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Utilization of 3D Information on Road Construction Projects in Japan

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Abstract. To promote innovation in public works, an environment is needed where three-dimensional (3D) information on structures can be used efficiently and smoothly throughout the lifecycle of projects. In Japan, there are a few examples of 3D information utilization on road construction projects. In this paper, to promote distribution and utilization of 3D information, several use cases for 3D information are investigated, and the work items required for utilizing 3D information are identified for road construction projects. This paper proposes establishing a utilization platform for 3D data, which requires that existing systems and standards be reorganized and new data exchange standardization proposed. Required steps to implement the use of 3D information in government policies are identified. There are four work items; construction of standardization for exchanging 3D information, construction of road data model, reconstruction of business process model and development of 3D CAD engine.

Keywords: 3D information, information management, product data model, business process modeling, road construction project.

1. Introduction

To promote innovation in public works through the use of information and communication technology, an environment should be provided in which three-dimensional (3D) information on structures can be used efficiently and smoothly throughout the lifecycle of projects. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism has established the Continuous Acquisition and Lifecycle Support / Electronic Commerce (CALS/EC) Action Program 2008[1], which advocates the development of a utilization environment for 3D information. At present, the use of electronic data in public works projects has not been optimized, and efforts have not been undertaken from the viewpoint of total optimization in the lifecycle of projects. Therefore, it is necessary to identify and define specific work procedures where utilizing 3D information is beneficial (quantity calculations, etc.) and uses with clear downstream process improvements such as data input into quantity calculation software. Furthermore, work processes must be designed based on these uses, and if necessary, systems should also be created and exchange standards developed.

The objectives of this research are to clarify the work items that should be carried out to realize a utilization platform for 3D information on roads construction projects in Japan, and to provide a roadmap for proceeding with the planned development of such a platform. The 3D information utilization platform considered in this research is an environment that could be used not only by the Ministry of Land, Infrastructure, Transport and Tourism, but also by local governments and medium- and small-sized private businesses. Development a successful 3D utilization platform would achieve practical and specific results in the construction of public works projects.

2. Use Cases for 3D Information

The industry has not been able to produce sufficient momentum to enable the truly widespread use of 3D information. It is important to build from simple and useful cases of how practitioners have implemented technologies on their projects in the past to gain momentum in the future [2]. In this paper, various uses

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relating to road surveys, planning, design, construction, operation and maintenance are investigated in existing academic papers, reports, and Web pages. In road surveys, 3D surveying and 3D virtual reality for design collaboration and explanation currently exist. 3D surveying can be classified into aerial surveying and ground surveying. At the planning stage, 3D information is used to simulate estimates, environment impact, and disaster scenarios. Simulation examples are presented in [3, 4]. In these examples, 3D information is used for resident outreach, education, and public relations in general. At the design stage, 3D information is utilized in road and bridge design using 3D computer-aided design (CAD) software. Examples include bridge design using a product data model [5], reinforcing bar arrangement design using augmented reality [6], and 3D design system [7]. In the future, 3D information will be used for planning routes and estimating supply quantities when designing roads and main structures. At the construction stage, 3D information is used as an observational method and a model for distributing product data from design to manufacture. Systems that have been developed include project management systems [8] and construction work control systems that consider temporal information [9]. 3D models help to determine overall site management strategies during the construction phase, the coordination of contractors, the planning of site logistics or access routing, or the phasing of handovers of completed parts of the facility between different subcontractors [2]. At the operation and maintenance stage, few examples using 3D information exist in the research results. In the future, it is expected that 3D information will be used for visualization of buried road objects, observation using 3D sensing technology, road maintenance management, and 3D simulation.

3. Product Data Model and Business Process Model

3D information should be standardized based on international de jure standards for exchanging and sharing data, as interoperability and compatibility are important in developing a platform for sharing road information. Therefore, it is useful to define the rules of information exchange and sharing using existing standards and specifications. This paper proposes the use of the following standard categories for defining road data model information.

- *Business process standards* are standards relating to business processes and the management and construction of information shared between companies and government agencies. These standards involve business processes, quality management, and project management.
- *Information infrastructure standards* are standards relating to the system infrastructure for exchanging and sharing information. These standards include the infrastructure requirements for middleware and platforms, operating systems, security, databases, communication networks, and information exchange media.
- *Information sharing standards* are standards relating to information that is exchanged and shared between companies and government agencies. These standards include requirements for information sharing systems and middleware, document structure, application system data, text data, and drawings.

In Japan, the two-dimensional (2D) CAD data exchange format “SXF” is standardized using ISO10303 Part 202, also known as STEP (Standard for the exchange of product model data) developed by the International Organization for Standardization (ISO) [10]. However, 3D information falls outside the scope of Japanese construction CAD data exchange. ISO 10303 Part 203 is used for standardizing, exchanging, and sharing 3D information [11]. A wide variety of construction projects involving roads, buildings, rivers, and the like generate information on geometric shape and attitude [12]. In standardizing 3D information, a product data model should be constructed for defining and systematizing the lifecycle information of roads. A product data model is defined by its method of representing product and shape information over the lifecycle of structures. Product data model contains the product’s attributes from documents, CAD data, drawings, design calculations, and other sources so that construction project participants can access this information. On the other hand, building information modeling (BIM), a 3D object-oriented CAD technique, is one of the most promising developments in the architecture, engineering, and construction (A/E/C) industries. BIM covers geometry, spatial relationships, geographic information, and building component quantities and properties. With BIM technology, an accurate virtual model of a structure is constructed digitally. This technique is effective for building an environment where various types of construction

enterprise information are used in an integrated manner [13]. The product data model is similar to BIM, as both have data on geometry, spatial relationships, and attributes. In this paper, the existing maintenance processes and information for constructing the product data model and business process model are analyzed. The results are used to model the process and data models as currently built. The required functions of the future model are analyzed and described through a use-case diagram in Unified Modeling Language (UML). Because "product" is equivalent to "road," this paper proposes the road data model shown in Fig. 1. The road data model consists of structural and work information that describe the project using the class diagrams. The information is standardized and defined in an XML schema.

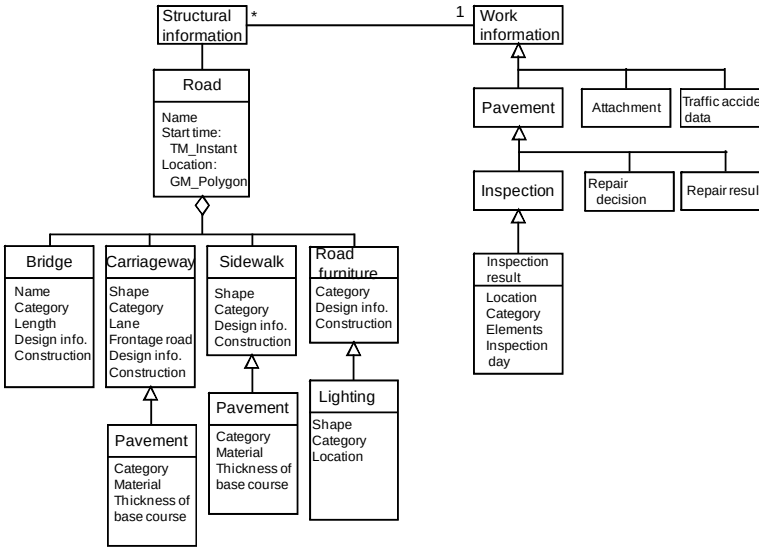

Fig. 1: An example of road data model.

It is important to explore ways to integrate the exchange of 3D-model-based information into the work and business processes of the construction industry [2]. Based on the survey results of the previous section, the business process model for the use of 3D information and future work processes was constructed [14]. UML activity diagrams are used to construct the model and the work processes that should be transformed as a result of 3D information were identified. Work processes are modeled by analyzing maintenance flow. The road data model is utilized in the work process. Also, the utilization flow of the constructed road data model is defined in temporal sequence.

4. Roadmap for the Utilization of 3D Information

In this section, a roadmap for the utilization of 3D information is proposed. Based on these results, work items that should be carried out to realize a distribution platform for 3D data are clarified, and a roadmap is proposed as an instruction manual for proceeding with the planned development. Specifically, Table 1 shows the work items for using 3D information on roads construction projects in Japan. Standardization and methods of producing 3D information, road data models, and business process models will be specified as previously discussed. In development of the 3D CAD engine, both a 3D CAD engine and domain-specific 3D CAD software will be developed. Considering past case studies, 3D CAD software should have the following functions:

- making 3D geography data;
- inputting 3D geography data and confirming certain data attributes;
- producing 3D simulation data using 3D geography and design data;
- conducting longitudinal design and calculations of earth volume using 3D geography and design data; and
- outputting machine control data using 3D design data.

Table 1: Work items for using 3D information in road construction projects

Work Item	Contents and Specifications
Development of standards for exchanging 3D information	Standards for exchanging 3D information based on ISO Specifications for producing 3D information
Construction of road data model	Road data model with definition of attributes
Construction of business process model	Future business process model Evaluation and spread of business process model
Development of 3D CAD engine	3D CAD engine Domain-specific 3D CAD software

In Japan, it is difficult to utilize 3D information in the product data models and business process models in local governments and small- and medium-sized private businesses. The potential application to local government and construction companies was investigated for the Iwate Prefecture. Awareness of the ability to submit deliverables in electronic form is not high in some local governments, so implementing work processes using of 3D information in roads construction projects would seem to be still difficult. Therefore, the merits of using 3D information should be widely communicated.

Fig. 2 shows the examples of simulation results using 3D information [15]. Road construction project participants can share the prospective simulation result of construction. Road administrators can mange the repair plan with temporal axis.

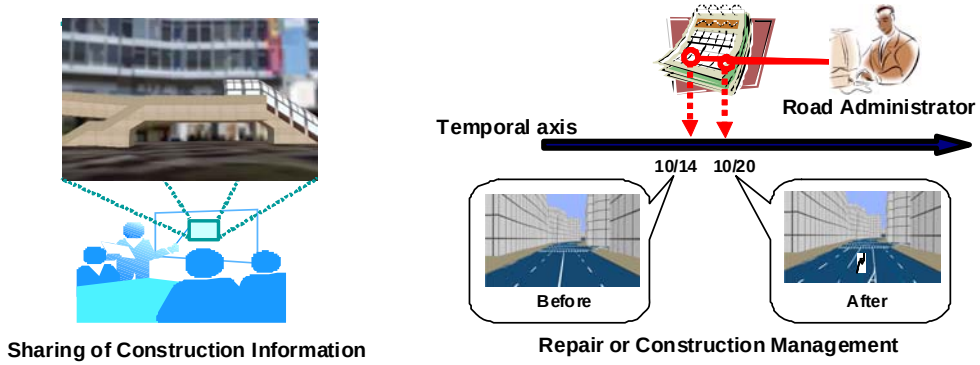

Fig. 2: Simulation results using 3D information.

5. Conclusions

This paper discusses the utilization of 3D information to clarify the work items that should be carried out in order to realize a utilization platform for it on road construction projects in Japan, and to provide a roadmap for proceeding with its planned development. The research included in this paper is summarized below.

- Specific situations where the utilization of 3D information can be effective were identified and the various uses described in existing academic theses, reports, and Web pages relating to road surveys, measurement, design, construction, and maintenance were investigated.
- To realize the utilization of 3D information, reorganization of the existing systems and standards, transformation of systems, and new data exchange standardization are necessary.
- The work items that should be carried out in order to create a utilization platform for 3D information were clarified, and a roadmap was proposed as an instruction manual for proceeding with its planned development.
- Standardization of data exchange is proposed. Establishing 3D data exchange standards and amending the draft requirements for submission of deliverables in electronic form and CAD drawing preparation standards is necessary to facilitate the exchange of 3D information. Furthermore, Japan

does not have a domestic 3D CAD engine, so development of such an engine should be accomplished as soon as possible.

6. Acknowledgements

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