Information Management in Infrastructure Project Delivery for Effective Usage of Construction Information Modelling in Japan

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***Abstract*—** In Japan, the application of Building Information Modeling (BIM) to public infrastructure projects is called Construction Information Modeling (hereinafter referred to as CIM). The Ministry of Land, Infrastructure and Transport has been promoting the utilization of BIM / CIM for public projects.

In the case of the construction project of underground facility, precise position information of underground buried facility is required in order to carry out so-called virtual construction in designing with the three-dimensional BIM model data linked with information on cost and scheduling.

In this research, firstly, we created a BIM model from two-dimensional drawings actually used in the construction project of a private railway underground station. It was confirmed that proper management of information from design phase was indispensable in order to utilize BIM technology effectively.

Next, we discussed the issues to raise the productivity of social infrastructure projects by appropriately managing the information of BIM. One of the most important issues is improvement of design quality considering the workability and maintainability by consultants responsible for designing. It is necessary to foster and secure human resources such as BIM creators, BIM managers and designers who understand construction and maintenance. Also, in order for designers to have an incentive to utilize BIM for designing, the copyright of the design result product should be left to designers and not transferred to owners. It is recommended for public sectors as owners to abolish the upper limit binding on the planned price and to introduce the negotiation method in the design work contract because these procedure would not greatly increase the life cycle cost of the project.

***Keywords*—** Building-Information Modelling, construction information modelling, design improvement, Infrastructure.

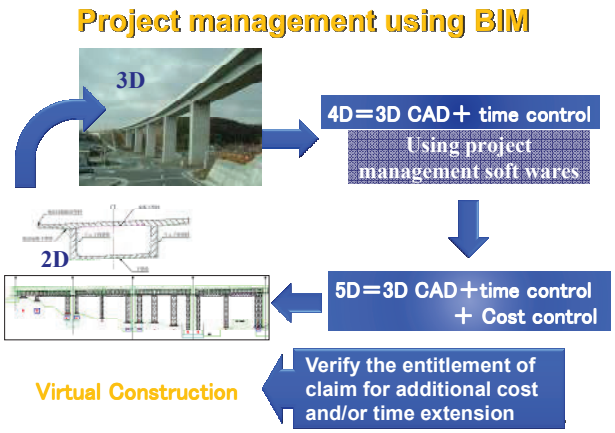

Fig.1 Front loading by using virtual construction with BIM [1]

I. Introduction

In Japan, CIM (Construction Information Modeling) was proposed under the leadership of the Ministry of Land, Infrastructure and Transport, in order to introduce the application precedent in the building field into the civil engineering field. However, information management in the life cycle, such as collaboration from design to construction, and discussion on the form of contract execution for that purpose are underway.

In this study, we show that management of information is indispensable for fully exploiting the usefulness of BIM model by constructing BIM model based on 2D drawing in an actual construction project. The authors identified obstacles to create 4-dimensional BIM data, in which three-dimensional BIM data and Gantt chart are linked, from two-dimensional CAD drawings and process chart. Also, design changes of the water stop wall position at the time of construction were classified for each cause. The main cause of the design changes was insufficient accuracy of grasping the position of the buried pipe at the time of designing. Consequently, in civil engineering works in urban areas, integrated management of underground information such as buried pipes is important for effective utilization of BIM.

Second, strategic issues for productivity enhancement of public infrastructure projects with BIM technology are discussed. Enhancement of BIM-related capability, establishment of collaboration strategy, and merit maximization of consultant companies, contractors and owners could lead to productivity enhancement of construction industry especially dealing with public works.

II. Issues in Actual Underground-Railway Station Construction

The authors show that management of information is indispensable for fully exploiting the usefulness of BIM model by constructing BIM model based on 2D drawing in an actual construction project.

Target construction project

The target construction is an underground railway-station building construction designed and constructed using two-dimensional drawings without using BIM technology. Unexpected buried pipes were found in the process up to temporary lining, which caused a schedule delay in construction. Targeted phase in this study is the temporary construction phase of this project. Cost and construction period of these kinds of projects are usually affected by the uncertainty of the position information of underground buried objects. Also, for a long period of time and for a wide range of construction, we analyzed processes up to road covering in some sections.

- Contractor: A Joint venture
- Construction Duration: Ten years from January 2005
- Provided data:
  - Two-dimensional design drawings
  - Monthly bar charts for three years
  - Cost evaluation tables

General drawings of the temporary work, sectional views of water barrier walls, side views of vertical lines, plane views of cutting beams and road covering drawings were used to make a BIM model. Fig.2 shows an example of 2-dimensional general drawings of a temporary work of the target underground railway station, and Fig.3 is its 3-dimensional model. Many inconsistencies among the 2-dimensional drawings were confirmed with respect to existing or planned buried pipe positions from the created simple three-dimensional model.

The authors identified the following obstacles to create 4-dimensional BIM data, in which three-dimensional BIM data and Gantt chart are linked, from two-dimensional drawings and bar charts:

- Inconsistency between 2D drawings,
- Information loss on removal of obstructions discovered during construction,
- Insufficient precision of monthly bar chart.

As a result of comparing two dimensional drawings, 40 design changes with respect to the positioning of the water stop wall in total at the time of construction were extracted. We classified these design changes with following five causes.

a) Change by the owner (4 places): Position change by intention of owner side. According to the interview to the constructor, the intention of theses design changes was not clear.
b) Change due to interference (21 places): Position change with respect to inadequate accuracy of buried pipe position in design. In some cases, there was no buried pipe at the position assumed in designing, and in other cases obstacles could be removed.
c) Distance taking between buried objects and water stop wall (4

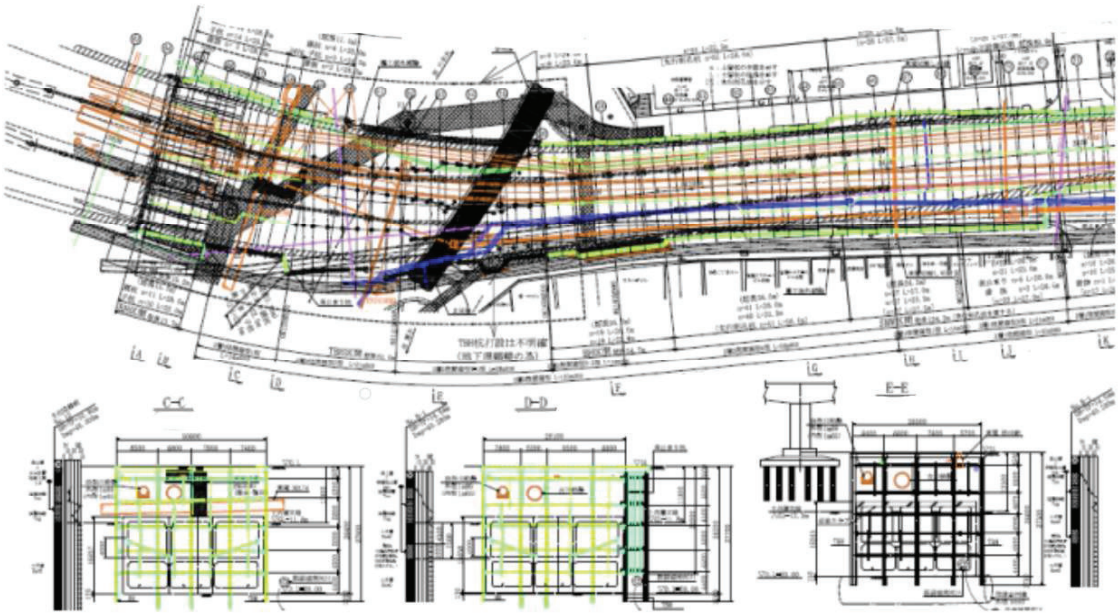

Fig.2 2-dimensional general drawings of a temporary work of the target underground railway station [2]

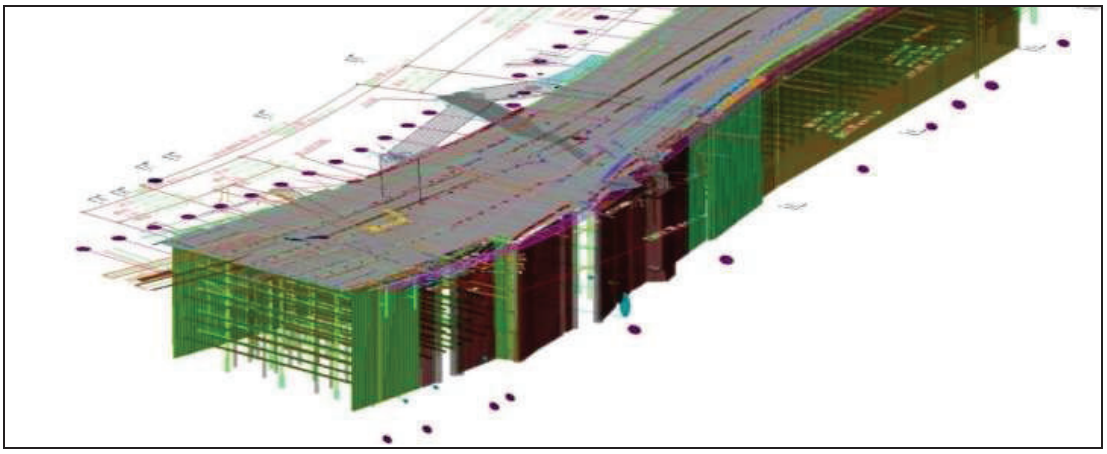

Fig.3 3-dimensional BIM model of the temporary work of the target underground railway station

places): Since the position accuracy of the buried pipe in the design was insufficient, the distance between buried objects and water stop wall was expanded considering the workability.

d) Change in consideration of workability (7 places): Changes according to the request of the constructor side considering the workability.

e) Other cases (4 places): Changes adapting to the situation of the site at the construction stage.

The cause of the 25 design changes was the insufficient accuracy of the position of the buried pipes at the time of designing. In addition, the cause of 7 design changes was consideration of requests from the constructor to improve the workability, and four were due to the request of the owner.

Fig.4 shows an example of the cases where the design change was made considering the inadequate distance between buried objects and water stop wall because the positions of the pipes actually spread compared with the drawing prepared in the design stage. Fig.5 shows the case where the owner accepted the request of the constructor to make workability improvement. Note that green parts show the water stop wall in the design stage and gray parts are the water stop wall according to the drawing after design change.

Many design changes occurred due to the lack of position information of the buried pipes at the design stage, similar to this case, while constructing underground facility in the city. As reported by the Ministry of Land, Infrastructure and Transport, "In the construction work excavating roads, accidents causing damage to underground buried facility occur frequently, because the location information of such underground buried objects is not necessarily accurate"[6]. Therefore, the advantages such as visualization of BIM and interference check are limited at the present time. From this, it is important to undertake a comprehensive management of underground buried pipe information that the Ministry of Land, Infrastructure and Transport initiated [6].

When information management with BIM is done from the design stage, the information to be incorporated can be integrated and version control of drawings can be thoroughly done with BIM technology. Version control of the drawing via BIM also guarantees the consistency of the drawing correction and even if the target construction involving many uncertain conditions can be flexibly performed without reworking due to the inconsistency of the information.

As described above, to construct an effective BIM model, it is necessary for each player such as designers, constructors, facility managers, etc. to ensure information accuracy considering cooperation and to perform information management.

III. Strategic Issues for Productivity Enhancement

In introducing BIM into public works in Japan, we have not reformed enough the system of contract and project execution. In order to improve productivity by introducing BIM, it is important to maximize the merit of related organizations. To that end, it is necessary to improve the response capacity of related organizations and to establish collaborative systems. Fig.6 shows the strategic issues for productivity enhancement of the infrastructure construction industry in Japan with introduction of BIM technology.

Human resource mobilization and education system are important for improving BIM-related capability of private sectors including contractors and consulting companies. It is important to nurture and utilize human resources who have BIM model creation capability, construction information management capability, and information policy comprehension capability, corresponding to each related organization. Regarding the modeling capability, in particular, highly skilled literacy skills are required, which are familiar with social infrastructure facilities and use 3D model creation and project management software.

In order to carry out cooperative work based on BIM among each affiliated organization, human resources having construction information management capability independent from consultants, contractors and owners are indispensable. In order to effectively utilize the model creation capability and the construction information management capability of related organizations, human resources who understand the information policy are indispensable for owners.

Regarding the establishment of the collaborative system, it is effective to accumulate experience through trials of new contract execution systems such as ECI (Early Contractor Involvement), trials of CIM management work, and active utilization of design-build contracts.

As mentioned above, it can be possible to maximize the merit of BIM utilization of consultants, constructors, and owners by capacity building of personnel having construction information management capability, information policy understanding capability, and establishing collaborative system.

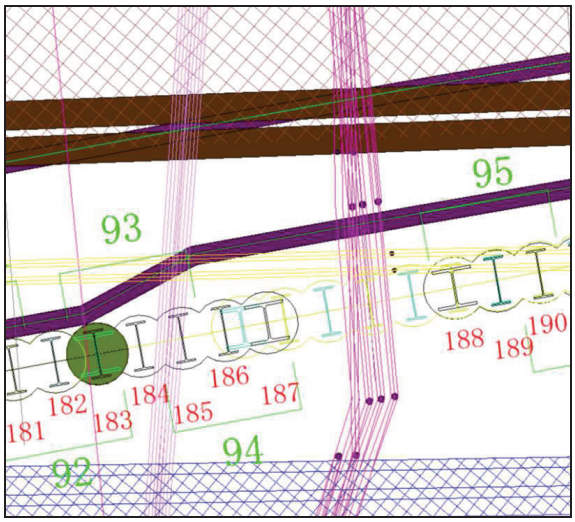

Fig.4 Interference of buried pipes and water-stop wall

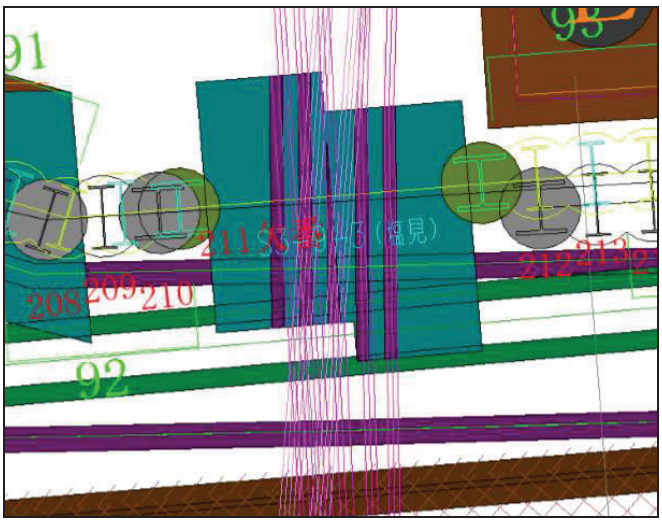

Fig.5 Position change of water-stop wall

Consultants should utilize knowledge concerning construction and maintenance to get many fruits by using BIM in design stage. As a result, the scope and quantity of the consultant's design work can be expanded. As construction feasibility at the design stage and consideration of maintainability are advanced, the workability is improved. As a result, the design change risk possessed by contractors at the time of construction can be reduced. Then, design quality can be improved, and construction of facilities with high workability and maintainability is advanced. Owners can fulfill the mission of improving productivity and reducing maintenance and management costs.

Human resource for BIM modelling

Needless to say, the main role of consultant companies is to design properly and not to make BIM model. In the near future it may be essentially important to become capable of designing based on BIM technology because the potential of the technology is promising. To that end, consultant companies who have intension to get fruit from the technology should pay cost to have the BIM related capability. However, this situation is also a problem inside the company, and it is a problem that other stakeholders such as owners cannot participate in.

Since consultant companies in charge of designing may not have enough human resources capable of utilizing CIM. In such cases, consultant companies let subcontract modeling specialists make BIM models. Under such circumstances, conventional business and modeling work diverges within the internal group, not only information management will not be established, but future development will be hindered. Since such a business model is not evolving, it is highly likely that such companies will be left out of the flow of CIM.

Issues related to design-bid-build contract

In design-bid-build contract (here after called DBB), there are two ways to possess the capability of sufficiently examining the workability and maintainability at the design stage. One way is to have personnel capable of adding information on workability and maintainability. The other way is to collaborate with external organizations. Early Contractor Involvement (here after called ECI) is one contract way to realize the involvement of the constructor in design stage. Success factors for ECI in public infrastructure projects are identified as follows:

Involve contractors early enough
Manageable risk transfer to the contractors
Project owners' competence
Proper compensation for the contractors' contribution
Qualification of the contractors
Trust between the project owner and contractors [4].

This contract is not preferable from the principle of the separation of designers and constructors because information produced in design stage can be open to the involved constructor if the owner cannot overcome these factors. Therefore, human resource mobilization is quite important for the consultant companies to get persons who have the capability and experience to carry out front loading in design stage.

Elimination of upper bund constraint of planned price

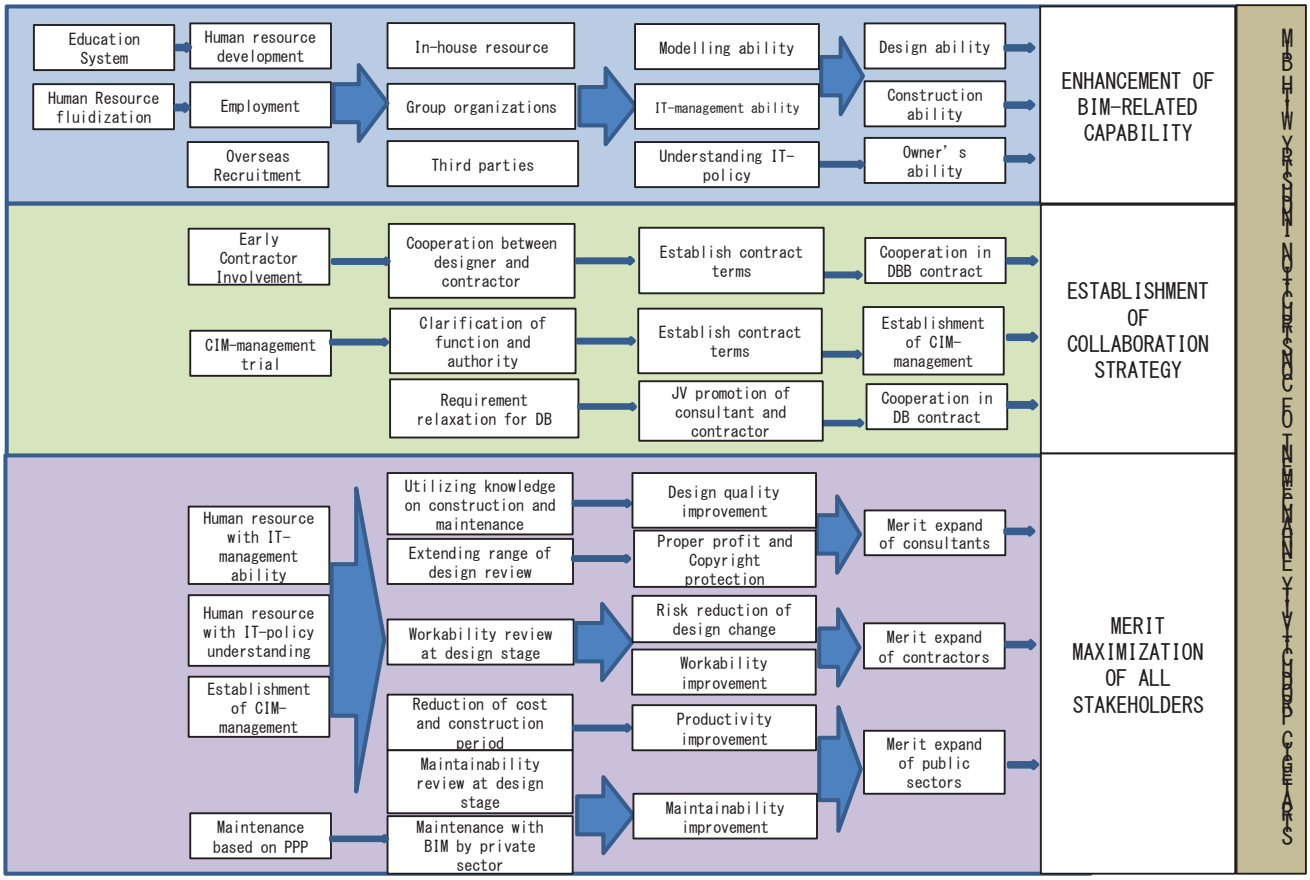

Fig.6 Strategic production enhancement of construction industry with BIM technology.

When designing based on BIM, front loading which sufficiently examines workability and maintainability in the design stage is essential for productivity enhancement. The ratio of the design cost in the life cycle cost is about several percentages of the life cycle cost at most, and even if it is increased, cost merit can be obtained by improving workability and maintainability drastically.

Since the possibility that the design quality will be remarkably improved by introducing BIM increases, it is important to eliminate the upper bound constraint of each planned price for design works and to introduce a negotiation method to decide the contract price for design works.

Copyright of BIM model

As far as design works of public infrastructure in Japan are concerned, the copyright of the documents and information produced by the design work should be transferred to the owner of the work according to the standard contract for design works of public infrastructure. It is important for the designer to leave the copyright of the documents and information produced by the design work to increase the incentive for enhancement of the quality of the design.

Cost and schedule management both in virtual construction in design phase and real construction phase

Cost and schedule management by using project management software (here after called PMS) in virtual construction and actual construction is important for cost and schedule estimation by front loading, construction plan change during construction and design change review. Currently it is inevitable to share cost and schedule information between constructors and owners, or between contractors and sub-contractors, with the required system and detail level. This will surely improve the productivity of construction projects and further increase the possibility of overseas business development.

Issues related to design-build contract

In Japan, design–build contract (here after called DB) is usually accepted in cases only contractors are involved. DB only with contractors should not be taken as a standard because it is out of the principle of the separation of designers and constructors. It is better for consultants and constructors to form a joint venture to carry out DB projects such as DB projects in overseas.

IV. ROLES OF INFORMATION MANAGER AND OWNERS

NEXT, we show that management of information is indispensable for fully exploiting the usefulness of BIM model by constructing BIM model. In order to improve information management in Japan, the authors show the policy to examine institution regarding information management in Japan from factors considered important in PAS 1192-2[5]. PAS 1192 - 2 is a supporting document of BS 1192[6], a standard for collaborative production of architectural, engineering and construction created by BSI, and provides concrete guidance on information management requirements related to projects provided using BIM. In contrast to the key elements in PAS 1192-2, we examine ways to improve the information management level in public construction projects in Japan.

Role of information manager

An information manager is defined as "a person appointed to play the role of information management by the owner" in the CIC BIM Protocol [7]. The owner is obliged to appoint a party who plays a role as an information manager. The role of information managers is to carry out by either a design leader or a project leader who is a consultant or contractor at various stages of the project. Also, in some cases, the owner can appoint an independent information manager. According to the CIC BIM Protocol, the key responsibilities of information managers can be summarized as follows [7].

- Management of processes and procedures for exchanging information in projects
- Start and implement project information plan and asset information plan
- Support for preparation of project outcomes such as information exchange
- Implementation of BIM protocol

In Japan there is no system related to information managers to control BIM procedures. It is essential to include information management function as a necessary item in contracts including BIM procedure.

In the case of DBB projects, it is necessary for the design consultant and the contractor to have the function of BIM management respectively. Since the isolation of information between design and construction is a factor impeding the effectiveness of BIM, it is necessary for the owner to conclude a BIM management contract with an independent third party with abundant experiences of BIM projects is desirable.

In the case of DB projects by JV with consultants and constructors, it is desirable to have a BIM manager with the capability and experience of information management by BIM among those organizations. As Liu et al. [8] pointed out, design consultants and constructors prefer to have BIM management capabilities within them because of their merit of maintaining their originality. However, since there are not many companies with the capability of BIM management, from the viewpoint of the owners, it should be taken into consideration that BIM consultants are chosen from third parties other than design consultants and constructors to make it easier for BIM's effect to be demonstrated.

Regarding early BIM partnering delivery method, which is similar to ECI contract, involving the constructor from the design stage, Porwal et al. [9] proposed the contract type which places a BIM consultant from the design stage to the owner side and utilizes BIM to design collaboration. It is desirable for the owner to clearly have a policy using BIM and to effectively utilize consulting of appropriate experts on information management.

In any case, BIM managers are desirable to have rich experience and knowledge on construction technology and maintenance technology, which means the construction industry has to have an appropriate capacity-building program for BIM management.

Role of owners

What is characteristic of the role of the owner in PAS 1192 - 2 is that, the work process should include the process that the contractor provides the appropriate answer to plain question by the owner side in design stage. In other words, even when an owner who does not have knowledge about advanced information on BIM is involved, sufficient communication must be guaranteed. The role of the owner is to clarify the significance of applying BIM to the project and to appropriately prepare Employer's Information Requirements (here after called EIR). Owners should also properly control BIM managers and contractors with policy. In this way, it is effective to construct a system that does not rely on knowledge about BIM on the owner side.

In promoting the introduction of CIM in Japan, external support is adopted as a technology supervision work in the trial project. In this work, owner-side engineers are to expect some advice on handling BIM as well as receiving proposals on CIM's concrete utilization measures at the upstream stage of work. This approach can be said to

be an effort aimed at enhancing the in-house BIM management function on the owner side.

However, the most important thing is to clarify the roles of the owner and the consultants in the BIM project. It is the role of the consultants to effectively utilize third parties rich in experience and knowledge to provide functions related to BIM technology and its management. The role of the owner is to understand the policy of using BIM and to design social systems to overcome the issues in order to realize the policy. Under these systems, owners are required to properly control the consultants and the BIM manager to realize integrated information management.

V. Concluding Remarks

THE, conclusions obtained in this study are as follows.

1) The authors identified the following obstacles to create 4-dimensional BIM data, in which three-dimensional BIM data and Gantt chart are linked, from two-dimensional drawings and bar charts
2) Many design changes occurred due to the lack of position information of the buried pipes at the design stage, similar to this case, while constructing underground facility in the city.
3) To construct an effective BIM model, it is necessary for each player such as designers, constructors, facility managers, etc. to ensure information accuracy considering cooperation and to perform information management.
4) It is important to nurture and utilize human resources who have BIM model creation capability, construction information management capability, and information policy comprehension capability, corresponding to each related organization.
5) Consultant companies who have intension to get fruit from the technology should pay cost to have the BIM related capability.
6) Human resource mobilization is quite important for the consultant companies to get persons who have the capability and experience to carry out front loading in design stage.
7) It is important for the designer to leave the copyright of the documents and information produced by the design work to increase the incentive for enhancement of the quality of the design.
8) It is inevitable to share cost and schedule information between constructors and owners, or between contractors and sub-contractors, with the required system and detail level.
9) It is better for consultants and constructors to form a joint venture to carry out DB projects based on DB with BIM technology.
10) It is essential to include information management function as a necessary item in contracts including BIM procedure.
11) The role of the owner is to understand the policy of using BIM and to design social systems to overcome the issues in order to realize the policy.

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