INTEGRATION FRAMEWORK OF BIM WITH THE LAST PLANNER SYSTEM™

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ABSTRACT

Lean construction and BIM are two rapidly growing applied research areas in the realm of construction management. Both have justified their implementation by the significant improvements in the cost, schedule and quality of construction. Lean construction aims to remove the wastes in the construction process while BIM aims for greater collaboration among the project teams during the design and construction phases of a project. Both have been implemented independently on projects but there is lack of research showing their applications together on construction projects. Using a case of a major renovation project at the University of Texas at Austin, this paper presents the benefits of BIM implementation and further focuses on developing an integration framework of BIM with the Last Planner System™ of lean construction. BIM with its tools like 3D visualization, 4D simulation and MEP clash detection leads to increased collaboration among the project team and when integrated with the Last Planner System™, it can help in reducing the variability inherent in the construction process. This paper presents an integration framework of BIM at three levels in the Last Planner System™ – at the Master Schedule level, Lookahead Schedule level and at the Weekly Work Plan level. The advantage of this integration is also discussed in this paper.

KEYWORDS

Last Planner System, BIM, MEP Clash Detection, 3D Visualization, 4D Simulation

INTRODUCTION

The highly fragmented construction industry has been significantly affected by the rapid development in lean construction and Building Information Modeling (BIM). More and more companies are taking to these two applied research areas to reap the benefits from their implementation. While lean construction is a construction management philosophy focused on creating value for the customer (and eliminating everything that does not add value) using the least resources, BIM is focused more on application of information technology to increase collaboration among the project participants in the entire project lifecycle. Construction labor productivity has declined by about 20% between 1964 and 2003, while other non-farm industries improved by more than 200% (Teicholz, 2004). Research by the National Institute of Standards and Technology (NIST 2004) has further concluded that on average information is recreated / reentered about 5-8 times in a project lifecycle and this process discontinuity accounts for about 30% of the total process (about $15.8 billion

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annually). Salmon (2009) reports that in the traditional design bid build projects over 80% of the claims made are by the main participants like the owner, contractor and Architects/Engineers (A/E) and 87% of the claims were based on Requests for Information (RFI) and change orders. These examples are one of the many problems being faced by the construction industry which can be remedied by lean construction and BIM. Although lean construction and BIM are not dependent on one another (i.e., lean construction practices can be adopted without BIM, and BIM can be adopted without lean construction) Sacks et al. (2010) hypothesize that the full potential for improvement of construction projects can only be achieved when their adoption is integrated, as they are in the integrated project delivery (IPD) approach. A similar notion is expressed in the American Institute of Architects document on IPD (Eckblad et al. 2007), “Although it is possible to achieve IPD without BIM, it is the opinion and recommendation of this study that BIM is essential to efficiently achieve the collaboration required for IPD.” This paper delves into the combined application of lean and BIM on a project and discusses possible advantages of this implementation.

LEAN PROJECT DELIVERY SYSTEM

Ballard (2008, 2000b) defined the lean project delivery system as a model for managing projects, in which project definition is represented as a process of aligning ends, means and constraints. Alignment is achieved through a conversation with the customer stating what they want to accomplish (their goals and objectives) and the constraints (location, cost, time) on the means for achieving their ends. The project is structured and managed as a value generating process. Downstream stakeholders are involved in front end planning and design through cross functional teams. Project control has the job of execution as opposed to reliance on after-the-fact variance detection. Optimization efforts are focused on making work flow reliable as opposed to improving productivity. Pull techniques are used to govern the flow of materials and information through networks of cooperating specialists. Capacity and inventory buffers are used to absorb variability. Feedback loops are incorporated at every level, dedicated to rapid system adjustment; i.e., learning.

LAST PLANNER SYSTEM™

"Last Planner" is the name for the LCI’s (Lean Construction Institute) system of production control. "Control" here means causing a desired future rather than identifying variances between plan and actual (Ballard (2000a), Ballard (2000b)). Production control consists of work flow control and production unit control. Work flow control is accomplished primarily through the lookahead process. Production unit control is accomplished primarily through weekly work planning (WWP).

Schedule planning for a project cannot be performed in detail much before the events being planned. Consequently, deciding what and how much work is to be done by a design squad or a construction crew is rarely a matter of simply following a master schedule established at the beginning of the project. LPS™ is based on a Should-Can-Will-Do system of project planning. It focuses on making a 6-8 weeks lookahead schedule with detailed weekly plans in discussion with the last planners (persons who actually execute the work) based on the current situations. Assignments are prepared for the workers to execute. In this way the workers are never overloaded, they only do what they promised and this helps to keep a track of the productivity.

Failure to keep commitments is investigated so that they do not occur again. This is done by a factor known as PPC (percent planned complete. As the Last Planner System^{TM} involves the pull approach to form a workable backlog, it utilizes the just in time tool, since all the project participants sit together to form the lookahead schedule, wherein continuous improvement is built into the process. Thus the Last Planner System^{TM} serves to remove the uncertainties in the construction process.

BIM

Building Information Modeling, better known as 'BIM' has been defined in different ways by different authors. According to Sacks et al. (2010) BIM is "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation". Smith (2007) has defined BIM as a "digital representation of the physical and functional characteristics of a facility. Its purpose is to serve as a shared knowledge resource for information about a facility and forming a reliable basis for decisions during its life-cycle from inception onward". The concept of Building Information Modeling is to build a building virtually, prior to building it physically, in order to work out problems, and simulate and analyze potential impacts. BIM is different from a 3D model is the sense that it expresses the form, function, and behavior of objects (Tolman, 1999)**.**

Sacks et al. (2010) have provided detailed discussion on the most popular uses of BIM. Important uses relevant to this discussion are as follows:

1. Visualization of Form (for Aesthetic and Functional Evaluation): All BIM systems enhance stakeholder participation by providing the ability to render the designs in 3D, making building designs more accessible to them.
2. Collaboration in Design and Construction: Collaboration in design and construction is expressed in two ways: "internally, "where multiple users within a single organization or discipline edit the same model simultaneously, and "externally," where multiple modelers simultaneously view merged or separate multidiscipline models for design coordination. Whereas in the internal mode objects can be locked to avoid inconsistencies when objects might be edited to produce multiple versions, in the external mode only no editable representations of the objects are shared, avoiding the problem but enforcing the need for each discipline to modify its own objects separately before checking whether conflicts are resolved.
3. Rapid Generation and Evaluation of Construction Plan Alternatives**:** Numerous commercial packages are available for four-dimensional (4D) visualization of construction schedules. Some automate the generation of construction tasks and modeling of dependencies and prerequisites (such as completion of preceding tasks, space, information, and safety reviews and resources crews, materials, equipment, etc.) by using libraries of construction method recipes, so that changes to plans can be made and evaluated within hours.
4. Mechanical Electrical Plumbing (MEP) Clash detection: MEP systems are extremely critical on technically challenging projects like hospitals, pharmaceutical industries. Deciding the routing and the spatial arrangement of the

MEP systems before construction execution hence plays an important role in the successful execution of a project. A/E's typically produce a schematic line diagram of the MEP system routing and the contractor relies on his specialty subs to come up with the precise dimensions of the systems given the required specifications by the A/E. Failure to identify the spatial dimensions of the MEP systems and checking for potential clashes between the different MEP systems before construction can result in a lot of rework which can further lead to time and cost overrun (Khanzode, 2008).

INTERACTION BETWEEN BIM AND LEAN

Sacks et al. (2010) hypothesized positive interactions between many lean principles and BIM functionalities. The lean principles that have the highest concentration of unique interactions are:

a. get quality right the first time and reduce product variability

b. focus on improving upstream flow variability, reduce production variability

c. reduced production cycle durations.

The BIM functionalities that have the highest concentrations of unique interactions are:

a. aesthetic and functional evaluation

b. multiuser viewing of merged or separate multidiscipline models

c. 4D visualization of construction schedules

d. online communication of product and process information

In another research, Sacks et al. (2009) while concentrating on fabrication, logistics and installation of a building on site emphasize on the implementation on BIM and lean together to achieve stable flows and communicate pull flow signals. They highlight that use of 4D CAD modeling can help to plan for stable work flow and to communicate standardized processes to workers. BIM models stored online on servers can be pulled up any time to look up detailed information on work packages. Due to increased collaboration between the project participants and increased confidence in the design, BIM implementation also aids in just in time delivery of materials and parts. BIM when combined with the Last Planner System™ can help in filtering work packages for maturity to ensure stability.

Thus, from the above we can conclude that there are significant benefits of implementing BIM and lean in synergy with each other. Though Sacks et al. (2009) have emphasized on the integration of LPS**™** with BIM, no framework has been proposed suggesting what BIM functionalities are to be used and when are they to be used to increase value and flow reliability. This paper focuses on presenting an integration framework of the LPS**™** with BIM to provide for stable work flows and reduce the uncertainties inherent in the construction process.

METHODOLOGY

To prepare a framework for integration of the Last Planner System™ with BIM, it was decided to select a project which used both the tools during the project execution. This was done to better understand the inherent practical issues in the application of both these tools simultaneously to find out synergy for the framework proposed in this paper. The renovation of the Lee and Joe Jamail Swimming Center at the University of Texas at Austin fitted the criteria thus established and was used to prepare the integration framework between the Last Planner System™ and BIM.

HYPOTHESIS TESTING

The hypothesis being tested in the paper is that BIM and Lean are not independent of each other, maximum benefits can be realized by simultaneous implementation of both of BIM and Lean. Increased collaboration between project participants, reduced number of RFIs and Change Orders leads to more value and greater satisfaction for the customer. Due to lack of resources, the project participants did not use all aspects of the Last Planner System™ and hence only the implementation of lookahead schedule and weekly work plans during construction were analyzed for the purpose of this study.

CASE STUDY: LEE AND JOE JAMAIL SWIMMING CENTER, UNIVERSITY OF TEXAS AT AUSTIN

The Lee and Joe Jamail swimming center at the University of Texas at Austin was completed in 1977; however, due to the heavy wear and tear, it underwent a major renovation in the year 2010. The renovation project was handled by the Project Management and Construction Services of the University. The contract required the use of BIM, however, the level of use / deliverables were not mentioned. It was the owner's first time experience with BIM whereas the contractor and the architect were familiar with BIM through past projects. The owner heavily relied on the experience of the contractor for successful implementation of BIM. Owner's initial expectation from BIM was only that of a 3D model which could clearly communicate the design. However, due to the contractor's successful past experiences with BIM, the realm of BIM was increased to incorporate MEP clash detection. As it was a renovation project, it was extremely important to accurately identify the existing utilities to develop the routings of the new MEP system. This proved to be extremely difficult due to the unavailability of 'as-built drawings'. All the drawings had to be created using the 2D plans and site surveys. This was then combined into a 3D model in Autodesk REVIT by the Architect. The design process took a total of 13 months and was followed by the construction phase. Before the start of the construction phase, the entire project team comprising of the owner's project management team, contractor with his team of subcontractors and the architect started weekly BIM coordination meetings. The objective of this meeting was to divide the project into different units and then identify clashes between the different utility systems like mechanical, electrical, plumbing, HVAC etc. to prevent late discovery of clashes that cause rework. These coordination meetings were lead by the contractor who used 4 week lookahead planning followed by a weekly work plan to identify and resolve the clashes. These meetings proved to be extremely useful as they were able to reduce the number of RFIs and Change Orders. Furthermore, there was extremely less rework leading to shorter project duration. The project manager, based on his experience of working on similar size projects remarked that a 50% reduction in RFIs, from the 300 change orders expected to the final total of 143, and considerable reduction in change orders, due to new discovery and unforeseen conditions, were observed due to implementation of BIM coordination meetings. The breakdown of the total 300 change orders issued is shown in the Figure 1 below.

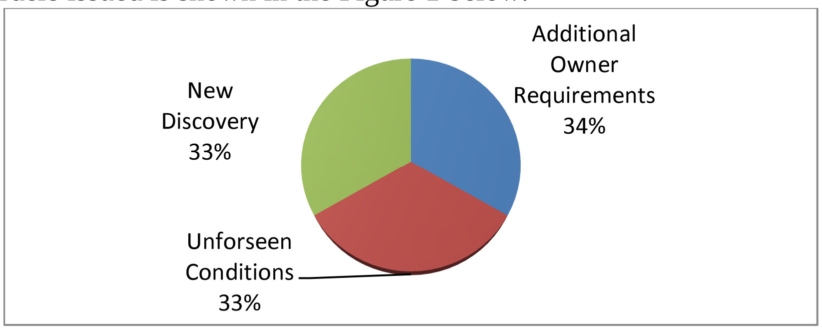

Figure 1. Classification of Change Orders

BIM implementation proved to be extremely useful in meticulous planning to expedite the construction. Due to the university's round the year tournaments and practice sessions, schedule was of paramount importance. BIM also facilitated in increased coordination among the project team which lead to better decision making. The owner was satisfied with BIM implementation and a decision was taken to use BIM and MEP coordination in all its projects. At present there are five projects utilizing BIM in the university campus.

INTEGRATION OF LPS™ WITH BIM

Although the above project was successful in terms of BIM implementation, more benefits / value could have been achieved if the BIM coordination meetings were implemented along with the LPS™. The 4 week lookahead planning and weekly work planning were limited only to improve the coordination between the different utility systems. No formal discussion of the rest of the scope of work was done during the BIM coordination meetings. The BIM coordination meetings spanned a total of 6 months and they ended well before the construction work was over. The project manager also revealed that many of the items in the weekly work plan, that were not there in the workable backlog, were included at the last minute. Furthermore, he also highlighted the need for better collaboration between the project participants. He remarked that not all of the subcontractors were present for the coordination meetings. The issues and resolutions to the subcontractors that were not present were communicated through the general contractor. This resulted in communication issues, which resulted in rework in the project. One can thus conclude that the lookahead planning which was being done in the project was not done in a systematic way with a well defined procedure. The project manager was critical of this fact and hoped for better and more systematic lookahead and weekly work planning on future projects. With an aim to find a solution to these needs of the project manager, an integration framework of LPS™ with BIM coordination meetings is proposed in the paper and is shown below.

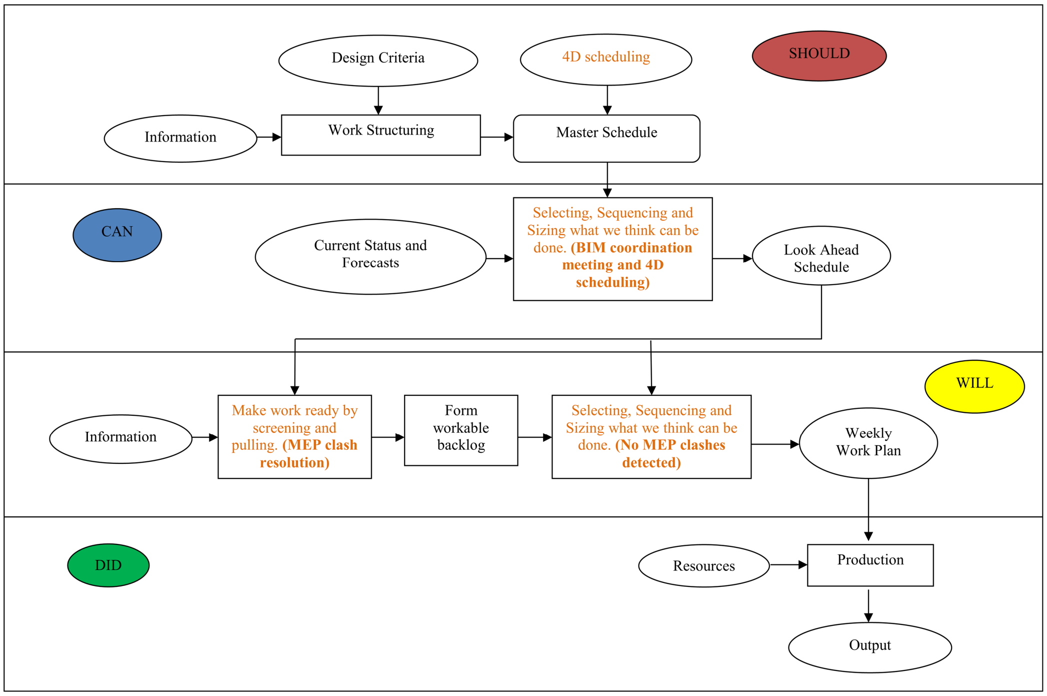

Figure 2. Integration of BIM with LPS™ (Adapted from Abdelhamid, 2006)

As shown in Figure 2 the LPS™ starts with establishing the milestone based master schedule for the project. This schedule forms the backbone of any construction project and hence it is essential that the reliability of this schedule be high as all other schedules are established using this. The reliability of this schedule can be increased with support from a 4D CAD model which shows the desired progress of the project over the project timeline. This will help the project participants to better analyze the construction progress and look for construction alternatives to better plan the flow of work. This should be followed by the development of the 4 week lookahead plan which includes the scope for BIM coordination meeting to identify clashes between the various utility systems. This lookahead plan forms the foundation for establishing the weekly work plan and hence its reliability should also be very high. It should be made taking into account the present situation, resource availability and the future requirements of the project. Once the resources for the activities have been identified and procured, all clashes between the utility systems identified previously have been resolved; then those activities should be included in the workable backlog. 4D scheduling can further add value to these meetings by comparing the desired to the actual progress. Although this was not done for this case study, progress tracking using 4D scheduling could have helped the project manager identify those tasks, during lookahead planning, that were included in the weekly work plan at the last minute. With the ability to view the virtual model of the structure, the progress of the project can be better analyzed and tracked, this will further enhance the decision making process. Finally, weekly work plans should be established from the workable backlog by selecting only those activities for which all constraints have been removed, resources and necessary information identified and procured. This needs to be done on a weekly basis which includes participation of the entire project team. Collaboration between the entire project team is required to prevent communication issues that the project team faced in this case study. This can help prevent major rework in big projects. Thus, clash detection should form an integral part of this system, which involves collaboration between the entire project team, and not be an independent process. Project progress reporting is another essential feature of these weekly meetings and the project team should make every effort to document the project progress.

SUMMARY AND CONCLUSION

BIM and Lean have been implemented independently on many projects to realize significant benefits to the customers. Past researches have hypothesized several interactions between BIM and lean which can lead to further benefits for the project participants and the customers. Despite these research efforts, no integration framework for implementing BIM and lean has been proposed. The aim of this paper was to establish a framework for incorporating BIM functionalities, like 4D scheduling, MEP clash detection, into the LPS™ to enhance work flow reliability during the construction phase. The framework was developed using a project at the University of Texas at Austin, which involved use of 3D visualization and MEP clash detection during lookahead and weekly work planning. This implementation of BIM with lookahead and weekly work planning reduced the RFIs, change orders issued and hence led to more value for the customer. The framework starts with the use of 4D scheduling to develop the master schedule. The 4 week lookahead schedule which is formed from the master schedule incorporates the BIM coordination meetings where potential clashes between the different utility systems are identified for resolution. 4D scheduling is also proposed to be implemented to form lookahead plans to better monitor the construction progress. Finally the weekly work plans are to be formed using the activities in the workable backlog for which all constraints have been removed and information, resources have been procured. It is hoped that this framework when utilized by the project participants will yield more benefits to the entire project.

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