

STUDY ON THE ELABORATION LEVEL OF CIM MODELS AIMED TO UTILIZE FOR MAINTENANCE OF SLUICE GATES AND SLUICE PIPES

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Abstract: As labor productivity in the construction industry is rather low compared with other industries currently, it is required to improve efficiency of construction projects by introducing production systems using ICT. As one of its measures, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is working on CIM (Construction Information Modeling), aiming to realize an efficient production system in good quality as well as advance maintenance work and improve its efficiency, by adding different kinds of information obtained in the phases of research and design, execution, and maintenance to three-dimensional (3D) models and utilizing them. In this study, I assumed a situation for applying CIM for the purpose of the efficiency of the maintenance for sluice gates and sluice pipes, each of which is a complex structure consisting of a civil engineering structure and mechanical equipment, and it verified the effectivity through the interviewing to the maintenance person in charge. Also, required in order to achieve strong need situation was verified what kind of functions 3D models should have, how to create them, and how to add different types of information. Furthermore, prototype models of CIM that embody these were evaluated through interviews with those in charge of maintenance.

Keywords: CIM, 3D Models, Sluice Pipe and Sluice Gate, Maintenance

1. INTRODUCTION

Some problems have surfaced in construction projects in that labor productivity is lower than in other industries for its distinctive character (such as built-to-order manufacturing of a single unit), as well as increase in the maintenance cost due to the aging of the social infrastructure stock, aging of engineers, and shortage of skilled workers.

As it is getting harder to get hold of personnel and budget for construction projects, it is required to improve efficiency of and advance the entire work through construction production processes utilizing ICT technologies in order to ensure the quality of constructed products and properly manage the aging social infrastructure.

MLIT is working on introduction of CIM (Construction Information Modeling), aiming to advance the construction production system with ICT technologies and improve productivity. CIM is representation of the forms and structures of a physical object as a 3D model with different kinds of information about design, execution, and maintenance as its attributes added to it, enabling their unified management and higher efficiency of the entire construction production processes.

There are also various efforts on CIM application made outside our official projects. For example, uses CIM as a tool for operational management (Kobayashi et al., 2014), while (Fujisawa & Yabuki, 2012) has been examining the use in collaboration with structural analysis softwares and for integration. In the maintenance field, many studies are conducted for the purpose of sophisticating the maintenance process. These include creating a product model that contains deformation of a concrete structure led by (Aruga & Yabuki, 2013), as well as (Sasakura et al., 2014)'s application on predicting deterioration in open-cut tunnels with it.

In order to expand and establish the use of CIM at the actual job sites, it's essential to demonstrate its positive effects within the framework of the existing working systems. As part of this approach, (Shimizu et al., 2013) have been looking into integrating 3D modeling with the existing bridge maintenance management system for a railway rigid-frame viaduct, while (Yokoyama, 2014) is examining the possibility of CIM application in dam operation. These studies, however, haven't covered the 3D model creation process itself, which suggests that the level of detail and the essential features on 3D models required for the practical use are yet to be examined.

The 3D model created at the designing or constructions process will be used in the maintenance stage as well. If the level of detail and the required features needed at the maintenance stage are not identified in advance, the concerns are either spending too much time in 3D modeling elaborating unnecessary details, or in contrast, lacking the features that's essential to the maintenance stage.

As part of investigation towards introduction and spread of CIM, this paper applied the mechanism of

CIM to the sluice gate and pipe, studying its effect on efficiency of the maintenance work. It is assumed that visualization by 3D representation and integrated management of information have high effects in that a sluice gate and a sluice pipe contain not a few invisible areas such as water-impermeable sheet piles or piles, that each one is a complex structure consisting of a civil engineering structure and mechanical equipment systems, and consequently that maintenance personnel range widely over different areas of civil engineering, machinery, and telecommunication. Specific procedure of study is as follows. Assuming the situations for applying a 3D model in the maintenance phase, we clarified the functions required for the 3D model, and what level of elaboration a 3D model with these functions should attain. Based on the results, a prototype of CIM was created by integrating different kinds of in-formation required for maintenance into the 3D model of the object structure.

2. SITUATIONS FOR APPLYING 3D MODELS IN THE MAINTENANCE PHASE

A 3D model can be created with limitless precision; however, it is hard to obtain sufficient cost-effectiveness unless it is created after setting the level of elaboration according to the usage, parts to model, and the range of creation. Regarding BIM (Building Information Modeling) for buildings, there are guidelines etc. that prescribe the level of detail of a 3D model (Government Buildings Department). Thus it was determined to set the level of elaboration according to the situation for applying 3D models after clarifying such situations in the maintenance phase for sluice gates and pipes.

Advantages of utilizing 3D models in the maintenance phase that can be mentioned are "visualization of facility-related objects" and "easy information management".

(1) Visualization of facility-related objects

Conventionally, multiple drawings have been used to confirm the structure of an object facility, surrounding conditions, equipment layout, and underground facilities. This requires long time to grasp the structure and its surrounding conditions.

Visualizing them on a 3D model not only allows instant grasp of the structure and surrounding conditions but also makes it easy for the concerned parties to share understanding (Economic Research Association, 2013) (Figure 1).

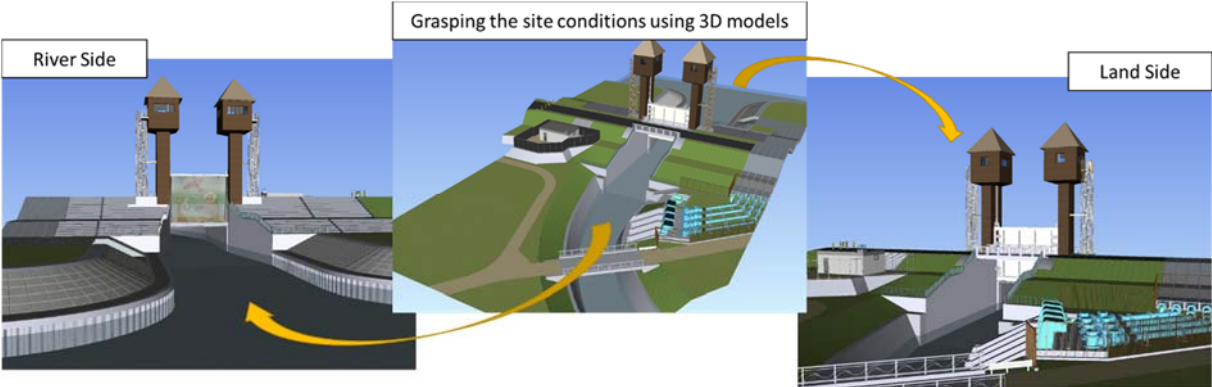


Figure 1. Visualization of the structures of object facilities and surrounding conditions

Also, visualizing the damage or changes in the structure on the model allows instant grasp of the correlation between the member or facility and the surrounding conditions. This leads to clarification of the cause of damage, decision of whether repair is necessary, or faster decision on the selection of the construction method (Figure 2).

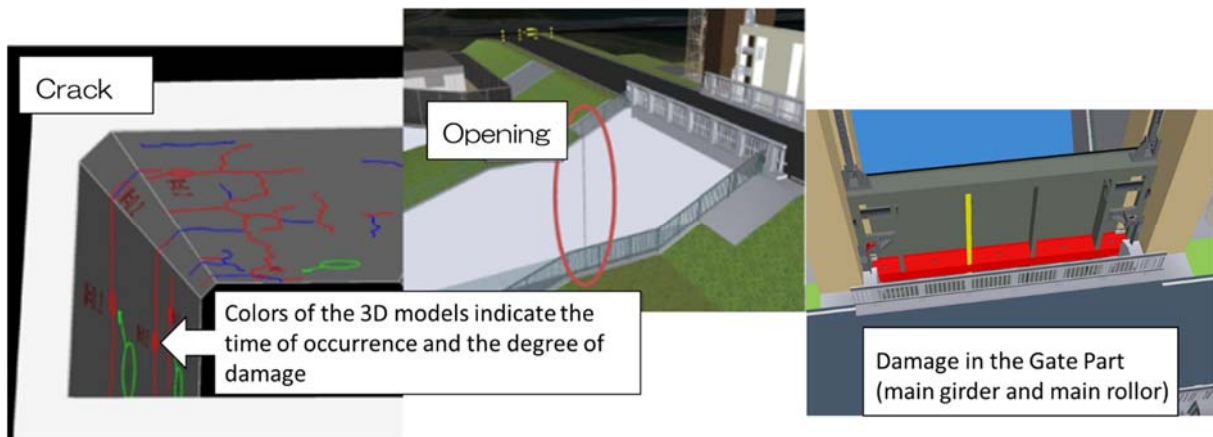


Figure 2. Visualization of member damage

(2) Easy information management

Many materials need to be referenced in the maintenance phase, such as ledgers, as-built drawings, inspection records, and repair records, in the form of both paper media and electronic data mixed up together. In addition, since those materials are kept here and there with multiple members in charge or in storages, there are risks that duplicate data are stored and that inconsistency or obsolescence of information occurs. Consequently, it takes much time to gather necessary information. Moreover, since multiple personnel or contractors perform maintenance work over a long period of time, management of the update history is a heavy burden.

In the current situation like this, if huge amount of complicated materials can be integrated as attribute information into one 3D model, unified management of different types of data will be enabled, leading to prevention of duplicated storage or inconsistency, as well as making it easy to manage the history. Further, linking the three-dimensional locations of individual elements that constitute the structure such as members and facilities with each piece of information enables visual and intuitive search and reference for necessary information (Taniguchi et al., 2013) (Figure 3).

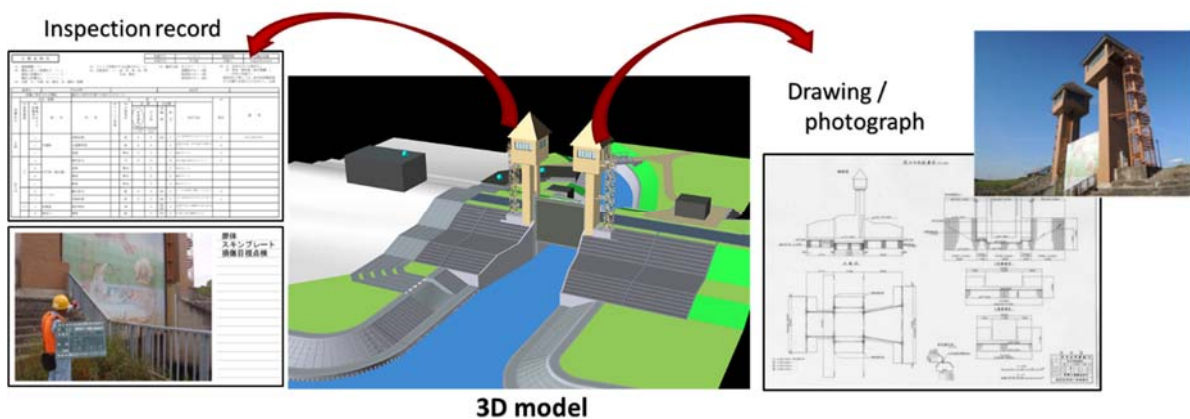


Figure 3. Unified management of information by 3D modeling and improvement in search ability

(3) Extracting situations for applying CIM models in the maintenance phase

Keeping advantages of 3D models in mind, we summarized the effects to be expected in certain situations for applying 3D models. We also interviewed river structure maintenance staff and inspectors for their opinions about the summarized results to confirm the needs. Table 1 shows their typical opinions.

From opinions of the maintenance staff, there was a strong need for "easy information management" both for civil engineering structures and mechanical equipment systems, and a necessity of a mechanism of managing various types of information in a unified way was confirmed. Regarding maintenance of mechanical equipment systems, it was found that a need for 3D models with elaborated sizes and forms is not so strong. Regarding civil engineering structures, on the other hand, it was found that there is a rather higher need for representing damage status on the 3D model to confirm at a glance, and that 3D models with detailed elaboration to a certain degree are necessary.

Table 1. Expected effects of 3D modeling and opinions of on-site staff

Situations for application	Expected effects	Opinions of maintenance staff
"Visualization of facility-related objects"		
Visualization of the structure of the object facility and surrounding conditions	Usable at the time of taking over duties, in technical guidance, or as materials for consultation or explanation	Needs for detailed and precise 3D models are low if they are used only for explanatory materials. Effective in taking over duties or education of new members, but the frequency that they can be utilized on site is low.
Visualization of damage of members etc.	Useful in cause investigation etc. for its ability of overlooking the positional relationship between the surrounding conditions and damage point.	Useful in making a repair plan or selection of a construction method because the entire damage status can be confirmed at a glance.
"Easy information management"		
Unified information management and higher search ability realized by 3D models	It becomes easier to manage related materials in a unified and structural way, as well as help reach the necessary material or information from each element quickly and sensuously.	As data can be structurally organized and managed unconsciously by linking them with 3D models, it makes easier to manage every type of data in a unified way and improves search ability, leading to higher work efficiency.
	Spatial positional information of a 3D model is easy to connect with ICT apparatuses (tablets etc.) that can range the self position, resulting into advancement and automation of inspection.	It can be expected to spread if it allows higher inspection efficiency by combining with ICT tools, without changing the current inspection approach.

3. FUNCTIONS REQUIRED FOR 3D MODELS

Based on the highly desired uses of 3D models for improving efficiency extracted from the opinions of maintenance staff in the previous section, the functions required for 3D models to have were summarized. Since "easy information management" with 3D models was highly desired both for civil engineering structures and mechanical equipment, it was decided that a 3D model should have a function to link each member or a position within a 3D model with attribute information such as a photograph or ledger from outside.

Regarding "visualization of facility-related objects", a 3D model of a civil engineering structure should have a detailed form so that it can reflect positions of damage etc. correctly. On the other hand, a 3D model of mechanical equipment was decided to represent with a simple method enough to distinguish the spatial positional relationship, names and types of facilities, rather than representing all the forms and components precisely, based on the opinions from maintenance staff such as "It is not necessary to precisely represent 3D forms of individual parts in the maintenance of equipment", or "For improving efficiency by visualization, it is enough as far as positional relationship can be grasped, like which equipment is put in where within the facility".

4. SETTING THE ELABORATION LEVEL OF A 3D MODELS

Based on the summary of the required functions for a 3D model, its elaboration level was set specifically. As to a civil engineering structure, it was set as a detailed model keeping precise 3D forms. As to a mechanical equipment model, it was decided to be a simple model that keeps a function of indicating names of the object facility and its spatial positional relationship. Settings were divided into two cases according to the maintenance approach and scale of the equipment. Table 2 shows an overview of the elaboration level of each model.

For a civil engineering structure, it was decided to create a 3D model representing the three-dimensional geometrical sizes precisely (Figure 4).

Among mechanical equipment, the door body, opening/closing mechanism, and power generator etc., which need managing with continuous maintenance, are large in scale. Thus it was decided to create each model as a block model that allows the viewer to confirm the appearance and direction of the object facility, by making a rectangular solid 3D model of approximately correct relative size with each other, pasting drawings or photographs on it as the texture (wall-paper image), and placing it in the position of the object (Figure 5).

For small-scale apparatuses such as meters, instrumentation boards, and water gauges etc. that are to be replaced periodically or when any abnormality is confirmed, it was decided to create a button-shaped model (button model) with a function of showing the spatial position within the 3D model and that of linking with external attribute information (Figure 6).

Table 2. Overview of the elaboration level of a 3D model

Object	Civil engineering structure	Mechanical equipment	
		Facility to be managed with continuous maintenance	Facility to be exchanged periodically or at abnormal conditions
Required functions	<ul style="list-style-type: none"> • Capable of linking information • Represent the 3D form precisely so that the position of damage can be clearly indicated 	<ul style="list-style-type: none"> • Capable of linking information • Appearance, direction, and position of the object facility can be confirmed 	<ul style="list-style-type: none"> • Capable of linking information • Spatial position of the object facility can be shown
Model name	Detailed model	Block model	Button model
Model outline	3D model having a precise form	Model deformed into a 3D form easy to create (a cube etc.) with a texture pasted on it	An object in the form of a button is placed in the position of the object facility without representing a 3D form
Example of object	Main body, blade wall, gatepost, sheet pile, foundation etc.	Door body, opening/closing mechanism, power generator etc.	Meters, instrumentation board, water gauge etc.

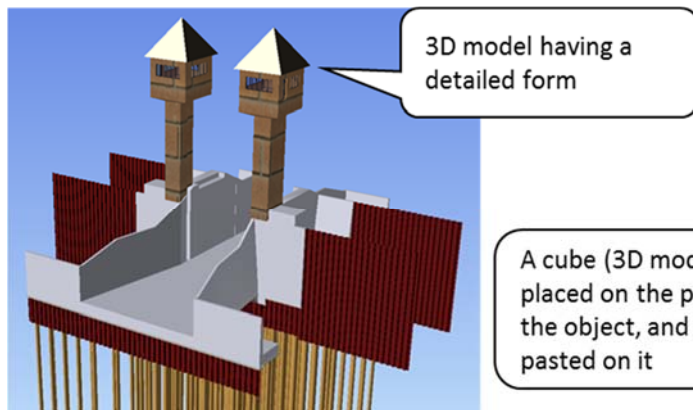


Figure 4. Detailed 3D model of a civil engineering structure

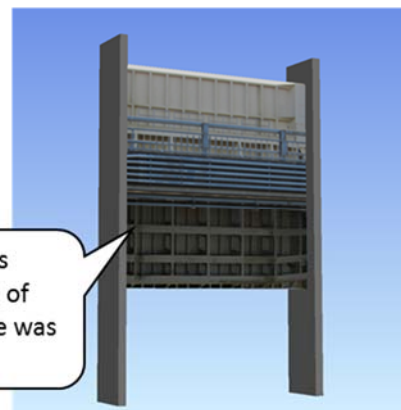


Figure 5. Block model of mechanical equipment (door body)

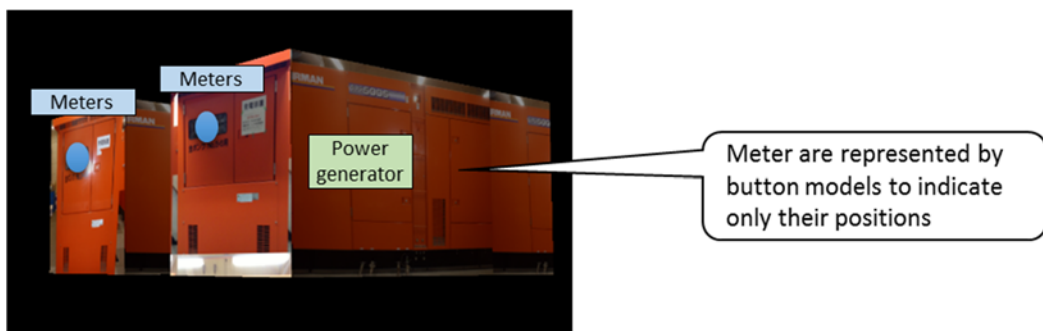


Figure 6. Button models of meter (the power generator is represented as a block model)

5. PROPOSED CIM PROTOTYPE MODEL

Figure 7 shows a CIM prototype model, which enables unified information management, excellent search ability, and traceability by linking different attribute data used for maintenance with each element of a 3D model.

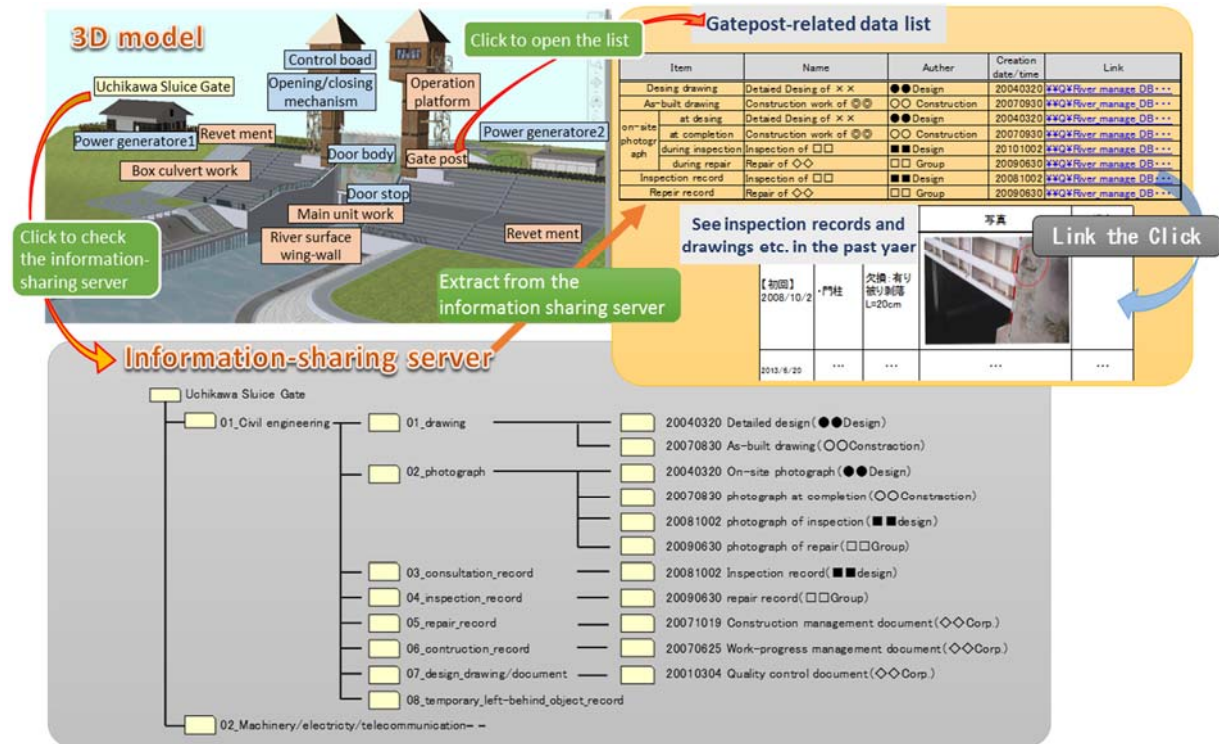


Figure 7. CIM prototype model for the sluice gate and pipe

This prototype model is built up of a 3D model and an information-sharing server that stores every sort of information. Attribute information used for maintenance includes data that cannot be directly stored within a 3D model, such as drawings, photographs, and inspection records. These are not directly saved in the 3D model but saved in the external information-sharing server, and linked with the entire facility targeted for 3D modeling or its individual elements. Maintenance staff can look at the aimed information easily and intuitively by clicking the corresponding element on the 3D model. Selecting the target element of the 3D model will open a list of related attribute information, allowing the required information to be selected from the list. Links of the attribute information with each element saved in the information-sharing server can be extracted and indicated on the list, enabling unified management of information.

The data saved in the external information-sharing server can be operated using the similar mechanism to a normal Windows Explorer, though folder configuration and the naming rules of files are fixed. This allows the maintenance staff to add or update attribute information such as inspection results, even if they are not experienced with operation of a 3D model.

6. THE VERIFICATION OF THE PROTOTYPE MODEL

We introduced the prototype model which was created this time to the maintenance staff and confirmed it by interviewing whether maintenance promoted efficiency. Table 3 shows their typical opinions.

Table 3. Opinion to prototype model

	Comment
Investigation into cause of damage	An association between neighboring situation and damage becomes clear, and it helps caused investigation by 3D model.
higher inspecting efficiency	The part that you should confirm in particular by visualizing a past check result becomes clear.
	The appropriate way of repairing and repair range can select by the visualization of damage status.
easy information management	Leading to efficiency by Unified information management to each facility
	Related information of the inspection target has been listed, to improve the searchability.
Requirements	Desire that efficient maintenance work is this model, it is not spread by changing the concept of the current maintenance methods.
	It is necessary to be able to simplify linkage of the attribute data.

7. CONCLUSIONS

This study established the elaboration levels of standard 3D models on the assumption of applying them in the maintenance phase of sluice gates and pipes, and created prototype models of CIM. A certain degree of evaluation was acquired by the maintenance staff for easy information management and improvement of search ability, higher inspecting efficiency, and application in investigation into the cause of damage.

However, this is not a result of the use in actual maintenance site, the evaluation results for demonstration using a prototype model. In the future, we plan to perform on-site experiments using these models to verify the effects, and examine further improvement of maintenance efficiency by increasing applicable situations and improving models.

We also believe that it is important "not to greatly change the method and concept of current approach to maintenance" and "not to increase the labor of site personnel by introducing a new tool" in introducing and spreading CIM smoothly. Keeping these in mind, we are willing to promote further study.

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REFERENCES

- Aruga, T. and Yabuki, N. (2013). Application of a product model of degradation for civil engineering structures management, *Journal of Japan Society of Civil Engineers, Ser.F3 (Civil Engineering Informatics)*, 69(2), pp.1_71-1_81.
- Government Buildings Department, Minister's Secretariat, Minis-try of Land, Infrastructure, Transport and Tourism; "Guideline on creation and use of BIM models in government maintenance work", 2014.
- Economic Research Association, "2012 Report of CIM Technology Committee", 2013.
- Economic Research Association, "2013 Report of CIM Technology Committee", 2014.
- Fujisawa, Y. and Yabuki, N. (2012). The cooperation between a 3D model and analysis software for railway viaducts, *Journal of Japan Society of Civil Engineers, Ser.F3 (Civil Engineering Informatics)*, 68(2), pp.1_1-1_8.
- Kobayashi, Y., Ogata, S., Hoshino, Y. and Kobayashi, I. (2014). A study of the project management technique by the CIM the model of which was new Suizenji station district transportation nod improvement business, *Proceedings of the 39th Symposium on Civil Engineering Informatics*, 39, pp.41-44.
- Sasakura, N., Nakayama, T., and Kudou, t. (2014). Toward the advancement of maintenance utilizing the CIM model, *Proceedings of the 39th Symposium on Civil Engineering Informatics*, 39, pp.53-56.
- Shimizu, T., Yoshikawa, M., Tatsunami, H., Misaki, N., Takahashi, y., Nakayama, T., Uchida, O. and Kondou, K. (2013). The development of the bridge development creating and the management system which used 3D model, *Proceedings of the 38th Symposium on Civil Engineering Informatics*, 38, pp.123-126.
- Taniguchi, H., Aoyama, N., Shigetaka, K. et al., "Integrated Information Management System using 3D Model for Maintenance of Bridge Construction ", *JSCE, ICCBEI 2013*, pp.419-424, 2013.
- Yokoyama, K. (2014). The efforts of the CIM to the Isawa dam management transfer, *JACIC Information*, 110, pp40-45.