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USE OF BIM TOOLS FOR SITE LAYOUT PLANNING

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Building Information Model (BIM) has a wide range of applications and benefits that can help in communicating a large amount of information of the entire project lift cycle. BIM allows for 4D construction sequencing and scheduling through visual simulation. This paper demonstrates how BIM tools can be used for construction site layout planning and simulation. A methodology framework is developed to create the workflow necessary for the planning. Bentley's AECOsim Building Designer V8i was used as a modelling tool. Available on-line 3D models were sourced and collected for the simulation. In the process, shortcomings, or lack of BIM tools specific for Site Layout Planning, were identified. It is hoped that this research could lead to further development of BIM software aimed at supporting the construction industry.

Keywords: Building Information Model, Site Layout Plan, Construction, Simulation.

1 INTRODUCTION

Well-established stand-alone construction tools such as CAD and Gantt charts are no longer sufficient to support the much needed productivity growth of the AEC industry. Stand-alone tools for different application (drafting, scheduling, and estimating) and faculties (architecture, construction, mechanical, electrical) are integrated into one model (Froese 2010), which serves as a database for all building information, known as Building Information Modeling (BIM). This integration facilitates collaboration, data exchange, and managing the entire life-cycle of a building. The ultimate goal of BIM is to make the built environment more economically, socially, and environmentally sustainable (Architects 2010).

BIM has a wide range of application and benefits, and as such its value means something different to each group of users (CRC 2009). In the design field, a BIM model enables simulation of building properties, design coordination, clash detection, and automatic safety checks (Branson 2013). In the construction field, a BIM model allows for 4D construction sequencing, and scheduling. 4D modeling or simulation/visualization of construction schedule presents opportunities for improved construction planning and management on-site (Wang et al. 2004), such as the generation of Site Layout Plans, which is the focus of this research.

2 BIM SOFTWARE AND STANDARDS

Software such as Graphisoft, Nemetschek Scia, 4M, Innovaya, Vico Software, and Tekla only support limited discipline or application, and are stand-alone software. Graphisoft is a BIM tool for architects (Graphisoft 2013). Bentley's AECOsim merges

Architectural, Engineering, Construction and Operations (AECO) applications into an integrated workflow (Bentley 2013). Autodesk also combined some of its existing software such as AutoCAD, Revit, & Navisworks into one package known as Autodesk Building Designer Suite (AutoDesk 2013).

There are currently no BIM Standards and Technical Codes in Australia. The National BIM Initiative Report (BuildingSMART 2012) recommended a target date of 2015-2016 for the development of Australian BIM technical codes and Standards. Industry Foundation Classes (IFC) is the standard for interoperability. Existing BIM Guidelines in Australia include the NATSPEC National BIM Guide 2012, The National Guidelines for Digital Modeling 2009, and the Australian/New Zealand Revit Standards. Other standards include ISO 10303, ISO 15531, and ISO 13584, which integrate product-development processes.

In Australia, the National Guidelines for Digital Modeling is developed by a Cooperative Research Center (CRC) Construction for Innovation initiative prepared with industry (ARUP, John Holland, Thiess et al.), government (Queensland Government, Building Commission, Government of WA Office of Strategic Projects et al.), and research partners (University of Newcastle, Curtin University, RMIT University). The document provides recommendation for key areas of model creation, development, simulation and measuring performance. The guideline is supported by six case studies including a summary of lessons learned about implementing BIM in Australian building projects.

NATSPEC is the National Specification System of Australia. The NATSPEC National BIM Guide provides guidelines for the use of BIM. This guideline assists clients, consultants and stakeholders to clarify their BIM requirements. This document defines roles, responsibilities, collaboration procedures, approved software, modeling requirements, digital deliverables, and documentation standards. It also documents a range of possible uses for BIM on projects. NATSPEC recommends clients to require the submission of BIM Management Plan (BMP) if BIM is used for a project. The BIM Management Plan is a formal document that defines how the project will be executed, monitored, and controlled with regard to BIM.

3 CONSTRUCTION SITE LAYOUT PLANNING

3.1 Site Layout Tools

Over the years, various optimization and heuristic models have been developed by researchers. The most common are genetic algorithms, neural networks, and hybrid methods. However, there is no standard tool that has gained wide acceptance by the industry (Sadeghpour et al. 2006).

Genetic Algorithms rely on grids to locate temporary facilities. It is robust, has the capability to efficiently search complex solution space (Sanad et al. 2008), and can accommodate various physical constraints (Easa and Hossain 2008). Some researchers explored the use of hybrid techniques. Zouein and Tommelein (1999)'s Hybrid Incremental Solution Method combined heuristics, linear programming, and algorithms to generate alternative layouts. In dynamic space scheduling, a knowledge base system and optimization process is combined. In another research, knowledge base system is combined with GIS.

El-Rayes and Said (2009) argues that the disadvantage of existing models (genetic algorithms, neural networks, hybrid systems), future implications of layout decisions in the early stages are not considered due to their static nature. They only generate a single layout, which does not reflect a real construction site, as site usage changes over project duration. Thus layout arrangements of all temporary construction facilities should be updated over the entire project's duration. Further, (El-Rayes and Said 2009) proposes that Site Layout Plans should be dynamic, and consider possible reuse of space, relocation of temporary facilities, and reflect changing space needs. Site Layout Planning Models should generate optimal site layouts for each stage in chronological order.

3.2 BIM-based Site Layout Planning

Site layout planning is a dynamic activity across the whole 3D site. The use of space in a construction site changes as each stage progresses. Heesom (2002) suggested that project managers and planners who use 4D simulation are likely to allocated resources more effectively than those who do not. Sadeghpour et al. (2006) presented an interactive Computer Aided site layout model to support site planning in CAD. Chau et al. (2004) developed a 4D simulation model to link 3D geometry to a construction schedule.

BIM-based site layout and safety planning was explored by Sulankivi (2009), who worked for VTT Technical Research Centre of Finland in partnership with the Finnish Institute of Occupational Health. 3D site planning objects were collected and created. Using data from a completed building project, the author carried out a BIM-based building site modeling and visualization tests. The object library was tested. The needs, ideas, potential of BIM-based safety management were surveyed by workshops and industry representatives. Sulankivi (2009) summarized the benefits of a BIM-based site layout planning as: visualization of site arrangements at different periods of time, more illustrative site plans for communication, and visual support for planning, discussing, and managing safety related issues.

BIM offers visualization opportunities regarding site arrangements and risk zones. NATSPEC clause 7.6.6 on Site utilization planning states that the "4D BIM [should be used] to model permanent and temporary on-site facilities, equipment and material locations and movements, including deliveries for planning purposes, and to communicate on-site activities to site personnel and building occupants."

4 THE METHODOLOGY FRAMEWORK FOR BIM-BASED SITE LAYOUT PLANNING

The developed methodology framework is shown in Figure 1. The Building Model and Construction Site were imported to the BIM software. The construction schedule can be created from scheduling software and imported into the BIM software. The site planner can make site layout planning decisions based on the construction simulation which shows the construction sequence and task duration, and available space. Site Layout Planning begins by identifying temporary facilities needed for each construction activity according to the schedule. The 3D site objects were then imported into the BIM software.

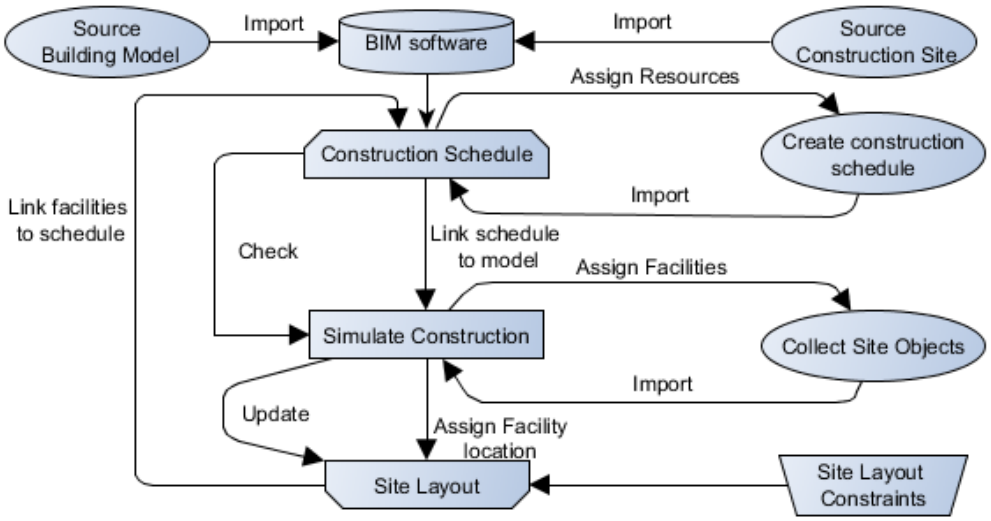

Figure 1. Methodology framework for BIM-based site layout planning.

The next step was deciding the placement and arrangement of temporary facilities, taking various constraints into consideration. The 3D site objects can then be attached to the task in the construction schedule. The placement and arrangement made was checked visually by running the 4D simulation. If change needs to be made in the site layout, the user can reposition the facilities or reassign duration. Site Layout Planning will be an iterative process, in which its suitability is verified through the 4D visual simulation of the whole site construction work.

While going through the process of planning the Site Layout via the construction simulation, the proposed BIM-based Site Layout Planning was evaluated. The BIM-software is also evaluated on its effectiveness, short-comings, and applicability to Site Layout Planning. Criteria used for evaluation were interoperability, usability, learnability, support services, site layout planning capabilities, visualization tool, and 3D modelling tool.

5 EXAMPLE

The Building Model and Construction Site Model were imported into the BIM software. The construction schedule was made by allocating time and materials to construction activities. The construction schedule was made with scheduling software and imported into the BIM software. The structural elements were attached to the construction schedule so that it can be simulated. Site layout planning decisions were made based on the construction simulation, which shows the construction sequence, task duration, and available space. Site Layout Planning began by identifying temporary facilities needed for each construction activity. Once temporary facilities were determined, ready-made 3D site objects were collected from a variety of sources. The 3D site objects were then imported into the BIM software. The next step was deciding the placement and arrangement of temporary facilities while taking various constraints into consideration. The 3D site objects were then attached to the task in the

construction schedule. The placement and arrangement made were checked visually by running the 4D visual simulation. Temporary facilities such as storage areas were repositioned until the best location was determined. BIM-based Site Layout Planning was an iterative process in which its suitability was verified through the 4D visual simulation of the whole construction work site.

The BIM software chosen was Bentley System's AECOsim Building Designer v8i, as Curtin University has full license to access the software and Bentley System's Academic Coordinator. For these reasons, Bentley AECOsim was chosen as the BIM software to be investigated due to ease of accessibility and access for support. The BIM models for the building and construction site were sourced from Bentley AECOsim's existing building samples. 3D site objects were sourced from Revit Autodesk, Revit City and Trimble 3D warehouse. The BIM models and 3D objects collected were site office, tower crane, concrete pump, site bin, fence unit, scaffold, and forklift. Sourcing these BIM and 3D models reflected an ideal BIM environment where BIM is used in all stages of the building's life cycle.

6 DISCUSSION AND CONCLUSION

BIM has shown good potential as a tool for Site Layout Planning. However, the extent to which BIM is a tool for decision-making is only limited to the 4D construction simulation of the building, which clearly shows available spaces throughout the construction stage. Positioning of temporary facilities entirely depends on the knowledge and experience of the user. The only tools offered by the BIM software used (in relation to site layout planning) are the ones allowing the user to define tasks as constructive, destructive, permanent, and/or temporary. Defining the task as temporary automates the appearance of the temporary facilities at the specified date, entire duration, and removal from the scene at the end date. This was very useful for visualizing site congestion (e.g., when materials arrived, and when plant moved around the site) at any time during the construction process. This is contrary to elements assigned as constructive, which appears green from the start and the end date of construction, and remains in the scene after that. With very limited tools available for site layout planning, it is not yet feasible to model the location and movement of the temporary facilities in a BIM model. It is time consuming, and, because animation movements are not plant-specific, movements on site would not be realistic. Figure 2 shows the structural components of the construction site model used in this research.

Improvements in user interface of BIM software, and further development of BIM tools specific to construction planning, would dramatically improve site management and operations. Based on this study, other areas that need improvement: (1) The materials schedule should be extractable from the construction schedule to generate requisition forms. (2) Unused space should be identifiable in BIM. (3) Time specified for soft clash should be automatically removed to allow use of the space.

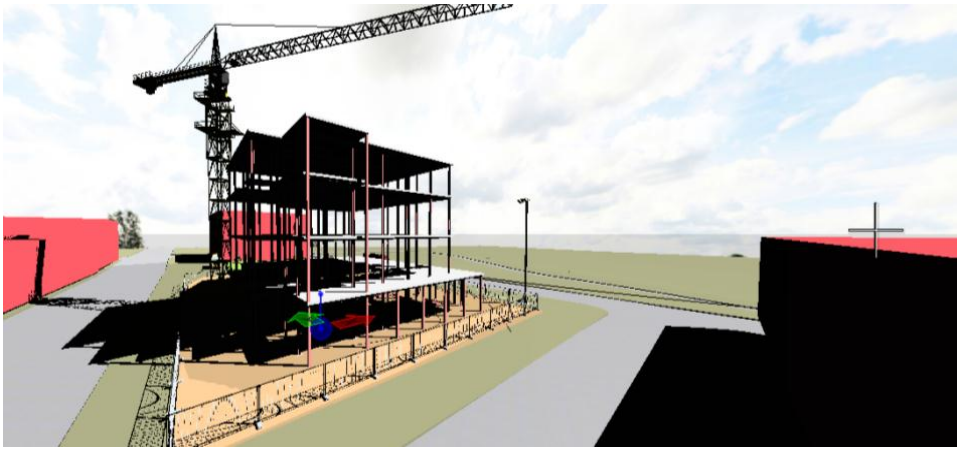

Figure 2. Construction Site Model.

References

Architects, Australian Institute of, *BIM in Australia (Report in BIM/IPD Forums)*, 2010.

AutoDesk, *Autodesk Building Design Suite*, http://www.autodesk.com/suites/building-design-suite/overview , accessed August 2013.

Bentley, *Bentley Products*, http://www.bentley.com/en-AU/Products/, accessed August 2013

BuildingSMART *National Building Information Modelling Initiative*, BuildingSMART Australasia, http://buildingsmart.org.au/the-national-bim-initiative, accessed March 2013.

CRC, *Towards Integration*, Cooperative Research Centre for Construction Innovation, Brisbane, Australia, 2009.

Easa, S., and Hossain, K., New mathematical optimization model for construction site layout, *Journal of Construction Engineering and Management* 134(8): 653-662, 2008.

El-Rayes, K., and Said, H., Dynamic site layout planning using approximate dynamic programming, *Journal of Computing in Civil Engineering*, 23(2): 119-127, 2009.

Froese, T. M., The impact of emerging information technology on project management for construction, *Automation in Construction* 19(5): 531-538, 2010.

Graphisoft, *Graphisoft ArchiCAD 17*, http://graphisoft.com.au/archicad/, accessed August 2013.

Heesom, D., and Mahdjoubi, L., A dynamic 4D simulation system for construction space planning. *Paper read at Decision Making in Civil and Urban Engineering* (DMinUCE), London, 2012.

Sadeghpour, F., Moselhi, O., and Alkass, S., Computer-aided site layout planning, *Journal of Construction Engineering and Management* 132(2): 143-151, 2006.

Sanad, H., Ammar, M., and Ibrahim, M., Optimal construction site layout considering safety and environmental aspects, *Journal of Construction Engineering and Management*, 134(7): 536-544, 2008.

Sulankivi, K., *BIM-based site layout and safety planning*, 2009.

Wang, H. J., Zhang, J. P., Chau, K. W., and Anson, M., 4D dynamic management for construction planning and resource utilization, *Automation in Const.* 13(5): 575-589, 2004.

Zouein, P., and Tommelein, I., Dynamic layout planning using a hybrid incremental solution method, *Journal of Construction Engineering and Management*, 125(6): 400-408, 1999.