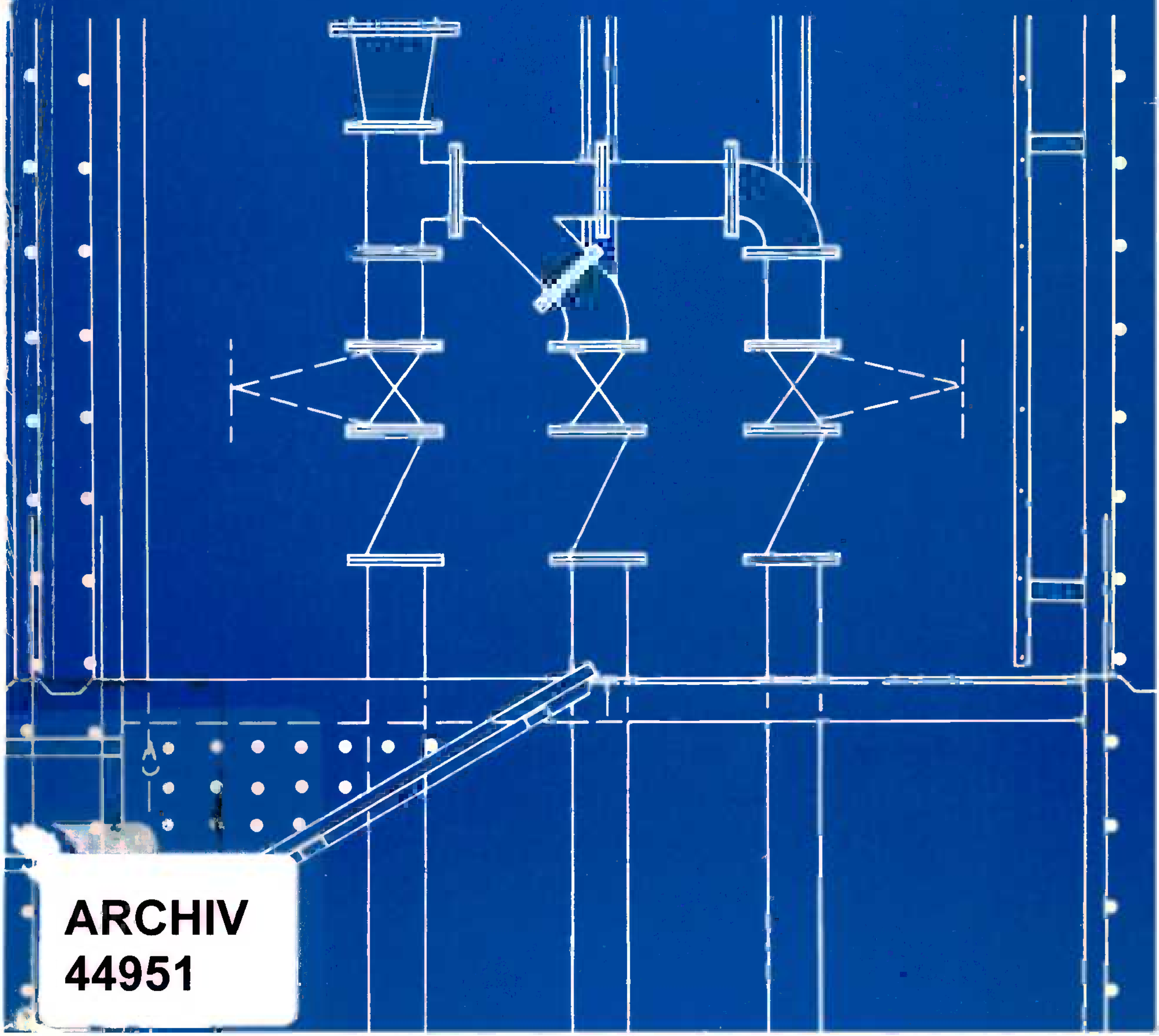
IDRC - 161e

Consulting and Engineering Design in Developing Countries

Edited by Alberto Aráoz



The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences; and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.

Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa

Aráoz, A.

IDRC-161e

Consulting and engineering design in developing countries. Ottawa, Ont., IDRC, 1981. 140 p.

/IDRC publication/, /engineering design/, /consultants/, /enterprises/, /developing countries/ — /case studies/, /Argentina/, /Korea R/, /Philippines/, /chemical industry/, /Brazil/, /research/, /government policy/.

UDC: 62.006.2 ISBN: 0-88936-278-5

Microfiche edition available

IDRC-161e

CONSULTING AND ENGINEERING DESIGN IN DEVELOPING COUNTRIES

EDITED BY ALBERTO ARÁOZ

CONTENTS

CHAPTER 3

DEVELOPMENT OF ENGINEERING CONSULTANCY AND DESIGN CAPABILITY IN KOREA

JINJOO LEE

SUMMARY

The Korea Engineering Co. Ltd (KECL) was founded in 1970 as a joint venture of the government with the Lummus Co. (USA), with equity participation by several leading Korean enterprises. In 1973, Lummus was replaced by the Toyo Engineering Co. of Japan as the KECL partner, and in 1978 the Korean Development Bank sold its stock, 50% of the Korean share, to the Sam Sung Co., which now has the control of KECL.

KECL is a multipurpose engineering company, making available all major services in the areas of plant and water resource engineering, harbour and coastal engineering, irrigation, sewerage, and agricultural engineering, collaborating whenever needed with competent foreign CEDOs.

In its first year, KECL had a large volume of work from the government, but this decreased in the second and third years, causing Lummus to retire. Contract amounts increased notably after 1976, and the company has now accumulated good experience and technical expertise. KECL is expected to grow rapidly after its transfer to private enterprise. Personnel went up from 66 in 1971–73 to 129 in 1974, and it doubled again to 238 in 1975. In 1978 it was expected to reach 500.

Most clients have been Korean enterprises. Some subcontracted projects have been made for foreign ones. Services have covered feasibility studies (15 projects), detailed engineering including procurement and construction management (45 projects), and detailed engineering including start-up (two projects). No basic engineering projects have been carried out: the firm's technical capability and expertise has not yet reached a sufficient level for this.

Among the problems faced by KECL, a crucial one is the scarcity of competent, experienced engineering and technical personnel, especially piping and instrument engineers with plant design expertise. KECL's growth, despite support by the government, has not been easy. This experience shows that the engineering industry cannot be fostered only with direct government support. Incentives are needed to enhance engineering capabilities and to create a demand, overcoming the hesitation of most entrepreneurs to use domestic engineering firms on account of supposed shortcomings in quality and efficiency.

KECL has steadily developed its technical capability to handle detailed engineering services. The 1960s were a period of foreign dependency for engineering services, with almost no Korean contribution. Partial localization of such services took place in the 1970s, KECL taking a leading role in this. However, no basic design and engineering service projects have been carried out as yet by domestic engineering firms using only their own capabilities. Perhaps this will be possible in the 1980s if high-risk entrepreneurship is forthcoming on the part of clients.

This case study analyzes two investment projects where KECL has had a major role. Both have been successful — as indeed have been all of KECL's projects to date.

One of the projects studied was a styrene monomer plant. The client was a company backed by the Korean Development Bank. A preinvestment study made by the client led to the choice of the Monsanto process. The Toyo Engineering Co. of Japan was chosen as the CEDO, because its parent company, the Mitsui Corp., was able to finance the project. The total cost was about U.S.$17 million, of which $2 million (12%) accounted for the engineering fee. KECL provided two types of engineering services: detailed engineering and plant construction management, through a subcontract with Toyo, and all engineering services for an off-site building through a direct contract with the client. The latter amounted to U.S.$600 000.

There were few alternatives regarding size, location, and product mix of the plant because there was a long-term government plan for petrochemical development. Because of the extent of the investment, which could not be funded solely by the government, decisions on technical matters were not made prior to financing decisions: financing and loans took priority over all other problems, and any alternative technological choices had to be made in accordance with financing possibilities.

The government required a breakdown of foreign and local procurement, the latter amounting to U.S.$4 million. KECL's role in procurement was the evaluation and recommendation of local vendors, supervision of vendor drawing, expediting of deliveries, etc. The project gave KECL a good opportunity to acquire expertise in activities where it had little previous experience. KECL's efficiency was satisfactory: the project was completed by the target date, there were no cost overruns, and the cost of the plant was evaluated as reasonable or even lower than expected. The quality of the engineering services was said to be good according to clients.

The other project studied was a resin plant. The client was a private company. KECL's services included planning and preinvestment analysis in collaboration with the client, detailed design and engineering, procurement services, and construction supervision. Basic design and engineering were provided by the Japan Synthetic Rubber Co., which was the ABS resin process licencer. The project cost about U.S.$10 million; KECL's engineering fee was about $400 000 (4%). In addition there was an undisclosed amount for basic design and engineering.

KECL made great efforts to localize plant facilities and equipment; only items such as high-precision equipment (process, control, and electrical) were imported. This high level of local purchasing was possible because the client itself financed the project.

The plant was completed on time and without cost overruns, and it is now in good operational condition, showing the satisfactory quality of the engineering services.

For comparison purposes, the case of a very large fertilizer project that was handled by a foreign CEDO is mentioned in the study. Investment was U.S.$419 million, most of which came from foreign loans. The general contractor was a large U.S. engineering firm, which was paid $42 million (10%) for the engineering services for basic design, procurement, guarantee of the start-up and operation, and construction. This amount surpasses the total amount spent on engineering services by all companies in Korea in 1977. Total plant facilities and equipment amounted to $219 million, of which only 27% was locally procured, i.e., about $60 million. The localization rate would have been higher if local engineering firms had taken responsibility for engineering services. It should be noted that three domestic engineering firms, including KECL, participated in the project through subcontracts.

The emergence of engineering design and consultancy organizations in developing countries has been stimulated by the increase and diversification of industrial projects. These organizations play an important part in economic and technological development, frequently providing a channel through which industrial technology is transferred from advanced countries to developing countries and performing a crucial role by linking four systems that need to be integrated for efficient industrial development: the finance system, which makes it possible to start a project; the engineering design system, which organizes the necessary resources, personnel, facilities, money, and skills to implement the project; the production system, which applies a specific set of techniques to the project; and the science and technology system, which creates/supplies the technology required.

Engineering and consultancy are therefore related to several issues of industrial development, such as technology transfer, production efficiency, local engineering capability, product and process improvement, etc. They are essential for fast industrial development and technological self-reliance. The important benefits from the development of reliable and competent engineering services can be realized through reduced engineering fees, localization of plant facilities and equipment, reduced plant construction costs, development and localization of technology, promotion of related technology especially for the machinery industry, personnel development, machinery exports, etc.

Few systematic studies have been carried out to analyze the factors in the evolution and the practices of engineering design and consulting organizations. Knowledge of engineering activities in developed countries is fragmentary and embedded in trade secrets, so that any systematic understanding of CEDO practice and behaviour is difficult to achieve. According to Machlup (1962), engineering services make up a typical subsector of the knowledge industry.[27] Engineering services apply scientific principles and knowledge to the planning, design, development, construction, operation, testing, and inspection of plants or facilities, which are an integration of machines, structure, and equipment for a manufacturing process. Table 3 specifies the activities needed for a number of main engineering functions and the organizations carrying out those activities.

This chapter will describe and analyze the development of engineering consultancy and design capability in Korea in the light of the knowledge industry, with special reference to Table 3. The levels of the analysis are three: national, i.e., Korean engineering service industry as a whole; company, i.e., a specific engineering firm, Korea Engineering Co. Ltd; and project, i.e., a few engineering projects.

Before 1961 almost no investment in engineering services took place in Korea. During the Five Year Economic Development Plan (1962–67), plants for fertilizer production and petroleum refining were built on a

---

[27] Machlup distinguishes five types of knowledge industry: education, research and development, communications media, information machines, and information services. CEDOs are concerned with certain kinds of information services, especially engineering and architectural services, business services, and services rendered to government.

turnkey basis, which resulted in little impact on indigenous engineering capabilities. Some pioneering efforts to establish integrated engineering firms by technical entrepreneurs in the 1960s were not successful due to restricted domestic demand and lack of technical capabilities. Only

Table 3. Activities in main engineering functions.

Engineering functions	Activities	Organization in charge
Consulting prior to design	Resource survey; labour study; market analysis; environmental study	Integrated engineering firm; resource development corporation; general trading company; survey and consultant organizations; industrial firm; project end-user
System design and basic engineering	Master plan for installation; urban planning feasibility study; technical feasibility; overall evaluation	General trading company; integrated R&D institute; specialized survey team or firm; integrated engineering firm; plant equipment manufacturer; industrial firm
Detailed engineering and design	Total system design; subsystem design; system element design; other design; technical evaluation	Integrated engineering firm; plant equipment manufacturer; specialized design company; technology-based venture business
Procurement	Preliminary procurement study; market survey; procurement; provision of loan	Integrated engineering firm; general trading company; construction company; plant equipment manufacturer
Construction and maintenance	Plant construction; installation of equipment; various civil engineering tasks	Integrated engineering firm; construction company; plant equipment manufacturer
Project management	Project control; inventory control; engineering cost analysis; supervision	Prime contractor; construction company; equipment manufacturer

Table 4. Status of engineering firms in Korea, March 1978.

Type of firm	Number of firms	Professional engineers	Engineers
Plant engineering	6	129	1254
Specialized services			
Integrated	9	59	419
Mechanical	6	8	441
Metallurgical	–	–	–
Chemical	2	2	11
Electrical	16	58	159
Electronics	–	–	–
Communications	2	2	84
Shipbuilding	2	4	181
Construction	35	68	714
Construction equipment	2	3	8
Mining	5	9	21
Textiles	2	2	222
Nuclear	1	11	78
Production	–	–	–
Geology	17	21	245
Information processing	–	–	–

construction and architectural design services maintained their operations.

In the late 1960s, a partial localization of engineering services was accomplished in the construction of several chemical plants by a fertilizer company's technical team. In the early 1970s the first integrated engineering firm, Korea Engineering Co. Ltd, was created under the auspices of the Korean government, as a joint venture with Lummus Co. of the U.S. The company participated in a few engineering projects, but Lummus withdrew owing to the lack of a market for engineering services, being replaced in the partnership by Toyo Engineering of Japan.

The government influenced the engineering industry through the Professional Engineers Law before 1973 and, thereafter, through the Engineering Services Promotion Law. The latter stipulated that a domestic engineering company should be the prime contractor for engineering services except when not feasible, and it required registration of engineering firms and an annual report of their activities.

Engineering firms registered in Korea[28] in 1978 comprised 6 plant engineering, 9 integrated engineering, 25 specialized, and 65 individual firms (Table 4). They employed 4213 engineering personnel. The value of engineering services was estimated at about 1 billion won[29] in the late 1960s, 2.1 billion won for 632 project contracts in 1973, 5 billion won for 1092 projects in 1974, 8.6 billion won for 1738 projects in 1975, 20 billion won for 2403 projects in 1976, and 24.6 billion won for 3031 projects in 1977.

[28] A registered engineering firm is required to have at least one professional engineer and four registered engineers.

[29] One U.S. dollar was worth 275 won in the late 1960s and 485 won after 1973.

Table 5. Size of Korean engineering firms.

	1975	1976	1977
Professional engineers			
1	58	80	65
2–4	26	29	23
5–9	7	10	8
10–19	7	7	6
>20	0	1	3
Engineers			
1–4	45	72	0
5–9	25	27	48
10–19	14	12	20
20–49	6	12	16
50–99	6	4	12
>100	2	0	9
Contract amount			
<W10 million ($20 000)	28	26	13
W10–50 million ($100 000)	20	29	24
W50–100 million ($200 000)	18	14	19
W100–500 million ($1 million)	18	25	33
W500–1 billion ($2 million)	3	3	3
>W1 billion (>$2 million)	1	4	13

Contract amounts have increased sharply since 1976 due to plant exports as well as the localization of power plants. Yet the engineering service industry is not mature (Table 5). Perhaps less than a dozen firms are true engineering firms. Most have only one professional engineer. Of the 105 registered engineering firms, 35 architectural service companies, 16 electrical service companies, and 17 geological service companies can hardly be considered integrated engineering firms. Contract amounts represent only about 10% of the potential market for engineering services (estimated as one-tenth of total capital investment in industrial plants). The potential market for 1977–81 is estimated at $1.6 billion, or more than $300 million annually.

Korean engineering services have passed through three developmental stages (Fig. 7). The first stage was a period of foreign dependence in the 1960s, with package-type foreign investment and engineering services; local participation was restricted to some construction activities. The second stage in the early 1970s was characterized by the birth of domestic engineering services, helped by an accumulation of technical experience, the enactment of a promotion law, and an increase in plant construction. Some development was achieved in the areas of detailed engineering, procurement, supervision of construction, and project management. Construction technology was enhanced significantly. During the second half of the 1970s the foreign construction boom (especially in the Middle East) spurred the further development of domestic engineering services. Turnkey engineering services and plant construction by domestic firms became feasible, and some plant exports were achieved. Government

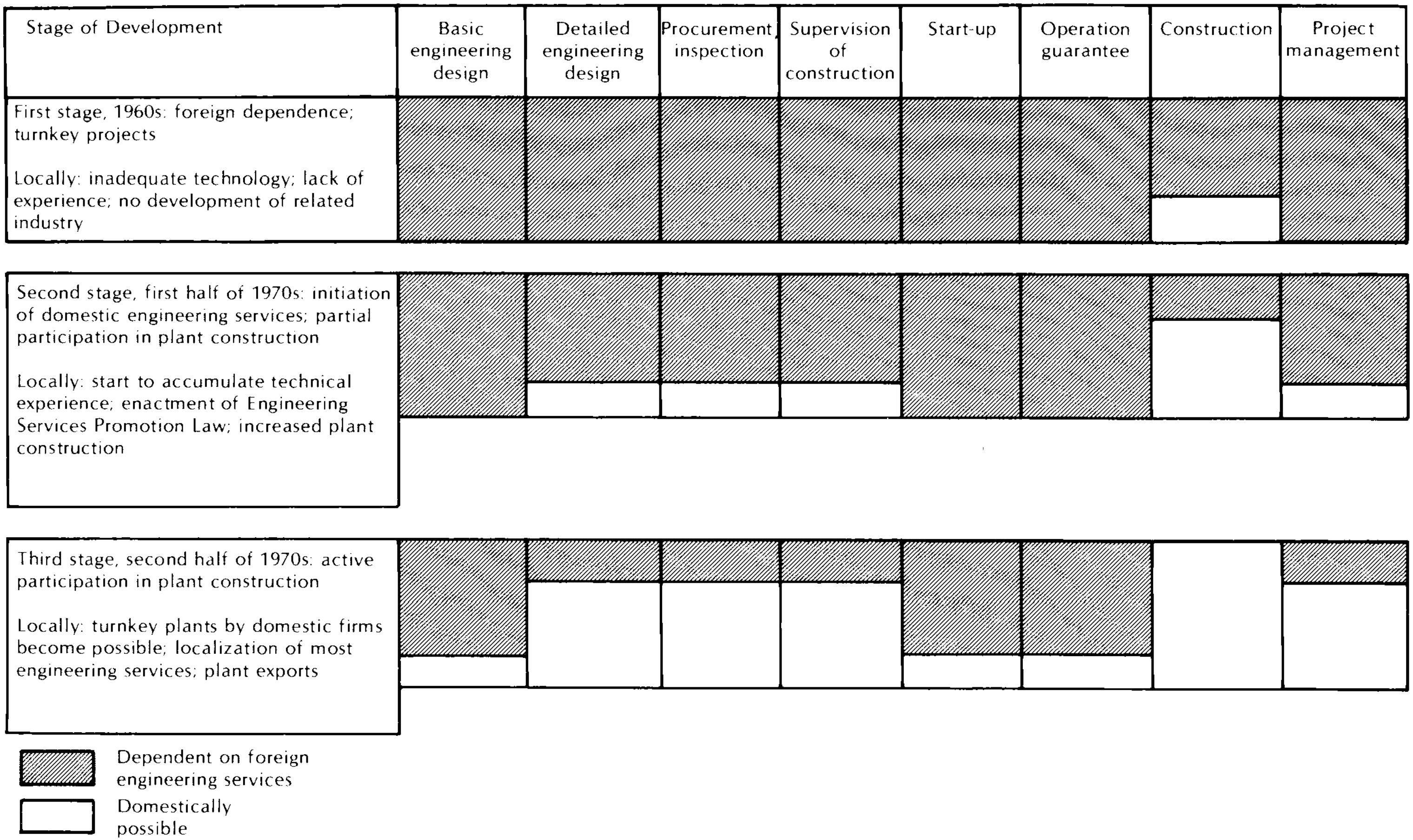


Fig. 7. Stages of development of engineering services in Korea.

intervention caused the localization of most engineering services, especially for power plant construction. A remarkable upgrading of domestic engineering services was, therefore, achieved except for basic engineering, start-up, and operation guarantee.

It is not yet feasible, however, for Korean engineering firms to construct various types of plants independently with only their own technical capabilities. A recent survey shows that plant construction capability is best for viscose textile plants, with 78.9 points out of a maximum 100, and worst for nuclear power plants with 28.9 points. Management and technical capabilities were examined for plant construction for 311 types of Korean industries and plants in terms of 33 factors such as R&D, plant operation, safety, planning, design, training, funding, machinery, start-up, construction, etc.

The future of Korean engineering is bound to be greatly influenced by plant exports tied to construction exports, which have grown steeply in recent years ($27 million in 1976, $400 million in 1977, and $800 million in 1978). Plant exports are bound to lead to the accelerated growth of the engineering services industry, and because of the low labour costs for engineers in Korea, it will be possible to compete internationally for engineering contracts.

Government Policy and Strategy

The profitability of the engineering services industry is very poor, mainly due to the uncertainty of demand. Government policy and strategy should focus on three issues to achieve the likely benefits and links from an expansion of this industry:

- The creation of demand for domestic engineering services and the guarantee of minimum profitability;
- The promotion and enhancement of engineering service, technical ability, and competence; and
- Balance of development with other related industries and realignment of environmental factors to promote domestic engineering services.

There are several causes for the slow development of domestic engineering services. An important one is the lack of demand resulting from the turnkey basis of plant construction. Other causes are the lack of capability for planning and feasibility study on the part of investors; the shortcomings of the domestic engineering firms themselves (lack of specialization, inadequate financing, poor knowledge of management techniques, small size, lack of credibility, and low engineering fees due to the excessive competition); the underdevelopment of related industries, especially the machinery industry, which is weak both in the quality of the products and in financing, i.e., provision of long-term loans especially for plant facilities. The competitiveness of the Korean engineering services industry is, therefore, far below the international level. It is difficult to solve these problems independently because they are interrelated and they overlap. This means that an action program should solve several problems at once. A systems approach is essential in analysis and promotion of the industry.

The Engineering Services Promotion Law, enacted in 1973 to promote the domestic engineering services industry, has two important features. First, it prescribes domestic engineering firms as prime contractors for domestic plant construction, except when there is technical inadequacy. This policy, aimed at creating a demand for engineering services, has not been effective in practice.[30] A second feature is that it encourages the undersized engineering firms to become large scale, specialized, and integrated organizations. The law sets minimum qualifications for registration: one professional engineer for a designated specialization, four registered engineers, and a set amount of capital or assets, now $40 000. These stipulations have contributed to the expansion of firms, but there may well be some adverse effects. Korea is now experiencing a severe shortage of high-quality personnel. For example, there are only about 600 professional engineers, and this number is far below present demand. Massive training programs such as in-house training, commissioned education at universities, and on-the-job or academic training abroad are urgently needed. Technical collaboration with engineering firms in advanced countries also seems necessary. Actually, several domestic engineering firms have joint ventures, and others have established a network for technical assistance.

Other policy instruments that might help the development of the engineering services industry in Korea are a fund for supporting domestic engineering services; tax incentives; credit incentives; creation of a trade association to support common interests and activities such as training, publications, etc.; drafting of a standard code for parts and plant facilities; support of exports of plants and engineering services, and development of personnel required for efficient engineering services. Basic to these is the voluntary participation by the engineering services industry as opposed to compulsory mandates by government.

Analysis of Korea Engineering Company Ltd

Although there are more than 100 engineering service firms in Korea, only 12 can provide authentic engineering services. One of the most important is the Korea Engineering Company Ltd (KECL), which was founded in January 1970 with the positive support of the Korean government, as an equal partnership, joint venture between the Han Kook Engineering Company Ltd of Korea and the Lummus Company of the United States. KECL is an integrated engineering and contracting company established in Korea to engage in plant design, engineering, water resource studies, etc. Whereas one of the original partners in the joint venture, the Lummus Company, is an engineering firm of world repute, the Han Kook Engineering Company was organized solely to serve as a holding company for KECL, with capital from the Korea Development Bank

---

[30] To help increase demand, the government is considering amending the foreign investment law to make it possible to separate capital investment and the engineering services embedded in the investment loan. Another policy alternative is to create a fund to support the preinvestment feasibility study or localization of plant facilities. It is reported that such a policy program has been successfully adopted in Brazil. The Korean government also has a program to promote the exports of plant engineering services and of complete plants.

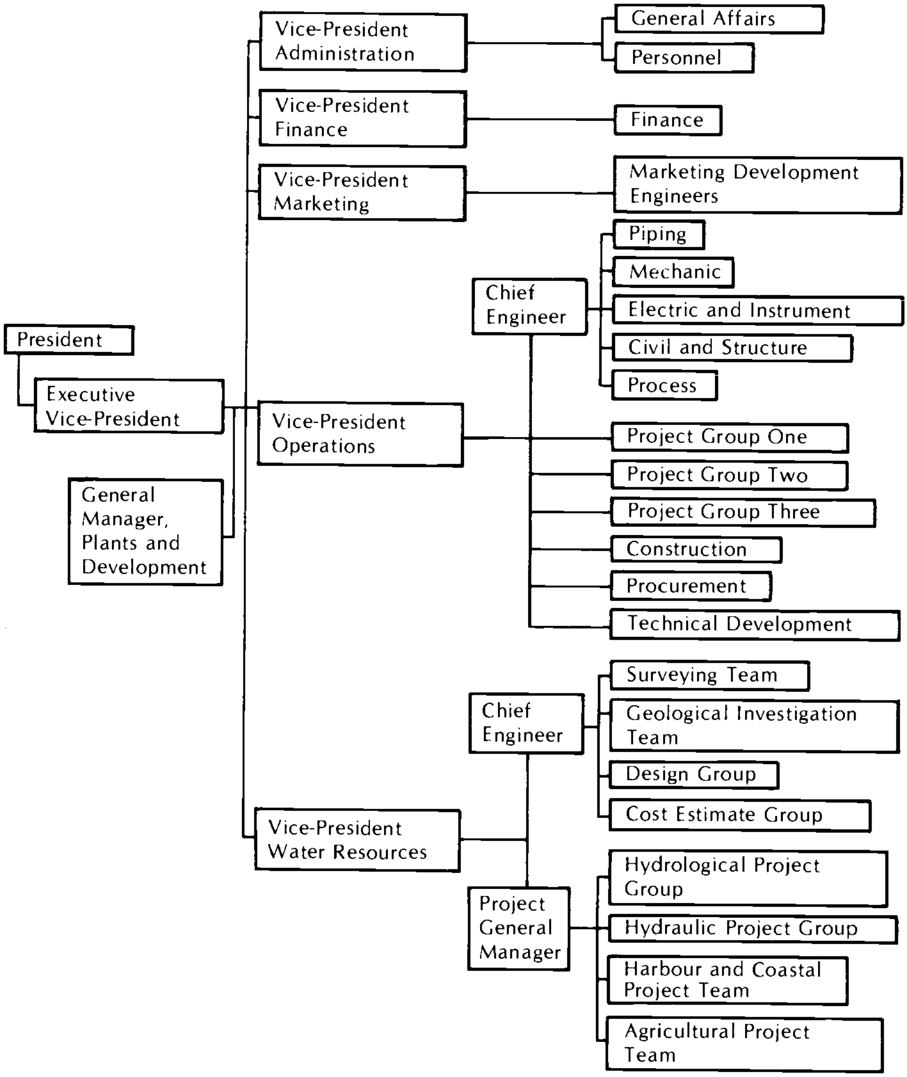


Fig. 8. Organization of KECL, 1978.

and from leading Korean enterprises such as the Sam Sung Company Ltd, Dae Woo Industries, and the Korea Institute of Science and Technology.

In September 1973 the Toyo Engineering Company (TEC) of Japan succeeded the Lummus Company as the KECL partner. TEC is also a world-renowned engineering company and has provided KECL with all available technical assistance. In April 1978 the Korea Development Bank sold its stock, 50% of the Han Kook Engineering Company's capital, to the Sam Sung Company, which has now become the majority owner of KECL. As a result, all of the large conglomerates in Korea now have engineering firms under their control.

KECL's organization chart is shown in Fig. 8. The firm has made available to its clients major services in the areas of plant and water

Table 6. KECL contract amounts in million won ($2000).

	1971	1972	1973	1974	1975	1976	1977
Contracted projects	5	3	6	27	6	17	20
Contract amounts	770	80	90	1622	390	1602	2330
Completion amounts	467	336	96	368	778	1490	2096

resource engineering, harbour and coastal engineering, irrigation, sewerage, and agricultural engineering in a reliable and expeditious manner, sometimes in collaboration with foreign CEDOs.

Because KECL was established in accordance with government policy and strategy, the government contracted actively with it during the first year. But in 1972 and 1973 the government offered no strong support, the contract amounts dropping to about one-tenth (Table 6). As a result, Lummus decided to withdraw, and Toyo Engineering Company became the substitute partner. Since 1976, KECL has performed at a reasonable level of activity because of the economic recovery and of its accumulation of experience and technical expertise. KECL is expected to grow rapidly now that a private enterprise, the Sam Sung Group, has assumed jurisdiction over it.

KECL's clients have mostly been Korean enterprises; a number of subcontracted projects have also been undertaken for foreign clients (Table 7).

One-fourth of the projects were feasibility studies and the rest, detailed design and engineering jobs. This means that KECL's technical capability and expertise have not yet reached the level of full-fledged engineering services. The number of engineering projects carried out by KECL is minimal compared with the total plant construction and engineering projects in Korea. Hence, KECL has contributed to the development of

Table 7. Breakdown of KECL engineering projects, 1971–78.

Type	1971	1972	1973	1974	1975	1976	1977	1978
Feasibility study	3	1	2	3	1	1	1	3
Detailed engineering including procurement and construction management	1		4	6	7	10	7	6
Detailed engineering including start-up	–	–	–	1	–	1	–	–
Basic engineering	–	–	–	–	–	–	–	–

Table 8. Distribution of KECL employees in mid-1978.

	Engineering and drafting		
	Permanent	Semipermanent	Administrative
Head office	247	125	32
Water resources office	28	25	3

the engineering industry as a pioneer, but its contribution to the development of Korean industry as a whole has not been high.

From 1971 to 1973 KECL had 66 employees. The number doubled in 1974 and doubled again in 1975, when it reached 238. Growth has continued at a slower pace, and in mid-1978 total staff was 460 (Table 8 and 9).

As KECL was founded by the Korean government, its marketing was done largely by the government at first. Despite strong government support, KECL experienced severe difficulties from the first moment. Its growth and development were hampered by the economic recession after the energy crisis. The path of KECL's development suggests that the engineering industry cannot be fostered only with direct government support. Indirect support or incentives to create a demand for domestic engineering services and to enhance engineering capability are almost essential. Because the quality and the efficiency of engineering services are crucial for plant production, most entrepreneurs still hesitate to use domestic engineering firms.

Table 9. Breakdown of personnel specialization in KECL, 1978.

	KECL staff	Semipermanent subcontractors
Project managers and engineers	24	1
Process engineers	10	–
Plant layout and piping engineers	20	–
Electrical/instrument engineers	23	–
Civil/structural engineers	26	–
Mechanical engineers	13	–
Agro-engineers	2	1
River engineers	11	2
Harbour engineers	1	2
Hydroelectric engineers	9	3
Water supply engineers	2	3
Plant facilities engineers	2	–
Procurement and inspection	5	1
Construction engineers/supervisors	14	–
Surveyors	3	14
Cost estimates and scheduling	10	–
Project control	6	–
Scale model engineers	6	–
Drafting personnel	88	123

Although KECL rates as one of the most capable engineering firms in Korea, it has many problems. A crucial one is a shortage of engineering and technical personnel. There are few qualified, experienced engineers, especially plant engineers; moreover, engineering colleges cannot completely prepare qualified piping and instrument engineers. Most engineers in KECL have come from chemical plants, especially fertilizer or petroleum refining. They lack plant design expertise like piping and instrument engineering, which is not usually taught in universities. The available electrical engineers are relatively competent and mechanical engineering can be done if appropriate blueprints are supplied. Most important, master planning for plant construction should be done locally, but the ability to carry out such an engineering service has not yet been developed. More effort should be put into providing internal as well as on-the-job training domestically or abroad. Culturally, knowledge such as engineering expertise has been regarded as private property in Korea. As a result, most Korean engineers are unwilling to exchange technical information or accumulate it systematically.

The future of KECL is uncertain, as is the future of the engineering industry in Korea, even though its growth potential is great. Now KECL has been transferred from direct government control to a renowned private conglomerate, the Sam Sung Group, its development seems promising, especially with the huge demand for domestic investment projects and great possibilities for plant exports.

PROJECTS

KECL carried out more than 60 engineering projects during 1971–77. Most were detailed design and engineering projects, which were difficult to execute in the early period but are now handled without difficulty. However, no basic design and engineering service projects have been carried out by KECL or other domestic engineering firms using only their own capabilities. Perhaps such a capability upgrading will be possible in the 1980s through collaborative efforts with high-risk entrepreneurship on the part of clients.

KECL has not failed in the execution of its engineering projects, so the two projects presented here have been successfully executed. The first deals with the construction of a styrene monomer plant and the other with the construction of an ABS resin plant. For comparison purposes, efforts were made to identify unsuccessful engineering service cases carried out by domestic or foreign engineering companies, but no data other than rumour regarding such failures were collected. As a compromise, a brief case study of a successful engineering project by a foreign engineering firm has been added for comparison.

CONSTRUCTION OF A STYRENE MONOMER PLANT

The styrene monomer plant project was initiated by the Niwon Company, which for various reasons could not carry on with it. Following government instructions, the project was taken over by the Korea Development Bank, which arranged to establish a firm, the Ulsan Petrochemical Company, with 75% of the investment made by the Korea Fertilizer Company and 25% by Niwon. The original idea was to obtain engineering services from Lummus using Monsanto's new process, but a shift was made to the Toyo Engineering Company of Japan because Lummus could not provide a suitable loan arrangement. Mitsui Company of Japan financed the project. As Toyo was a Mitsui subsidiary company, it was natural that Toyo should take the project's engineering services. As this was a lump-sum contract between Ulsan Petrochemical and Toyo, information concerning the specific amount allocated for engineering services is not available, but the total payment including foreign procurement and the engineering fee was $17 million. According to an informal source, the engineering fee was around $2 million (Table 10).

KECL provided two kinds of engineering services through two channels. One type was detailed design engineering, through a subcontract with Toyo Engineering, and the other was construction management, supervision of local procurement, and all the engineering services for the construction of an off-site building, via a direct contract with the client, Ulsan Petrochemical. The amount of the subcontract is not known, but the amount of the direct contract was around $600 000. KECL has a special relationship with both Toyo and Lummus, so it was not difficult for it to contract successfully. Also, KECL is in a good position for contracting for the engineering services on government-investment projects.

The preinvestment analysis for this project was prepared by Niwon. It was decided to entrust the engineering services to the Japanese company, Toyo, because of its capacity to provide financing. The choice of technology and equipment was thus naturally determined. Although Monsanto's new process was chosen as the basic process technology, Toyo exercised great influence on the foreign procurement, which is closely related to the choice of technology as well as to the localization of process equipment. It should be added that there were few alternatives regarding size, location, and product mix of the plant, because the Korean government already had an integrated long-term plan for the promotion of the petrochemical industry. Because of the extent of the investment, which could not be supported solely by the government, decisions on technical matters were not made prior to financing decisions. In other words, financing and loans took priority over all other problems. Thus, the technological choice had to be in accordance with financing or loan possibilities.

Because of government intervention in the procurement of process equipment, a breakdown into foreign and local sources was carefully made. As a result, Toyo was in charge of $17 million of foreign procurement, whereas KECL was responsible for $4 million of local procurement. Procurement services may be regarded as an advance in engineering services as compared with mere detailed design engineering, and they are closely related to the social efficiency of engineering services, i.e., contribution to the localization of equipment and machinery, balance of payments, employment, etc. KECL's role in procurement was the evaluation and recommendation of local vendors, supervision of vendor drawings, expediting of deliveries, etc. Actual procurement was made by the client, i.e., the owner of the plant, through direct contracts.

In addition to procurement services, KECL was responsible for plant construction management as well as the construction of an off-site building. KECL recommended the builders, supervised the progress and

Table 10. Data on engineering services for styrene monomer plant by KECL.

Project	
Client: Ulsan Petrochemical Int. Ltd	
Product: Styrene monomer	
Capacity: 60 000 t/year	
Location: Ulsan, Korea	
Period of services	
June 1976 – February 1978	
Scope of services	%
Basic design	–
Detailed design	70
Progress	100
Process design	–
Equipment design	5
Piping design	35
Civil/struc. design	30
Inst./elec. design	15
Project management	15
Procurement and progress: requisition, bid evaluation, vendor recommendation, expediting, inspection	100
Construction and progress: supervision, management	100
Foreign collaborators	
Process licencer: Monsanto	
Design collaborators: Lummus and Toyo engineering corporations	

Table 11. Data on engineering services for ABS resin plant by KECL.

Project	
Client: Lucky Co. Ltd	
Product: ABS resin	
Capacity: 6000	
Location: Yeosu, Korea	
Period of services	
September 1976 – October 1977	
Scope of services	%
Basic design	–
Detailed design and progress	100
Process design	5
Equipment design	12
Piping design	38
Civil/struc. design	20
Inst./elec. design	15
Project management	10
Procurement and progress: requisition, bid evaluation, vendor recommendation, expediting, inspection	100
Construction and progress: supervision, management	100
Foreign collaborator	
Process licencer: Japan Synthetic Rubber Co. Ltd	

completion of the building and plant, etc. It had little previous experience in construction supervision services, and this assignment allowed it to accumulate a significant amount of expertise.

As far as the efficiency of KECL in the production of engineering services was concerned, the project was completed within the target date, there was no cost overrun, and the cost of the styrene monomer plant was evaluated as reasonable or even lower than expected. The quality of the engineering services was considered to be good by the clients. Even though KECL thought the engineering fee was not sufficient, it did its best to build a good reputation, which would be helpful for long-term marketing.

ABS Resin Plant Construction

Whereas the styrene monomer project client was a government-owned company, the ABS (acrylonitrile butadiene styrene) resin project client was a private company, the Lucky Company for which KECL had earlier provided engineering services (the construction of a paste PVC resin plant). Because of KECL's good performance, Lucky decided to use

KECL's engineering services again. Like the Ulsan Petrochemical Complex located on the southeastern coast of Korea, the Yeosu Petrochemical Complex on the south coast of Korea was an offspring of Korea's industrial development plan. As Lucky is an integrated chemical firm and produces various types of resin products, the company decided to establish an ABS resin plant for high-quality resin products.

The KECL engineering services included planning and preinvestment analysis with the collaboration of the Lucky Company, detailed design and engineering, procurement services, and construction supervision. Basic design and engineering were provided by the Japan Synthetic Rubber Company, which was the ABS resin process licencer. Project investment was about $10 million, and the engineering fee for KECL was around $400 000. The engineering fee for basic design and engineering is not known (Table 11).

Japan was thought to be the best source of the technology because its resin technology was advanced, the language does not present a communication barrier, and it is geographically close to Korea. As the decisions on size, location, and product specifications had almost all been taken in advance by the Korean government, there were no alternatives on these aspects.

The level of technical sophistication for an ABS plant is lower than that for a styrene monomer plant. KECL was in charge of procurement services and detailed design and made great efforts to localize plant facilities and equipment. As a result, most items were obtained through local vendors, the exceptions being high-precision process, control, and electrical equipment that could not be produced domestically. Another reason for the high rate of localization was that the client financed the project itself, so fund utilization was not tied up. Although the basic design was done by the licencer, the Japan Synthetic Rubber Company, KECL made slight adjustments in the layout of the process and also provided detailed design and engineering, construction supervision, and the construction of utility facilities. KECL executed complete engineering services for the utility facilities from the basic design to guarantee operation and performance.

The construction of the plant was supervised carefully by KECL according to the engineering services contract. Because the technical level of the client firm's personnel was the best among Korean firms, there were no serious problems in the technical follow-up services. The completion target for the plant was easily met, and there was no cost overrun. The ABS resin plant is in good operational condition, an indication that the quality of the engineering services was excellent.

Construction of a Fertilizer Plant

A case where engineering services were provided by a foreign firm is noteworthy for comparison purposes. The Nam Hae Chemical Company procured the services for the construction of a fertilizer plant, one of the largest in the world, from the following sources: $52.5 million from the Korea Integrated Chemical Company, $17.5 million from Agrico of the USA, a loan of $103 million from the national investment fund, and $246 million in foreign loans. The general contractor for the engineering

Table 12. Data on plants of the fertilizer complex.

Plant name	Size	Process licencer
Ammonia	907 t/2 days	Kellogg, USA
Urea	1000 t/day	Toyo Engineering Co., Japan
Composite fertilizer	1080 t/2 days	Davy Powergas, USA
Phosphoric acid	660 t/day	Davy Powergas, USA
Sulfuric acid	1050 t/2 days	Chemico, USA
Nitric acid	180 t/day	Chemico, USA
Nitric acid (concentrate)	100 t/day	Chemico, USA
Nitrate	50 t/day	Chemico, USA

services was Fluor Engineers & Constructors, Inc., of the U.S. The main facilities of the fertilizer complex were eight plants (Table 12).

The Fluor Company was paid $42 million for the engineering services for the basic design, procurement, and guarantee of the start-up, operation, and construction. The contract was based on a fixed-fee-plus-cost method, i.e., a fixed fee of $42 million for engineering services including licence fees and construction costs and procurement costs as they occurred. The amount of $42 million for engineering services surpasses the total amount spent on engineering services by all companies in Korea in 1977. This does not mean that the engineering fee was outlandish; on the contrary, Nam Hae Chemical invited bids from all major international engineering firms. It does imply, however, that engineering services are important not only to the engineering service industry but also to industrial development as a whole. For example, total plant facilities and equipment amounted to $219 million, and only 27% of the total facilities and equipment were localized. In other words, foreign procurement amounted to $159 million, and the amount of local procurement was only $60 million. Although such a low percentage of localization might be attributed to the Korean manufacturers' lack of technical capability in the production of capital goods, the localization rate would have been higher if local engineering firms had taken the responsibility for engineering services. The project lasted 36 months, from February 1974 to February 1977. Three domestic engineering firms including KECL, as well as several construction companies, participated in the project through subcontracts. The quality of the engineering services, including duration and cost targets, was assessed as excellent.

Concluding Remarks

One crucial problem in studies of engineering services and engineering firms is the difficulty in hypothesis formulation. As suggested by Aráoz (1977), one must focus on the social efficiency of the engineering firm and its services as well as the productive efficiency of the firm. Finally, he suggests that the efficiency of engineering services distribution be considered. None of these criteria–variables are easily measurable, either qualitatively or quantitatively. One indicator or measure of social efficiency or utility is the contribution to industrial development. It is extremely difficult, however, to ascertain the effects of the engineering service separately from those of the investment project. If the engineering firm is involved in the project from the first moment of planning or preinvestment analysis, the effect of engineering services from the point of view of social efficiency would be large. If not, the effect would be minimal and could be adverse if there were failure in engineering services. To measure such effects is extremely difficult.

Productive efficiency is also difficult to assess, although less so than social efficiency. Productive efficiency should be considered in terms of both the engineering firm and the engineering services. The latter can be measured by cost target, duration target, and engineering service quality. Again, it is difficult to measure engineering service quality. The productive efficiency of the engineering firm as a whole must be gleaned from a general evaluation of the firm. One must borrow various evaluation tools for the purpose.

There are many factors or independent variables that influence the criteria–variables. The variables may be divided into uncontrollable (parameters or environmental variables), semicontrollable (policy variables or macrovariables), and controllable (project level variables or microvariables). It is best to develop a model that delineates all the interrelationships among the variables. Thus one can derive hypotheses regarding the engineering services and firms. Some basic data may be obtained through case studies. Without a set of such specific hypotheses, the subject can hardly be analyzed systematically. A comparative study for each variable or hypothesis is desirable. Without proper comparison, the result of research is mainly descriptive and not too helpful in the search for conclusions and implications.

The next important issue for the study of engineering services and firms in the developing countries is the analysis of the impact of engineering services at the project level. Emphasis should be put on the execution of the project, with a focus on the role of engineering services. Thus, it is useful to compare similar projects to distinguish various ways of using engineering services, and their effects. For example, the portion of in-house engineering services is probably more significant than that of engineering services supplied by independent specialized firms.

Finally, a longitudinal analysis of a specific industry with a focus on the role of engineering services is recommended as a research tool. The analysis of an engineering project across various industries seems to give less useful information than a longitudinal analysis. A combination of longitudinal and cross analysis is ideal. The longitudinal analysis, however, should be adopted only in the case of relatively mature industries; otherwise little information will result.

References

Aráoz, A. 1977. Consulting and engineering design organizations in developing countries: outline for a conceptual framework and guidelines for case study. Papers prepared for IDRC, December.

Machlup, Fritz. 1962. The production and distribution of knowledge in the United States. Princeton, N.J., Princeton University Press.