VISILEAN: DESIGNING A PRODUCTION MANAGEMENT SYSTEM WITH LEAN AND BIM

Bhargav Dave[1], Stefan Boddy[2], Lauri Koskela[3]

ABSTRACT:

Conceptual analysis of lean construction and Building Information Modelling indicates significant synergies between the two. Interactions between the two range right from the design phase to handover and facilities management. Although lean construction is being applied throughout, application of BIM still remains predominant in the design phase. Previous case studies have proven that the use of BIM with lean practices during the construction phase improves the efficiency of planning. A software system - VisiLean is proposed that provides the construction team a lean production management system that is integrated with Building Information Modelling. The system provides clear visualisation of work status through visual indicators on the 3D model and also integrates several information sources to enable a truly integrated system that the construction industry lacks. In this paper, the basic underlying concept and a brief overview of the system are provided. The system has yet to be implemented on site so practical findings are not yet reported. However, it has been demonstrated to construction and major client organisations with positive feedback. Further work is under way to improve the system based on the initial feedback received and also to implement it on a pilot project to evaluate its performance.

KEY WORDS:

Lean Production Management, Building Information Modelling, .Net, Web Services, Information Integration

INTRODUCTION

Recently, an increasing number of researchers have discussed the potential synergies between Lean Construction and Building Information Modelling (BIM). These separate initiatives have risen to prominence in the construction industry in recent years. The lean construction concept addresses the problems inherent to the construction process, whereas BIM overcomes the hurdles that the 2D Computer Aided Design (CAD) technology presents and offers solutions to efficiently handle the product model (of the construction project).

Simultaneous implementation in the field of BIM and lean has shown promise as exemplified by recent case studies (Eastaman et al, 2007). This is due to the fact that there are significant synergies between the two as discussed by Sacks et al (2010). Here, the authors have identified 56 unique interactions between the two where BIM

[1] Research Fellow, School of the Built Environment, University of Salford; UK. Phone +44 161 2953431; B.Dave@salford.ac.uk

[2] Research Fellow, School of the Built Environment, University of Salford; UK. Phone +44 161 2953204; S.C.Boddy@salford.ac.uk

[3] Professor, School of the Built Environment, University of Salford; UK. Phone +44 161 2953178; L.J.Koskela@salford.ac.uk

seems to support the majority of lean concepts. However, no mature application yet exists that enables Lean and BIM simultaneously in the field. We propose “VisiLean” – a lean production management system that uses BIM as the visual platform and enables pull flow scheduling on the construction site.

We begin by explaining why VisiLean is needed and what critical shortcomings of the construction process it aims to solve. Following this, the general concepts underlying the system are explained as well as the overall system architecture. A typical workflow is then described, followed by concluding remarks.

WHY IS VISILEAN NEEDED?

Literature review in the subject area was carried out first to identify current issues and previously suggested solutions to overcome them. Followed by the literature review, a number of workshops, case studies and expert interviews were carried out to capture feedback from the construction professionals.

LITERATURE REVIEW

The problems associated with construction can be classified in two major categories: problems with the construction process and problems with the product representation (i.e. what is to be constructed). To improve the efficiency of the overall construction process, both the process and the product representation have to be efficient in their individual capacity as well as in an integrated capacity. Limitations of the traditional “T” based processes that are followed in construction such as CPM are well known. Also, the limitations of 2D based product representation tools such as 2D Computer Aided Design are well documented.

The lean production management system offers an effective way to solve the process related problems as it is based on the improved “TFV” theory. However, it only solves a partial problem, i.e. the problem related with process. Building Information Modelling (BIM) systems through an improved product model, solve many of the problems associated with the 2D CAD tools. BIM also offers a solution to overcome many process related issues as it provides an intelligent product model that resides in a visual platform. Researchers have discussed the potential of the synergy between Lean Construction and BIM (Sacks et al, 2010). Also, from initial implementations in the field, positive results have been reported (Khemlani, 2009). Sacks et al (2010), carried out an extensive analysis of the interactions between Lean Construction and BIM at the conceptual level and found significant synergies between the two. It was noted that the interactions/synergy between lean and BIM are found across the lifecycle of the project, and some especially strong interactions are reported during the construction phase, backed up by empirical evidence. This clearly demonstrates a potential to develop a system that integrates the process model of lean with the rich product information model offered by BIM.

The efficiency of the production planning and control process in construction depends significantly on the reliability and timely availability of resource information. The Last Planner system for production control mandates that a construction task should not be started unless all the seven resource prerequisites are in satisfactory condition. Failure to do so results in wasteful processes. However, this information is not readily available due to the lack of systems integration that prevails within the industry. Current implementations of the last planner system mostly rely on the team leaders' and foreman's ability to gather the required information for the weekly planning meetings and also for the look-ahead planning. However, much time is wasted chasing relevant information due to the above-mentioned problems.

INFORMATION SYSTEMS IN CONSTRUCTION

According to a 2006 survey carried out by ebusiness-Watch (2006) on ICT adoption level by several industry sectors, construction came low compared to other industry sectors in several categories. Especially to note are the process innovation and supply chain management categories where only 33% and 7% participants indicated the adoption of ICT respectively. The problem of construction supply chain has been discussed before (Vrijhoef and Koskela, 2002), where poor communication, articulation and activation of commitments are attributing factors. Koskela and Kazi (2003) have discussed the effectiveness of ICT within the construction sector. They have reported that although ICT has improved productivity on a general level as far as individual tasks are concerned, productivity of the industry on the whole has not benefited.

Specifically the site and project management activities have not been addressed properly by the ICT implementations. The earlier consensus amongst researchers has been that implementing enterprise resource planning (ERP) systems results in a well-integrated system, which will reduce duplication of work and increase efficiency in general. However, previous research shows that ERP and other similar systems do not address the core construction processes and hence have constantly underperformed (Dave et al, 2008).

DATA COLLECTION

It is important to get feedback from the experts and also potential users from the industry before designing a system such as VisiLean. Hence, data collection in the form of expert interviews and user workshops were carried out. Key points from the data collection are presented here. Workshops with three major construction companies in the UK and two expert interviews were carried out. The authors are collecting further data to gain further insight and the results shared here are based on the information on the initial data collection.

Use of BIM is still limited to Clash Detection and 4D

Although use of BIM is increasing on the construction site, it is still limited to basic 4D simulation where a master plan is attached to the model and the project schedule can be simulated in 3D at a macro level. Also, BIM is used for clash detection on projects. This is a valuable feature but it was reported by participants of the workshop that they understand that BIM offers many more functionalities. There are also some reported uses of BIM on site for budgeting and quantity take off on the go (Kala et al, 2010). Some innovative organisations are using BIM to manage daily/weekly-planning activities in the field during the lean planning sessions to some positive results. However, such practices are limited to the very few companies and there is still no system available that helps link both the lean and BIM process.

Lean production management systems mostly rely on manual information retrieval

Even after almost two decades following the launch of International Group for Lean Construction and numerous construction organisations around the world adopting lean practices, hardly any software systems exist that specifically support the lean production process. Each organisation is left to design their own system, which mostly comprises of Excel spread sheets or similar systems. Use of such a system is counterproductive as it cannot easily integrate information from other management systems and is not standardised across projects.

Field BIM is now increasingly becoming accessible due to advanced hardware and maturing/new software

Use of BIM technology on construction sites is increasing due to the advantages that it provides such as physical and process clash detection as well as clarity on the design intent. Some case studies such as Castro Valley project (Khemlani, 2009) and Maryland General Hospital (Eastman et al, 2011) are such examples where BIM has been utilised quite successfully along with other tools and techniques such as lean construction. From the workshops and interviews it was found that construction companies are looking for innovative solutions to take BIM to the worksite. Software such as Vela systems that offer mobile integration on Tablet Computers is becoming popular. During the field visit to R.H. Lurie hospital in Chicago, it was found that mobile workstations were being used along with tablet computers to give workers on the site access to the BIM model.

Current BIM coordination systems are not yet capable for detailed planning needed to support the lean process

Although the popularity of BIM is increasing on construction projects, from the user workshops and interviews, it was found that not many software systems exist that go beyond macro level 4D planning. Hence, construction personnel are left to devise their individual solutions on their own. In case of some companies, they hire a trained BIM technician or architect to personally facilitate use of BIM during daily construction activities and other planning sessions.

DISCUSSION

From the data collection and literature review, it emerges that there is a distinct potential for a system that can integrate lean construction to Building Information Modelling systems. The interest of construction organisations in BIM is increasing, which reflects in the use of BIM on construction sites, however they are limited by the solutions available to them, which can assist in construction activities. This was also reflected in the latest BIM SmartMarket report (2010), where 54% contractors said that they use BIM on 11% of projects and expect that number to increase to only 30% by 2012. It is interesting to note that in the same report, findings suggest that the percentage of contractors who use BIM is expected to rise from 11% to 54% by 2012, as they perceive BIM as a valuable tool. This clearly shows that there is a need for a software system that will better facilitate the integration of process and product model through lean and BIM.

WHAT IS VISILEAN?

THE PROCESS SIDE:

As we have alluded to in the introduction for this paper, VisiLean is the synchronisation of construction project product and process models using a software system. Specifically it is a system to support pull flow scheduling (through Last Planner™) in a collaboratively built, live and actionable process model for the construction project. As such the model incorporates the operations that need to be undertaken to progress the project on site from first site preparations through to commissioning and handover. These operations are modelled at the phase, task and sub-task levels, though it is not envisaged that a complete project plan would be created at the beginning of a project as it is the collaborative co-production of the plan based on operation and resource dependencies that is at the core of the pull flow scheduling method. As such we envisage that the initial master plan will be imported from the traditional planning software such as MS Project or Primavera with the operations defined therein being either high level for later refinement or fully defined but not yet scheduled in detail. Dependencies are defined in the model, both between different operations and between operations and resources required for their completion. These dependencies are employed to determine which operations are ready for release to the weekly plans for work to commence. The dependencies are analogous to the seven constraints of the Last Planner system, with all constraints on an operation being classified prior to the operation being classed as ready for work.

Of course, if one is to have dependencies on resources, then it is essential that those resources too are incorporated into the process model. This we have done in VisiLean with the intention of linking those resource representations to external systems via web services where such services are available. Such external systems would include those of product manufacturers or suppliers, materials suppliers, design team organisations etc with a view to tracking the availability of resources, both actual and forecast, in an automated fashion. This allows us to update resource status regularly with the most current information available thereby saving site personnel much of the lengthy period of time they currently spend chasing-up this kind of information in preparation for meetings etc.

THE PRODUCT MODEL INTEGRATION THROUGH BIM:

The other major aspect of VisiLean is its integration of Building Information Models as a graphical representation of where operations are physically located within a project and how they are progressing. This borrows from another lean production principle, namely 'visual management' (Tezel B. A., 2010), whereby a number of visual devices are used to convey information about the workplace and to manage it. For example, the popup that relates to a task (a type of operation within VisiLean) has action buttons that allow users to change the status of the task by marking it as started or stopped etc. These buttons are inactive if the task's current status doesn't indicate that it is ready for work to begin. This is a device known as poka-yoke, which roughly translates from the original Japanese as mistake-proof or fail-safe. The very act of placing a task popup adjacent to the model elements to which it relates, with those elements highlighted, is another visual management device in which the workplace becomes self describing: 'this is where to carry out task xyz, and these are the building elements involved'. The visual task representation is designed to make it easier for those in collaborative planning meetings and those actually carrying out the work to see how the task relates to others in the same area and to record progress towards its completion.

As we develop VisiLean further, we envisage a deeper integration with BIM, in particular the 'Information' element therein. For example we do not currently interrogate the model to derive project plan resources from it. This should be possible in at least a semi-automated fashion as much of the information required for the plan will exist in various project BIM models.

HOW IT WORKS

From a software architecture perspective, VisiLean is composed of a data store accessed, in the initial instance, by a client desktop application running under the Microsoft .NET framework. The data store can be, and currently is, located on the same physical machine as the desktop client. It is planned however to make the data store component and its interfaces client/server capable in a distributed environment such that we may have multiple clients accessing concurrently. This migration to a distributed architecture was envisaged from the outset and the work to enable it is ongoing. This would further enable different client applications, such as mobile interfaces to the data store, to be provided for different end user groups.

Returning to the current client application, we have implemented a project planning component integrated with a BIM model viewing component derived from Autodesk's Navisworks product. The whole is implemented as a number of individual libraries constituting the business object model, the data store model, the BIM visualisation model and the user interface components. The software has been architected this way to make future expansion with different end user applications and different BIM applications simpler to implement. The entire application, with the exception of the third party BIM viewer component, is implemented in Microsoft C# with Microsoft Windows Presentation Foundation furnishing the GUI components and interaction.

The business model supports the core project planning operations and relies heavily on five primary classes which are Project, Phase, Task, SubTask and Resource. Various sub class derivations from these classes are defined for different purposes, but those five classes represent the core of the application. The main project plan elements are obviously Phase, Task and SubTask, all of which have a number of common properties such as a name and description, start and end dates etc. Task and SubTask have an assigned actor, the project entity responsible for a carrying them out and also a priority which helps to determine which of a set of Task or SubTask items with similar start and end dates should be processed first. From a user perspective the VisiLean user interface is divided into a number of parts:

1. Activity tab panel containing the interface for the current activity.
2. Details area showing the details of the element currently selected in the activity tab panel. This may be expanded and collapsed as required so that more of the lists in the activity tab area can be seen. A header area remains permanently visible which displays actions that may be performed on the selected item.
3. Status area showing the name of the current project, the date and time and any information messages the application wishes to convey to the user

4. Model viewer showing the BIM model associated with the project and the model location and status of the selected element in the activity tab panel if a link has been defined.
5. Toolbar detailing actions for the currently selected element in the activity panel, plus standard application buttons such as exit and buttons to manage links to the building model.

The activity tab panel holds tabs broadly divided into two functional areas, namely project administration and project planning, which are described below.

PROJECT ADMINISTRATION

This part of the VisiLean application is designed to allow for the definition and management of project resources. Those resources might include personnel, information, equipment, materials, components and the spaces defined within and/or around the proposed structure. In our first iteration of the software, all such resources must be manually input to the system by appropriate users with the relevant privileges. The information required includes name and description for the resource, when it is anticipated that it will be delivered to the project, whether or not it is available at any given moment in the project and what task, if any, within the project a resource is currently assigned to. In future releases of the software, it is envisaged that a large proportion of this information will derived from third party data systems via web service interfaces designed to extract the relevant information from those systems. Further, whilst at present the anticipated and actual delivery dates for a resource are input and updated manually, we intend that where possible this should be achieved via a live or semi-live link to external systems such that information coming from product suppliers etc is automatically incorporated into VisiLean ensuring that it is always up to date. Such a link would be implemented using web services, both the WSDL/SOAP (W3C 2001,2007) and REST (Fielding 2000) varieties as necessary for integration of external systems into the workflow of the project.

PROJECT PLANNING:

The bulk of the VisiLean application's user interface is given over to project planning operations modelled as we have said on the last planner system and reverse phase scheduling. The user interface is further divided into sections dedicated to individual aspects of these processes as follows:

- Phase planning: Here the overall structure of the project plan can be defined down to the sub-task level, though in the initial planning phase we wouldn't anticipate users going beyond phases and basic tasks. In later planning phases users could return to this section of the application for more detailed task break down if they wish. Alternatively tasks can be added directly in the subsequent lookahead planning interface as and when they are identified.
- Lookahead planning: In the lookahead planning tab, tasks are pulled from the phase plan and scheduled into the work plan for some point in time within the lookeahead window. The lookahead window is configurable on a project wide basis, with a default value of 3 weeks. The tasks selectable from the phase plan are filtered by date such that only those falling within the lookahead

window are available. If tasks have not yet been defined, it is also possible to create new ones at this stage and assign them to an existing phase whose duration coincides with all or part of the lookahead window. As with other tabs, the selected item in the lookahead tab has its details displayed in the details area beneath the activity tab area. One of the more important actions shown in this area is the 'Release to weekly' action button. This action is only available given a status of 'Ready' for the selected task, meaning that all the task's prerequisites are met and it is ready to start. Initiating this action adds the selected task to the weekly plan in preparation. If the task duration is over one week, the task is automatically split into sub-tasks of one week or shorter duration and the relevant sub-task is added to the weekly plan.

- Weekly planning: The weekly planning tab is where tasks for the current week (the executing plan) or the coming week (the plan in preparation) are listed. There are buttons to navigate between the current and in preparation plans, and also previous plans which are archived for future reference. There is a filter function that allows users to show only certain tasks and sub-tasks assigned to a given actor or between certain dates for example. The details area once again displays detailed information for the selected item (task or sub-task) in the weekly planning panel. The actions available for the selected item will now include those to start, stop and complete the item thereby updating its status, which will be reflected in the model viewer overlay for the item if links to the model have been created. Also, if the item is not completed by the target completion date, the option to define a reason for variance from plan becomes available. Users can select from a number of categories for the variance and provide extra descriptive detail as to the exact nature of the variance.

The activity tab area supports a process of work planning from initial phase definition through later collaborative sessions to define lookahead and weekly plans based on current information regarding resource availability and defined priorities for tasks. The application does not automatically select tasks which should appear in lookahead and weekly plans beyond filtering to those which fall wholly or partly within the requisite date ranges, the final decisions being left to the project actors involved in the collaborative planning meetings.

The BIM model viewer shows graphically which model elements are related to which tasks in the project plan. This is achieved by selecting the relevant model elements in the viewer window and further displaying an adjacent popup window with the name of the task or sub-task related to those elements. The popup window also displays a description for the task, its status, the project actor responsible for the task and the actions that are possible for the task such as start, stop and mark complete. These windows will eventually display a broader range of information about prerequisites for the task.

This necessarily brief overview of the VisiLean application and its operation gives an insight into how it works. Figure 1shows a snapshot of the system with the phase planning module selected. The system is still being developed, and this is the next phase for us to address with end user evaluations on construction sites in the UK. We are in the process of arranging such trials at the time of writing and hope to gain some feedback from them, which will help us to refine the system to better suit its target audience.

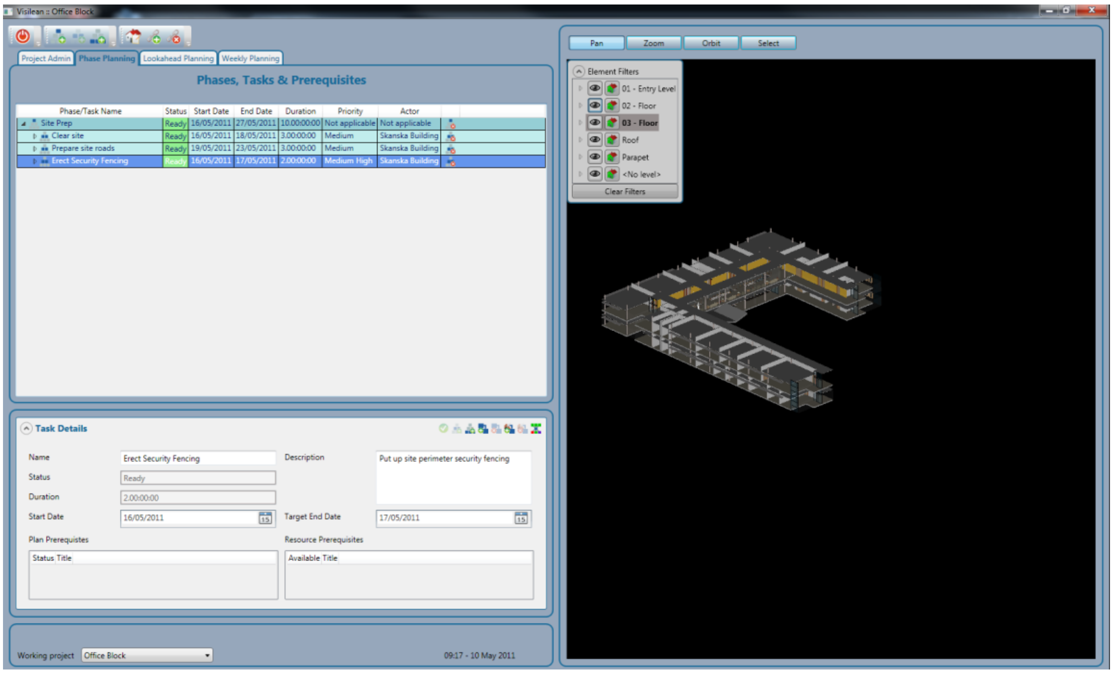

Figure 1: The VisiLean Application

DISCUSSION

Although, the system is still under development and yet to be implemented on a construction site, demonstrations have been held with construction companies to get feedback on the system's applicability on the same. The key points that emerge from discussions are discussed below:

- The system provides a systematic way to carry out the Last Planner™ sessions, as compared with the Post It™ notes and Excel spread sheets.
- The integration with BIM enables better visualisation of the project where it would have been difficult to discuss using the CAD drawings, especially with tradespersons.
- As the system records each change in the tasks scope, it would be easier to go back and trace the changes in case something goes wrong
- Automated generation of PPC and constraint relation charts would be very useful

CHALLENGES

- To ensure a link to a live Building Information Model where it is still undergoing changes is a challenge.
- When multiple tasks are associated with the same model element, how it would appear on screen.

- Acceptance from construction project team may be a challenge as they may perceive it as yet another system to deal with

CONCLUSION

VisiLean is still a system under development, however, it demonstrates a concept that is of a system that enables integrated lean production management with Building Information Modelling for the construction industry. There are challenges ahead in all the three aspects – people, process and technology. BIM technology is still evolving and has yet to solve issues such as interoperability. Also, there are many “flavours” of BIM systems in the market, where their parametric capabilities varying significantly. On the process side, Lean Construction is becoming popular and replacing traditional practices, however, not all construction companies are still implementing Lean and the degree of competence varies greatly. On the people side, there is a great skills shortage in the industry for people who can work with BIM systems – both in authoring as well managing them.

Even though there are challenges ahead, the industry is certainly moving forward in adopting both these initiatives – lean construction and BIM. It is only a matter of time when lean will be accepted as a standard production management system in construction. On the other hand, BIM is also fast replacing the CAD technologies and in many countries the tipping point is fast approaching. With that, systems such as VisiLean that integrate both these systems will be prove to be a key to an efficient production management system. Further research is needed to identify the key drivers for successful implementation and develop the system further to incorporate features that are crucial for project success.

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