Study of Data Exchange for Use by Construction Information Systems

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ABSTRACT: Information technology (IT) that is achieving astounding progress has been applied to rationalize construction project management and is expanding the potential for the automation and use of robots in construction work. But the development of IT based systems has often resulted in cases where it is difficult for multiple systems to share electronic data because these systems were developed independently by different makers for use in different types of construction sites and to perform different types of work. In order to use information efficiently to gain the full benefits of such systems, it is vital to be able to transfer electronic data smoothly between construction information systems and between their sub-systems. This will also sharply reduce the cost of using construction information systems.
The authors have organized data exchange concepts and studied the data exchange standards needed to realize these concepts in order to propose a method for the sharing and exchange of data by a number of different construction information systems used to support the execution of civil engineering work. And taking a compaction control system as an example, they have analyzed the categorization and hierarchical structure of data to prepare a data model as the foundation for the construction of data exchange standards.

KEY WORDS: Construction Work, Construction Information System, Data Exchange, Data model, Data Exchange Standards

1. INTRODUCTION

Information technology (IT) that is achieving astounding progress has been applied to rationalize construction project management and is expanding the potential for the automation and use of robots in construction work. But the development of IT based systems has often resulted in cases where it is difficult for multiple systems to share electronic data because these systems were developed independently by different makers for use in different types of construction sites and to perform different types of work. In order to use information efficiently to gain the full benefits of such systems, it is vital to be able to transfer electronic data smoothly between construction information systems and between their sub-systems. This will also sharply reduce the cost of using construction information systems.
This paper considers the significance of and need for ways for multiple construction information systems of different kinds to exchange and share data, and proposes data exchange concepts. It also discusses the merits and demerits of the data exchange standards and describes the composition of them, and based on it, takes an earthwork compaction control system as a specific example to analyze the categorization and hierarchical structure of data in order to establish a data model as the foundation for the construction of data exchange standards.
The results of this study were proposed as part of the standardization activities of the ISO/TC127/WG2 (Earth-moving machinery – Worksite data controlled earth-moving operation) that are now in progress and will be studied to provide basic documents for the preparation of data exchange standards [1].

2. FUNCTION AND ROLES OF IT BASED CONSTRUCTION SYSTEMS

To create construction robots or automated construction systems or any other IT based construction systems (below called, " IT based construction systems"), their functions must go beyond controlling the operation of machinery to include interacting with the world of information. An IT based construction system should be equipped with interfaces to link it with the world of information and with the material world as shown in Figure 1 and with a function that translates meaningful content in each of these worlds so that it is understood in the other [2]. If this is impossible, an IT based construction system

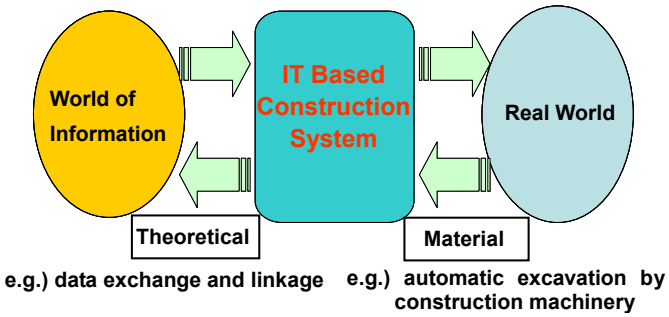

Figure 1. Function and Roles of an IT based Construction System.

cannot automatically and autonomously do the work that people intend it to perform, because it fails to comprehend human intentions. Therefore, studying the interface to link an IT based construction system with the world of information is just as important as researching what kinds of work the IT based construction system will perform.

The part of an IT based construction system that is an interface with the world of information is a system built centered on IT technology and is called a construction information system.

There have been many cases of automated construction system development where a big challenge that had to be overcome to create a final working system was the inability to efficiently and skillfully inform the machinery of human intentions. For example, an automated asphalt finisher that was developed in Japan could perform highly precise work by three-dimensional control of the screed, but during the work, it was necessary to provide pavement design data in detail using three-dimensional data. For normal work, pavement design data is usually provided on plane, longitudinal section, and lateral section drawings as data that the operator refers to during the work, but this meant that preparing and entering the three-dimensional data required to perform automated finishing was an excessively time-consuming task. To apply the system to actual work, it was necessary to write software to read in electronic data such as CAD data etc. or to perform data entry.

3. NEED TO EXCHANGE DATA BETWEEN DIFFERENT IT BASED CONSTRUCTION SYSTEMS

To widely use IT based construction systems for construction work it is of course essential to provide an interface between humans and IT based construction systems as explained above, but it is also necessary to guarantee conditions permitting accurate data exchange between different IT based construction systems.

An interface between an IT based construction system and humans always depends on display and entry systems of some kind. This is true, because although a construction system can respond only to electronic data represented according a previous agreement of some kind, a human can understand text represented by ordinary characters, natural language, drawings, tables, images, moving pictures, and not electronic data, which means that every interface must have a translation function.

Characteristics of construction work relevant to the utilization of IT based construction systems are (1) it generally includes multiple (many) types of work, (2) construction work is work that is completed in a limited period of time, and (3) a necessary construction system is planned and created especially for each construction project. And it is predicted that because of the variation in construction machinery used to perform different types of work and the fact that they are supplied by different manufacturers, there will be construction systems with varying functions and that are used in different ways, so that (4) every construction system will have a unique interface.

Normally, an engineer who is responsible for executing a construction work wants to do it with an integrated system in order to smoothly perform the series of work steps that constitute the work. Therefore, separate construction information systems must function as a single system to be integrated, and to provide this capability, it is essential that electronic data handled by all the construction information system that are positioned as sub-systems of the integrated system can be exchanged by these individual sub-systems. It is also predicted that in more advanced automated construction systems, data representing the results of a prior work step will become entry data needed to perform a later step in the work. But this level of data linkages will only be possible if all construction information systems can exchange electronic data.

4. PROPOSAL OF DATA EXCHANGE STANDARDS

We believe that data exchange standards must be enacted as a basic method to achieve data exchange between different construction systems. In order to realize data exchange between different

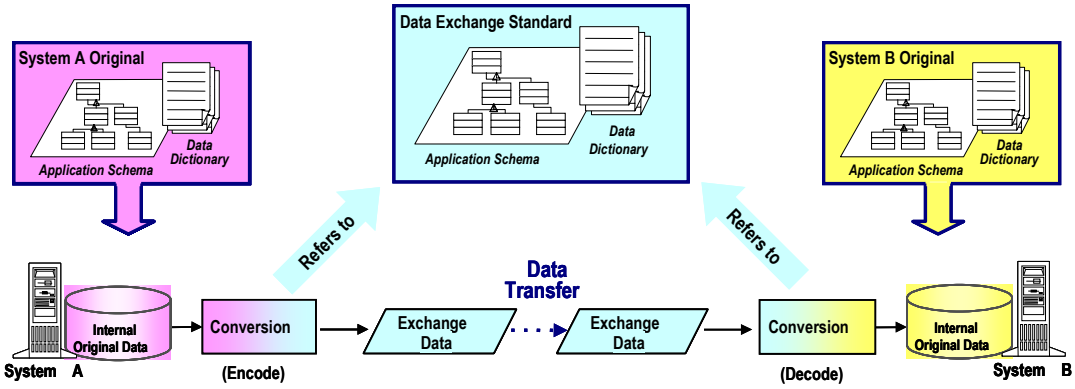

Figure 2. Concept of Date Exchange Using Data Exchange Standards.

systems, many requirements, such as cable connection, electrical connection, protocol and data contents, should be satisfied. Above all, the interoperability of data is the most essential and important. Therefore we focused on the data.

Data exchange based on data exchange standards will be performed by the following procedure [3]. Figure 2 shows an example of the use of data exchange standards to exchange data between two different systems: the smallest unit of data exchange by construction systems.

Data handled by a construction information system is, as explained below, generally defined by an application schema and a data dictionary.

Figure 2 shows how data is transferred from System A on the left to System B on the right. The data transfer is done by converting the data to data based on data exchange standards (below called "standard format data") . Therefore, original format data in system A is converted to standard format data that is received by system B by referencing the data exchange standards. In system B, the standard format data is converted to system B's original format data and used by System B. In order to perform such data exchange, it is essential to guarantee that the data in System A and in System B are both in a one-to-one correspondence with the data in the data exchange standards.

5. MERITS AND DEMERITS OF THE DATA EXCHANGE STANDARDS

It is assumed that using data exchange standards will increase the number of situations where systems can be used over the number of such situations without exchange standards, and the more situations where systems can be used, the greater their beneficial impact on the market. In other words, if exchange standards are not used, conversion software will be needed for each situation where data is exchanged between systems, and if data exchange standards are used, each system will be capable of exchanging data with all construction information systems if it is equipped only with conversion software for the data exchange standards. Needless to say, to use data exchange standards, accurate data exchange standards must be provided.

Preparing and using data exchange standards are expected to have the following useful benefits for parties playing various roles in the market.

- Suppliers (makers) of construction information systems will, by developing and supplying systems that comply with data exchange standards, gain opportunities to participate at sites where systems from different makers are used if the systems comply with data exchange standards. In other words, they will enjoy expanded business opportunities.
- Users of construction information systems can use systems supplied by different makers without being limited to the systems they now use, sharply expanding their freedom of choice.
- As a competitive market for the procurement of construction information systems is formed in this way, it is counted on to contribute to lower costs and higher quality and performance, spurring the development and wide use of these systems.

But on the other hand, it is also predicted that the preparation and use of data exchange standards will, of course, bring disadvantages.

- Because the standards must be created premised on present technologies or those that will be developed in the near future, once a set of standards is in operation, there is a danger

that it will unavoidably apply the brakes to the advance of technological progress or impede technological development. There is also concern that cases where there are existing technologies will incur great cost and trouble in order to adapt them to the standards.

These points must be considered when preparing and applying standards.

6. COMPOSITION OF THE DATA EXCHANGE STANDARDS

Data normally consists of a number of data elements. If, in a case of few data with a simple composition, a data dictionary that stipulates each element is provided, the data may be usable, but generally, an application schema that stipulates the categorization and hierarchical structure of the data and the interrelationships between the data is necessary. A data dictionary stipulates definitions and attributes of data elements positioned in the application schema. The application schema is a conceptual schema obtained from a specific data model.

7. STUDY OF A DATA MODEL

The authors have taken information handled by a construction information system at an earthwork site to analyze and study the data model that will be the foundation of data exchange standards in order to construct an environment that permits the mutual exchange of data between construction systems: a capability that construction systems must have to be of any practical use.

In this chapter, figure 4, figure 5 and figure 6 are drawn in the UML (Unified Modeling Language) notation [4].

7.1 Target Range

The study of data exchange standards have been done focusing on the on-site construction work performed by construction machinery during actual work.

The exchange of data throughout the execution of a construction project involves organizations, systems, and equipment in a variety of positions, but one simplified form can be shown by the model outlined in Figure 3.

To concentrate on data exchange in work site execution, the study first dealt mainly with data concerning the site information system (SIS) shown in the figure [2]. SIS corresponds to the on-site construction information system that is used in ordinary construction work.

The principal uses of SIS were hypothesized to be the use cases in Figure 4.

7.2 Listing Data in an Actual Construction System

The example of a construction information system that was selected was a system used to control embankment compaction work that is a part of earthwork actually performed in Japan, and the data items used for this purpose were listed. Table 1 shows this example.

It shows that these items consist of data concerning work planning or instructions, data concerning the machinery used, data concerning the state of machinery during the work, data

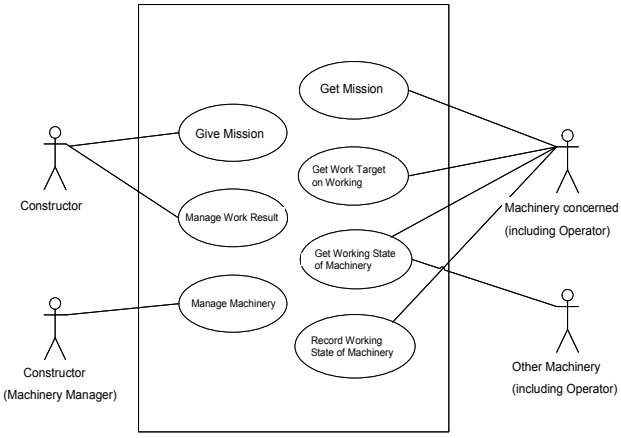

Figure 4. Principal SIS Use Cases.

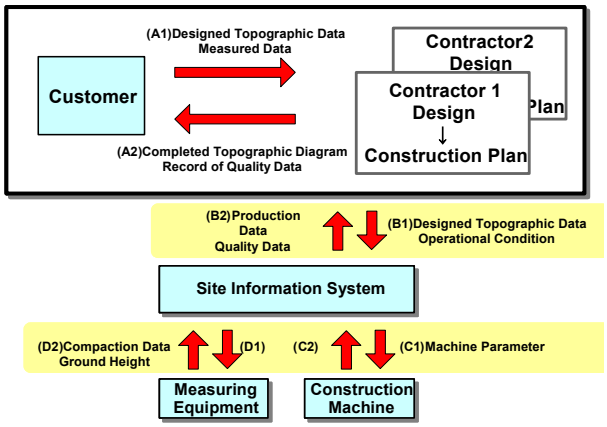

Figure 3. Data Exchange Model of On-site Construction.

concerning work results, and data used to judge whether the work results are suitable.

Table 1. Data Items in Embankment Compaction Work(Example).

1	Work date	2	Supervisor name
3	Operator name	4	Axial direction start point of the construction range
5	Axial dirction end point of the construction range	6	Construction range(Width)
7	Gradient	8	Machinery name
9	Model	10	Serial number
11	Specifications	12	Mesh number
13	Forward/backward	14	Course traveled
15	Data/time	16	Elevation
17	Equipment position	18	Machine position
19	Machinery orientation	20	Roller width
21	Vibromotive force	22	Quality judgement result
23	Difference between compaction heitght and target compaction height	24	Target compaction height
25	Target compaction quality	26	Compaction height
27	Compaction quality	28	Vibration(on/off)
29	Leveled height	30	Target leveled height
31	Difference between leveled height and target leveled height	32	Leveled thickness
33	Target leveled thickness	34	Blade position
35	Blade position	36	Traveling speed
37	Compaction work time	38	Leveling work time
39	Fuel status		

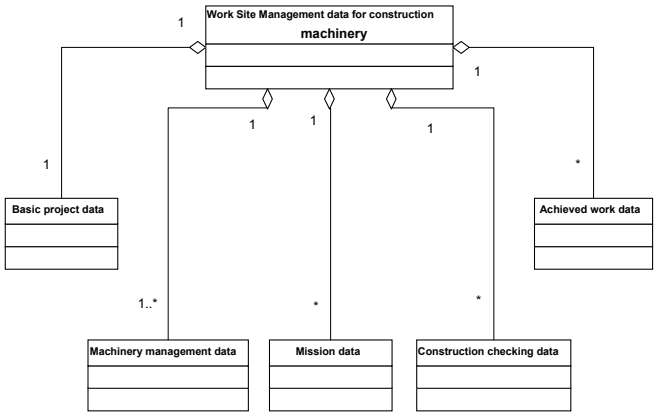

Figure 5. Outline of Date Focused on SIS.

7.3 Study of the Concept of Data Model Preparation

The data model that was prepared was the foundation for the preparation of the application schema of the data exchange standards, and it was necessary for it to be easy to understand and for it to reflect the state of work at work sites in order that an undetermined number of people who use it can gain a common understanding of the model.

Specifically, data centered on SIS used at a work site can, as shown in Figure 5, be broadly categorized as five kinds of data: basic project data, machinery management data, mission data, achieved work data, and construction checking data. This was concluded based on the on-site work contents and work process with reference to the data list described above.

There are also data in these different categories that are extremely closely related and their relationships are indicated by adding sub-categories such as “target data” for the work. At the machinery construction stage, data presenting the state of the work is consecutively produced, recorded, exchanged, and utilized during the work. Therefore, sub-categories that correspond to these (working state of construction machine, etc.) were described. It was also hypothesized that it would be necessary to handle “machine control data” when advanced work or automated work using information is done.

7.4 Results of the Study of the Data Model

Figure 6. shows the framework of the data model that was prepared.

This figure was prepared as the first proposal of a framework for the construction of the data model. In the future, the attributes of each class must be clarified by further studies performed with reference specifically to the ways that various kinds of construction information systems are used.

8. CONCLUSION

This paper has shown that the exchange of data between construction information systems must be achieved in order to make further progress in the introduction of construction robots and automated construction systems etc. and revealed that the following measures will achieve this goal.

- Taking measures based on data exchange standards is the best way to realize the exchange of data between construction information systems. It is counted on to provide manufacturers with new business opportunities and to give users improved freedom of choice, lower costs, and higher quality.
- Data exchange standards consist of an application schema and a data dictionary, and the application schema is developed from a data model.

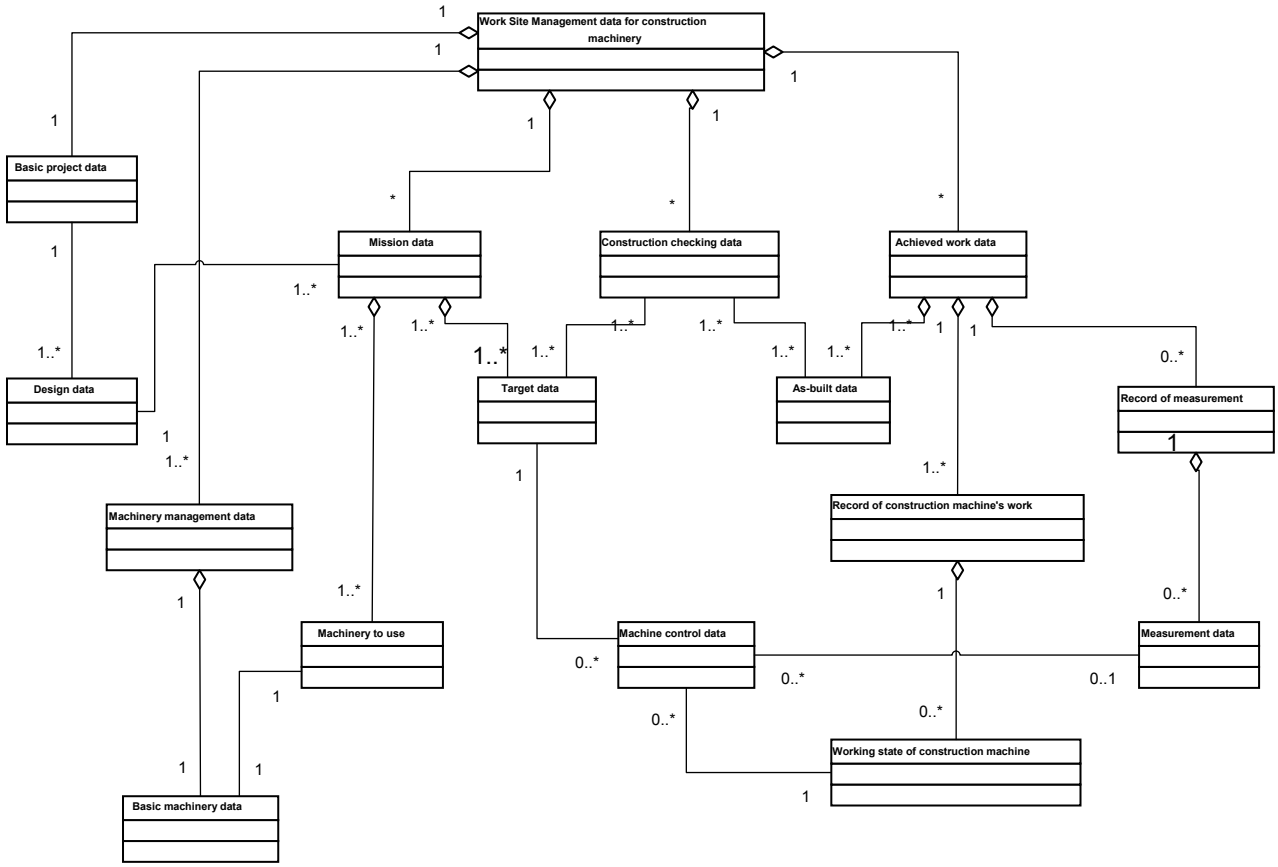

Figure 6. Framework of the Data Model

- The model of the framework shown in Figure 6 was presented as a proposal for a data model of on-site execution.

A detailed data model presenting concrete data elements will be prepared and the application schema of data exchange standards based on this data model will be completed in the future.

The results of this study were proposed as part of standardization activities by ISO/TC127/WG2 that are now in progress and will be studied to provide basic documents for use in preparing data exchange standards.

The data dictionary also will be studied in this WG2.

9. ACKNOWLEDGEMENTS

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