CHALLENGES AND OPPORTUNITIES IN IMPLEMENTING LEAN AND BIM ON AN INFRASTRUCTURE PROJECT

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ABSTRACT:

It has been realised through research and practice that lean construction and Building Information Modelling (BIM) have significant synergies, and can bring benefits if implemented together. VisiLean has been developed as research software, which provides integration between the lean workflow and the BIM model, enabling simultaneous visualisation of the product and process model. VisiLean supports the Last Planner™ workflow, and is aimed to be used by the construction teams on projects. The main purpose of the research is to partially evaluate the findings from a brief pilot project, where VisiLean was implemented on an infrastructure project. Through this paper the authors wish to highlight the challenges and opportunities that were identified during the pilot implementation. Specific challenges were encountered pertaining to the level of detail, and the parametric nature (or the lack thereof) of the existing Building Information Model of the project. Also, issues were identified regarding the synchronisation of the lean workflow with the BIM model. Overall however, the project team perceived the integration of Lean and BIM through VisiLean positively. As the implementation of lean and BIM is relatively new to infrastructure projects, the findings are of importance to potential lean and BIM implementers in the infrastructure field. However, on a broad level the findings are of interest to those in the construction industry wishing to implement Lean and BIM on projects.

KEY WORDS:

Lean Construction, BIM, Lean and BIM, Product and Process Visualisation, Infrastructure.

INTRODUCTION

Sacks et al (2010), identified significant synergies between Lean and BIM, where the authors developed a matrix between Lean Principles and Building Information Modelling functions. The authors identified 56 unique interactions, where 52 interactions were positive, and majority of the interactions were backed up with empirical evidence. Eastman et al (2010), have also shown through several case studies that simultaneous implementations of lean and BIM in the field have been promising.

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Application of Building Information Modelling in construction projects is increasing rapidly. Researchers are suggesting/recommending the use of BIM throughout the lifecycle of the Building, from design to demolition. However, the application of BIM in the infrastructure domain has been somewhat limited (Yabuki, 2010, Shah et al, 2009). Also, there are specific characteristics of the infrastructure domain, which should be taken into account while implementing production management related initiatives.

VisiLean is a research software that aims to integrate the process and product visualisation, support the Last Planner process and improve the efficiency of the construction management process. It should be noted that VisiLean is not a commercially available software and is currently in a prototype stage. This paper partially reports on a pilot project where VisiLean was implemented on an infrastructure project. The process of implementation, existing systems in use and lessons learnt for future implementations are the key issues are briefly covered in the paper. Due to the limited scope (restricted by the length criteria), the paper focuses only on the specific technical challenges that were encountered during the pilot. It is possible that some of these issues are known to practitioners, however the authors feel it is important to report on these and make a contribution to the academic and research community.

The paper begins by providing a brief summary of production management in the infrastructure domain, including specific challenges it faces. It then details the production management process with lean and BIM through VisiLean, along with the main features of the VisiLean system. The paper then provides the details of the pilot project, outlining existing systems prior to implementation, the implementation process (and the changes it necessitated), feedback from the users and lessons learnt. Finally, brief discussion and conclusions are provided.

PRODUCTION MANAGEMENT IN THE INFRASTRUCTURE DOMAIN – SPECIFIC CHALLENGES

Infrastructure projects (such as a rail and road) are often linear in nature and are spread across a large geographic area (Yabushi, 2010). The effectiveness of traditional planning and scheduling techniques, such as being applied in building construction projects have a limited application in infrastructure projects, due to the inherent differences between the two (Hammerlink and Yamin, 2000, Kang, 2007). Also, the traditional planning, scheduling and control techniques fail to address the spatial nature of the construction project, which become significant for a large (and often linear) infrastructure project (Shah et al, 2009, Koo and Fischer, 2000). Research into the benefits of visualisation of the construction process and integration with Building Information Modelling (3D modelling) has also been limited compared to the Building sector (Shah et al, 2009, Yabushi, 2010). Kenley & Seppänen (2010) discuss the application of linear scheduling method – Line of Balance in construction projects. The linear scheduling method is relevant for road projects as they are linear in nature and there are commercial software available such as DynaRoad and Tilos. However, due to the limited scope, this paper does not compare different software systems or production control methods but outlines specific challenges that could be faced when applying lean and BIM together in a construction projects. It is envisaged that these challenges are somewhat independent of software packages but depend on BIM practices and Lean processes of relevant organisations.

However, infrastructure projects are often of high value and significant strategic importance for a country, region or organisation, and also to general public. With this view, it is important to understand the application of Lean and BIM in order to improve the production management in the infrastructure domain.

Tezel (2010) discussed the importance of Visual Management in many facets of production management, and provided examples of the use of Visual Management as an integral part of continuous process improvement. The in project continuous improvement may have a better chance of realisation due to the relatively larger size and longer duration of infrastructure projects. The integration of lean and BIM (such as through VisiLean), provides a technological platform for realisation of the Visual Management principles and may support the in-project continuous improvement.

RESEARCH METHODOLOGY

The overall research was being carried out using the Design Science method. This particular part of the research fell within the evaluation stage of the research. However, due to the highly iterative nature of the development process, the evaluation stage also provided inputs to the development (design and development of the artefact) stage.

PRODUCTION MANAGEMENT WITH LEAN AND BIM - VISILEAN

VisiLean is a production management system, especially geared towards planning, scheduling and control operations. It supports the Last Planner™ workflow including detailed constraints analysis and resource allocation to tasks. It also allows for simultaneous visualization of process and product by integrating the Building Information Model in the same system. The following section provides a brief introduction to the main features of the system.

PLANNING WORKFLOW SUPPORTING THE LAST PLANNER™ SYSTEM

VisiLean supports the Last Planner™ (Ballard, 2000) Workflow, including Phase, Look-Ahead and Weekly Planning modules. It also offers a functionality to import master plans from applications such as Primavera P6, although this functionality currently is only one-directional (with no inputs going back to the planning application). The VisiLean system also offers detailed constraints analysis and management, where conflicts in resource allocation are flagged up to users.

It should be noted that VisiLean does not aim to replace the "human" or the collaboration aspect from the LPS™, but rather support it.

PROCESS AND PRODUCT INTEGRATION

This is one of the most significant features of the VisiLean system. It aims to bring the simultaneous visualization of process and product to production management through a single interface. The system achieves this by providing visualization of the production planning process (the Last Planner™ workflow), visualization of the BIM model, and a one-to-one mapping of the task to the corresponding BIM element (at all three – phase, look-ahead and weekly levels). Such simultaneous visualization (and integration) of planning, control and product (BIM) model aims to improve the reliability of planning as the Last Planners™ get access to the most complete and up-to-date information on production in a single interface during planning and execution.

VISUAL CONTROLS AND INFORMATION IN PRODUCTION

VisiLean builds on Visual Management principles such as KanBan, and Andon. It supports the "pull" method of production by directly supporting the Last Planner™ workflow in a visual way. The synchronization of colour coding of tasks in the planning window as well as BIM window help improve the visualization of production status at any given point in the project. Also, the visual tracking of constraints and association of colour (i.e. red for tasks with unremoved constraints, green for ready tasks etc.) also improve the visualization during planning and control activities.

PILOT IMPLEMENTATION IN A UK MOTORWAY PROJECT

The project was to install automated traffic control gantries on a major UK motorway. The client was the UK's Highways Agency, who was also the main project sponsor. The total project duration (starting from January 2012) was approximately 26 months.

The main purpose of this project was to reduce congestion and improve the flow of traffic, especially during the peak hours. This would be achieved by imposing variable mandatory speed limits and allow the use of hard shoulder (emergency lane at the side of the motorway) as an extra traffic lane. The variable speed limit imposed will be displayed on the newly installed gantries, which will also house automated speed cameras to enforce the limit.

The main objective of the pilot was to receive feedback about the Lean and BIM implementation (through VisiLean) from those involved in the planning session. In parallel, it was also important to identify what are the other requirements, i.e. from process, training and technology perspective that have to be met in order to implement a production planning tool such as VisiLean. The following section describes the pilot implementation process in more detail.

The pilot project was commissioned by the client organisation, and the main stakeholders during the execution were the main contractor and the design organisation. In particular the individuals listed in Table 1 took part in the trial.

Table 1 - Main participants in the pilot project

Main contractor:	**Designer:**	**Client:**
i. Group Business Improvement Manager ii. Project Manager iii. Lean Project Planner iv. Project supervisor (Ductwork) v. BIM Manager	i. Managing consultant ii. Chief Engineer iii. Senior Group Engineer (Design, BIM support)	i. Lean Engineer (Project Sponsor)

When implementation started, almost 80% of the project scope was complete. The main activity that was left to complete was cable ducting and installation. Hence, these activities were the main focus of the pilot project, and only the tasks related to ducting and cable installation were focussed upon during the implementation.

EXISTING SYSTEMS BEING USED

The project started with a review of the existing systems and methods currently being used on the project. This helped the VisiLean team plan the best possible way to implement Lean and BIM on the project.

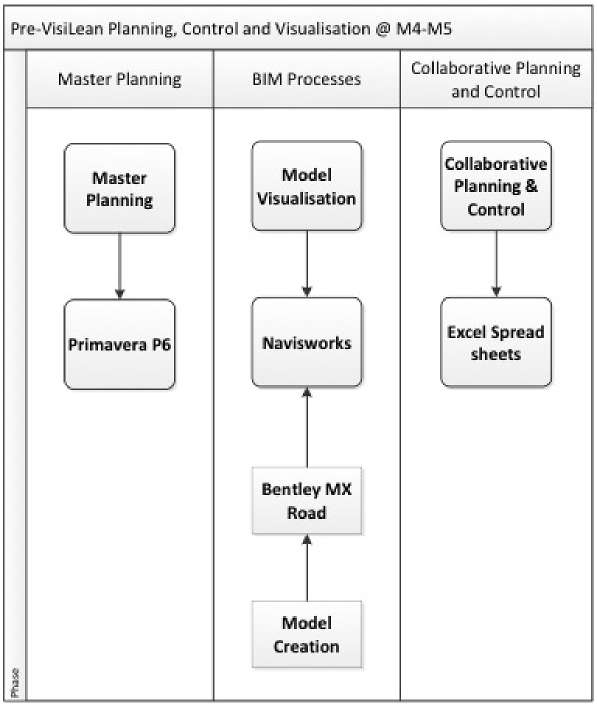

Figure 1 - Pre-VisiLean workflow

LEAN PROCESS/PRODUCTION MANAGEMENT

The project was already following the collaborative planning process, where the look-ahead window was 2 weeks long, and the project team met every week for the commitment planning session. There was also a “daily huddle” at the end of the day to discuss the progress (for that day) and also to discuss the next day’s tasks. There was however one variation, during the look-ahead planning meetings, instead of doing a detailed constraints analysis, the site manager delegated the responsibility of removing the constraints analysis to each team. This followed on with the assumption that if the team leader commits to a task, the constrains for that task have been (or will be) removed in due time.

The project used a shared meeting space to organise collaborative meetings, where progress charts were also displayed, along with the PPC and a “Concern and Countermeasure” board. The “Concern and Countermeasure” board can be likened with the constraints removal process; here each concern (i.e. constraint) related to the project was listed along with the responsible person to remove that constraint and the status (i.e. whether it has been removed or not). This room also hosted a number of large-scale drawings with visual tracking of activities (colour coded to demonstrate completed, on-going and future activities).

The team used Primavera Project Planner as the chosen project planning tool to carry out master planning activity. For collaborative planning, Microsoft Excel was used, where each task manager had developed his or her own project planning worksheet. Bentley ProjectWise was used as a project information management system (project extranet), which stored relevant project information and also provided shared access to the project team.

BIM MODEL

The project was designed using Bentley MXROAD, which is a software for road design. It is a road design software that enables 3D model creation, it is however a string based design software, which does not allow for creation of parametric objects. As a result, the designer used a special software process to export the model in VRML that created solid objects from strings, and then added parametric information manually. This however, posed a challenge in terms of the pilot implementation, as VisiLean relies on the parametric objects in the model in order for them to be linked to the tasks in the planning window. Hence, the model had to be modified accordingly so that it included identification information for individual objects.

Also, as the model was exported in VRML format and then imported in Navisworks, the hierarchy of model objects was not very clearly present in the model. The VisiLean system depends on this object hierarchy to build a tree of elements that helps in selection of objects, which can be easily linked to tasks. Due to this lack of hierarchy, a custom object tree had to be created in VisiLean.

The collaborative planning meeting space also housed a large screen (72”) SmartBoard that was connected with a laptop computer running Autodesk Navisworks 2012. This SmartBoard also offered touch capability, which were useful in navigating the model by using either the fingers or the SmartBoard pen.

Figure 1 shows the pre-VisiLean workflow with the existing systems in use, i.e. Primavera, Bentley MX Road and Navisworks, and Excel Spread sheets for Collaborative Planning and Control. Essentially, prior to VisiLean the integration between Master Plan, BIM Model (visualisation and 4D) and collaborative planning was missing. These systems were in place, however they were used in isolation. This meant that although it was possible to visualise the model during planning meetings, it was not possible to simulate the plan or to carry out collaborative planning in a single integrated system. The model was brought (imported) from Bentley MX Road to Navisworks, however this model was not structured or segmented (sectioned) so that it could be used to identify individual objects that would correspond to plan items.

PLANNED IMPLEMENTATION PROCESS

The originally planned implementation process consisted of three main stages namely, preparation, implementation and feedback gathering. The intention was to import the existing plan information from Primavera P6 and MS Excel, and import the project BIM model in VisiLean. Once imported, the VisiLean team will help facilitate the linking of tasks to BIM elements and input other resource related information. Once the system would be setup, the VisiLean team would facilitate the look-ahead and weekly planning sessions over the next three months, and get feedback from the project team on its use. However, certain challenges encountered, especially while importing the BIM model meant that the original plan could not be pursued, and the VisiLean system could not be used until these issues were resolved. Once resolved, a modified implementation process commenced, and feedback was gathered over a period of 2 months. The following section outlines the challenges encountered and feedback received from the team.

CHALLENGES ENCOUNTERED DURING PREPARATION

The following section describes the specific challenges were encountered while importing the model in VisiLean and the solution reached.

- Lack of parametric information and unique ID of model elements in the original BIM model
- Issues with how the model had been structured/organised, especially as it had several thousand of model elements without the possibility to automatically filter them for selection

Reaching a solution

The first and most significant issue with the model was the lack of a natural candidate for model element 'identity' in technical terms. Resolving this issue, involved work on the part of both the VisiLean team and the project's BIM modeller (who belonged to the Design organisation). Firstly, the modeller assigned a unique label to model elements that were of interest (in this case the ducting and communication equipment), aggregating a number of geometric entities into a pseudo 'object'. Once this task was complete, the VisiLean team was then able to implement a data provider that allowed the software to interpret the provided identifiers and map them into selections on screen as required.

The second issue was of having unstructured model and a significant number of un-classified model elements, and a lack of automatic selection mechanism. For example, there were just over 1700 model elements just in the ducting segment that the pilot project was addressing. In the end, the decision was taken to manually remove the elements from the selection tree to only leave those elements (in the selection tree, not the BIM model), which had corresponding tasks in the look-ahead planning window.

Figure 2 shows the Post-VisiLean workflow during the pilot implementation. It can be seen that VisiLean provided a link to both the Planning and BIM applications and also helped integrate the collaborative planning process with the project BIM model as opposed to the lack of integration between systems prior to the implementation.

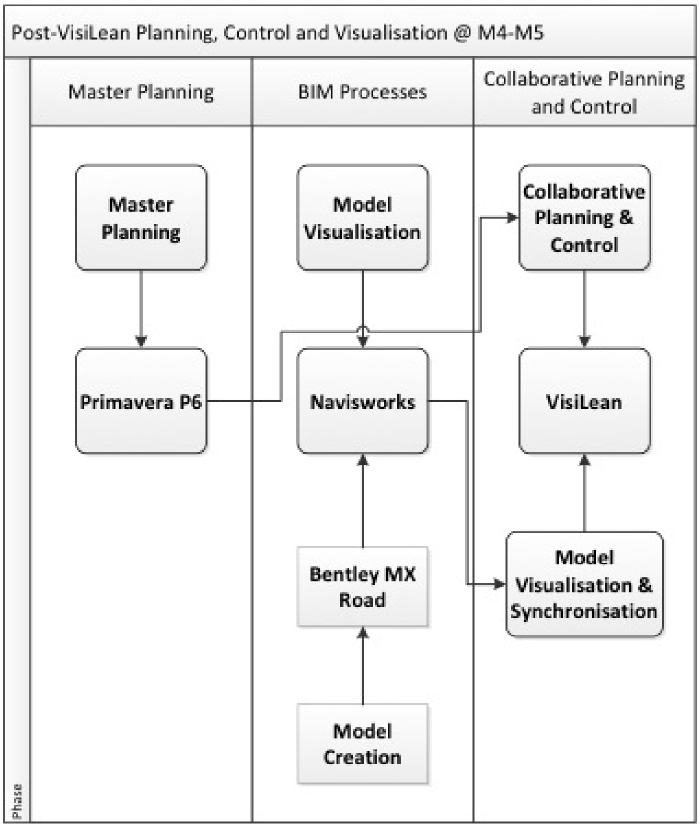

Figure 2 - Post VisiLean workflow

IMPLEMENTATION/DEMONSTRATIONS AND FEEDBACK

Following the resolution of model issues and setup of VisiLean complete, a series of demonstration sessions were held at the site office where the look-ahead and weekly plans were simulated in VisiLean with the site team present, and their feedback was captured. To a certain extent, the feedback captured also informed the VisiLean development process and helped identify some critical features for a production management system that integrates Lean and BIM. The following section outlines the feedback received from the project team during the implementation sessions.

Another major consideration regarding quality and depth of information emerged during the pilot. For VisiLean to succeed, it requires on-going near real-time input and update of planning information so that it accurately reflects the status of the project at any given time. Without this daily updating of the system, it couldn't function properly and would probably provide inaccurate information, which could even be detrimental to the overall efficiency of the production system.

Beneficial Features

- The section engineer and project manager highlighted that having visual representation of the project through BIM (which is also linked to) with planning, would be beneficial while scheduling tasks for complex intersections.

- Currently the Team had to manage a number of disparate systems in order to get an accurate status of the production. Having a visual and accurate status/snapshot of production information from an integrated system was thought to be time saving.
- The VisiLean system has a feature, which helps identify conflicts in allocation of non-consumable resources, i.e. teams, workers, equipment, etc. This is done by displaying a visual flag against the resource, when the same resource has been allocated to multiple tasks at the same time. The team thought this feature would be beneficial as on several occasions, due to lack of an automated system, multiple booking of resources had happened leading to delays on the project.
- Overall, the visual nature of planning and support of the constraints management process in VisiLean was considered to be important. It was suggested by the team that it would help improve the understanding of planned tasks within the team and help improve the involvement of subcontractors during planning (due to the visual nature of the system).

Scope for improvement

During demonstrations, several feature requests and need for improvements within the VisiLean system were captured.

- Simultaneous visualisation of multiple tasks in BIM window. The existing VisiLean prototype can only provide one-to-one mapping between tasks and BIM elements during visualisation. The project team felt that having support for multiple tasks visualisation in both the planning and model window would be highly beneficial while evaluating weekly or look-ahead plans (or specific selection of tasks).
- Automated synchronisation of production information. Currently, the VisiLean system only allows for manual data input for resource related information. However, the Business Improvement Manager highlighted the need to synchronise information systems such as procurement and logistics (for equipment tracking) to have real-time accurate information availability and reduction in manual input of information.
- Capturing notes during planning and execution. There was a specific request to provide a feature that will enable capture of notes linked to tasks during planning and execution to help provide an accurate history of important decisions taken (in case of changes in schedule or problems during execution etc).
- Internal messaging and notifications. The project team highlighted a need to provide notifications for several purposes. For example, prior to the weekly meeting, “owners” of the tasks with pending constraints should be notified. At the same time, if a task is getting delayed during execution, notifications to downstream task leaders (who are affected) and responsible managers (such as foreman and project manager) should be notified automatically.

CONCLUSIONS

The main lesson learnt during the pilot was that for any software system such as VisiLean to succeed, it is important to not only have the BIM model in place, it is equally important for it to be developed with proper parametric capabilities, to an appropriate level of detail and structured with the process of construction in mind. It is also important to note that without proper collaborative planning in place, i.e. without detailed constraints analysis, the effectiveness of VisiLean (or a similar system) will be reduced. One consideration here is to involve the downstream supply chain members (main and speciality subcontractors) during the design phase, where their feedback on constructability and model structure and level of detail can be taken into account.

Overall, the users received the VisiLean system in a positive way, and found it to be a supporting system that could be utilised if it could be developed further, when the required features could be added and it could be made stable (not a prototype).

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