Application of Civil Information Modeling for Constructability Review for Highway Projects

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Abstract –

Usually, it is necessary for general contractor to handle constructability review of infrastructure and civil projects during the construction phase. Generally, constructability review usually be analyzed and applied at job onsite using 2D CAD drawings. The constructability review integrated with 2D CAD drawings usually cause time-consuming problems and problem misunderstandings. Civil information modeling (CIM) is one of the latest concepts and technologies in infrastructure and civil projects. The major function of CIM includes presenting and simulating operations by 3D model, and making constructability review through 3D BIM models. In order to enhance the performance of constructability analysis in infrastructure projects, this study proposes a CIM-based constructability review framework and approach for general contractors during the construction phase. The proposed approach is then applied in the selected highway case study in Taiwan to demonstrate the effectiveness of CIM-based constructability review in practice. Finally, this study identifies the benefits, limitations, and facing problems through the case study. Finally, conclusion and suggestion are summarized for further applications and researches.

Keywords –

Civil information modeling; CIM; Highway; Constructability; Construction phase; General Contractor

1 Introduction

Construction phase is the most important stage of the project, because in the construction phase construction company need to achieve the construction form the designer and a lot of subcontractors will join into the project in this stage, therefore construction engineers need to collaborate with those subprojects, to decrease construction disputes between subcontractors.

For the traditional solutions of the disputes between subcontractors, construction engineers will solve the problems by constructability analysis on 2D diagrams, but the results of traditional solutions not as expected, it is because 2D diagrams just present the two dimensions of the project in once, the information for third dimensions are depend on the experiences of construction engineers. In addition, every pages of 2D diagrams are individual, so the updates of the project need pages by pages to correct the exchanges link diagrams, however each correction have connected a lot of diagrams, and construction engineers have to correct every correction hand by hand, thus there is easy to get the mistakes or miss correction by the construction engineers.

Recent 30 years, construction industries are improving computer information technology with construction operations combine applicate [1]. In recent years, the most promising and commonly technic used in the construction industry is BIM (Building Information modeling) [2]. BIM technology has the function of synchronization, parameterization, three-dimensional models, and BIM 3D models have complete linkage. Besides that, BIM can eliminate engineers to imagine the 2D information to 3D imagination, improve the integration form the various units, and reduce problems of review and communication in the construction.

But BIM technology is more focus using in the building construction, not in the civil construction, therefore in this case study will implementation CIM (Civil Information Modeling) technology for constructability review for highway projects, for the application of CIM technology in the construction engineers, plan out the flow chart of CIM technology implement in constructability before the construction phase, to improve the efficiency of CIM technology.

2 Literature Reviews

The concept of the constructability was came for United States in 1970, the aim of the constructability is

found the ways to improve and increase the cost efficiency of the construction project, improve the quality of the project, and this concept as a bridge between designer and construction companies [3]. Construction Industry Institute(CII), defined constructability as reducing costs, improve project quality, shorten the duration as the goals, knowledge applied to planning, design, procurement and construction of the various stages to achieve the overall project objectives [3].

CIM technology can use the previous data to backup the new project data, in the project manage, plan, design, build and facility management, to let engineers can easier to hit target of the project [4]. CIM technology is reference BIM technology [5], but there are three using different between CIM technology and BIM technology, first different is building project is a fix point project, and the building is vertical built, but civil project is a horizontal construction, and information of CIM project suspected of a wide range, second different is the professional word to both technology are different, in building project the vertical structure to support the building call column, but in civil project vertical structure to support the project call pier, third different is the construction method, in building project will built floor by floor, but in civil project is built pier by pier [6].

And Cheng et al. have generalize nine categories of civil project, show as below [6],

1. Bridges,
2. Roads,
3. Railways,
4. Tunnels,
5. Airport, port and harbors,
6. Energy infrastructure,
7. Utility infrastructure,
8. Recreational facility infrastructure,
9. Water management infrastructure,

Besides that, the development and adoption of civil project have separated into six categories [6],

1. Number of industry cases and academic papers
2. CIM uses,
3. Level of detail,
4. Data schema and representation,
5. Data delivery and management,
6. Software tools,

In addition, CIM technology can use in whole life cycle of construction, and in different phases of construction, the information of the CIM models need by user are different, to difference the level of information need Cheng et al. propose the information level of CIM models into five level, level of details (LOD) 100, it is present the information of construction in a 3D block model and using in architectural design, LOD 200 present the generic elements and using in architectural design, LOD 300 present the detail and refine assemblies, using in architectural design, LOD 400 present the construction level detail components, using in structural and MEP(Mechanical, electrical, and plumbing) design, LOD 500 present the as-constructed model, using in maintain phase [6].

Discusses how to promote the use of 3D information, including the establishment of the basis of 3D information exchange, modify the relevant system, road construction model, the production of engineering process model (4D) and the use of 3D to provide environmental information [7]. Research on 3D information and structural analysis software applied to railway viaduct cooperation information sharing [8]. Present a methodology for capturing and analyzing the communication patterns between project participants in the coordination room and understanding what participant actions normally take place during the design of the coordination meeting are necessary to provide them with adequate infrastructure support [9]. Based on the study of the use and use of BIM in infrastructure projects in Australia and the People's Republic of China, the BIM use and relate technologies of the project were analyze based on the research methods [10].

Comprehensive the use of CIM technology and the introduction of BIM technology in infrastructure relate to foreign literature, although the introduction of CIM technology in the construction analysis, but the construction of the analysis of the content and methods with this study is not the same. In view of the current Taiwan BIM technology into the organization of the majority of the factory for the trend, this study will explore the CIM applied to analyze the national construction project by the construction company as case study.

3 Research Content

The construction analysis is a pre-operation, that is very important for the construction build, but it is easy to be technically limited in the traditional construction and cannot complete the purpose of construction analysis. It is because in 2D diagrams is hard to sense the third dimension information, and sometimes those senior engineers also cannot found the overlap of the components in third dimension. In addition, the clarify of the construction interface are hard to explain to the field workers by the 2D diagrams, because the components build is present in 3D, but in the diagram just can show the 2D information. Therefore, in this case study applicate CIM technology for constructability reviews for highway project in Taiwan, because the traditional constructability has a lot to

improve, so the following describes of constructability issues that have not been effectively improved for traditional construction, and introduce of CIM technology to explore the constructability. In traditional construction, the discusses of construction interface are in depend on the experience of field engineers, but the limitation of traditional discusses are the field workers cannot synchronize with the engineers, so the construction interface cannot solve as engineers wish, therefore in this case study will develop CIM 3D models as a communication platform to decrease the misunderstanding between field engineers and field workers.

1. CIM technology not a new technology in Taiwan, but the cognition of CIM technology for users is too less, so the result of the constructability analysis not in expected.
2. Therefore, in this case study will applicate CIM technology to assist the construction of national road construction, establishment a CIM construction review for the operating mode, and actual into a case study, to explore its benefits and difficulties.

But there is a lot kind of constructability analysis in the construction phase by using CIM technology, such as clash detection, simulation of construction process, construction interface review, regulation review, suggestion evaluation and many more. The constructability applicate of CIM technology in this study are clash detection and construction interface review, the description and function of the application analysis project are as follows.

- Clash detection

In the general construction, the 2D drawings of the project are divided into structural, construction and MEP, so the field engineers will receive the three individual drawings file, therefore, the field engineers need to integrate the three drawings into one interface, and use the process of mapping to find the overlap problem of the three units in the same interface. However, it is difficult for the field engineers to judge the overlap of the 2D interface and in the construction process will still have a lot of clash problems, which make the construction need to rework. So the construction company plant with use CIM 3D model for integrate three units drawings, and the use of CIM technology as a platform to analyze the clash and find a solution to the problem.

- Construction interface review

When the construction in progress, the same construction interface will often encounter multiple of projects at the same time, so the construction project will have the opportunity to meet the interface overlap,

If the more serious situation will lead to extension of the project, and the main reason are the field engineers before the construction cannot be detail division the job of the labor and the poor communications between two sides. Therefore the construction interface analysis are important for the construction, implement CIM technology can let those field engineers and labor more understand the certify of the construction interface and let field engineers could be more easy to solve construction interface problem.

To let the constructability analysis in this case study get more smoothly, in this section would discusses about the chart flow for clash detection analysis and construction interface review.

First for both analysis, are consolidate project information and checking the requirements of CIM 3D models by the analysis, and second for the clash detection analysis, will check the overlap in the CIM 3D models, the clash analysis will just check about the overlap between pier foundations and pipelines, and it is not include the overlap between the different pipelines, after checking the clash detection analysis, get the result to check is it requirement by the analysis need by the field engineers, the flow chart shown in Figure 1.

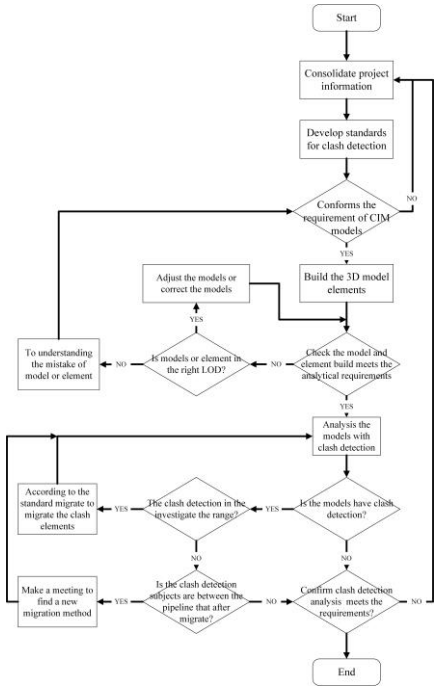

Figure 1. Flow chart of CIM clash detection analysis

In addition, the second part for the construction interface review in input the data of the construction interface into the CIM models, and checking the overlapping of the interface, lastly check the result is it

as requirement need, the chart flow shown in Figure 2.

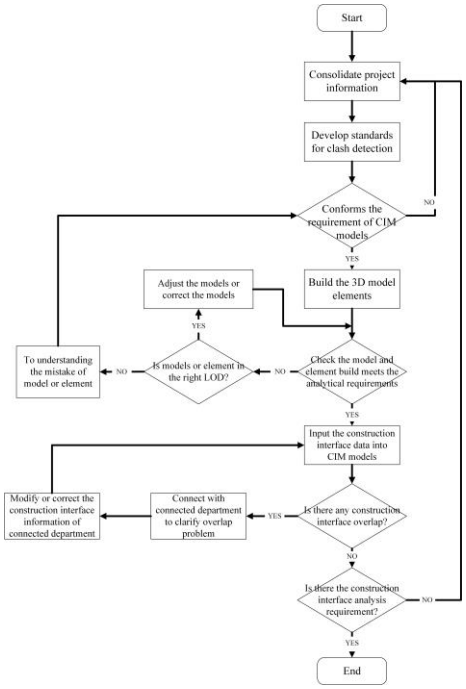

Figure 2. Flow chart of construction interface review

4 Case study

BIM has start actively used in building projects in Taiwan, but not in infrastructure projects. The viaduct project is select as the case study, the project locate in Taipei city and surrounding of this case study has a lot of residential area and offices area, and the piers foundation has been design in the underground for decrease the surface area need on the ground surface. So, normally the construction engineers will get the 2D pipelines diagrams and the 2D design diagrams, integrate both diagram to find out the overlap, and solve the overlap in the assembly, but in traditional solution is too slow and high risk for the construction, because the information can get form 2D diagrams just a two dimensions and the overlap of both are three dimensions, often produce misunderstand of acknowledge and the third dimensions information, it will cause field engineers wrong excavation or in the excavation project spoil the pipeline needed. Therefore, construction company decide to applicate CIM technology, to solve the problem about the overlapping between pipelines and piers foundation before the construction project start.

In addition, the steel rebar of the piers foundation design in viaduct project are high dense, in order to meet the body structure, vehicle high speeds and vehicle load, so the high dense of steel rebar is a complex design, and the field engineers need to make an order to input the steel rebar step by step to avoid the process have dispute, and delay the construction period, therefore construction company applicate CIM technology to decrease the construction interface problem, and make the construction get more fluent when the construction is processing.

1. The model planning and built

To improve the efficiency of the project for the construction of the project, it is necessary to construct a CIM model conforming to the construction analysis. Therefore, this study will carry out the pre-operational planning and the basic requirements of the model for the analysis of this case study, and the considerations staffs of the CIM 3D models include CIM manager, CIM engineers, and 3D models users. In this case, the CIM manager is required to provide the model requirements and limitations of the model in terms of their own engineering experience, and to confirm whether the model can begin to use. CIM engineers needs to collect the construction information of different units, as well as understanding the operation of the complex CIM modelling software, so that the model can be built and the content can be the best display effect, in addition, CIM engineers need to clarify the interface of each unit has been identified construction sequence and review the demand for construction. CIM models users need to recommend the lack or inconvenience use of the CIM 3D models, and feedback to the CIM engineers, those relationships are shown in Table 2.

Future more, the color identification to differentiate the pipelines system are needed in the 3D models, to highlight the different of the pipelines system, let CIM models users could more easier to distinguish the pipelines system, so that can easier to discusses and analysis the constructability. And the pipelines system in this case study are included main power system, sewage system, running water system, gas system, and telecom system (see Table 3).

Table 2. Relationship of consideration staffs and responsible for work items

Consideration staffs	Responsible for work items
CIM manage	To organizing and assigning CIM engineers working projects, developing CIM technology standards, standard program content, understanding the contents of CIM technology, and decision makers of CIM technology
CIM engineers	To build CIM model, review the correctness of models, using CIM

	models to analysis constructability of project, and provide field engineers 2D diagram form CIM models.
CIM models users	Feedback CIM engineers about CIM 3D models problems, and the scene required CIM technical analysis

Table 3. Pipelines system in CIM 3D models

Pipelines system		Color identification	Models
Main power system	High power		
	Low power		
	Street light power		
Telecom system			
Sewage system			
Running water system			
Gas system			

In this case study, there is a lot of overlap between the pipeline and the pier, although the pipeline has been embedded in the original components, but the modified pipeline is low cost than modified structure of the pier design. Therefore, the problem of overlap between all pipelines and piers in this case study will be handled by the migration pipeline.

The build of pier foundations and the pipeline systems in the CIM 3D models, will get the models as shown in figure 3, and found that some of the pipeline systems have overlap with the pier foundation, and those pipeline systems are included high power system, running water system, gas system and telecom system, after CIM engineers done the models, the models will be discusses with CIM manage to solve the clash between the pipeline and pier foundations, after the discusses CIM engineers will revise the CIM 3D models, as shown as figure 4.

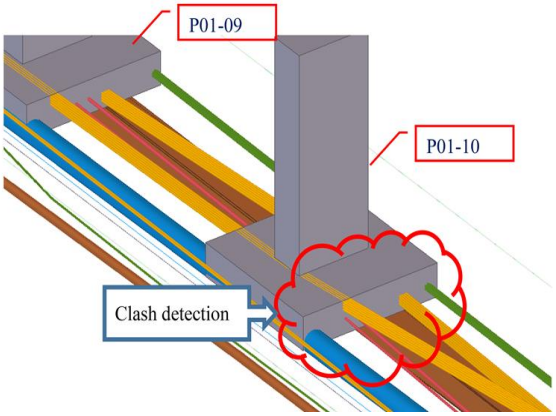

Figure 3. Overlap between pier foundations and pipeline systems

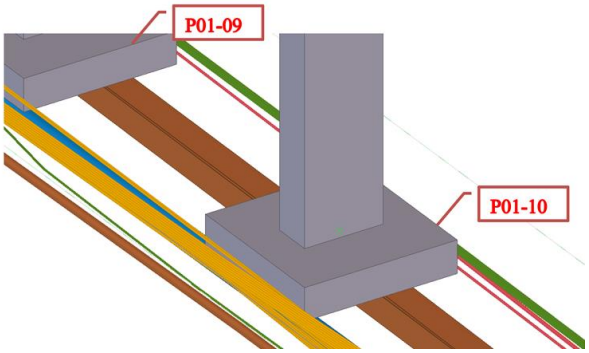

Figure 4. After revise by CIM engineers

To allow all the relevant personnel involved in the project to be able to communicate with the model to discusses the construction, and let the site construction staff as soon as possible to understand the scope of application, so the contents of the pier foundation will be targeted for the construction interface between the steel rebar by color distinction, as shown as figure 5.

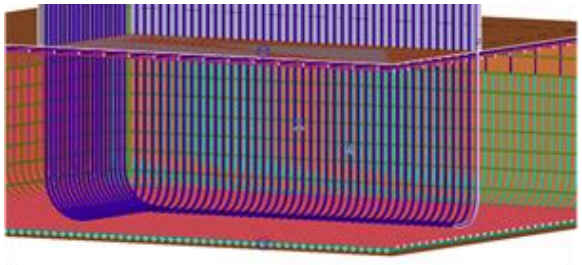

Figure 5. Construction interface of the steel rebar

Form the literature reviews and the constructability analysis develop in this case study, found there are quite different between BIM technology and CIM technology on the constructability analysis, so in this section will discusses about the differences of both technology. The first differences is the clash detection analysis, the clash detection analysis are using to check the overlap

between two or more elements, to decrease the percentage of rework on site field and making the decision on the site field. So, in CIM technology the most clash detection analysis results are form the environment elements overlap with the construction elements, but in BIM technology the results of the clash detection analysis results are form the elements overlap between elements in the construction. The second differences is environment analysis, civil construction is a horizontal construction, therefore the implicate of environment are extreme more than building construction, so the construction engineers need to analysis more environments data for the civil construction to make sure the construction could complete in expected time. The third differences is the traffic maintain during the construction, civil construction is a moving construction during the construction going on, therefore applicate CIM technology could let construction engineers earlier to plan the traffic maintain need. But building construction is a fixed point construction, therefore the traffic maintain for building construction will be less analysis need then civil construction.

Therefore, this study utilizes the visualization characteristics of CIM technology, participants the analyze and communicate with the CIM model, explore the constructability of the project, immediately identify the problem in the meeting, let the relevant professional engineers to immediately solve and propose a program to speed up the benefits of engineering construction analysis.

- Benefits of CIM technology in the constructability analysis

1. If the overlap of the entity may be dealt with directly by the engineers, but the overlap at the construction interfaces are not physical conflict, so the engineers needs to have a limit to the simulation of the 2D plan, and the process will be quite complex, therefore, the visualization of CIM model and the use of colour, engineers can more easily understand the interface of the conflict, to speed up the engineers in the interface to clarify the time-consuming.

- Difficulties of CIM technology in this case study

1. The expectation of the CIM 3D model can be closer to the entity, but the models more closely will cost more time on built, and the information actually more important than the model closer or not, but it will be other units require upgrade their models LOD to enhance as entity.
2. The clash detection between each other pipeline are normal, it is because the field engineers could be solve the problems in the site situation, it is not the main question for the clash detection analysis, but during the discussion process, some other will require to present a zero clash detection analysis as a report.

5 Conclusions and suggestions

5.1 Conclusions

1. The underground pipeline will be exchanged when the other construction are going, but the 2D diagrams of the concerned department have not updates those diagrams, therefore the information of 2D diagrams obtain by the next contractor are mistaken.
2. The reality of the CIM 3D models are expected by the owners but the more reality of the 3D models will waste more time of CIM engineers and extra data for the construction analysis will cause the analysis slow, therefore the LOD used for those 3D models should just reach the minimum need of analysis.
3. Less peoples are current understanding of CIM technology, so they are unbelieve the analysis of the CIM technology, thus blocked the efficiency of CIM analysis and some other will increases unnecessary analysis of the project.

5.2 Suggestions

1. CIM technology in the construction analysis to bring some benefits to enhance, if the future can be based on the quality control system into the project of CIM technology, will be able to confirm the quality of CIM technology imported.
2. Construction companies could be applicate the technic of virtual reality (VR), to let the construction 3D models more reality, to easier make the decisions in more reality environment and reduces the dispute when the project complete.
3. Relate units could setup CIM execution plan as a standard operation procedure, to obvious the goals of the project.
4. CIM technology applicate in the constructability could make a lot of benefit for the construction companies, but the quality control also need for the CIM technology develop.

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