On Site BIM Model Use to Integrate 4D/5D Activities and Construction Works: A case study on a Brazilian low income house enterprise

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ABSTRACT

This paper presents a practical application of integrating an integrated model (BIM) with scheduling and cost planning. It also describes the steps undertaken to plan and re-plan a project, at each new decision taken by the multidisciplinary team. The study was conducted during the development of a low income housing enterprise nearby the city of Curitiba in Brazil. The undertaken application demonstrates how to extract information from the BIM model for uses to production planning and control on site construction. Throughout the work breakdown structure and the unit costs for bill of materials, the model can be integrated with planning and helps the execution phase as well. With 4D/5D simulation, the information and decision of design phase was taken to the construction site. The results show some decisions and uses of the integrated model on the design phase and production planning and control on construction site. Some difficulties experienced by the development team are also reported. The main conclusions of this study confirm the advantages and disadvantages of using 4D/5D BIM modeling found in the literature, such as supporting lean construction principles on production.

INTRODUCTION

There's great difficulty on the AEC sector to maintain information online available to all team. It is difficult to the organizations see the planning during the activities in the construction site (Ferreira *et al*. 2012). To control all the information produced by the construction project team, the information model is used (Ferreira 2007). This information model, called Building Information Modeling (BIM) (Eastman *et al*. 2011), acts as a change in paradigm for the integration of data and professionals, and in this paper it will be called integrated model. Distribute task and responsibility, given efforts to design phase of the project (Eastman *et al*. 2011).

In this context this paper aims to show the work with the integrated model and a multidisciplinary team. The research method was the case study developed in a city in the South of Brazil.

RESEARCH METHOD

The research method used for this study technique was the case study with researchers' intervention. The case is a construction project located nearby the city of Curitiba, capital of the State of Parana in the South of Brazil. There are four towers with four stories each, totaling 96 residential units. The designs were done in a CAD2D model during the early development of the integrated BIM model. The integrated model was then prepared by the owner´s management team. This team was also composed by the researchers.

The team was a multidisciplinary one consisted of the researchers, three professionals with skills on the BIM modeling tools like Autodesk Revit, Navisworks and also Microsoft Project used together with MS Excel for LOB (Line of Balance) planning and five engineers of the owner’s management team.

RESULTS

Based on the 2D model, a Work Breakdown Structure (WBS) of the activities was prepared and used to elaborate a LOB plan. The multidisciplinary team only could take the model to the construction phase, if all items of the WBS were in a nD classification (3D, 4D e 5D) with production procedures and construction materials.

At the same time, the Construction was going on. From Last Planner System®, with an eight weeks of anticipation the Lookahead Plan order to start the modeling process, picking the activities from the CPM plan. Figure 1 shows the BIM modeling process.

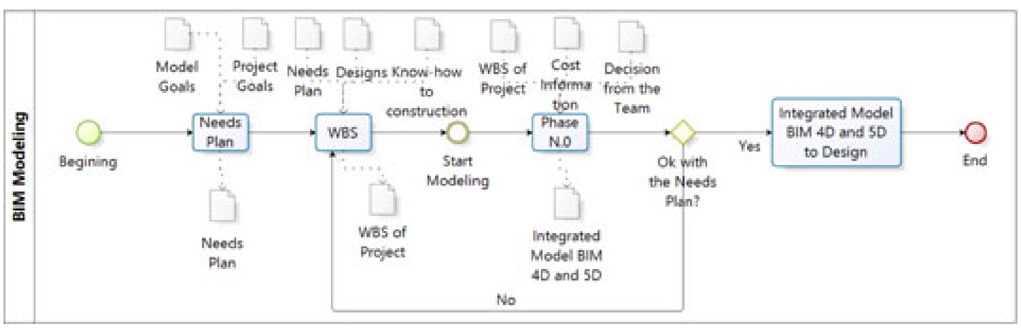

Figure 1. BIM Modeling process.

Phases were the form used to organize meetings integrated with the model. At each meeting, phase activities were discussed appearing on the LOB that should be modeled. The information of the activities was inserted in the integrated model on each phase. Figure 2 shows a view of the phase modeling process.

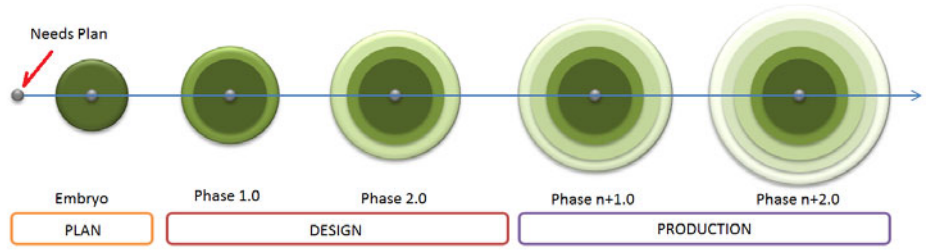

Figure 2. Modeling by phases.

At each end of the modeling phase, the integrated nD model had time (4D), costs (5D), and even the WBS activities that had not been modeled yet. These costs were only estimative. The clash detection was applied in the 3D model and the clashes were sent to the engineers. Therefore, these engineers could work to solve these problems and take decisions forward to the construction. Figure 3 is a picture taken in a phase meeting, with the multidisciplinary team in the so called 'BIM immersion room'. This meeting happened as a constraint in the Lookahead plan. These decisions were sent to site.

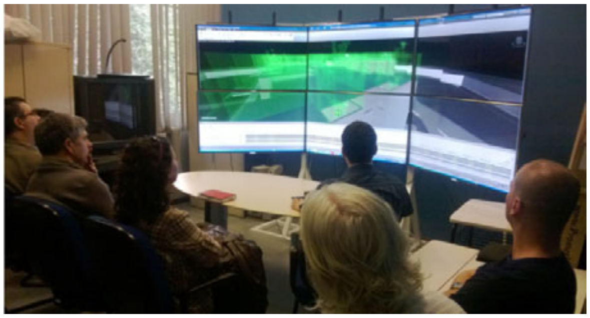

Figure 3. 'BIM immersion room' and meeting with the multidisciplinary team.

Integrated 3D Model. Any WBS activity was inserted in the integrated BIM model,. After the work, accomplished in Autodesk Revit 2013, a file was exported to Autodesk Navisworks Manage 2014 to the clash detection task and 4D modeling. Drawings were taken from the model, with specifications. The model was sent to site making possible the subcontractors to work with it.

Integrated 4D Model. The durations of the WBS activities were obtained, based on productivities and the Line of Balance Plan was taken from the integrated 4D model. This model was used to give instructions for subcontractors, like production sequence, important dates and production needs. These instructions was discussed and validated by the managers and subcontractors Last Planner weekly meetings on site.

Daily, a team from the Contractor, on site, collected information of the production related to the WBS activities, with a system integrated with the model by the WBS code.

After the production of the WBS activities, the information of fulfill activities was inserted again on the 3D model. The results were compared with the planning model.

Integrated 5D Model. Quantity takeoff was directly generated from the integrated 3D model. This quantity takeoff was associated with a unitary cost service composition, from the contractor's database. With this work done, the bill of materials and costs, from each WBS activity, was sent to site and to the responsible for purchasing.

At the window of time of the Lookahead planning it was needed to get the bill of materials for the WBS activities. After purchasing it, deliver to site, the materials were separated to the production locations. The consumption and the costs were controlled from every WBS activities of the model.

Use of the integrated nD model on the construction site. It was developed a number of monitoring and controlling tools in order to help the management team and the contractor in the work at the construction site. All the informations in the BIM could be accessed by the subcontractors and contractor. This information used on site could take a feedback. Production rates, costs, planning done feedbacks the database. Daily, the production happened taken informations from model (provided) and the results were collected back from it (fulfilled).

The decisions, information, solutions, risks and provided information was sent, in the integrated model, to the construction site. The objective was to use the integrated model to help the production process on site with production planning and control.

Furthermore, the information is taken daily from the model and feedback. The results and discussion was done at Last Planner weekly meetings.

FINDINGS

In the following sections, the findings of this research are discussed shortly. These findings were obtained with the help of researchers of the Civil Engineering Research Center (CESEC) at the Federal University of Parana.

Modeling Process. Four phases were performed with the multidisciplinary team. Phase 1.0 (01/24/2013): Earth moving, shallow foundations and deep foundations. At this phase it was possible to harmonize the activities of earthworks and foundations. Phase 2.0 (02/27/2013) – Structure, seals, coatings, frames and coverage. In the integrated BIM model, it was inserted information of constructive processes and construction materials. Phase 3.0 (03/15/2013) – Plumbing, electrical and telecommunications systems; and, firefighting system (Figure 4).

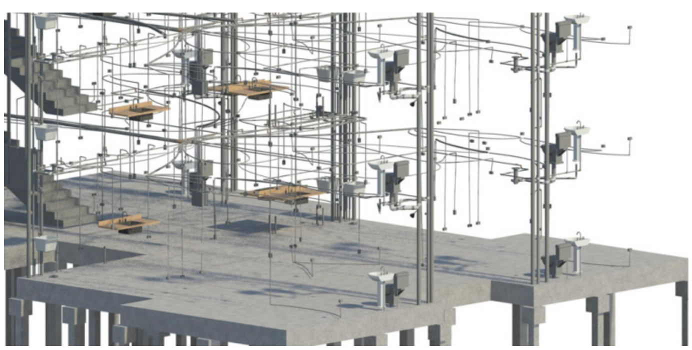

Figure 4. Phase 3.0.

As pictured in Figure 5, the clash detection was done and some problems sent to the responsible person.

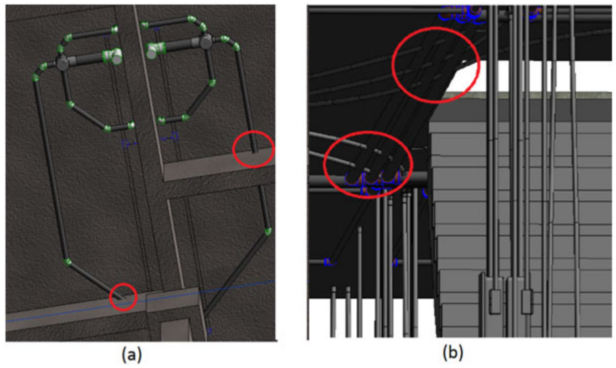

Figure 5. Phase 3.0 – (a) Clash detective structure x plumbing; (b) electrical x plumbing.

Phase 4.0 (07/25/2013) – integrated 4D/5D model with Line of Balance. In the integrated 4D model, some interference of activities were checked and subsequently re-planned as the following Figure 6: (a) the worker needs to move himself between two places of work for the same activity. The change brings work in the same place and in the same time; (b) the piping activity would be produced after the structure, according the planning. The replanning let the plumbing before the structure.

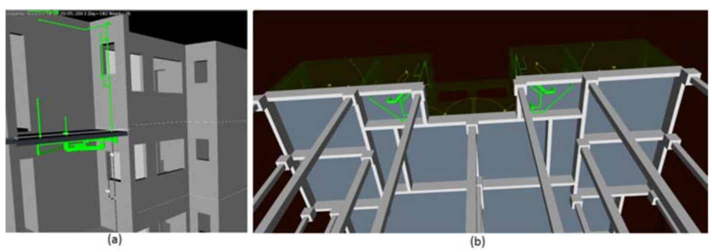

Figure 6. Phase 4.0 – Interference between activities (a) plumbing after concrete; (b) two places for the same activity.

Use of the integrated nD model on construction site. The 3D model was sent to the construction site. Therefore, the workers could work with harmonized designs and model. This practice promoted the chance to use pre-fabricated kits of piping. And the activities like piping, structure, floor etc., could reduce variability and reduce cycle times of production. Figure 7 is an example of this use.

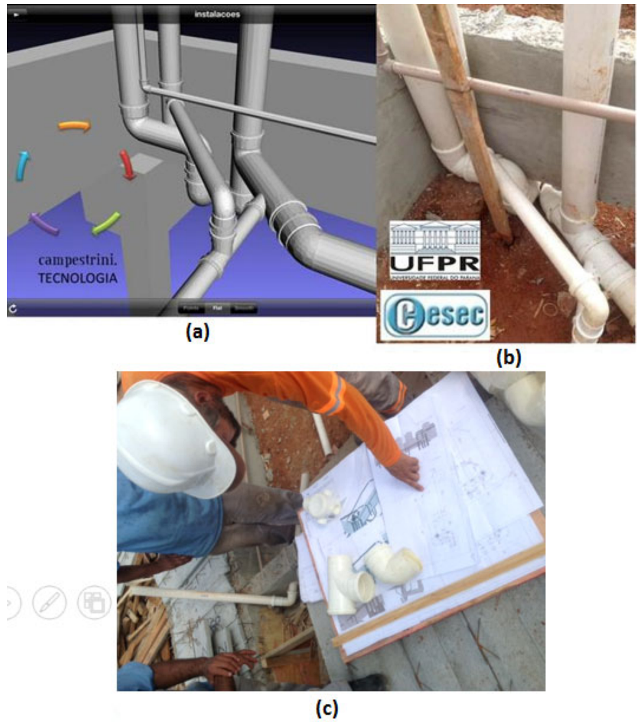

Figure 7. Model on site – (a) integrated model – 3D view; (b) activity developed on site; (c) subcontractor working.

The integrated 4D model (Figure 8) was used to support the project management together with the control panel (Figure 9). The 4D was updated daily and the diagnostic was taking. The late activities were on red color. The control panel show some performance indicators, updated daily. The metric performance indicators were used to manage the costs (5D), the planning (4D) and the quality of the production (3D). This tool allowed a visual management of the production position on site to the contractor manage team. The manage team could verify and validate decisions and control with accurate information.

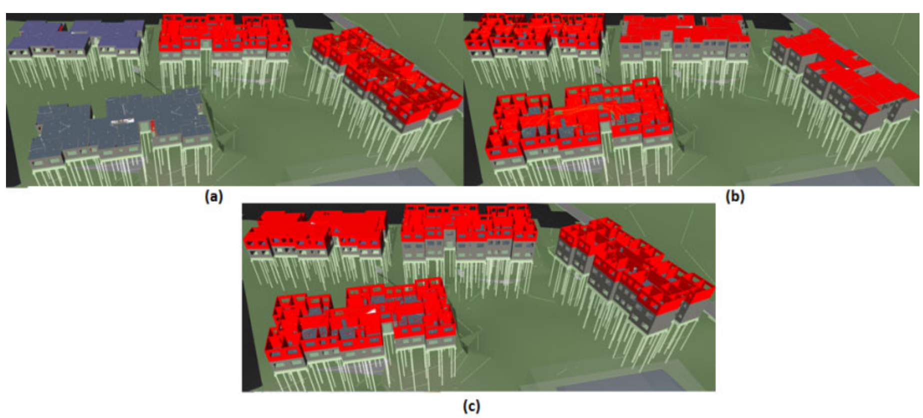

Figure 8. Model on site – (a) 08/02/2013; (b) 08/09/2013; (c) 08/16/2013.

Figure 9. control panel: indicators to manage daily integrated with model.

CONCLUSIONS

The modeling team with three members took five months to learn to work with the software. Many trial and error tests were performed for interoperability between software. For this work, the level of detail was set equal to the WBS, except for electrical installations that had no wiring or circuit breakers modeled in 3D.

The multidisciplinary team did not realize the advantage of using BIM on first meeting. This fact forced the team of researchers intervene in the process to improve the perception, adapting the team to work with the integrated BIM model.

Changing production sequence as detected in 4D, could be done without help of the BIM tools. But the mental effort carried for such a task would be too much.

With the Last Planner System®, the integrated model helped to pull activities and reduce variability. To pull the production, it was verified and validated by the integrated model and a visual management with metric performance indicators supporting Lean Construction principles of improve transparency, visual management, reduce errors, improve communication, reduce variability and cycle times and elimination waste in design process and in production on site.

The work of production planning and control could be done without BIM. But the use of integrated model helped the work and could let the process lean.

The contribution of this paper is to illustrate the possibility of using BIM bringing the design process information to the construction site and the use of the integrated model to production planning and control with Lean Construction principles.

REFERENCES

Biotto, C. N. (2012). "Method of management of production on civil construction with the use of modeling BIM 4D". Master thesis, Universidade Federal do Rio Grande do Sul, Porto Alegre. (in Portuguese)

Eastman, C.; Teicholz, P; Sacks, R; Liston, K. (2011). "BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors" 2 ed. John Wiley& Sons. New Jersey,

Ferreira, E. A. M.; Matos, F. D.; Garcia, M. S. (2012). "Evaluation of the Building and Construction Site Development Modeling Process in 4D Designs". In:XIV ENTAC, Juiz de Fora. p. 3558 - 3563. (in Portuguese)

Florio, W.; Aaraujo, N. S. (2007). "The importance of information technology and 3D/4D Models in Process and Design Management and Architecture". 2In:VI ENTECA, Maringá. (in Portuguese)

Menezes, A. M.; Viana, M. L. S.; Pereira Jr, M. L; Palhares, S. R. (2010). "The appropriateness (or not) of BIM applications to contemporary theories of teaching building design". In: SIGRADI. Bogotá. (in Portuguese)