# BIM functions for optimized construction management in civil engineering

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**Purpose** The aim of this study is to suggest configuration methodologies of active building information model (BIM) functions that enable to practically control limitations by optimizing schedule overlapping linked to its space models after analyzing workspace conflict analysis for a bridge model. This study also suggests development methodologies of active BIM-functions, linking an optimized method and improved strategies of future BIM-operation model through an analysis of limitations of a passive BIM-operation system for architectural projects. **Method** The existing BIM-system manually performed a simplified comparison review of 3D-shapes and its virtual reality (VR) analysis with visual manipulation of 3D-models in a virtual environment. Such BIM functions require a separate analysis process to organize BIM-output data as reprocessed business data. This has many limitations when directly utilizing the visual information produced by commercial BIM-systems as practical operation data. Accordingly, this study develops functions of an active BIM-system so that the managers can directly analyze practical requirements by integrating an optimized analysis algorithm with the BIM-system to improve the passive BIM operation environments. As a method of configuring the active BIM-functions, an optimized algorithm for establishing resolution strategies for workspace conflicts is constructed. As functions for supporting active BIM-operations, this study utilizes fuzzy and genetic algorithm (GA) approaches. These approaches will be used to develop visualized risk assessment model and workspace conflict optimization model based on active BIM. **Results & Discussion** By enhancing fragmentary analysis functions of simplified 3D-models with the development of an active BIM-system, the BIM-system can utilize output information derived from a process of analysis, evaluation and control of the BIM-models as a practical operation information model for both design and construction phase. Therefore, it is expected that an active BIM can simplify data analysis and the system operation process for managers with virtual object models and expand the active BIM-system to the life cycle of civil engineering projects.

***Keywords**: active BIM, passive BIM, optimization, risk assessment, workspace conflict*

## INTRODUCTION

Recent trends in BIM (Building Information Modeling) are that it has been applied as a passive process that is centered on a simple visualization analysis process. Existing researches are also focused on the development of IFC (Industry Foundation Classes) for securing interoperability between information for building project[1], development of 4D CAD system for sequential visualization of 3D object over time[2], and an integration of design and manufacturing and construction[3]. In addition to the BIM system, such as Navisworks, Revit Architecture, these researches require a separated procedure in order to control schedule, workspace and risk level after operating the BIM system, which includes modeling software, 4D CAD, and structural analysis.

Unlike such researches, this study attempts to develop a BIM-based system for controlling all the construction data, such as schedule and risk within a single BIM system based on a 4D CAD platform without requiring a separated control procedure or expert knowledge.

Therefore, for the more advanced BIM in the future, active BIM environments that could provide such project management data as schedule, resources, costs, space and risks should be established[4]. This study improved the existing BIM operation system and suggested a methodology that could develop an active BIM operation strategy for civil engineering projects. In order to do so, this study analyzes problems of a passive BIM and derives an improvement strategy of the active BIM that is based on the 4D CAD platform. This study suggests the active BIM functions using ‘Genetic Algorithm’ and ‘Fuzzy Theory’, which are utilized for schedule optimization, workspace optimization and risk analysis. Those functions are simulated with 4D objects using V-CPM, which is developed by the research team (V-CPM)[7].

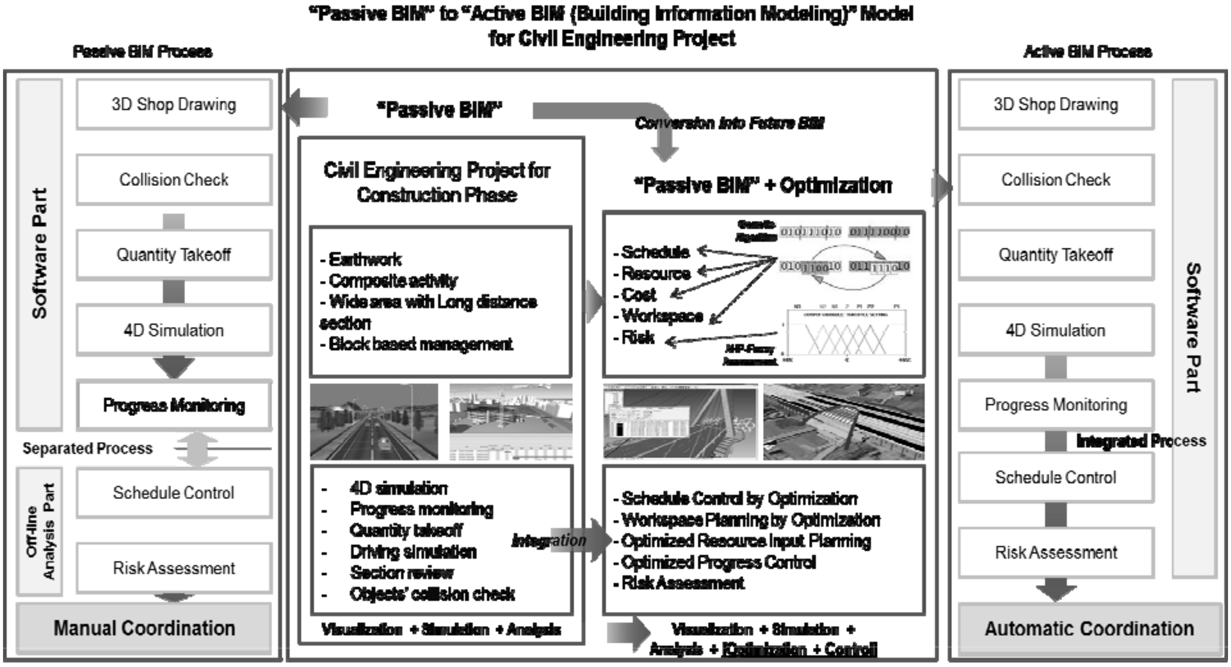


*Fig. 1. "Passive BIM" to "Active BIM" model for a civil engineering project*

The purpose of this study is to develop a methodology and a system that can improve passive BIM environments and eventually establish 4D CAD based active BIM environments. An active BIM system can secure a project's productivity and safety through a schedule optimization that reflects on-site conditions; therefore, it is expected that the system will be effectively used as a decision-making tool for construction project management. Besides, the suggested active BIM operation system can be easily utilized without requiring a distributed control procedure or expert knowledge within a single system

## "PASSIVE BIM" VS. "ACTIVE BIM" FOR CONSTRUCTION INDUSTRY

Most of BIM features including 4D simulation are focused on the simple visualization functions of numerical construction data. Project managers can identify the visual status of construction project by current BIM functions. That is, they cannot provide an analytical data, such as an optimal schedule plan considering site conditions and activity's constructability that can assist project managers. Besides, the current BIM system requires a separated analysis process in order to control project data risk after its visual simulation. If those current functions are classified by passive BIM system, the active BIM system has various decision making functions to provide the optimal plans of the project. Using the suggested workspace analysis method by 3D object and simulation method by 4D object, a project manager can have an optimal schedule plan that the workspace conflict is minimized. Those methodologies can be used for the active BIM system which may be a representative construction management tool.

Civil engineering works require a methodology for the establishment of an active BIM that could manage various construction types (i.e. wide-area works, earthworks, combinational works, etc.) and minimize diverse related risks. Fig. 1 shows how an active BIM model is built from a passive BIM model.

Controllable factors during the construction phase in the building works include schedule, costs, resource, workspace dependent constructability and safety. Under the current BIM environments, these factors have not been effectively controlled, and there were, consequently, a number of restrictions to active utilization of BIM for such critical processes as optimal schedule management and workspace conflict management[6]. Especially, if such critical functions as schedule conflict optimization, workspace conflict optimization, risk assessment and optimal equipment layout are available under the BIM environments, these functions will become fundamental functions of an active BIM system.

## ESTABLISHMENT OF ACTIVE BIM FUNCTIONS DURING THE CONSTRUCTION PHASE

### Workspace conflict optimization methodology

The purpose of a workspace conflict optimization function is to secure the safety and constructability of various construction works. This function can search for an optimal schedule model that minimizes workspace conflicts between the two schedules performed concurrently in neighboring spaces. That is, this function provides essential data for an optimal workspace plan during the construction phase. Fig. 2 shows a GA-based optimization methodology to minimize workspace conflicts.

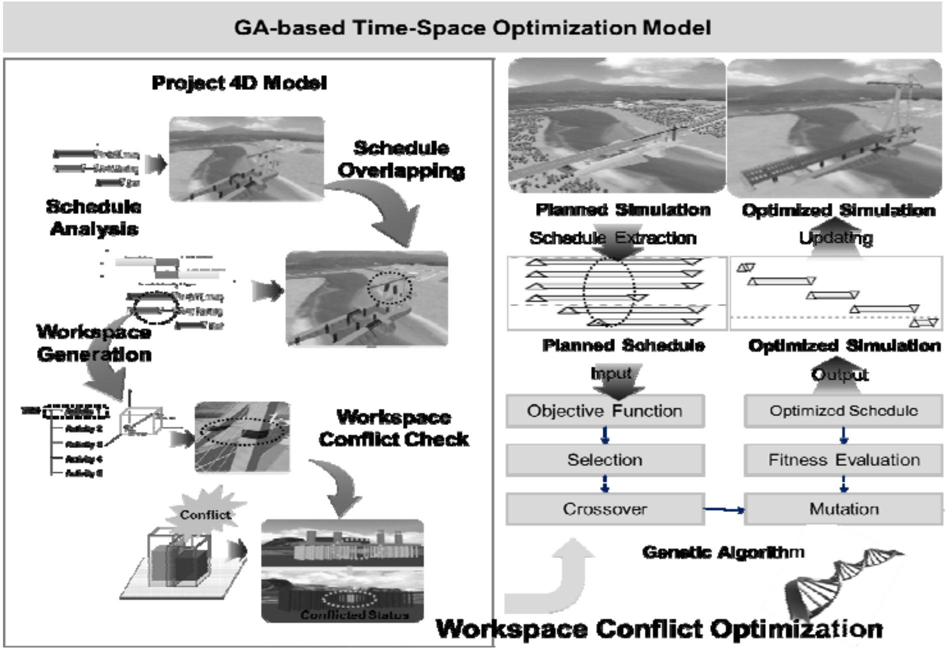


*Fig. 2. Workspace conflict optimization by genetic algorithm*

For the optimization of workspace conflicts, creation process of a workspace model should be preceded, and a schedule conflict ratio can be computed through sequential check of schedule conflicts for a basis schedule and a conflict schedule. Then, the adjacency of mutual workspaces for each activity with schedule conflicts should be reviewed to derive certain workspace conflict results. These results can be obtained by searching for particular distance values that are less than the designated tolerance values. Throughout these procedures, those activities with schedule and workspace conflicts can be detected. However, there should be optimization processes that could minimize the conflict duration of fixed workspaces in order to resolve the workspace conflict results.

Based on the workspace conflict results, those schedule data linked with a workspace model can be extracted. These schedule data should be optimized through GA for the search of certain results with minimum schedule conflicts, therefore optimizing the workspace conflict duration. Here, workspace conflict optimization can be performed by controlling the schedule overlapping duration. Since each activity has own total float (TF), the conflict status is solved by changing activity within the total float maintaining activity relationships with GA operation. Then, the optimized schedules will be updated into a workspace model, and a new optimal workspace-planning model can be created. Workspace conflicts created from the planned 4D model are optimized and then compared with those from the new 4D model, thereby allowing workers to check conflict management conditions. In this way, a schedule-based workspace optimization can be executed during the construction phase.

**Risk visualization methodology**

A risk assessment model is designated to quantify such project risk factors as project period, costs and work conditions and interface the quantification results with a 4D model, therefore visually assessing a certain risk level for each construction type.

For the visualization of risk factors, a series of risk analysis procedures should be integrated into a 4D model. Risk priorities for such risk factors as project period, costs and work conditions are determined through AHP (Analytic Hierarchy Process) and applied to a risk assessment algorithm by Fuzzy analysis method. This can visually analyze risk levels for each activity. In addition, diverse analysis conditions that multiply project period, costs and work conditions can be reflected into those risk levels. The risk levels of each activity can be categorized into a risk impact (P1: Very Low ~ P5: Very High) and a risk probability (I1~I6), thereby enabling a project manager to discretionally select a certain linguistic variable for each activity type. This variable can vary according to each activity's characteristics. These variables will be factored into a Fuzzy membership function in order to compute risk levels, which will be finally set by GMV (Generalized Mean Value).

These risk levels are classified into 5 types of colors as per each grade, and the computed risk levels for each activity are used as visual attribute values for objects. Based on these data, if risk data for the planned 4D model are updated, risk level for each activity can be visually determined. This is important because each activity's risk levels for all risk factors can be visually checked. Therefore, it is possible to intensely manage those works with high risk levels.

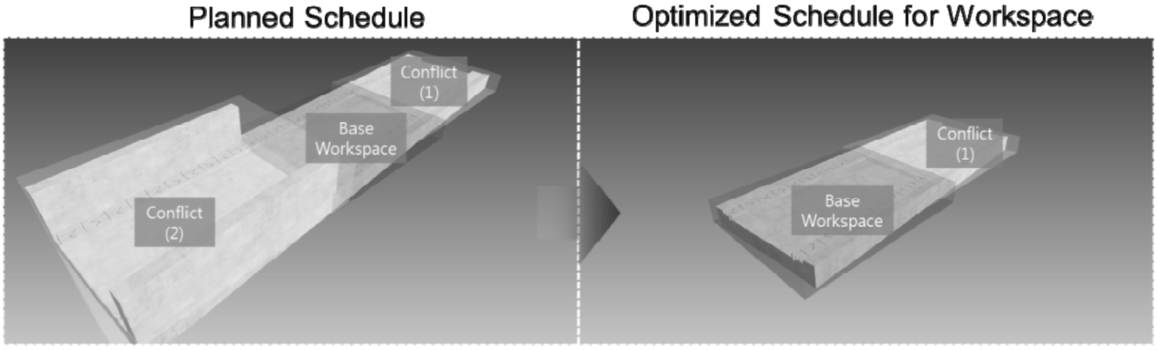


*Fig. 3. Workspace conflict optimization module by genetic algorithm*

## DEVELOPMENT OF THE ACTIVE BIM FUNCTIONS FOR THE CONSTRUCTION MANAGEMENT

### Workspace conflict optimization module

Fig. 3 shows the developed 4D simulation screens that simulate the minimization of workspace conflicts based on the GA-based workspace conflict optimization methodology. The left figure in Fig. 3 shows a workspace conflict simulation model before optimizing schedule overlapping status. Conflict (1) and (2) for base workspace was occurred based on planned schedule. While, the right figure in Fig. 3 represents a workspace simulation model after optimizing schedule conflict with GA approach. Compared to the former model, it is recognized that the workspace conflict is occurred only in conflict (1) for base workspace.

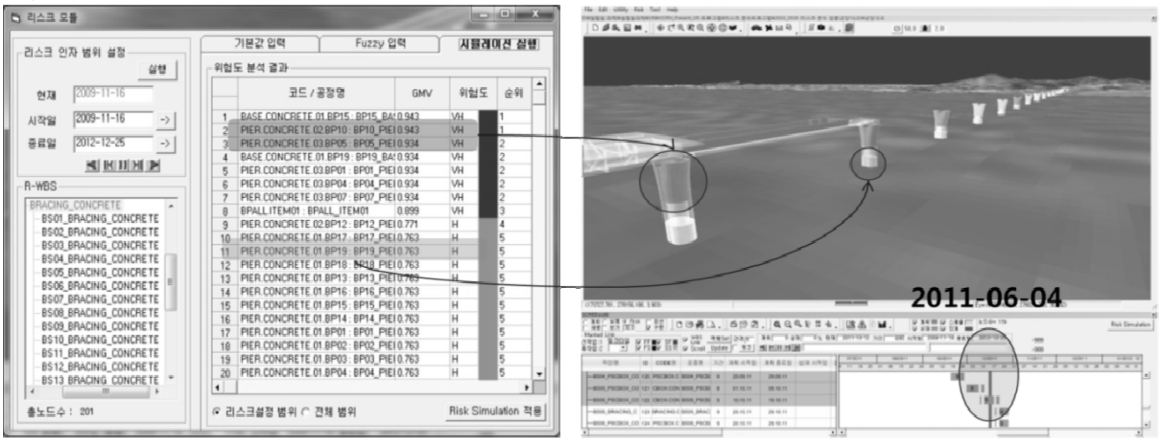
A workspace conflict optimization analysis verifies an element model for WBS and each interface activity with the planned 4D model and creates a required workspace. Then, schedule conflicts and workspace conflict are simultaneously analyzed in order to search for those activities with both conflicts. For the search of workspace conflicts, those activities with schedule conflicts are analyzed by checking the workspace adjacency distances between overlapping schedules. If the analysis results go through 4D simulation, the corresponding schedule conflicts and workspace conflicts can be visually checked over the period of time.

Since these simulation results are based on 4D modeling of the planned schedules, an improved optimization 4D model that minimizes workspace conflicts should be created. By minimizing the overlapping of the workspace-interfaced schedules, a combination of optimal schedules that minimizes the total conflict ratio can be searched. Hence, the 4D simulation results that resolved workspace conflicts can be derived as shown in the right screen of the Fig. 3.

### Development of a system that is interface with risk assessment module

Fig. 4 shows the developed 4D simulation screens that quantify a project's risk factors and convert them into visual data. The left screen of Fig. 4 shows the results of risk assessment by Fuzzy-AHP approach. We can identify risk degree on how much level each activity has for risk factors with color-coded property. The right screen of Fig. 4 represents the 4D simulation model of risk factors for each element model.

Items for risk analysis should be first selected through WBS, and analysis priority values for a project's risk factors such as project period, costs and work conditions should be defined. Then, particular linguistic variables for each activity's risk probability and impact are registered by a construction manager. Once the risk analysis is executed, each activity's risk levels are depicted in colors as per an embedded fuzzy analysis algorithm. If these risk levels are updated into a 4D model, then the right screen of the Fig. 4 will be displayed, which shows the risk levels in color-attribute values. Therefore, risk levels for all



리스크 인자 범위 설정

현재: 2009-11-16

시작일: 2009-11-16

종료일: 2012-12-25

R-WBS

BRACING_CONCRETE
- BS01_BRACING_CONCRETE
- BS02_BRACING_CONCRETE
- BS03_BRACING_CONCRETE
- BS04_BRACING_CONCRETE
- BS05_BRACING_CONCRETE
- BS06_BRACING_CONCRETE
- BS07_BRACING_CONCRETE
- BS08_BRACING_CONCRETE
- BS09_BRACING_CONCRETE
- BS10_BRACING_CONCRETE
- BS11_BRACING_CONCRETE
- BS12_BRACING_CONCRETE
- BS13_BRACING_CONCRETE

총노드수 : 201

위험도 분석 결과

| | 코드 / 공정명 | GMV | 위험도 | 순위 |
|---|---|---|---|---|
| 1 | BASE.CONCRETE.01.BP15 : BP15_BA | 0.943 | VH | 1 |
| 2 | PIER.CONCRETE.02.BP10 : BP10_PIE | 0.943 | VH | 1 |
| 3 | PIER.CONCRETE.03.BP05 : BP05_PIE | 0.934 | VH | 2 |
| 4 | BASE.CONCRETE.01.BP19 : BP19_BA | 0.934 | VH | 2 |
| 5 | PIER.CONCRETE.03.BP01 : BP01_PIE | 0.934 | VH | 2 |
| 6 | PIER.CONCRETE.03.BP04 : BP04_PIE | 0.934 | VH | 2 |
| 7 | PIER.CONCRETE.03.BP07 : BP07_PIE | 0.934 | VH | 2 |
| 8 | BPALL.ITEM01 : BPALL_ITEM01 | 0.899 | VH | 3 |
| 9 | PIER.CONCRETE.02.BP12 : BP12_PIE | 0.771 | H | 4 |
| 10 | PIER.CONCRETE.01.BP17 : BP17_PIE | 0.763 | H | 5 |
| 11 | PIER.CONCRETE.01.BP19 : BP19_PIE | 0.763 | H | 5 |
| 12 | PIER.CONCRETE.01.BP18 : BP18_PIE | 0.763 | H | 5 |
| 13 | PIER.CONCRETE.01.BP13 : BP13_PIE | 0.763 | H | 5 |
| 14 | PIER.CONCRETE.01.BP16 : BP16_PIE | 0.763 | H | 5 |
| 15 | PIER.CONCRETE.01.BP15 : BP15_PIE | 0.763 | H | 5 |
| 16 | PIER.CONCRETE.01.BP14 : BP14_PIE | 0.763 | H | 5 |
| 17 | PIER.CONCRETE.01.BP01 : BP01_PIE | 0.763 | H | 5 |
| 18 | PIER.CONCRETE.01.BP02 : BP02_PIE | 0.763 | H | 5 |
| 19 | PIER.CONCRETE.01.BP03 : BP03_PIE | 0.763 | H | 5 |
| 20 | PIER.CONCRETE.01.BP04 : BP04_PIE | 0.763 | H | 5 |

● 리스크설정 범위 ○ 전체 범위

Risk Simulation 적용

*Fig. 4. Risk visualization module by fuzzy algorithm*

activities as per a project's progress can be visually provided through 4D simulation. This will allow workers to selectively sort out those activities with higher risk levels and generate a report. That is, optimal risk assessment can be attained.

## CONCLUSION

This study has developed an active BIM methodology and system that improves the passive BIM system in order to provide an integrated workflow during the construction phase. To do this, this study has developed a module that could optimize such project management data as schedule conflict and workspace conflict, and also a module that could assess those risks associated with construction works. These modules were integrated through a 4D CAD system that was developed in the study. With all these modules and systems, this study could verify that active BIM functions providing such schedule management data that are optimized for each project could be developed from current BIM functions that are focused on the simple visualization. It is expected that all these advanced functions would be used as basic data for the establishment of active BIM environments.

## ACKNOWLEDGEMENTS

A part of this study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (No. 2011-0016064).

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