STUDY ON THE OVERALL SYSTEM ARCHITECTURE OF CONSTRUCTION EQUIPMENT SUPPORT INFORMATION SYSTEM

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ABSTRACT

The construction industry has made active efforts, such as CALS/EC, to realize seamless and smooth data integration during a whole project lifecycle. In the construction stage of a project, an automatic control equipment, which needs only to input design data, would be desirable. Utilization of construction records for quality control and inspection is also expected. Construction equipment will likely play an important role in seamless data sharing.

Standard definitions of information items and adequate rules of information exchange should be created to exchange information between machines working at different stages. In construction projects, coordinate data, which are basic information and quality control data for each position, are especially important, and it should be standardized with consideration of site management.

This paper summarizes construction projects that are used recent survey and information technologies. It also investigates standardization methods that will help the utilization of design information in machine operation and construction data in quality control taking account the fact that most of Japanese construction companies usually share to use the same construction machines.

1. INTRODUCTION

Recently in Japan, various information systems that collect construction data from GPS and on-machine instruments and communicate such data through information networks have been developing and used in construction projects to help workers to operate construction equipment. These systems are one of the attempts to realize the construction CALS/EC.

At the present moment, design data and survey data have not utilized in the real construction site. These dvanced information technologies are expected to innovate construction works: construction machines will share information, projects will be performed automatically based on design information, and records acquired during construction work will be utilized for quality control (in Fig.1). These systems will exchange information between machines and different construction processes, which will consist of coordinate data (as the basic data) and the construction and quality data that are controlled in relation to the coordinates. Information items should be defined, and rules for exchanging the information (standardization) should be created to popularize the technologies.

If ISO is established on these items without consideration of the difference of unique characteristics of construction method in each country, the standards may impede both the internationalization of construction projects and the development of construction equipment in the world.

This paper summarizes construction equipment support information systems developed not only in Japan, also outside of it, which utilize recent survey and information technologies. And it also summarizes construction methods for developing construction equipment support information systems from the view of an international perspective to perform rational construction works by sharing and utilizing construction-related data, such as design and quality control information.

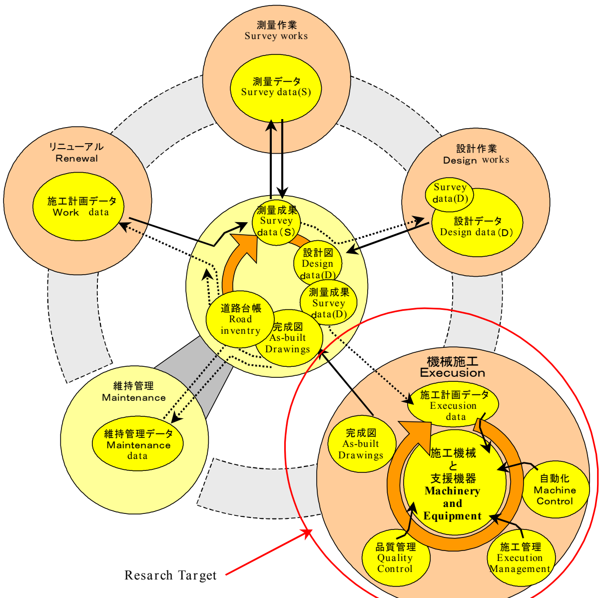


Figure 1. Project cycle from the viewpoint of information

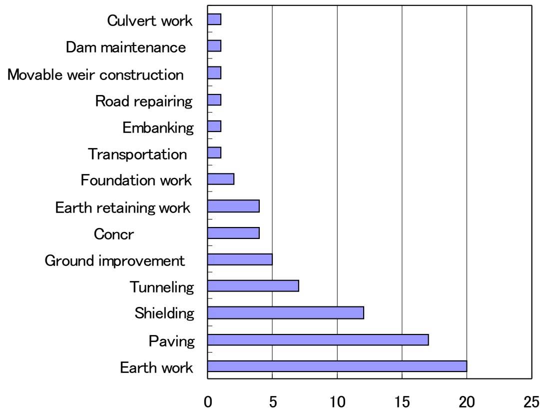


Figure 2. Introduction of information technologies for each kind of work

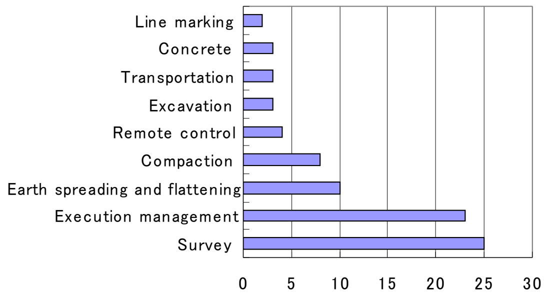


Figure 3. Utilization of information technologies for each kind of operation

2. TRENDS OF CONSTRUCTION EQUIPMENT SUPPORT INFORMATION SYSTEMS

Presently, exist of construction equipment support systems, and control systems are summarized in the rest of this section.

2.1 Survey method

(1) Technologies developed inside of Japan

The technologies developed in Japan were surveyed by sending questionnaires to the governmental authorities that used information technologies in the construction projects that the Ministry of Construction supervised in the past two years and construction companies that have been reviewed in magazines for the utilization of information technologies. These questionnaires were sent to the following offices and companies:

1) Ministry of Construction, Japan Highway Public Corporation, Tokyo Expressway Public Corporation, Honshu-Shikoku Bridge Authority, Water Resources Development Public Corporation
2) 16 major construction companies in Japan.

(2) Technologies developed outside of Japan

Technologies developed outside of Japan were surveyed by using the reference system of the Japan Information Center of Science and Technology, searching for papers published in magazines, and conducting interviews with seven manufacturers of construction machines and measurement instruments that have Japanese branch offices.

2.2 Results of survey

(1) Present states of information technologies in and outside Japan

The survey showed a total of 85 technologies developed. The number of technologies for each works kind is shown (in Fig.2). Earth works, paving and shielding combined account for 58% of the total (49 cases). The numbers of technologies are unevenly distributed.

The number of technologies for each operation is shown (in Fig.3). The figure shows that information technologies are profoundly introduced in surveying, spreading and compaction.

(2) Comparison between information systems in and outside of Japan

Information systems used for earthworks (excavation, flattening, and compaction), that use relatively many technologies, in and outside of Japan are compared in Table 1.

Table 1. Comparison of information systems in and outside of Japan

Operation	In Japan	Outside Japan
Excav-ation and grading	Information technologies are rarely used in general construction works. Remote-controlled construction machines, automatic tracking total stations, GPS, clinometers, and execution management data, such as current positions and expected work progress, were utilized in the unmanned restoration works for Unzen Fugen-dake.	We found no excavation work that used information technologies, but there was a case that loaded a GPS system on a loading shovel in a mine to help measurimg the current position. A guidance system was developed and is loaded on flattening bulldozers and motor graders that work in mines and large-scale construction sites. The system uses GPS to determine the positions and the height and inclination of the blades, and displays the information and any differences to the plan on monitors in front of the operators. However, information technologies are rarely used for construction work that requires accuracy. Information technologies of efficient accuracy should be developed.
Comp action	The numbers of projects are increased by using GPS for monitoring the positions of compactors, recording the compaction courses and numbers, and using the data for execution management. Attempts are made to eliminate the need for preliminary survey by investigating the response characteristics of the ground or conducting three-dimensional positioning with GPS. This is the field where information technologies are most widely spread in construction.	In Europe, compaction meters are widely used to manage, and to evaluate the degree of compaction by vibration rollers, which is determined from the compaction speed and the repulsive acceleration of the ground. Output records of the compaction meters are accepted as official construction management records. Positioning accuracy is a modt topic of the compaction meters for automatic operation, and a system is being developed by combining the meters with GPS.

2.3 Trends in the development of construction equipment support information systems and issues

Information from construction equipment support systems is now used only for construction, but it would be utilized for designing, such as CAD, and quality control. In the field of civil engineering, such development may confront issues listed in Table 2. Therefore, standards should be created for information of construction equipment aid systems.

Table 2. Issues for using construction equipment support information systems at sites

Organization involved	Issue
Construction company	• Systems are developed to apply for each construction site. And difference of conditions of each construction site, such as application methods, machines to use, and combination of professional organizations differ by project, cause higher cost. • The knowledge related to the developed system, which belong to each company, are including their own original techniques. And these systems are spent on huge investment. These facts make it difficult to compromise to develop common system.
Subcontractors	Different information system is needed for each construction project or construction company. Since construction machines are purchased from various manufacturers that may be using different methods for data input and output, additional cost and labor are needed to coordinate and share data.
Client	Different information system would be needed for each construction company, and it would be difficult to share, coordinate, and integratedly manage data.

3. FUTURE SYSTEM DEVELOPMENT & ISSUES FOR STANDARDIZATION

3.1 Necessity for sharing information in machine application

The coodinate system, which is the basis of construction equipment information system and utilized for other operations, and information items, which is linked to the point in the coordinate system, is summarized (in Fig 4).

The kinds of information that is exchanged in the system such as coordinates for expressing lines, are classified into various patterns so to be used for other operations (earth spreading, paving, etc.). However, each operation may be using different information exchange methods, and systems may not be compatible, even though they may be using the same kinds of information, such as positions.

Standardization of information exchange methods will promote such aid systems in Japan since most construction machines are leased, and a machine that loads a measuring instrument is used in various projects.

Advantages result from the standardization of construction equipment information is listed at the end of this section. Since such an aid system, which would not only lead automatic machine operation and saving labor and energy, but be closely related to construction management and quality control, standardization activities will be unique in terms that not only manufacturers but construction companies and clients will engage in them.

(Advantages of standardization)

- Systems and equipment will be more compatible and useful.
- Adequate competition will be promoted, and costs will be reduced.
- Applicable market will be enlarged.
- The development and production costs of the systems and equipment will be reduced.
- International technological exchange will be activated, and technology will be advanced.
- Procurement costs of orderers will be reduced.

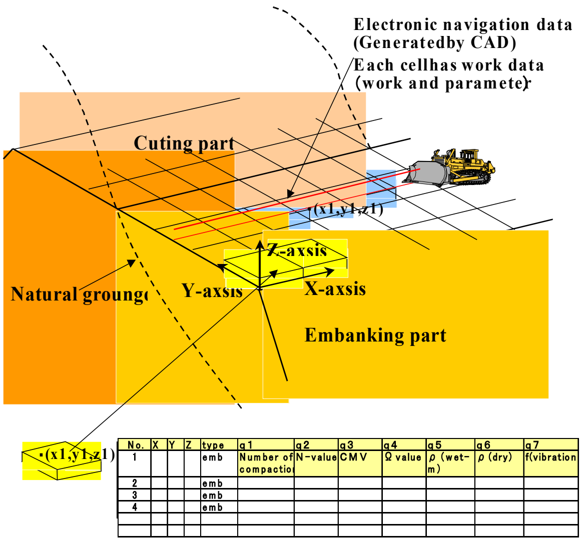


Figure 4. Image of quality linked to coordinates

3.2 Approaches for standardization

3.2.1 Standardization of systems that considers the entire construction process

As information technologies advance, information systems that support construction equipment will be developed and introduced further.

More advanced information systems will be realized by combining technologies for treating and communicating information that have been developed independently.

In construction projects, that are combinations of various operations, mutual coordination of systems requires 1) formation of common understanding among systems, organs concerned, and processes, 2) efficient reconstruction of the entire system, and 3) integrated utilization of the system. Common understanding means rules needed for sharing and utilizing acquired data among systems (definitions of terms, protocols, etc.).

As the first step of standardization, a system architecture (of a construction equipment support information system) should be constructed by considering the mutual relationships among each aid systems, that are developed for each machine, and each information system that is used for each step of construction, such as designing and maintenance.

A system architecture is a framework that expresses all factors constituting the entire system (for example, subsystems) and their relationships and is indispensable for designing and developing a large-scale system (for example, a combination of subsystems) that works as a whole. This concept is already used in the field of road communication standards, such as ITS. Construction of system architecture should also be useful for efficient development of a construction equipment support information system. The method for creating such architecture is given in the rest of this section.

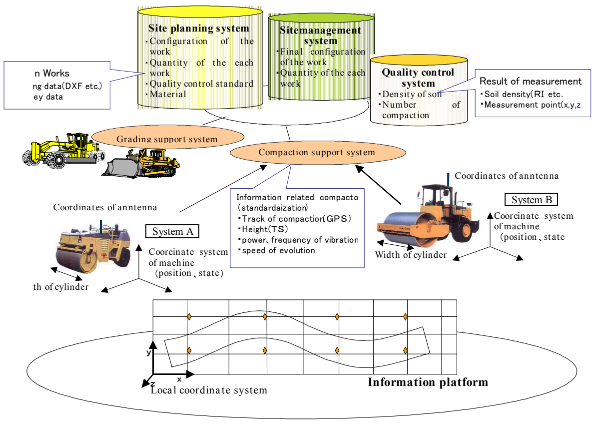


Figure 5. Efficient utilization of construction equipment support information systems

3.2.2 Construction of a system architecture

The objectives of forming system architecture for a construction information system are to create an efficient, integrated and extendible system and an environment that promotes international and national standardization.

System architecture is created by 1) defining the services that the aid system will provide, 2) drafting a theoretical architecture, 3) forming a physical architecture, and 4) determining the scope of standardization.

(1) Defining services

The types of services that will be analyzed while drafting a theoretical architecture should be defined.

A construction project is a complicated system composed of various operations. Overly focus on individual machine information systems may lead to an inefficient system as a whole. To prevent this, services must be organized to clarify their mutual relationships.

The flow of each service, from data collection to utilization, may be classified into subservices in terms of user, when and how it is used and information it provides. Since it is difficult to show an entire image of construction here, we will give an example of a service system for embanking.

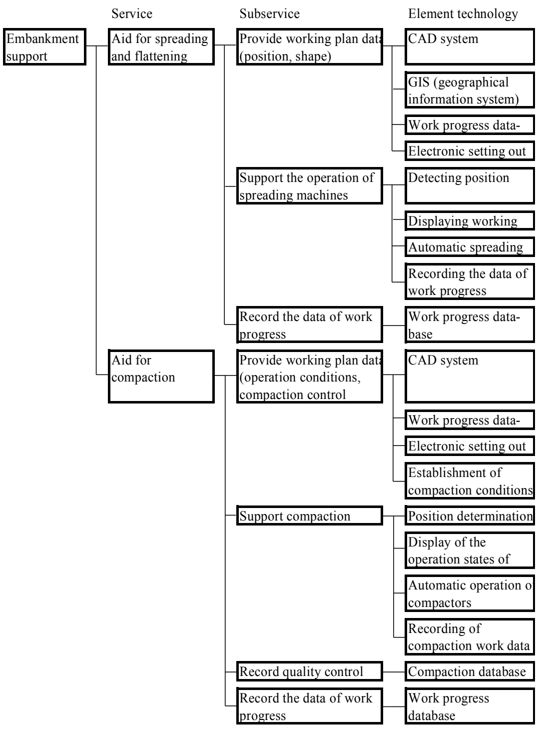


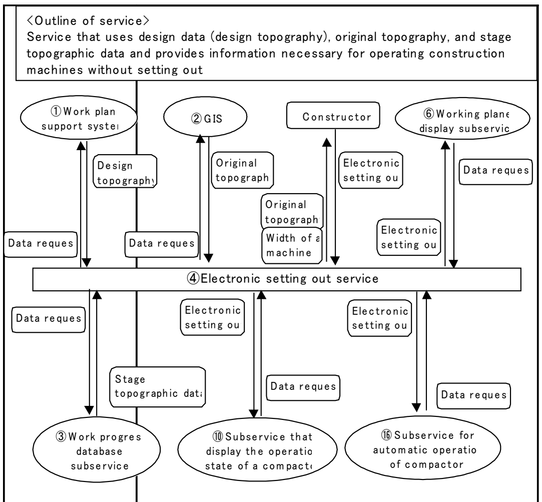
Figure 6. Service system for embanking (ex.)

(2) Drafting a theoretical architecture

A theoretical architecture is a model, 1) to clarify the flow of information between users and a system, 2) to identify the process inside the system, 3) to determine the "information" and "functions" used in the process, 4) to organize "information," and 5) to use a common format to express the relationship between "functions" that necessary for realizing the services and "information" it provides.

The results of a theoretical architecture are 1) an "information model" that has a hierarchical structure of inclusive links among information and 2) a "control model" that uses a single format and expresses the relationships between "functions" necessary for realizing services and "information" the system provides.

A theoretical architecture helps identify "information" and "functions" that can be shared among various subservices. Therefore, a single item must be never expressed with different terms, and each term and its content must be defined.



Data name	
Original topography (input and output)	topographic data before executing project (Examples of data items): position (X, Y), elevation (Z), inclination (transverse / lateral)
Stage topographic data (input)	Topographic data before executing operation, and may be either the original topography or work progress topography. (Examples of data items): position (X, Y), elevation (Z), inclination (transverse / lateral)
Design topography (input)	Topography given by a designer for after the termination of the project (Examples of data items): position (X, Y), elevation (Z), inclination (transverse / lateral)
Electronic setting out (input and output)	Aimed work progress topography for each work stage and control plane data (Examples of data items): position (X, Y), elevation (Z), inclination (transverse / lateral)
Control plane	Unit plane established between two points on aimed work progress topography, and is used to control machines. It may be linear, grid, etc.
Linear plane	Control plane that is composed of a single plane since the topography is laterally symmetrical about the central axis of the structure
Grid plane	Control plane that is composed of various

	different planes since the topography is complex
Width of a construction machine	Width that a blade, roller, or construction machine touches earth (Example of data item): width (B)

Figure 7 Links among systems (image)

(3) Forming a physical architecture

A physical architecture is a model of the entire system for realizing a construction equipment support information system, which shares the combinations of "functions" identified in the theoretical architecture and "information" in all subsystems and distributes them to the client's office, constructor's office, and construction machines.

To be exact, Figure 7 is not architecture, but is an image of a physical architecture for a construction equipment support information system, and it shows the links between subsystems.

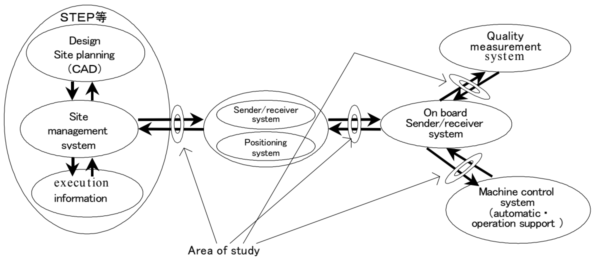


Figure 8. Links among systems

(4) Determining the scope of standardization

The scope of standardization should be organized by evaluating "information" in terms of the degree that is shared among services in the diagram showing the links among subsystem, which is a result of physical architecture formation. An objective of the act is to identify the priority of standardization activities of the organizations and companies that are involved in the standardization of "information" and "communication methods" that are used in many services.

4. FUTURE PROSPECTS

This paper proposed a method for standardizing information exchange rules for construction equipment in order to efficient utilize data collected during the execution of construction projects.

A construction project involves various and complicated organizations, people and systems. The method we proposed may need further investigation and revision. Creation of standards for concrete applications will lead to more advanced construction equipment.

We will also attempt to establish a committee in the Japan Construction Mechanization Association, which is the ISO deliberation organization in Japan, to discuss ISO information systems for construction equipment.

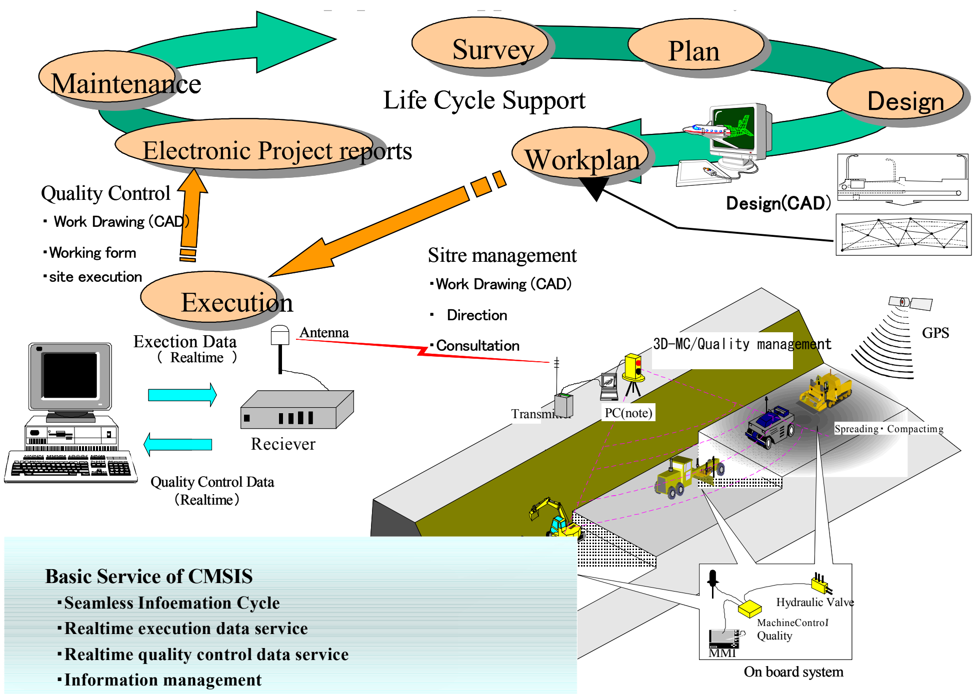


Figure 9. Image of a construction equipment support information system