

PROBLEMS AND EFFECTS OF AUTOMATION AND ROBOTIZATION

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ABSTRACT

This paper deals with major tasks to be carried out in promoting the automation and robotization of construction works and with the effects of these advanced technologies when commercialized. The two subjects were derived from a detailed analysis of each category of diverse construction works with respect to: ① problems and topics to be dealt with in the current state of the works, assuming that they are automated or robotized; ② the future image of these works envisaged with their automation and robotization; ③ functional requirements for materializing their automation and robotization; and ④ technical development tasks to be carried out in promoting their automation and robotization. Of the tasks involved in automating or robotizing construction works, this paper focuses on the topics to be addressed in commercializing and fielding out to construction sites as quickly as possible new technologies that have been or will be developed. These topics are discussed in four aspects, i.e., the setup for technical development, measures required at the planning and design stages of construction projects, measures at their execution stage, and other steps to support the promotion of automation and robotization. Meanwhile, the effects of introducing automatic or robotized systems in the construction sector are dealt with based on their detailed analyses in their technical, social and economic aspects. It may be argued that the discussions here most accurately reflect the current state of automation and robotization technologies for construction works in Japan, indicating the future course of construction management.

1. INTRODUCTION

Since the mid-1970s, active automation and robotization investments have been made by the Japanese manufacturing industry to achieve higher labor productivity by increasing the efficiency of production activities through factory automation. Meanwhile, the construction industry has suffered from low productivity of labor over the last 15 years, which has combined with a recent sharp increase in construction projects to press industry members hard with work discharging the backlog of orders. The difference of labor productivity between the construction and manufacturing sectors is thus widening more than ever. What is worse, a tendency among young people to keep away from construction jobs has come to the fore over the last few years. Under these circumstances, much is expected of high-technology systems that may be introduced in construction sites through further progress in automation and robotization.

Against this backdrop, a mix of steps have recently been taken to facilitate and spread the automation and robotization of construction works so that these works as a whole will be upgraded eventually. Among these measures are reviews on the applicable legislation and the method of estimation, tax incentives, the institutionalization of a support system for pilot projects, and the promotion of joint development activities. It is hoped that favorable results will be achieved by these measures. However, a look at individual categories of construction works found that various other steps have yet to be taken urgently in many areas. The following sections give a general view of the current state of things in Japan in respect of both the tasks to be carried out in promoting the automation and robotization of construction works and the propagating effects of new technologies that may be introduced or developed for this purpose.

2. TASKS IN PROMOTING AUTOMATION AND ROBOTIZATION

This section discusses the tasks to be carried out in commercializing and spreading at construction sites in Japan as quickly as possible new technologies that have been or will be developed for automation or robotization of construction works. These topics will be analyzed in four aspects - a technical development setup, measures needed at the planning and design stages of construction projects, measures at their execution stage, and other steps to support the promotion of automation and robotization.

2.1. Development Setup

(1) Current State

Against the backdrop of the recent trend in construction techniques toward the spread of high-technology systems, automation techniques have been developed in substantial numbers at construction sites, but only few of them have been made commercially available for the execution stage of construction projects mainly because many of them are stalled at the demonstration stage. Furthermore, most of commercialized techniques have been developed to replace handwork by machines, and this implies that these techniques do not have the desired effects which would have resulted from development activities intended to introduce high-tech systems. On the whole, it may safely be argued, technical development in this field is at a transient stage toward the automation and robotization of construction works.

Major causes of these inadequate results include, among others, the lack of executional conditions and a working environment geared to the introduction of automation and robotization technologies. Another primary cause is the exceedingly high level required of the automation and robotization efforts. In addition to technological issues, there are serious constraints resulting from the problems of a technical development setup stated below:

- ① Many of development activities are lacking in adaptability to construction sites in general because they are intended for specific job sites and are carried out under joint projects by individual construction companies and robot manufacturers. Also notable is the reluctance of construction companies to accept the results of technical development achieved by their competitors, which retards the horizontal diffusion of new technologies developed in the construction industry.
- ② In many instances, technical development projects are financed by individual construction companies and robot manufacturers, and therefore, lack of the diffusion of new technologies they develop makes these projects unprofitable to either of them.
- ③ Failure to divert developed technologies to other construction sites results in the loss of a feedback function, the most essential element of technical development, which in turn hinders further improvement of the technologies to upgrade their performance.
- ④ Robot manufacturers, although well aware of the growth potential of the construction robot market as a "needs-led business sector," hesitate to add the development and production of these robots to their regular operations.
- ⑤ Another impediment is a shortage of service engineers capable of handling automatic or robotized systems, the maintenance and management of which on the whole require greater technical expertise than general construction machinery. Besides, equipment leasing companies are reluctant to include these systems in their business lines because of the limited adaptability of the systems and great difficulty in securing a necessary technical staff.

Newly developed technologies, if economically feasible and given a wide scope of applications, will spread so much earlier as a matter of course. The automation and robotization of construction works require huge funds while their economical efficiency is totally unpredictable and technologies developed for this purpose have only limited adaptability. Under these circumstances, it may be argued that the principal drag on the diffusion of technologies developed in this area is the financial infeasibility of research and development projects for these technologies.

Examination of measures to give these technologies better economics and a wider scope of applications found that what are needed include the improvement of elemental technologies in terms of their perfectness and cost-effectiveness, the development of

proper standards for automation and robotization, the standardization of designs and execution methods for construction projects, the education and training of system operators and maintenance mechanics, and a review on the systems of issuing and receiving orders. Strenuous efforts are being made to automate or robotize field works as an urgent need of the whole construction industry. A major consideration in achieving this end is how to carry out technical tasks involved, but the most important of all is to remove the impediments noted above. Unless it is done, the automation and robotization efforts will probably remain no better than a public relations tool of individual industry members.

Customers are studying various measures to develop and spread automatic or robotized systems, and through such organizations as Advanced Construction Technology Center, Inc. and National Land Development Technology Research Center, Inc., they are also conducting surveys on the requirements for these systems, proposing research and development topics, and studying equipment and systems. In addition, efforts are being made in academic circles and industry associations to find the needs for and a future image of these systems. Energetic research activities for the automation and robotization of construction works are thus carried on by the interested parties from their respective standpoints, but none of these activities goes beyond the boundaries of mere studies or an exchange of information and most of them overlap one another in many instances. This may be considered something unavoidable because it was only a few years ago when the interested parties began moving toward the automation and robotization of construction works. What will have to be done from now on is that all interested organizations, including not only robot suppliers and users (the construction industry) but also customers (construction contract awarders) and other associations surrounding the industry, should fully perceive their respective roles and join their efforts to carry out development and diffusion activities in such a manner that they can expect to achieve practical, concrete results.

(2) Guide to Joint Development Setup

Development activities for evolving field work techniques into high-tech systems are often undertaken by a group of organizations led by a construction company or a robot manufacturer. Under the circumstances, these efforts seldom lead to the promotion of automation or robotization projects because of conflicting views among the parties involved regarding returns on development investment or their respective interests. It is desirable that customers, specifically government agencies, should take the lead in working out a technical development and diffusion strategy for automating or robotizing construction machines which are frequently used for public works.

(3) Support to Development of Elemental Technologies

A look at current topics of automation and robotization research activities indicates that the results of these activities will have only limited adaptability to construction sites because many of them cover large construction machines (or systems). This is among major factors that retard the diffusion of new technologies developed by these activities. What is worse, most of technical development projects in this field are affected by a strong sense of rivalry among construction companies, resulting in an additional impediment to the spread of new technologies. It is hoped, therefore, that customers (government agencies) will take a set of effective development and diffusion measures, including encouragements and incentives to development topics, particularly those elemental technologies which may be used frequently (or have many opportunities of service) and extensively applied to construction works. The measures should also include the recommendation that these technologies will be used for different construction works continually under the same specifications. Another important step is that a joint research and development project should be worked out by various organizations, such as government research institutes, academic societies and industrial associations, to commercialize promising new technologies quickly.

2.2. Measures at Planning and Design Stages of Construction

(1) Guidance at Planning Stage

The current state and problems of the setups for issuing and receiving construction orders were discussed earlier in this paper. From the viewpoint of facilitating the automation and robotization of construction works, however, it is essential that the Japanese administration should guide customers and consulting firms to give careful

consideration to the planning and cost estimation of construction projects at the planning stage, assuming that automatic or robotized systems will be extensively used for works under the projects. The automation or robotization of field works can bring about desired effects only if it is based on a consistent idea over the whole process from the planning and design stages to the execution stage.

(2) Freer Choice of Construction Methods and Easier Design Changes

Under the present system of construction contract, the means of construction, including the selection of engineering methods and equipment, are often set forth in the specifications attached to the order, narrowly limiting the available means of field works for the contractor. This practice itself has many advantages in some other respects, but in view of the need for automation and robotization of construction works, we have to remind ourselves that it gives a grave discouragement to construction companies in their effort to actively develop field work techniques into high-tech systems. In other words, the practice is one of the problem areas that need immediate improvement.

(3) Review and Refinement of Standards and Guidelines

Among major impediments to the development of field work techniques into high-tech systems is the backwardness of design and field work standardization due to the inherent nature of construction companies that their operations fully depend on contract awards from customers and that an apparently optimum plan has to be developed for each part of construction works because design conditions differ from part to part. This implies that the applicable standards and guidelines, especially for the specifications of materials and the design of structures, have to be reviewed exhaustively with consideration given to the automation and robotization of works at construction sites. The review and refinement of these specifications, standards and guidelines are among the highest-priority tasks to be carried out by expert committees of academic societies and industrial associations.

2.3. Measures at Execution Stage

(1) Review of Execution Setup

With progress in automation and robotization of construction works, investment in equipment and systems holds a greater share of the total construction cost, and the quality and schedule of construction works are significantly affected by whether such investment cost is managed properly or not. Another important consideration in technical development is to gather and analyze various data during the operation of automatic or robot systems at construction sites and to so reflect the analysis findings in the equipment or systems that newly developed technologies will soon come to maturity and perfection. This means that the day will come before long when automatic or robot systems have such high technologies incorporated in them that they can no longer be handled properly by construction companies' existing technical staff alone. Following the example of modern medical science which provides proper remedies for different diseases with the support of electronic equipment and their operators, a study should be conducted immediately on the establishment of a joint field work setup by construction companies which are responsible for execution of works and robot manufacturers which take charge of equipment or system operation.

(2) Development of Special Contractors

Among conceivable measures to cope with increased use of electronic elements resulting from the development of field work techniques into high-tech systems is the establishment of special contractors. Expert personnel with good technical knowledge and sufficient experience are required for operation and maintenance of automatic or robotized systems, acquisition of necessary techniques for their management, and quick repair service for any trouble with them. It is advisable that arrangements should be made by robot manufacturers and construction companies to organize special contractors for this purpose. In the near future, building engineers, quite different from those we see now, may appear at construction sites and take active part in field works.

(3) Establishment of Maintenance System

As the automation and robotization of construction works advance, it is likely that troubleshooting for these sophisticated systems will become a time-consuming job, sometimes affecting the progress schedule for the rest of the construction project. To cope with this problem, efforts will have to be made to provide automatic or robotized systems with self-diagnostic or self-checking capability, while incorporating a system of

maintenance services, such as periodic inspection and maintenance outages, in job-site organizations and progress schedules for individual construction projects.

(4) Labor and Safety Management

In the area of personnel administration and industrial safety management, a study should be conducted to find a new method of management fitted to the working environment where high-tech systems are installed for field works. To make these high-tech systems compatible with skilled workers and increasing participation of women workers in construction works, it is essential that reasonable standards and programs should be worked out jointly by construction companies, their customers and the competent authorities. In other words, all interested parties must be prepared to introduce a new management system for a new age.

(5) Expansion of Support Setup

The introduction and diffusion of automatic or robotized equipment and systems involve efforts to build up a satisfactory checkup and maintenance system, including spare parts inventories and other service programs provided mainly by robot manufacturers. The development and diffusion of equipment or systems largely depend on the quality of after-sale services offered.

(6) Assistance to Leasing Companies

There are many equipment and systems which have rapidly come into wide use after they are included in the business lines of leasing companies. To facilitate the diffusion of new automation and robotization technologies, some assistance has to be extended to leasing companies so that they can easily acquire and hold advanced automatic or robot systems. This is one of the measures to be taken by customers of construction companies (i.e., government agencies).

(7) Review of Regulations for New Technologies

While the automation and robotization of construction works are expected to relieve human workers from dangerous, hard jobs, new accident risks may arise from errors in operating automatic or robotized systems or their malfunctions. Needless to say, safety standards based on the failsafe concept will have to be provided for these new systems. Many of high technologies have never been introduced or actually used in construction sites. Accordingly, all applicable regulations, including those on output, frequency, operating areas and working environment, should be reviewed in an effort to make these advanced technologies available for construction sites. In view of the strong demand for diversification of construction specifications and improvement of productivity, it is predicted that new automatic installations, such as unmanned high-speed systems operated in an unusual environment (under extreme conditions) and heavy material handling systems, will come into general use. A review on the existing statutory regulations to meet these requirements is also among the essential tasks to be carried out.

(8) Review of Inspection Methods

With progress in automation and robotization of construction works, it is expected that favorable results will be achieved in a form different from the conventional process (i.e., in terms of accuracy, speed and quantity). For each of new automatic or robot systems that are commercialized for use at construction sites, the inspection method should be reviewed or, if necessary, replaced by a new method to facilitate the spread of the system. In addition to the review of the legal regulations noted above, this is among the measures to be taken by customers (government agencies).

2.4. Other Promotion and Support Measures

(1) Expansion of Training Institutes for Special Operators

Progress in the development of high-tech systems for construction works involves the employment of large technical personnel with expertise in electric, mechanical and control engineering for operation and maintenance of these advanced systems. With this in mind, arrangements should be made with technical colleges and vocational training institutes to provide special educational and training courses in construction machinery, equipment and control devices to secure a stable supply of technical work force.

(2) Enlightenment on Personnel Training

As noted above, the maintenance of large technical personnel is essential to progress in the automation and robotization of construction works. However, only limited results can be achieved by the reeducation of technical workers already employed at construction sites. Persevering efforts should be made, therefore, to carry out more

effective measures, including the enlightenment of schools and other educational institutions on the need for technical personnel training, a request for them to take this into consideration when guiding students in their future course of study, and the provision of a scholarship or loan program for technical students. Preferably, these measures will come to stay as regular activities of academic societies and industrial associations.

(3) Information on Commercialized Technologies

As a major element of their action policy, it is hoped, academic societies and industrial associations will provide information continually and regularly on examples of automatic or robot systems developed for construction works and of construction projects carried out with these high-tech systems. What is important here is that taking every opportunity available, they should actively approach the manufacturing and other industries directly or indirectly involved in the automation and robotization of construction works in an attempt to enlighten these industries on the need for introduction of high-tech systems in the construction sector.

(4) Public Information on Government Measures

It happens sometimes that interested parties are not fully informed of measures government research institutes or customers have planned and are implementing for development and diffusion of new technologies. Satisfactory public information should be provided on these government measures in bulletins published by academic societies or industrial associations or on such occasions as meetings for technical presentations. Regular information activities by these organizations will play an important role in the formation of public opinion.

(5) Enlightenment of General Public

The reluctance of young people to work in the construction industry and low productivity of labor in this sector are partly attributable to the business structure and technical problems of the industry, but a more essential cause of this situation is the lack of interest on the part of the general public in construction business. An important task here is to make effective public information activities, including the distribution among educational institutions of public relations magazines and video tapes on high-tech systems installed at construction sites, group tours of construction sites and other events prepared for citizens at large, and public relations through mass media. In this context, academic societies and industrial associations are responsible for promoting the activities to stir up citizens' interest in construction business.

3. EFFECTS OF AUTOMATION AND ROBOTIZATION

The aim of technical development efforts for automation and robotization of construction works is both extensive and profound. If a certain technology covered these development efforts is used at two or more different places, the specifications of the system based on that technology vary in many instances. This is why the development of high-tech systems for construction sites involves great difficulty. On the other hand, technical development for automation and robotization of construction works has great propagating effects which are likely to extend over many different sectors.

A decryption of these propagating effects becomes more dependent on the category or process of construction works covered as it goes into further details. This section gives a general description of these effects in technical, social and economic aspects.

3.1. Technical Aspect

Automatic or robotized systems for construction works are operated mainly under adverse conditions, such as a vast, complicated working environment or severe working conditions. In carrying out technical development for these systems, needless to say, efforts should be made to identify the functions to be provided for each of the systems based on an analysis of the characteristics of the job category and working environment for which it is intended. These development efforts may lead to something new in the area of execution techniques or processes that has been unavailable before. Also it is likely that the progress of automation or robotization in a certain area will set off a chain reaction at other construction sites through its underlying technologies and concept.

(1) Effects on Design Methodology

In promoting the automation and robotization of construction works, it is

execution management.

(7) Effects on Order-Receiving Setup

- ① So far, technical development projects for automation and robotization of construction works have been undertaken mainly by private construction companies. Naturally, the promotion of automation and robotization of these works requires lots of time and money. From their financial and economical feasibility, development projects launched under the setup as noted above could not last long. In the future, the government, academic and private sectors will move toward the formation of a new development setup, making the most of their respective structural features.
- ② Needless to say, it is desirable that new technologies developed by corporations should be used widely in society. For this purpose, arrangements will be made to evaluate new technologies properly and make good use of them in such a way that their developers can enjoy their due shares of benefit.
- ③ Mechanized execution of construction works with automatic or robotized systems will be pushed on along with studies on related topics, including execution methods, execution control standards and inspection standards for execution setups. As an inevitable consequence, there will be a growing tendency among interested parties to review and improve the existing execution setup.

(8) Effects on Corporate Organizations

In view of the need to provide a better working environment at construction sites and improve the social climate for the construction industry especially in respect of securing a necessary work force, as stated earlier, the automation and robotization of construction works are an urgent task for the whole industry. With this in mind, industry members will develop a setup (or a mood) in their respective organizations to promote the development and operation of automatic or robotized systems.

3.3. Economic Aspect

(1) Effects on Cost Estimation

As discussed earlier, the promotion of mechanized execution of construction works with automatic or robotized systems requires the formulation of a new concept of cost estimation standards and machinery hire or rent based on the assumption that such mechanized execution will be introduced in construction sites. To streamline the cost estimation standards, as was also stated earlier, efforts are needed to accumulate and analyze relevant data obtained from repeated experimental execution of works and performance records. As a matter of course, a sufficiently large construction contract has to be obtained to cover the rent for automatic or robotized systems (construction robots) which are very costly in general. If a reasonable system of cost estimation is worked out and introduced for mechanized execution of construction works, it may safely be argued, automatic or robotized systems with greater accuracy and increased functions will be developed and spread widely.

(2) Effects on Construction Cost

The basic trend of development efforts for automation and robotization of construction works is toward a combination of different functions (i.e., multifunction capability) and the establishment of an integrated execution system for the whole construction process. With this in view, steps will be taken to reduce the construction cost and time by changing the ordering structure according to the progress of automation and robotization.

4. CONCLUSION

According to a perception which is coming to stay among the Japanese people now, it is essential that construction projects should be carried out more efficiently by developing and introducing new technologies in order to steadily build up social infrastructures toward the oncoming mature society while meeting diverse, sophisticated needs for housing and public facilities. For this purpose, strenuous efforts are being made to develop new construction techniques incorporating, among others, automation, unattended operation, systematization, robotization and prefabrication technologies.

Needless to say, well-balanced measures based on a sound idea have to be taken in both

unadvisable that design methods in the upstream section of the whole construction process should be left out of consideration. This means that the design process changes with the spread of high-tech systems at construction sites. In other words, improvements in design work uniformity and quality, standard design capability and consequently a faster design process will be realized by establishing an integrated work system based on the assumption that automatic or robotized systems will be introduced for construction works.

(2) Effects on Construction Methods and Procedures

Automatic or robotized systems can work most effectively when all processes are operated as a single integrated system. The development of a total work system for each category of construction works will remain infeasible until construction robots with artificial intelligence appear in the market. In the meantime, however, we can reasonably expect a rapid change in conventional construction methods and procedures that are based on handwork or human labor. Progress in high-tech systems also involve a significant change in the materials used at construction sites.

(3) Development of Systematization Technology

The further the systematization of functions advances, the more centralized control each automatic or robot system will receive from the control center at each construction site. Then information on different parts of each system will be gathered and analyzed at the control center to operate the whole system efficiently. For this purpose, a highly-sophisticated information processing system will be developed which can simultaneously perform periodic checkups on the operation of automatic or robot systems, the management of remedies for troubles, quality control and the management of the amount of work finished. As a result, technical development efforts will be made to build up a total system which makes each system function work efficiently as a component robot. This is a new concept and a new technology that cannot be found in conventional construction sites.

3.2. Social Aspect

(1) Effects on Living Environment (Creation of New Living Space)

As is widely known, living environments for the people are becoming very complex and diverse these days. Undoubtedly, one of the greatest supports for these diverse living environments is the social infrastructure provided by the construction industry. With progress in automation and robotization of construction works, much more social infrastructures will be improved and provided more rapidly than ever, resulting in further diversification of people's lifestyles. In addition, the advancement of automation and robotization technologies will enable the construction of facilities in such locations as underwater, deep underground and outer space sites which have been unavailable for this purpose in the past. It is predicted that new living environments will be developed for an advanced system society in the not too distant future.

(2) Effects on Labor Management

With the introduction of automatic or robotized systems, construction sites which have been considered to involve tough, dangerous jobs will be recognized anew as general job sites, not special ones. This will lead to a better working environment, increased willingness of personnel to work, and a more favorable public image of construction sites, giving more encouraging prospects for offering jobs to aged workers and securing a sufficient young work force.

Meanwhile, workers at well automated and robotized construction sites will have to receive necessary training and develop their abilities sufficiently to properly handle the systems in their charge. Accordingly, elaborate care will have to be taken in giving new assignments to those workers who are skilled in the conventional construction methods. The maintenance and hiring of employees are among the essential elements of labor management.

(3) Effects on Industrial Safety Measures

One of the greatest advantages of automation and robotization is the conversion of construction sites from a human-system-dominated environment to a mechanical-system-dominated one. Naturally, this will significantly reduce the risk of human casualties, and increased safety will help improve the public image of the construction industry as a whole, bringing about great propagating effects. However, as the size of advanced total work systems at construction sites increases very significantly,

they will inevitably result in a substantial increase in the size and complexity of a contingent accident should it ever happen. It is essential, therefore, that a study should be conducted on systems for precluding such accidents.

(4) Effects on Statutory Regulations

As noted above, many of the existing construction sites have a work process mainly consisting of human labor. Accordingly, the legal regulations applicable to construction sites naturally assume that jobs at these places are mostly performed by human workers. Understandably, these regulations often serve as an impediment to the introduction of automatic or robotized systems in construction sites. In other words, the regulations now in force are based on the assumption that human workers, while visually examining the state of things, operate construction machines. Meanwhile, an automatic or robot system operates machines using sensors and computers as substitutes for human eyes and brains in perceiving and judging the state of things. It is hoped that the regulations should be streamlined to meet the requirements of the oncoming new age based on the identification of topics to be dealt with in removing regulatory hindrances (related legislation and qualification and licensing systems) to the introduction of automatic or robot systems and in facilitating the spread of these systems for each category of construction works.

(5) Effects on Development Setup (Human and Institutional)

- ① From development cost and effects, it is becoming increasingly difficult for individual private construction companies to carry out technical development projects for automation and robotization of construction works. This has led to a strong need to provide a setup for joint development activities. As a result, the government, academic and private sectors will actively set about joint research and development projects, making the most of their respective features, specifically the promotion of technical development mainly under a technologies assessment system and a joint technical development program.
- ② As stated earlier in this paper, the automation and robotization of construction works require lots of time and money, and their introduction in construction sites involve great economical and financial risks. To reduce these risks, arrangements will be made for energetic economic support activities, including financial assistance to technical development projects under subsidizing, special lending and tax credit programs, the offer of demonstration test sites, and the installation of developed systems in pilot project and other construction sites that offer economic incentives.
- ③ Currently construction works are carried out efficiently under the inspection and cost estimation standards set for each category of works. These standards will have to be reviewed drastically when high-tech systems are introduced for field work execution techniques.

(6) Effects on Ordering Setup

- ① Progress in mechanized construction works through the use of high-tech systems for execution techniques will necessarily involve a change in construction and inspection methods. In addition, the execution control standards, cost estimation standards, and rent and hire will have to be modified for mechanized execution of construction works. Also specifications accompanying orders will have to be reviewed.
- ② It is predicted that highly automated and robotized construction sites will tend to seek further improvements in economy and safety, making the most of their special features. This may lead to the development of new execution and design methods.
- ③ Any substantial progress can hardly be achieved in automation or robotization of construction works unless the customer and contractor share the same technological perception and have necessary arrangements to enjoy the benefit of such progress. This condition will inevitably give rise to a new concept of deriving advantages from the evaluation, development and introduction of new technologies.
- ④ In the area of mechanized construction works, new technologies developed for this purpose will be demonstrated and improved through the accumulation of performance records. The installation of this system will make it no longer warrantable to continue the conventional way of execution which relies on the experience and intuition of technicians. Progress in automation and robotization of construction works will inevitably lead to the establishment of a new practice to gather, accumulate, analyze and feed back various data for cost estimation and

hardware and software areas to achieve rationalization and labor-saving effects at construction sites mainly through the development and introduction of new technologies. It is not unlikely that the current trend of technical development in Japan geared to develop new automatic construction machines and systems using high technologies ahead of other countries in the world will spread far and wide overseas. It is important to look at both the horizontal diffusion of technical development results and the development of elemental technologies from a worldwide point of view.