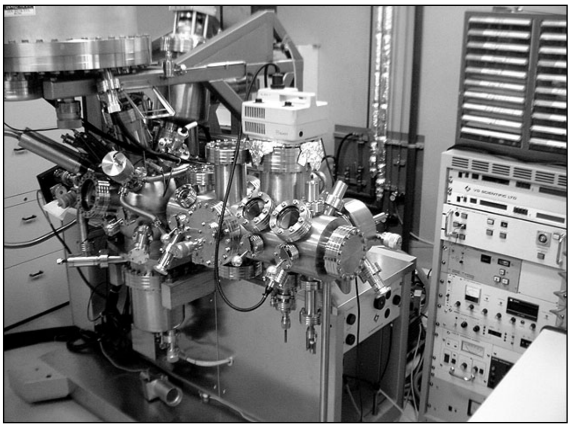
Korea

Research Equipment Reinforcement Project

Field Survey: August 2003

1. Project Profile and Japan's ODA Loan

Project Site



Electron spectroscopy for chemical analysis under the project

1.1 Background

At the time of appraisal, South Korean industries were concentrating on introducing and acquiring foreign technology and export products. As a result, investment by private companies in research and development tended to be insufficient. These delays in research and technological development became more apparent with the growth of the South Korean economy. A survey by the Korea Development Bank concluded that production technology had advanced to a level comparable with major industrialized countries, while product development technology was at a relatively low level. The survey also found that among product development technology, analyzing technology was at a relatively high level while designing technology was lagging behind, particularly in the area of system designing requiring technological know-how and advanced software.

Considering advanced technology and product development technology had not shown progress, the South Korean Government adopted trade control measures including import restrictions, foreign exchange management and tax and financial measures, and industrial measures including measures to encourage introduction of foreign capital and foreign technology to promote advancement of the industrial structure while maintaining high growth. In particular, the government emphasized the promotion of research and technological development as part of efforts to raise the technological level.

1.2 Objectives

The objective was to promote advanced research and development activities in the areas of biotechnology, machinery, semiconductor analysis, and chemistry by installing state-of-the-art equipment at research institutes in these areas, and thereby contribute to human resource development and advancement of IT in South Korea.

1.3 Output

Purchase and installation of 271 types of research material and equipment necessary for research and development at the institutes listed below.

1) Genetic Engineering Center

41 types of research equipment in the following 8 areas: microbiology; molecular biology; biochemistry; cell cultivation; bioassay; analytical chemistry; biochemical engineering; and information

2) Korea Institute of Machinery and Materials

87 types of research equipment in the following 5 areas: automation technology; machine parts technology; materials and component technology; vessel and offshore structure technology; and production base technology

3) Electronics and Telecommunication Research Institute

15 types of research equipment for the analysis of semiconductors including analyzers, observing equipment and measuring apparatuses

4) Korea Research Institute of Chemical Technology

128 types of research equipment necessary in the following 4 areas and analyzing and testing devices to be used for all these areas: applied biology; organic and inorganic chemistry; polymer chemistry; and chemical industry/industrial chemistry

1.4 Borrower/Executing Agency

Government of the Republic of Korea/Genetic Engineering Center (GEC), Korea Institute of Machinery and Materials (KIMM), Electronics and Telecommunications Research Institute (ETRI) and Korea Research Institute of Chemical Technology (KRICT)

1.5 Outline of Loan Agreement

Loan Amount / Loan Disbursed Amount	2,679 million yen / 2,644 million yen
Exchange of Notes / Loan Agreement	April 1988/ June 1988
Terms and Conditions - Interest Rate - Repayment Period (Grace Period) - Procurement	 4.25% 25 years (7 years) General untied
Final Disbursement Date	August 1993

2. Results and Evaluation

2.1 Relevance

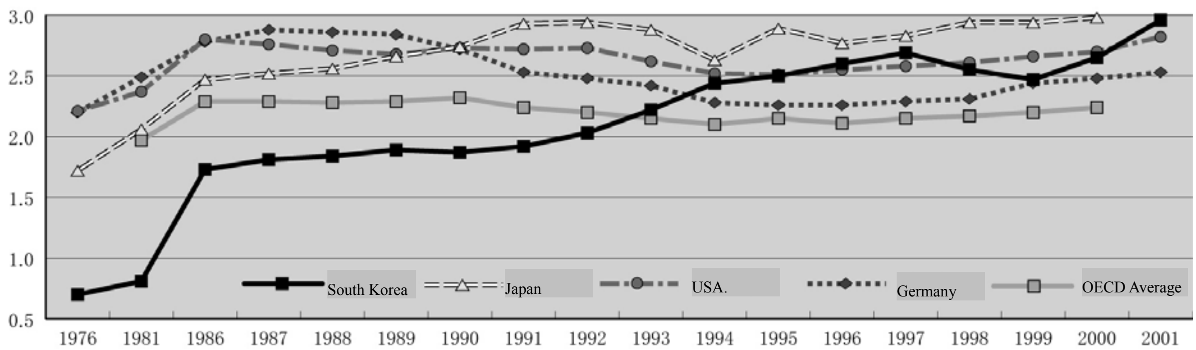
2.1.1 Relevance of Project at Appraisal

At project appraisal, the South Korean Government was focusing on encouraging research and technological development to enhance the country's level of technology with a view to promoting advancement of the industrial structure while maintaining high growth. In line with the government policy, the Ministry of Science and Technology began national research and development (R&D) programs in 1988. These programs were designed to provide support mainly in the priority R&D areas in conformity with the Technology Development Promotion Law enacted in January 1982.

In these programs' implementation plan, 12 priority R&D areas were designated and approximately 70% of the programs' budget was allocated to these areas. Among priority R&D areas, the 4 areas of biotechnology, machinery, semiconductors, and chemical substances were recognized as most important because these areas, with their relatively small technological gap with advanced countries, were expected to contribute to export industries and have a large ripple effect on other industries. This project was to provide research equipment to 4 research institutes appointed to manage R&D programs in these 4 areas. Therefore, this project was relevant as it was consistent with the policy of the South Korean Government.

2.1.2 Relevance of Project Plan at Evaluation

The South Korean R&D expenditures' share of GDP kept on increasing under the Five Year Plan for Scientific and Technological Innovation (1992-1997), established in December 1992, and exceeded the average of OECD countries[1] in 1993 and U.S. and Germany in 1997 (see Fig.1). After that, it temporarily declined due to economic crisis led by the Asian currency crisis at the end of 1997 and austerity measures implemented under the supervision of IMF and began to rise again in 1999 after the National Science and Technology Council, chaired by the President, was formed following the revision of the Special Law for Scientific and Technological Innovation and establishment of the Long-term Plan for Science and Technology Development for 2025 ("Vision 2025") in September. In 2001, a record share of 2.96% was attained.



Source: Main Science and Technology Indicator 2001/2. OECD

Fig.1 GDP Share of R&D Expenditures of South Korea and Developed Countries

In Vision 2025, the government set the target of enhancing the R&D level of the country to that of G-7 countries*[2] by 2025 by reinforcing R&D equipment in addition to establishing a legal framework for R&D (see 2.5.4 of this report for details). Thus, the South Korean Government is making efforts to promote R&D based on the recognition that R&D is important for supporting sustainable economic development in the future. Therefore, the project objectives of this are still relevant today.

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[1] OECD (Organization for Economic Cooperation and Development): a group of developed countries having market economy principle with 30 members as of October 2003.

[2] G-7: 7 countries of Italy, Canada, Germany, France, UK, US and Japan

2.2 Efficiency

2.2.1 Output

At appraisal, a total of 271 types of research equipment were to be procured and 191 types were actually procured. With technological innovation in the target areas between appraisal and start of procurement, the list of equipment to be purchased needed to be changed. Each research institute resubmitted a new list of state-of-the-art equipment for approval by JBIC and procured the listed equipment.

2.2.2 Project Period

The initially planned output was completed as scheduled. Installation of the procured equipment was completed in November 1993 because some equipment was added as a result of the above changes to the plan.

2.2.3 Project Cost

According to the estimate at appraisal, the ODA loan was to finance the entire foreign currency portion, which accounts for 93.1% of the total project cost (2,877 million yen). The foreign currency portion was to cover the prices of equipment and CIF[*3] prices of spare parts and supplies for 2 years of operation. The local currency portion to cover customs fees, inland transportation, insurance, value-added tax, defense tax and other taxes and public charges for the procurement of equipment was to be paid from the budget of each institute.

The ODA loan was used to cover the entire foreign currency portion as planned and a total of 2,644 million yen, or 93.7% of the approved amount was disbursed. Details of the local currency portion (approximately 6% of the total cost) are unknown because necessary documents were not made available to confirm.

2.3 Effectiveness

2.3.1 Advancement of Research Activities

Under this project, 191 types of research equipment were provided to 4 national research institutes in 18 study areas from 1988 to 1993. As a variety of equipment was installed in a wide –range of study areas and more than 10 years have passed since the completion of the project, it is difficult to know how all this equipment has been utilized. Therefore, it is presented some examples of how the equipment procured under the project contributed to the advancement of research activities, focusing on expensive research equipment worth over 20 million yen at that time that is still used now.

a) Electronics and Telecommunications Research Institute (ETRI)

In ETRI, 8 types of equipment worth 590 million yen in total for surface analysis of semiconductor materials were installed. Surface analysis of semiconductor materials is necessary to improve product reliability by identifying and resolving the causes of defects generated during semiconductor production. Surface analysis is indispensable for research and development of more complicated and high precision semiconductors. The equipment procured was the most up-to-date available and very expensive,

[3] CIF price (Cost, Insurance, and Freight Price): price including the price of equipment, insurance and freight to the point of import

including 2 types worth over 100 million yen each.

The equipment installed under the project is still used as the main analyzing equipment at ETRI and contributes greatly to the research and development of semiconductor technology. In recent years, for example, analyzing equipment procured under the project such as Auger electron spectroscope (Photo 1), secondary ion mass spectrometer (Photo2), X-ray diffractometer and scanning electron microscope have been used in the development of the latest technology such as HBT[*4] and organic EL devices[*5]. As of August 2003 when the field survey was conducted, all the equipment procured under the project was utilized in various kinds of research, although 8 items had minor problems caused by creaky computers for analysis. The equipment plays a direct or indirect role in improving the production process and quality of semiconductor-related products.

Photo 1: Auger electron spectroscope

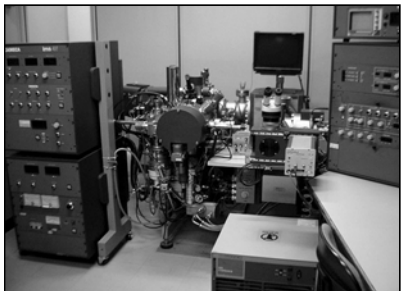

Photo 2: Secondary ion mass spectrometer

The analyzing equipment installed under the project is frequently used not only in the R&D of ETRI but also for analyzing materials brought in by laboratories of private companies and universities, thus contributing to semiconductor study in South Korea as a whole. Since South Korea is regarded as one of the most advanced countries in the study of semiconductors, ETRI has many visitors from Asia, including Japan, and Europe.

b) Korea Research Institute of Chemical Technology (KRICT)

For KRICT, 65 types of research equipment worth 650 million yen that are necessary in 4 areas were installed: applied biology; organic and inorganic chemistry; polymer chemistry; and chemical industry/industrial chemistry. Nearly half of the equipment is for research in applied biology, such as the development of agricultural chemicals and pharmaceuticals, which was KRICT's priority study area at that time.

In the upstream stage of drug development, it is necessary to find a drug candidate from an extremely large number of compounds and combine it with other substances. This process requires screening[*6] using binding protein. The centrifuge procured under the project is used to screen substances that are indispensable for the creation of new substances for agricultural chemicals and pharmaceuticals, and the automatic synthesizer is used to automatically synthesize various kinds of amino acid at the same time. The Fourier transform nuclear magnetic resonance instrument (FT/NMR) (Photo 3) is used for quantitative analysis and component

Photo 3: FT/NMR procured under the project

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4 HBT (Heterojunction Bipolar Transistor) is a transistor using SiGe materials (germanium added to silicon, which is the basic material of semiconductor devices) that has faster processing speed than other semiconductor devices by having a thinner SiGe layer, which shortens the vertical electrical path, while greatly reducing power consumption.

5 Organic EL (Electro Luminescence) is attracting a lot of attention as an illuminant for next-generation liquid crystal displays. As its saturation and luminous intensity vary depending on the ratio and molecular structure of organic matter, component analysis is very important.

6 "Screening" means the process of sifting the target substance from a large quantity of compounds.

analysis of synthesized organic matter. Thus the equipment plays an important role in the development of new drugs and agricultural chemicals.
In particular, the FT/NMR is indispensable for the structural analysis of synthesized organic compounds. Therefore, it is installed in the common equipment room of the R&D Department and is used by all the department's research teams. It is still in good condition and used to analyze approximately 20,000 compounds a year related to drugs and agricultural chemicals.

c) Korea Research Institute of Bioscience and Biotechnology (KRIBB)

For KRIBB, 67 units of research equipment comprising 51 types worth 680 million yen were procured and installed in laboratories in 8 areas: microbiology; molecular biology; biochemistry; cell cultivation; bioassay; analytical chemistry; biochemical engineering; and information.
Among them, major equipment in terms of price and function, such as high performance liquid chromatography instrument (HPLC)[*7](Photo 4), sterilizer, high-speed refrigerated centrifuge, automatic-control incubator, cell separation system and nuclear magnetic resonance instrument (NMR), are often used even now over 10 years after procurement.

Photo4. HPLC

These and other equipment procured under the project are used for various kinds of research in each area of study, including the research on the application of a growth factor called IGF-1[*8] in the treatment of fractures, diabetes and pulled muscles and research on the improvement of an HIV reagent and seed potatoes mentioned in "2.4 Impact."

d) Korea Institute of Machinery and Materials (KIMM)

At KIMM, 67 types of research equipment worth 720 million yen were installed in laboratories in 5 areas of study: automation technology; machine parts technology; materials and component technology; vessel and offshore structure technology; and production base technology. Those that were procured for vessel and offshore structure technology were transferred to the Korea Ocean Research & Development Institute (KORDI), which was separated from KIMM on March 31, 1999.

Photo 5: Precision laser cutting system

Major equipment includes the precision laser cutting system (Photo 5) for welding, cutting, heat treatment and alloying of precision parts, X-ray diffractometer for the analysis of metallic crystal, vibration test equipment to perform burst tests of structures using a hydraulic shaker, and an ultra-high temperature vacuum furnace to heat and pressurize metal or ceramic powder or preformed substances in a vacuum and mold them.
Except for the vibration test equipment, which has not been used since 1999 when it partially broke down due to creaky, these major items of equipment are still used to supplement the newly installed latest equipment.

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7 High Performance Liquid Chromatography (HPLC) is used to separate substances soluble in liquid solvent such as protein, saccharide and nucleic acid. It is now the mainstream in liquid chromatography instruments.
8 IGF-1 is one of 4 growth factors that mediate the human growth hormone (hGH) and is generated in the liver in response to stimulus from hGH. It acts on the formation of tissues of muscle, cartilage, bone, liver, kidney, nerve, skin, lung, etc.

2.4 Impact

2.4.1 Increase in Patent Applications and Patents Obtained by Each Institute

Table 1 shows changes in the number of patent applications filed and the number of patents obtained by each research institute covered by this project. For each institute, both numbers grew substantially starting around the implementation of this project (1988-1993). The number of patents issued to these institutes has increased from 334 in 1991-95 to 1,354 in 96-2000.

Table 1: Changes in the Number of Patents Obtained and Annual Average Number of Patent Applications Filed by Target Research Institutes (unit: case)

	1981-1985		1986-1990		1991-1995		1996-2000	
	Patents Obtained	Patent Applications	Patents Obtained	Patent Applications	Patents Obtained	Patent Applications	Patents Obtained	Patent Applications
Electronics and Telecommunications Research Institute (ETRI)	2	3	7	159	252	769	1,104	1,213
Korea Research Institute of Bioscience and Biotechnology (KRIBB)	N/A	N/A	5	13	9	50	73	139
Korea Institute of Machinery and Materials (KIMM)	N/A	N/A	12	N/A	14	N/A	17	N/A
Korea Research Institute of Chemical Technology (KRICT)	5	7	35	56	59	147	160	233
Total	N/A	N/A	59	N/A	334	N/A	1,354	N/A

Source: Data by each institute

2.4.2 Examples of Practical Applications of Research Conducted with the Procured Equipment

As stated above, each target institute has been actively engaging in research since the installation of equipment under this project. There are many cases where the patents obtained through such research were sold to private companies and directly or indirectly put to practical use. Here are 4 cases where the research conducted utilizing the equipment procured under the project led to the development of products or was otherwise put to practical use.

a) Development of AIDS diagnostic kit

Research group of molecular biomedicine of KRIBB successfully developed an improved HIV reagent for the ELISA (enzyme-linked immunosorbent assay) method with utilizing the equipment procured under the project. The existing reagents took 3-7 hours to detect HIV. The new reagent developed by KRIBB made it possible to know the test results in only 15 minutes.

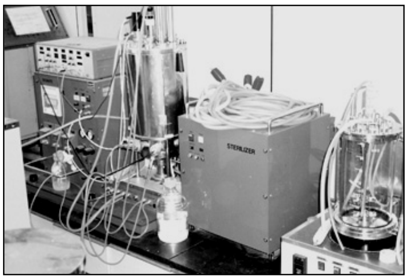


Photo 7: automatic-control incubator

This reagent was developed by recombining genes of antigens highly immune to HIV. The equipment procured under the project, such as the automatic-control incubator (Photo 6), cell separation system, high-power refrigerating machine and scanning electron microscope, played an important role in the research. KRIBB was granted 4 patents in connection with this research. The patent licenses were sold to a private company, which commercialized the product under the name 'AIDS dear one two'. This product generated domestic sales of 4.5 billion won and overseas sales of 100 million won from 1995-1998. According to KRIBB, it is expected to gain a 20% market share in Southeast Asia over the next several years.

b) Development of master model production technology using epoxy resin

The Advanced Materials Division of KRICT successfully developed the technology necessary for molding epoxy resin with the master model (mold) using a capillary rheometer, an instrument to measure the shear viscosity[9] of polymer materials, procured under the project.
The patent license of this technology was purchased by a private polymer manufacturing company, which uses it to mold automobile parts.

c) Seed potato variety improvement

Research group of biological resource of KRIBB succeeded in improving a variety of seed potato jointly with a domestic private company using technology for potato tuber formation. The equipment procured under the project, such as an HPLC instrument, sterilizer and high-speed refrigerated centrifuge, were used. The improved seed potato is resistant to disease, fast growing, and has a high yield. Therefore, its production costs are substantially lower than that of existing seed potatoes. Two patents were issued in South Korea for the technology developed during this research. The technology is also patented in 18 other countries.
As the improved seed potato's quality is of high and supplies are stable, it has an approximately 50% share of the seed potato market in South Korea and is exported to Sri Lanka and other countries.

d) Improvement of technology for oil fan heater

Using mixed fuel of kerosene and light oil with low ignitability for oil heaters results in low combustion efficiency that causes tar to adhere to the filter and a bad odor. In order to solve these problems, KIMM used the infrared heat measurement system, etc. procured under the project to research optimization of the mechanical burner for burning evaporated fuel. The technology that was developed was sold to a major home electronics maker in South Korea and has been applied to oil fan heaters sold after 1997.

Photo 7: Korea Institute of Machinery and Materials

2.4.3 Promotion of Science and Technology in South Korea and Domestic Development of Technology and Products

In this section, it is examined the macro impacts of this project by analyzing how KIMM and KRICT's research increased domestic production of machinery & precision machine products and chemical substances & chemical products as well as improved the trade balance.

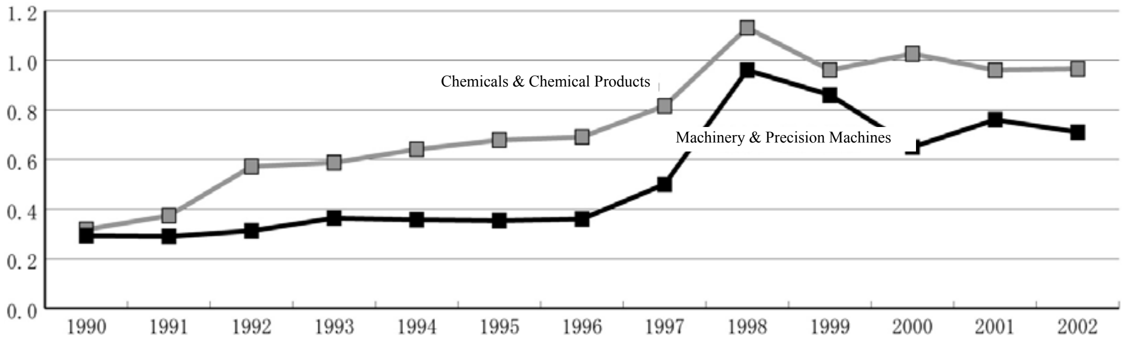
a) Domestic production of machinery and precision machine products

9 Shear viscosity is an indicator of flow characteristics. When used for oil, it represents performance of lubricating oil, etc. In this context, it means the flow characteristics of epoxy resin.

South Korean industry in the 1980s was assembly-oriented; materials and machine parts were imported from abroad and exported after assembly. This system had the disadvantages of high import costs and low added value. Therefore, the government started to promote domestic production of machine products and depart from the assembly-oriented stance, with the goal of developing an extensive machinery industry, including assembly, that generates additional value. Based on this policy, "machine parts and materials domestic production plan" was an important issue in the 6th and 7th Five Year Plans (1986-1996).

From 1986 to 1996, KIMM conducted research on 60% of the themes presented by the Korea Advanced Institute of Science and Technology in line with the above-mentioned plans. 67 types of equipment procured under this project from 1989 to 1990 were thought to be played an important role.

KIMM's taking the lead in promoting domestic production of machine parts and materials raised the export-import cover ratio (export value÷import value) of machinery and precision machine products from 0.29 in 1990 to 0.71 in 2002, although before this, ratio had been making losses for years because of the extensive imports of materials and parts (see Fig.2).



The high export-import cover ratio in 1998 is thought to result from the substantial decline in imports due to the Asian currency crisis in 1997.
Source: Data by Korea National Statistical Office

Fig. 2: Changes in Export-Import Cover Ratio of Chemicals & Chemical Products and Machinery & Precision Machines

b) Improvement of the trade balance structure by producing import substitutes for chemical products

KRICT has been actively conducting research and development mainly in fine chemistry. Since it was founded in 1976, it has succeeded in commercializing 151 kinds of technology. According to KRICT, the technologies it commercialized have resulted in approximately 2,700 billion won in export value so far. As shown in Fig.2, the export-import cover ratio of chemicals and chemical products improved from 0.32 in 1990 to 0.97 in 2002. Moreover, a trade surplus was recorded (export-import cover ratio>1) in 1998 and 2000. The equipment installed at KRICT under the project is thought to have contributed to improve the trade balance by allowing production of import substitutes for fine chemical products, thus reducing South Korea's dependence on imports.

2.5 Sustainability

2.5.1 Executing Agency (Target Institutes)

(1) Technical Capacity and Operation and Maintenance System

Since the target 4 national institutes of this project belonged to the ministries, they were under the strong influence of the respective ministries. Also, lack of cooperation by institutes under different ministries was an issue.

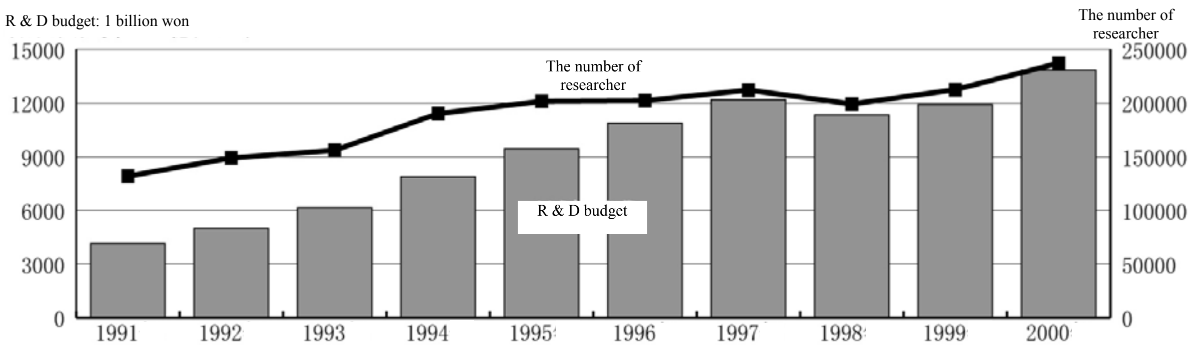
With the aims of removing the negative effects of the existing system, improving research efficiency, encouraging transfer of research results to industries, and ensuring the independence of research institutes, the South Korean Government amended the Special Law for Scientific and Technological Innovation in January 1999 and established the National Science and Technology Council chaired by the President. Thus, the government was committed to developing policies and comprehensive plans to coordinate science and technology research and improve the efficiency and productivity of the national investment in research and development. The amended law granted each institute greater autonomy in operation, management and decision-making. In March of the same year, all national research institutes were placed under the Office of the Prime Minister in order to strengthen collaboration among institutes and lessen the influence of the ministries.

The number of researchers in South Korea has been growing except for a temporary decline in 1998 due to the economic crisis (Fig.3). This rise is attributable to active research and development by the private sector in addition to the increase in the government research and development budget.

Regarding the number of researchers at the 4 target institutes, there was little change at KRICT (188→189) and KIMM (453→454[10]) between 1985 and 2003. On the other hand, the number at ETRI and KRIBB tripled (526→1,564 and 51→174, respectively).

(2) Financial Status

Just as the number of researchers has been increasing, budget of research and development around the country has been rising. With the expansion of the research system, the research and development budget of each institute has also been increasing. According to the staff in charge at institutes visited during the field survey, budget for the operation and maintenance of the research equipment installed under this project is generally sufficient.



Source: Data by the Ministry of Science and Technology

Fig.3: Changes in the Number of Researchers and R&D Budget in South Korea

Table 2: Average Annual Research Budget of Each Institute (unit: million won)

	1981-85	1986-90	1991-95	1996-00	2001-03
ETRI	4,109	11,499	28,773	44,630	118,543
KRIBB	268	3,055	10,196	33,214	50,700
KIMM	N.A	N.A.	36,498	74,756	87,898
KRICT	6,380	17,140	29,640	54,100	74,567

Source: Data by each institute

[10] For comparison purposes, the number for 2003 includes 191 researchers of the shipbuilding department, which was separated as an independent entity from KIMM in 1999.

2.5.3 Operation and Maintenance Status

The research equipment procured under this project is basically maintained and operated by the staff of each institute. In addition to the top-level expertise and techniques in South Korea, researchers at each institute have acquired techniques for operating, maintaining and analyzing equipment through the foreign training program conducted at project implementation. Repair of problems that cannot be handled at each institute and measurement accuracy adjustment that requires special instruments are performed by the manufacturers' agents in South Korea or their headquarters in other countries.

Most of the equipment has been used for more than 10 years. In some cases, researchers themselves procured cutting-edge components to improve the equipment for research and technological innovation. Thus, the procured equipment is operated and maintained mostly in good condition.

2.5.4 Role of National Research Institutes in Future Research and Development

"Vision 2025" adopted at the 3rd meeting of the National Science and Technology Council in December 1999 has the basic policy of promoting drastic shifts in the following 4 fields in order to raise South Korea's competitiveness in science and technology to the level of G-7 countries by 2025: 1) a shift from government-led to private-led development; 2) a shift from focusing on the expansion of investment to a distribution strategy focusing on the efficient use of investment; 3) a shift from a domestically self-sufficient research and development system to a global networking system; 4) a shift from short-term-demand-oriented technological development to creation of a long-term market.

As the development of science and technology shifts from the government to the private sector, national research institutes, including the 4 target institutes of this project, are expected in the future to concentrate more on research in basic fields that have high risk for private institutes, such as research in which it is difficult to achieve results in a short period of time or that requires a large amount of capital investment.

3. Feedback

3.1 Lessons Learned

None

3.2 Recommendations

None

Comparison of Original and Actual Scope

Item	Plan	Actual
1) Output		
Number of items of procured equipment		
- GEC	41 types	51 types
- KIMM	87 types	67 types
- ETRI	15 types	8 types
- KRICT	128 types	65 types
2) Project Period		
GEC	May 1988 – Dec. 1991	Apr. 1989 – Dec. 1992
KIMM	May 1988 – Nov. 1990	Dec. 1989 – Jan. 1991
ETRI	May 1988 – Aug. 1989	Sep. 1991 – Nov. 1993
KRICT	May 1988 – Dec. 1989	Mar. 1988 – Dec. 1991
3) Project Cost		
Foreign Currency	2,679 million yen	2,644 million yen
Local Currency	198 million yen (1,094 million won)	Unknown
Total	2,877 million yen	Unknown
ODA Loan Portion	2,679 million yen	2,644 million yen
Exchange Rate	1 won ＝ 0.18 yen (1987)	

Third Party Evaluators' Opinion on
Research Equipment Reinforcement Project

Professor Keun Lee
Economics Department
Seoul National University

Effectiveness and Impacts

This project is to provide the ODA loan to several research institutes in South Korea to purchase and install equipment for research and development (R&D) in the areas of biotechnology, machinery, semiconductor, and chemical substances. The four research institutes which had utilized this program and got the loan were: Genetic Engineering Center (GEC), Korea Institute of Machinery and Materials (KIMM), Electronics and Telecommunication Research Institute (ETRI), and the Korea Research Institute of Chemical Technology (KRICT).

Overall, the project can be considered successful, especially in terms of the criteria of effectiveness and impacts, as it provided a very "critical inputs" to the enhancement of R&D capability of key research organizations in South Korea. The word, "critical," is used in the above for the following reason.

Although South Korea is one of the most successful developing countries with remarkable economic achievement, one of the weakest points of the economy has long been its weak ability in the core parts and materials which require more deeper grasp of science and accumulation of experience and knowledge. While the Korean economy was successful in producing and exporting final goods, she has had to rely on imported goods for core parts and materials. These core parts and materials are not easy to localize by Korean private companies as they require more serious and fundamental scientific efforts. Practically, doing R&D on these items require a huge sum of money and risk with a very low chance for success. More specifically, one critical element among others is the need to have at hand the necessary experimental, research, and testing equipments and facilities. The current ODA loan project is marvelous at it directly targeted this problem.

The four selected research organizations all represent those sectors which are very critical for the whole national economy and waiting for breakthrough in R&D. These four R&D organizations seem to have used the money effectively to buy the necessary equipment and to have used them wisely and consistently. We have a very clear-cut evidence of their performance, and the evidence is the patents by them. As shown by the patents acquired by these 4 research organizations, there have been a remarkable increase of the patents around the time that they installed new R&D equipments. Furthermore, it is now generally (my own research confirms this, too) acknowledged that the four industries of biotechnology, machinery, semiconductor, and chemical substances in Korea have made meaningful progress, closing the gap with the advanced countries. For instance, among others, semi-conductor industries in Korea is now the world leader, especially in memory chips.

While these achievements are often associated with private companies, we all know that government research institutes including the four in this projects, have played the critical role. The reason that private companies were often not able to conduct R&D in these hard technologies is that R&D equipments are so expensive so that private companies cannot afford to buy them. This ODA loan program was effective in solving this money problem, and it helped the government research organization to borrow the money and purchase the needed equipment.

Its impacts on the private sector and the overall national economy is obvious as these equipments are often used by private sectors, too, as indicated in the evaluation report. Furthermore, it is written that those equipment and facilities have been used for an extended period of time so that their impact may have been more lasting than otherwise.