainees' responsibilities. Nearly all the materials brought back by the trainees were preserved as microfilms, which were used to educate other employees or make POSCO's technology plans. The overseas trainees endeavored to transfer their new knowledge and fresh ideas through in-house training.¹³

Most of the technology obtained by POSCO through overseas training was for plant operations, which was already mature and standardized in the developed countries. Because POSCO's overseas training targeted mature technology, it was relatively easy for the company to acquire the technology and obtain visible results in a short period of time. In the case of the steel industry, however, it was impossible to accumulate operation technology without actually operating the facilities, and production processes were not sufficiently computerized in the early 1970s, so this made on-the-job training even more important. Moreover, considering that Korean iron and steel industry had no experience in the operation of comprehensive steel mills, operation technology for large facilities can be interpreted as a kind of state-of-the-art technology at the time.¹⁴

While acquiring operation technology through overseas training, POSCO wanted to reach normal capacity as soon as possible through systematic preparation for plant operations. POSCO formed an operations group and a maintenance group from the beginning rather than after the plant construction, putting the former in charge of construction work and assigning the latter to supervise the construction.¹⁵ POSCO also wanted to preempt potential problems due to defects in facilities by

eration with Korea (Tokyo: Samwondang, 1997), pp. 154, 168 [有賀敏彦 外, 『浦項綜合製鐵の建設回顧録: 韓國への技術協力の記録』].

¹² Lee Ho, *Who Burns the Dawn?: Park Taejoon's Personal History in Steel* (Jayusidaesa, 1992), pp. 239-240 [이호, 『누가 새벽을 태우는가?: 박태준 철의 이력서』].

¹³ POSCO, *POSCO in 10 Years* (1979), pp. 165-166 [포항제철, 『포항제철 10년사』].

¹⁴ For more discussion about the characteristics of technological transfer from Japan to POSCO, see Song Sungsoo, “Technological Acquisition in Early POSCO,” *The Korean Journal for the History of Science* 28-2 (2006), 329-348, esp. 339-342 [송성수, “포항제철 초창기의 기술 습득,” 『한국과학사학회지』].

¹⁵ POSCO, *POSCO in 7 Years*, p. 341.

test operating the facilities before plant construction was completed. For instance, its iron-making department provided technological staffs with professional training in three stages in February-May, 1973, in preparation for operations.¹⁶ This can explain the technological reason why POSCO was able to make profits, just one year since its plants began operation.

After real operations commenced, the university-graduate engineers who received overseas training took charge of operations in each process, the other technicians and skilled workers supported these engineers, and Japanese technicians provided advice. POSCO's university-graduate engineers played a supporting role during overseas training, but played a leading role at operation sites. The company hired Japanese on-site technicians who had retired in their mid-50s as technical consultants for one year or two years to allow its workers to gain valuable on-the-job experience.¹⁷

Although accidents and mishaps were inevitable in the early stages, the employees at POSCO rapidly became accustomed to operating the plant, and POSCO's operation technology improved at a rapid pace. For example, keeping in mind the operational capacity of Japanese steelworks that were of similar sizes as the blast furnace of Pohang Steelworks, JG advised that POSCO's daily production would reach its design capacity in 12 months. However, POSCO aimed to reach the normal capacity within six months, and moreover, managed to shorten it to 107 days.¹⁸ After the plant secured normal operations, the company's dependence on foreign technicians sharply decreased, and it acquired sufficient on-site know-how within four or five months of operational experience. The decline in its dependence on foreign technicians was confirmed by the facts that starting with the project for Pohang Works Phase 2, guidance on operations was not included in the technical service contract with JG, and that the contract to hire retired Japanese technicians as technical consultants was terminated.

POSCO could fast acquire operations technologies mainly because of good policies on managing technological manpower. First, university-graduated engineers were assigned as foremen on the production frontline and were put in charge of factory operations. Back then, it was deemed unconventional for engineers with degrees to work as foremen on the production site instead of being assigned a post in the administrative field. They acquired knowledge through overseas training, applied it efficiently to the frontline, and made creative proposals, contributing greatly to improving technologies.¹⁹ Also, POSCO implemented the Saint Technician (기성, 技聖) System under which special treatment was given to those whose skills reached a "sacred stage", in order to stimulate the development of the technicians' abilities.²⁰

¹⁶ POSCO, *POSCO in 7 Years*, pp. 608-613.

¹⁷ My Interview with Lee Ilok (1999. 6. 30).

¹⁸ POSCO, *POSCO in 7 Years*, pp. 603-604.

¹⁹ Byun Hvangvun, "Technological Accumulation in Korea's Steel Industry", p. 131.

²⁰ POSCO, *POSCO in 20 Years* (1989), pp. 668-669 [포항제철, 『포항제철 20년사』].

POSCO not only has secured operation skills, but also endeavored to improve the equipment. In the course of using imported equipment on the frontline, many problems arose for which no solutions could be given by the manufacturers. While POSCO was addressing the problems, it changed or improved the equipment to adapt to the conditions of the frontline. In the 1970s, for technological improvement aimed at reducing costs, POSCO simplified relevant equipments, partially changed their operation methods, and additionally installed a few devices.²¹ This kind of technological improvement significantly increased the efficiency of factory operation and improved productivity, but efforts for radically improvements were scarce, based on the sufficient understanding of technologies embodied in the equipment.

As discussed thus far, POSCO's technological activities in the 1970s focused on the acquisition of technologies that had already been standardized in advanced countries. The development of technological capabilities at the time had the features of accommodating the technical system of advanced countries to a different space of the Pohang steel mill. The company swiftly applied the existing technical system and partially improved some of its components, but these efforts could neither lead to developing new components nor a new technical system. In this sense, technological activities in the 1970s are deemed to have focused on an effective representation of the existing technical system.

Technological Catch-up through Task Force Teams

POSCO assumed the imitator type of acquiring widely adopted technologies in the 1970s, while from the 1980s, it responded swiftly to advanced technological innovations by assuming the fast follower type.²² In the 1980s, a large number of state-of-the-art equipment was introduced through the construction of the Gwangyang Steelworks, making the securing of technologies for smooth operation of this equipment an important issue. However, developed countries were reluctant to transfer such technologies, or advanced steelworks in foreign countries were also in their early stages. POSCO could not obtain the technologies it needed all at once as in the past, and was forced to independently develop important technologies.

POSCO began to drastically reorganize the technology institute established in 1977 to set up a new R&D system. This led to the establishment of the Pohang University of Science and Technology (POSTECH, 포항공대) in 1986 and the Re-

²¹ Park Woohee and Bae Yongho, *Korea's Technological Development*, pp. 175-189.

²² Shaker A. Zahra, et al. classified four types of technological strategy such as ① first-to-the-market who creates new technology for the first time, ② fast follower who swiftly responses advanced technologies, ③ imitator who acquires widely-adopted technologies, ④ application-oriented who applies existing technologies to specific fields. See Shaker A. Zahra, Rajendra S. Sisodia and Sidhartha R. Das, "Technological Choices within Competitive Strategy Type: A Conceptual Integration," *International Journal of Technology Management*, 9-2 (1994), 172-195. I applied this classification to the case of POSCO.

search Institute of Industrial Science and Technology (RIST, 산업과학기술연구소) in 1987. POSCO thereby became the first Korean enterprise to build a “triangular R&D cooperation system” that connected an enterprise, a research institute, and a university.²³

While securing technologies in the 1980s, POSCO benchmarked steelmakers in Japan, who had the world's best steel technology at the time. If Japanese technological achievements were reported in official documents or through informal contacts, the company made enormous efforts to meet and surpass those achievements. In this regard, Baek Deokhyun (백덕현), who through the 1980s served as the head of equipment and technology, as well as the executive vice president in technology at POSCO indicated, “We were much stimulated by our neighboring country, who was the world's top steel maker, and to how to surpass Japanese steelmaking was the imperative problem. In particular, since Japan's technological achievements and productivity indexes were known only as end results, we had to make tremendous efforts to achieve corresponding technologies. This kind of competition with Japan served as the driving force for POSCO's technological efforts.”²⁴ Although Japan had already begun to avoid transferring technology in the 1980s and therefore failed to directly participate in improving POSCO's technology, the country indirectly stimulated POSCO's technological development through reported information on its technological accomplishments.

In the 1980s, POSCO began to examine and analyze various documents and materials in earnest to obtain information on advanced technologies essential to technological catch-up. Based on their collection and analysis of technology information, RIST steadily published references necessary for R&D in all areas, such as iron making, steelmaking, control, energy, steel materials, special steel, welding, and surface treatment.²⁵ In 1979, the company also signed MOUs with foreign steelmakers and secured an official route of technology exchange. These efforts occurred in the form of exchanging engineers for each sector and holding briefing sessions on technology, and it was used as a channel to obtain new technology information.²⁶

In the 1980s, advanced steel makers began to hold POSCO in check, and were reserved with providing information. Therefore, a method that might be called a “surreptitious glance” was frequently used in the course of acquiring technological information. For example, POSCO's overseas trainees secretly copied confidential data and photographed materials and facilities if training institutions did not cooperate actively. In many cases, they made use of personal relations to collect

²³ Choi Hvungsup, *Research Institutes Never Stop Lihtenina: The 30-Year Dawning of Science and Technoloav in Korea* (Chosunilbosa, 1995, in Korean), pp. 154-155 [최형섭, 『불이 꺼지지 않는 연구소: 한국 과학기술 여명기 30년』].

²⁴ My Telephone Talk with Baek Deokhyun (2000. 11. 16).

²⁵ RIST (Institute of Industrial Science and Technology), *Iron and Steel Technology*, 8 vols. (1992) [산업과학기술연구소, 『철강기술』].

²⁶ POSCO, *POSCO in 25 Years: History of Technoloical Development* (1993), pp. 242-243 [포항제철, 『영일만에서 광양만까지: 포항제철 25년사, 기술발전사』].

materials or observe facilities in order to obtain information, and this contributed considerably to POSCO's planning and development of technology. This data were effectively put to practical use because POSCO had already secured a considerable knowledge base.

In this regard, Shim Jangseop (심장섭), who served as the general manager of equipment planning in the second Pohang cold rolling factory and as the staff in charge of technological planning in the third Gwangyang cold rolling factory from 1983, indicated that his observation trip in 1982 to the cold rolling factory of the Hirohada steel mill through personal relations contributed greatly to designing the current factory in Korea.²⁷ Likewise, Shin Yeonggil (신영길), who worked as an R&D personnel in POSCO and RIST from 1981, recollected that he could secure materials on continuous casting and relevant specifications through unofficial contacts, and this served to enhance POSCO's continuous casting technologies greatly.²⁸

POSCO made many trials and errors in developing technologies based on technological information acquired through these methods. First attempts seldom produced successes, but repeated trials could produce desired results through failure analysis. Also, development of certain elemental technologies was delayed, causing bottleneck phenomena, but this prompted POSCO to attempt again by securing additional information. These trials and errors made POSCO engineers understand the features of relevant technologies and provided opportunities to secure know-how on technological development, thus diminishing the occurrence of problems and systematically defining the causes.²⁹

To effectively push ahead with technological development, POSCO organized a task force team (TFT) to focus on managing core technological tasks. To shorten the technological development cycle and the market entry cycle, the TFT carried out R&D, developed pilot products and mass production technology in parallel, rather than in succession. Also, because the TFT often encompassed RIST, POSTECH, and other companies as well as POSCO, the team could solve problems in a more comprehensive manner. Through this, an atmosphere was created in which appropriate and relevant groups jointly conducted R&D. While running the TFT, POSCO granted an unprecedented cash prize to any team that achieved their targets in a short period of time, and actively promoted this as a strategy, thereby triggering competition among the teams and accelerating technological development. As a result, the engineers involved had to work much harder, but this greatly facilitated POSCO's effort to catch up to its leading competitors in a short period.³⁰

In the 1980s, POSCO secured technology in three ways. First, the company introduced technology from abroad and then sophisticated it, for example, the

²⁷ Lee Ho (ed.), *Chorus of Bewitched People*, pp. 149-152.

²⁸ My Interview with Shin Yeonggil (2001. 9. 4).

²⁹ My Telephone Talk with Baek Deokhyun (2001. 7. 20); My Interview with Shin Yeonggil (2001. 9. 4).

³⁰ My Telephone Talk with Baek Deokhyun (2000. 11. 16); My Interview with Hong Sangbok (2000. 11. 23).

pulverized coal injection technology and the slab quality improvement technology. Second, POSCO independently developed technology because advanced countries refused to transfer technology including the extra deep drawing steel and the thermo mechanical control process (TMCP). Third, Korean engineers developed technology custom-made for POSCO, the representative example being the computerization of blast furnace operations.³¹

As such, technological activities in the 1980s, in comparison to those of the 1970s, were very diverse, but the scope of technological innovation covered nearly all fields. This can be evinced by the comparison of technological achievements shown in official records published in 1981 and 1993 by POSCO. As shown in [Table 2], the 1981 materials described a few technological improvement cases sporadically, while the 1993 materials discussed relevant technologies systematically and comprehensively.

Division	1970s	1980s
Iron making	- Instrumentation and control technologies - Operations indexes management - Life lengthening measures - Heavy oil injection amount reduction	- Supplementary fuel injection technology - Particle distribution control technology - Blast furnace computerization - Furnace wall renovation technology - Furnace rebuilding technology
Steel making	- High carbon steel blowing pattern establishment - Slag inflow prevention after tapping - Large-scale slopping restraint - Residuals stabilization	- Hot metal preliminary treatment - Steel converter operation technology - Furnace outside refinement technology - Powder injection technology - Temperature increasing technology
Hot rolling	- Heating furnace high-pressure pipe installation - Rough rolling cylinder retainer detachment prevention - Cooling water line improvement	- Heating furnace combustion control - Size precision improvement technology - Form control technology - Online roll grinding technology - Material forecasting technology

Table 2. Comparison of Major Technological Enhancements Between the 1970s and the 1980s [Source: POSCO, *POSCO's Construction History for 8,500 Thousand Ton* (1981), pp. 189-190, 213-214, 230-231 [포항제철, 『포항제철 850톤 준공사』]; POSCO, *POSCO in 25 Years: History of Technological Development*, pp. 46-54, 73-78, 101-106.]

Through these efforts, POSCO transformed itself into a world-class steelmaker. Its production yield was just about 80% in the 1970s, but it surpassed 90% by 1987. In 1992, it reached 94.4%, nearly the same as Japan, at 94.8%. As of 1992, the

³¹ For the detail information about these cases, see Song Sungsoo, “The Historical Development of Technological Capabilities in Korean Steel Industry: POSCO from the 1960s to the 1990s” (Ph. D. Dissertation, Seoul National University, 2002), pp. 226-230 [송성수, “한국 철강산업의 기술능력 발전과정: 1960-1990년대의 포항제철”].

product output per man was 880 tons, making POSCO second in the world, second only to the Japanese at 1,102 tons. The energy basic unit was 5.29 million kcal, a little lower than the Japanese figure of 5.89 million kcal.³² Considering all these facts, POSCO could be considered as having reached world-class productivity by the early 1990s. In fact, based on the development of its operation technology, POSCO has been the world's leading steel maker in comprehensive price competitiveness since the mid 1980s.

As discussed thus far, POSCO's technological activities in the 1980s focused on catching up with advanced technologies that had begun to be applied in advanced countries. The development of technological capabilities at the time focused on modeling after the technical system of advanced countries, and using introduced technologies or developing technologies aimed at securing necessary components and integrating them. This pattern was similar to the 1970s in that POSCO did not create a new technical system, but different in that it furthered or developed element technology comprised of the existing technical system. In this sense, technological activities done in the 1980s carried the features of innovating some components within the existing technical system.³³

Technological Creation of Next-generation Steel Technology

Around 1990, the global steel industry entered a phase of rapid technical change, far reaching enough to be called a "technical revolution." It was during this time that the next-generation steel technology, which made it possible to skip or directly connect previously separated production processes, began to emerge. This next-generation steel technology can be categorized into the new iron making technology and the new casting technology. The former involves direct reduction and smelting reduction, and the latter involves thin slab casting and strip casting. Direct reduction is a technology designed to produce an alternative to steel scrap as the supply shortage of steel scrap deepens. Smelting reduction is a method that reduces melted iron ore in order to directly produce pig iron or molten iron. Thin slab casting integrates the continuous casting process and a part of the hot rolling process, while the strip casting integrates the continuous casting process and the entire hot

³² Korea Development Bank, *Industry of Korea* (1993), p. 89 [한국개발은행, 『한국의 산업』].

³³ In this point, I applied Henderson and Clark's ideas to the case of POSCO. They classified types of technological innovation with reference to core concepts and components such as incremental innovation (innovation without changes of core concepts and components), modular innovation (innovation with change of components under existing core concepts), Architectural Innovation (innovation with change of core concepts utilizing existing various components), and radical innovation (innovation both with changes of core concepts and components). See Rebecca M. Henderson and Kim B. Clark, "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms", *Administrative Science Quarterly*, 35-1 (1990), 9-30.

rolling process.³⁴

Classifi- cation	Iron making			Steel making	Contin- uous casting	Hot rolling			Cold rolling
	Coke	Sinte- ring	Blast furnace			Heating furnace	Rough rolling	Finishing rolling	
Smelting reduction									
Thin slab casting									
Strip casting									

Table 3. Outline of next-generation steel technology [Note: The shaded parts are the processes that can be skipped or integrated.]

As POSCO pushed ahead with R&D on next-generation steel technology, investment sharply increased. For example, between 1999 and 2000, 81.7 billion won was spent on the strip casting project, and 60.0 billion won was spent on the smelting reduction project. While only about 1 billion won was spent even on a large-scale technology development project in the 1980s, tens of billions of won were spent on next-generation steel technology projects in the 1990s. Obtaining an enormous budget for R&D became a pressing task. For the smelting reduction project, POSCO managed to obtain 22.2 billion from the government, but it had to press forward with the strip casting project alone, provoking a great deal of controversy.³⁵

To develop next-generation steel technology, POSCO established a new organization in the form of a project team and recruited excellent research personnel for it. This project team was a more advanced version of the TFT in the 1980s. Whereas the TFT functioned for a relatively short period, this project team was intended to function for over 10 years. Since 1987, RIST has been conducting basic study on smelting reduction and new casting technology. Also, the strip casting (S/C) project team was launched in March 1990 and the smelting reduction (S/R) project team in February 1991. These project teams had the same level position as their parent organization. The strip casting project team was led by Dr. Shin Yeonggil, and the smelting reduction project team by Dr. Lee Ilok (이일옥) from 1992. Most of the researchers in these teams either had Ph.D. degrees or abundant research

³⁴ For the change of technological paradigm in the iron and steel industry, see Song Sungsoo, “The Patterns and Directions of Technological Innovation in the Iron and Steel Industry”, *Journal of Korea Technoloav Innovation Society* 3-2 (2000), 94-110 [송성수, “철강산업의 기술혁신패턴과 발전과제”, 『기술혁신학회지』].

³⁵ POSCO, *Steel Making in 25 Years* (1998), p. 242 [포항제철제강부, 『제강 25년사』].

experience.³⁶

The development of a next-generation steel technology started with gathering technological information. Some of these methods had only just been attempted to commercialization, there were no obvious and definitive results, and this caused many difficulties in establishing the directions of R&D. In the case of smelting reduction, Vöest of Austria developed the coal ore reduction (COREX) process in early 1985. In November 1987, a plant with an annual production capacity of 300,000 tons was completed at Iscor's Pretoria Steelworks in South Africa and began normal operations in November 1989. In case of thin slab casting, Germany's Schloemann Siemag developed the compact strip production (CSP) process in December 1986. In July 1989, a plant with an annual capacity of 600,000 tons was completed at Nucor's Crawfordsville Steelworks in the United States, and this steelworks was striving to obtain operation technology.³⁷

RIST researchers collected information on the existing situation and problems of technological development by individually reaching out to their contacts that were involved in R&D on next-generation steel technology in advanced companies. The information obtainable from developed countries at that time was neither complete nor fully reliable. For such reasons, RIST continually corrected and supplemented the information through laboratory tests. Unlike the past technological activities, the technological achievements of foreign countries were not obvious, which meant that a separate work was required, even when specific goals for technological development were established. In the case of the next-generation steel technology, all the basic technologies necessary for the three stages of process design, facility manufacturing, and plant operation had to be domestically established. Therefore, if an error were found in one part, then the direction of R&D itself had to be revised. The past technological activities were successively performed for each stage, but the next-generation steel technology was developed as each stage was repeated and gradually progressed like moving in a spiral.³⁸

Unlike in the past, various methods of the next-generation steel technology tended to appear concurrently, enough to be called a “renaissance of steel technologies.” The smelting reduction method not only included COREX, but also direct iron ore smelting reduction (DIOS), high intensity smelting (HISMELT), and cyclone converter furnace (CCF). Likewise, the thin slab casting method not only included CSP, but in-line strip production (ISP), flexible thin slab casting (FTSC), and quality strip production (QSP).³⁹ Among these, POSCO decided to select

³⁶ My Interview with Lee Ilok (1999. 6. 30); My Interview with Shin Yeonggil (2001. 9. 4).

³⁷ KANIST (Korea Research Association of New Iron and Steel Making Technology), *New Iron and Steel Making Technology in the 2000s: R&D Projects* (1990, in Korean), pp. 26-28, 58-60 [한국신철강기술연구조합, 『2000년대의 신철강기술: 연구개발 과제』].

³⁸ My Interview with Lee Ilok (1999. 6. 30); My Interview with Shin Yeonggil (2001. 9. 4).

³⁹ For the detail information about various methods in the next-generation steel technology, see KANIST, *New Iron and Steel Making Technology in the 2000s*, pp. 13-86; Lee Ilok, “The Present and Future of Iron and Steel Technology”, *POSRI Steel Journal* 2-3 (1997), 21-42. [이 일록, “철강기술의 현재와 미래”, 『POSRI 철강경제』].

COREX and ISP, which were deemed to be the most favorable in terms of both technological and economic aspects. As to smelting reduction, Iscor was operating a plant with a capacity of 300,000 tons based on COREX, but POSCO decided to use the capacity to 600,000 tons, a volume high enough to realize economy of scale. In thin slab casting, Nucor was operating a plant with a capacity of 600,000 tons where CSP was applied and it planned to expand the capacity to 1.8 million tons in 1994. POSCO decided to build a plant with a capacity of 1.8 million tons using ISP, which required a shorter production process and was thus less expensive to install than CSP.

Around 1990, by building a pilot plant, POSCO repositioned itself to securing technology necessary for commercialization. The pilot plant was designed and manufactured jointly by foreign and domestic engineers, with the design led by foreign teams and the manufacturing by domestic teams. Vöest participated in smelting reduction and Britain's Davy Distington participated in strip casting through joint R&D. It was relatively easy to build the pilot plant for smelting reduction because Vöest had already accumulated relevant experience, but there were many difficulties in constructing the pilot plant for strip casting because Davy lacked the ability and made frequent design modifications. Davy had been recruited because leading global plant builders, including Mannesman Demag, had refused to cooperate with POSCO.⁴⁰

After the pilot plants were built, POSCO conducted dozens of pilot operations to increase the production capacity, improve quality, and complement facilities, and in doing so, the company worked to determine the plant specifications and operating conditions applicable to actual plants. In this process, the company developed a technical system with a high possibility of commercial use, before the plant construction project was started. For smelting reduction, the daily production output increased from 10 tons to 150 tons, while the thin slab casting secured technology designed to mass-produce cast strips with the thickness of 14mm.⁴¹

Based on these preparations, POSCO organized the COREX project team and the strip casting team in October 1992 to push forward with a project for constructing an actual plant. The construction of a new COREX iron-making plant with an annual capacity of 600,000 tons began at Pohang Steelworks in November 1993 and completed in November 1995. POSCO began normal operation of this new iron-making plant in December 1996, and in early 1998, exported COREX operation technology to Saldanha of South Africa and Jindal Vijaynagar Steel Ltd. (JVSL) of India.⁴²

The construction of Mini Mill 1 with an annual capacity of 1.8 million tons was carried out from December 1994 to October 1996. Because ISP selected by POSCO was less technically stable than CSP, problems such as breakout of steel and poor quality were prone. As a result, Mini Mill 1 underwent trial and error for

⁴⁰ POSCO, *Steel Making in 25 Years*, pp. 243-244.

⁴¹ RIST, *RIST in 10 Years* (1997), pp. 473-484 [포항산업과학연구원, 『포항산업과학연구원 10년사』].

⁴² POSCO News 포스코신문 (1998. 5. 28).

about three years before attaining standard operation in July 1999. POSCO's thin slab casting technology was praised by Mannesman Demag, and POSCO reaped the benefits of selling this technology to Hoogovens of the Netherlands in October 1999.⁴³

As such, POSCO secured manufacturing technologies regarding the smelting reduction and thin slab casting methods, and exported them to foreign countries, thus paving the way for the company to grow as the world's top steel maker even in new steel technology paradigms. This process shows how POSCO has changed the pattern of its cooperation with advanced foreign steel makers. POSCO received the transfer of technologies from advanced countries directly or indirectly in the past, but recently, the company has started to pursue technological cooperation with advanced firms on an equal stance. With Vöest's and Mannesman Demag's plant manufacturing technologies combined with POSCO's operation technologies, technologies of smelting reduction and thin slab casting are now being exported in the package form. In particular, Mannesman Demag, which initially refused to cooperate with POSCO regarding thin slab casting, later pursued technological cooperation with it. This achievement was made possible as POSCO has secured complementary assets.⁴⁴

Moreover POSCO went on to propose a new idea in the process of commercializing next-generation steel technology. COREX is problematic because it requires use of pellets of 8~35 mm as raw material in order to allow smooth passage of reaction gases inside the container. To overcome this shortcoming, the company sought for a new method that could utilize fine ore with a particle size of less than 8 mm and called it fine iron ore reduction (FINEX). After succeeding in the test operations at a daily capacity of 150 tons in August 1999, POSCO began to jointly develop the FINEX method with Vöest in November 1999. A FINEX demo plant with an annual capacity of 600,000 tons was completed in May 2003, and it secured plant technology for commercialization and completed the development of operation and maintenance technology. The construction of a FINEX commercialization plant with an annual capacity of 1.5 million tons was started in August 2004 and completed in May 2007. The basic design was accomplished by Vöest, and the detailed design and construction were carried out by POSCO. POSCO produced 4,300 tons of steel a day at the FINEX commercial plant in September 2007, thereby reaching normal operation for the first time in the world.⁴⁵

In addition, POSCO endeavored to establish a mini mill within an integrated mill (MMIM). This aimed to use smelted iron produced from the blast furnace as the

⁴³ POSCO News 포스코신문 (1999. 10. 14).

⁴⁴ For the importance of complementary assets in technological cooperation, see David. J. Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy", *Research Policy* 15- 6 (1986), 285-305.

⁴⁵ For the detail information about the process and characteristics in the development of FINEX, see Song Sungsoo and Wichin Song, "From COREX to FINEX: The Case of Path-revealing Innovation in POSCO", *Journal of Korea Technology Innovation Society*, 13-4 (2010), 700-716 [송성수, 송위진, "코렉스에서 파이넥스로: 포스코의 경로선행형 기술혁신", 『기술혁신학회지』].

primary material, giving hot-rolled steel plate in the mini mill as the end product, thus resolving shortcomings of the iron-making process that makes it difficult to flexibly respond to demand and supply, as well as that of the mini mill, which makes it difficult to secure superior quality.⁴⁶ This scheme was not realized for the second mini mill construction was halted in May 1998 with the backdrop of the IMF crisis, but the attempt was evaluated as POSCO selectively integrating diverse technological possibilities and establishing its own technical systems.

As discussed thus far, since the 1990s, POSCO maintained the posture of the first-to-the market, and undertook to create flexible-stage technologies for which no clear-cut achievements were attained or little precedents existed even in advanced countries. In the development of next-generation steel technology, POSCO used components that only partially appeared in advanced countries and complemented them, establishing new technical systems. In this respect, technological activities since the 1990s transcended the level of component innovation within existing technical systems into the stage of developing new technical systems all together. While such kinds of technological activities had yet been limited to a few cases, and commercialization effects had yet to be fully realized, it implies that POSCO had started to lead technological innovation in the world's steel industry.

Summary and Implications

Technological capabilities of POSCO have been developed through the acquisition, catch-up, and generation stage. In the 1970s, basic technologies for steelworks operations were acquired mainly from the Japanese firms. Overseas training was the primary route of technology transfer, and acquired technologies were articulated through actual operation. Technological activities in the 1980s concentrated on intentionally catching up to the advanced technologies. Technological information was broadly accumulated, task force teams were constructed for developing important technologies, and the scope of technological innovation was broadened to cover nearly all fields. In the 1990s POSCO launched long-term projects based on the large-scale investments, and challenged the frontiers technology. Next generation steel technologies were promptly commercialized with proper technological choices and new technological concepts were developed.

Some implications can be induced from this paper as follows.

First, activities related to acquiring technological information, the starting point of innovations, show different features in different periods. During the stage of technological acquisition with barely any knowledge base, technological information focuses on quantity rather than quality, and is not collected systematically. During the technological catch-up stage, technological information began to be gathered systematically, and with a somewhat structured knowledge base, unoffi-

⁴⁶ Hong Sangbok, "Hybrid Steel Works at POSCO: Mini Mill within an Integrated Mill", *POSRI Steel Journal* [『POSRI 철강경제』] 1-5 (1996), 108-129.

cial methods are effective to acquire actual information. In the stage of technological creation, technological information collected is partial and incomplete, so additional activities are needed to revise and reconstruct it.

Second, characteristics of technological cooperation vary according to periods. In the stage of technological acquisition, advanced countries are positive in technological cooperation, and particularly, the transfer of mature technologies is feasible. During the technological catch-up stage, advanced countries tend to avoid technology transfer, but contribute indirectly to the development of technological capabilities as they serve as the models of technological catch-up. In the stage of technological creation, the importance of technological cooperation is not necessarily lessened, but is effective only when the relevant actors secure complementary assets.

Third, to effectively pursue innovations, it is necessary to appropriately form relevant organization. In the case of POSCO, it deployed engineers with degrees in higher education in the production site and gave special treatment to superior technicians during the technological acquisition stage. In the technological catch-up stage, R&D organization was constructed and task force teams on major technological tasks were formed and managed intensively. In the technological creation stage, investments were remarkably increased, long-term project teams were formed, and high-class research manpower with new knowledge was recruited.

Fourth, some Korean firms have shed innovations under existing technical systems, and are entering into the stage of making new technical systems. For example, POSCO has begun the stage of developing new technical systems, leaving behind the stage of representing its existing technical system and components, and of innovating some components under the existing technical systems. Nowadays, the capabilities to explore and navigate uncertain technological paths, to move beyond acquiring and catching up with advanced technologies through known technological paths are required. To reveal this point, additional research needs to be carried out on the development of technological capabilities in Korean firms after the 1990s. This will lead to insight on the mechanisms of development of Korea's technological capabilities, which are still left obscure, in the black box.

Abstract

This paper examines the historical development of technological capabilities in Korean steel industry focusing on the case of POSCO (Pohang Iron & Steel Co.). Technological capabilities of POSCO have been developed through acquisition, catch-up, and generation stage. In the 1970s standardized operation technologies were acquired based on Japan's technological cooperation. The prime route of technological acquisition was overseas training and operation technologies were more articulated by real operation. In the 1980s POSCO focused to catch-up advanced technologies through in-house R&D activities. Technological information was broadly accumulated, task force teams were constructed for important technological tasks, and the scope of technological innovation covered nearly all fields. Since the 1990s POSCO launched long-term projects based on the large-scale investment and challenged the new fronts of steel technologies. Frontier technologies such as smelting reduction and thin slab casting were early commercialized and new technological concepts were emerged. In conclusion, this paper suggests some implications on the development of technological capabilities in Korea.

Key Words: POSCO, technological capabilities, acquisition, catch-up, generation