Task 056 Collaborative Planning & BIM

M4/M5 VisiLean Implementation Report

Highways Agency

May 2013

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This document has 18 pages including the cover.

Document history

Job number: 5116663			**Document ref: M4/ M5 Benchmarking Report**			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 0.1	Draft for Issue	B Dave	S Boddy	K Harrison		28/2/13
Rev 0.2	Final for Issue	B Dave	S Boddy	K Harrison		28/5/13

Client signoff

Client	Highways Agency
Project	Task 056 Collaborative Planning & BIM
Document title	M4/M5 VisiLean Implementation Report
Job no.	5116663
Copy no.	V0.2
Document reference	VisiLean Implementation Report/V0.1/5116663

Table of contents

Figures

Tables

Introduction

The report has been prepared as part of a pilot project exploring the implementation of integrated Lean Construction and Building Information Modelling through a prototype software application called VisiLean developed at The University of Salford.

The purpose of the report is to capture the implementation process, main issues encountered during implementation including positives and negatives, and feedback captured regarding the need for new features from a system such as VisiLean.

This document sets out:

- Main implementation process;
- Feedback and outcomes;
- Conclusions.

1. Background

This report describes the outcomes from an initial trial of the VisiLean software on the Highway Agency's M4/M5 project. It is a part of a series of three reports that outline the process of implementing lean and BIM, and recommends the process and technological changes needed to implement lean and BIM in an integrated manner. VisiLean is a software system developed by researchers at The University of Salford, which provides a lean production management system integrated with Building Information Modelling. VisiLean supports the lean collaborative planning workflow (also known as the Last Planner System™), while at the same time providing visual integration with BIM. The VisiLean system has been designed to be used by construction teams, to help improve the efficiency of the production planning and control processes.

As the Highways Agency has been actively implementing lean techniques on its construction projects, especially the collaborative planning techniques, and also due to the recent drive in implementing BIM (and being level 2 BIM compliant by 2016), the agency has been interested in exploiting the synergies between these two initiatives and testing the possibilities through a pilot project. The M4/M5 project in Bristol was selected to be the pilot project as it has been implementing lean collaborative planning and also had a BIM model.

1.1. Preparatory sessions before the pilot implementation

To prepare for the pilot and to get a buy-in from the team, the first task during the VisiLean pilot was to understand the existing lean and BIM processes that the main contractor (on the M4/M5 project) had been following and to identify their major requirements from VisiLean. The first two sessions listed in Table 1 refer to the preparatory sessions prior to the pilot study. The first meeting was held with the Business Improvement Manager, who provided information regarding their current processes, and feedback regarding the applicability of VisiLean to their collaborative planning process.

The company had been using their own collaborative planning approach, where there were four main planning levels, i.e. master planning, stage planning, look ahead planning and weekly planning. Also, the company use a visual measure called "concern and countermeasure" board to manage some of the constraints. The main feedback received during this meeting was that the construction organisation had been looking for a solution which helped integrate/synchronise a number of information sources such as safety management, field inspections, knowledge management to the production management process. It was also mentioned that identification of temporary work areas/zones and treating them as constraints would also be very useful. This would ensure that there are no more than maximum possible workers sharing the space and that there are no conflicts in space utilisation. The Business Improvement Manager also expressed interest in linking daily progress update photographs with the VisiLean system (in both the planning and modelling windows).

1.2. Existing systems in use

1.2.1. Pre-VisiLean Workflow

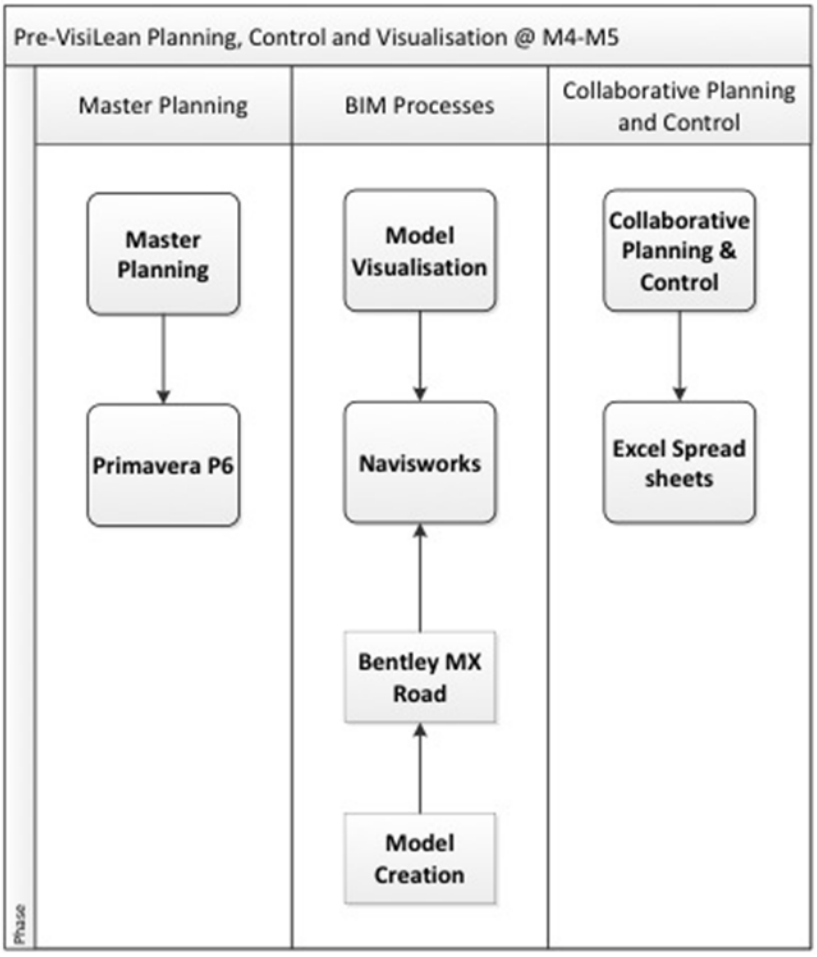


Figure 1. Pre-VisiLean Workflow

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.

1.2.2. Lean Process/Production Management

As mentioned above, the project was already following the collaborative planning process. The look-ahead window was 2 weeks long, and the project team also met every week for commitment planning sessions. There was also a “daily huddle” at the end of the day to discuss the progress (for that day) and to discuss the next day’s tasks. There was however one variation, during the look-ahead planning meetings, instead of doing a detailed constraint analysis, the site manager delegated the responsibility of removing the constraints to each team. This followed on from the assumption that if the team leader commits to a task, they are confident that the constraints have been removed 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.

1.2.3. BIM Model

The M4/M5 project's design was undertaken using Bentley MXROAD, which is a dedicated road design software application. While MXROAD is a capable product in its target role and enables the production of 3D models of road infrastructure, it is not currently able to produce parametric object based models. As such, the design team used a bespoke translation process involving a proprietary software utility to export the MXROAD model geometry in VRML format wherein higher level 'objects' are created from that geometry. These objects were then augmented with further properties to make them more meaningful to users and the resultant file was further converted into Autodesk's nwd format for final viewing and manipulation in the Navisworks product. For viewing the model during collaborative planning meetings, the planning space housed a large screen (72") SmartBoard connected to a laptop computer running Navisworks 2012. The SmartBoard featured touch capability, which was useful in navigating the model using either fingers or the included pen.

1.3. Scope of the pilot implementation

Due to resource constraints and time limitations, the overall duration of the pilot project was 3 months. However, only two months were available for actual implementation due to planned and public holidays, and also due to the desk based research and preparation work involved. When the pilot project started 80% of the construction work had completed and only ducting and communication installation activities were remaining. Hence the pilot project focussed on implementation of these activities. The following project processes were within the scope of the pilot.

i. Modifying the BIM model
ii. Training the team in use of VisiLean
iii. Importing tasks in VisiLean and getting ready for the pilot
iv. Supporting/simulating 2 look-ahead planning sessions
v. Supporting/simulating 3 weekly planning sessions
vi. Supporting/simulating 3 daily planning sessions
vii. Receiving feedback from users, identifying what worked and lessons learnt
viii. Identifying model requirements for future implementation of VisiLean

One of the original deliverables to measure the changes in performance during the implementation of VisiLean was deemed out of scope due to the above-mentioned limitations. It was envisaged that future trials of VisiLean (or Lean and BIM implementation) should aim to measure such changes in performance.

The main objective of the pilot was to receive feedback from those involved in the planning session on VisiLean to validate the prototype. In parallel, it was also important to identify what are the other requirements, i.e. from process, training and technology perspectives 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.

2. VisiLean Implementation Process

The implementation process consisted of the three main stages as detailed below, namely, preparation, implementation and feedback gathering. A trial implementation was carried out, which incorporated the actual project BIM model and collaborative plans of the “duct installation” in the VisiLean software. Also, collaborative planning sessions were simulated within the system, including look-ahead and weekly plans, constraints analysis and management, task management (including starting, stopping and completing tasks), and some reporting functions. Feedback was gathered during each demonstration session, and was taken into account during the on-going development process with any suggested features that could not be implemented within the timeframe of the trial being documented for future development.

2.1. Preparation

During the initial meetings and discussions prior to the official start of the pilot project, it became clear that a number of modifications to both VisiLean and the project's design/construction model would be required in order for the pilot to go ahead. These modifications are detailed in section 2.4 (Major Issues Identified) of the report, but briefly they involved model element identification from a technical perspective and element selection from a user perspective. Neither of these facets of the software and model in combination were satisfactory for the pilot to take place without significant up-front effort on the part of a number of the project team members.

Once the model was properly imported and navigable within the VisiLean system, the plan was manually input in the phase planning module. The planning tasks had to input manually as they were created in custom Excel spread sheet used by the contractor. The plan tasks were then linked with the model elements. Once the tasks and BIM elements were linked the system was demonstrated to the contractor’s lean planner and process improvement managers for their approval to try the system during their next look-ahead and daily planning sessions.

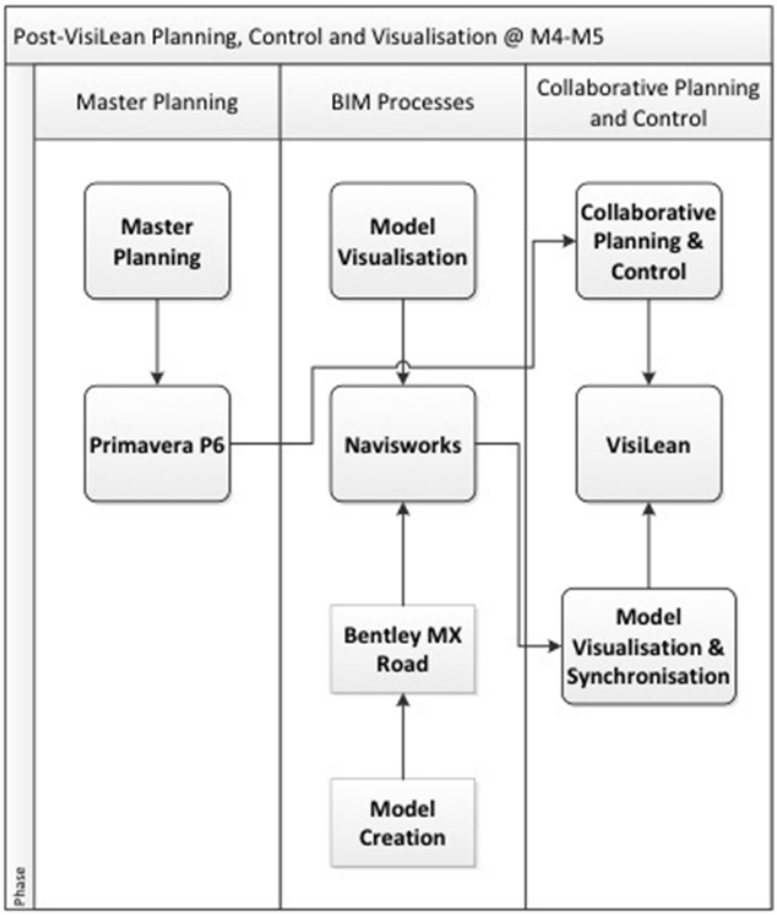
Apart from getting the model ready and importing in VisiLean and to create tasks and add their details in the system, a number of meetings and demonstrations were organised to familiarise the team with the VisiLean system. Initially, the demonstrations served to get the “buy in” from the team and to capture their feedback on the system, which also helped to identify their requirements. Subsequently the meetings were organised to demonstrate the progress with the imported model and discuss specific changes that were needed to be made.

2.1.1. Post-VisiLean Workflow

As shown in Figure 2, the post VisiLean workflow supported integration between master planning, model visualisation and collaborative production planning functions. In contrast with the pre-VisiLean workflow, where the master planning and collaborative production planning were carried out in isolation, the post-VisiLean workflow provided a one-way link between Primavera (master planning) and VisiLean (collaborative production planning). Also, quite importantly it supported deep integration with the project’s BIM model that was imported from Bentley MX Road software in Navisworks (and VisiLean). This enabled visualisation of tasks at collaborative planning level, which was not possible in the pre-VisiLean workflow.

Although, the post-VisiLean workflow improved the integration between systems, and facilitated simultaneous visualisation of the process and product, there was still room for improvement. For example, a bi-directional link between the master planning (Primavera) and collaborative planning (VisiLean) is recommended. This would improve the visibility of project progress and critical path, and would make it possible to immediately identify issues with progress (at a higher level). Also, collection of as-built information and facility related information is also envisaged. This would later integrate with HA’s maintenance system to provide a highly integrated model of the motorway, which would be kept updated throughout the lifecycle.

Figure 2. Post-VisiLean Workflow



2.2. Implementation Sessions

The VisiLean demonstration/implementation consisted of a series of planning sessions where the VisiLean team facilitated the demonstration of the system and simulated the collaborative planning sessions using actual project information.

Figure 3. Discussion during the final feedback session

Table 1 provides details of the implementation/demonstrations sessions, which were carried out during the pilot. The VisiLean team was present during all sessions. The first two sessions refer to the preparatory sessions, which were organised before the actual pilot implementation.

Figures 1, 2 & 3 are photographs taken during one of the implementation sessions at the M4/M4 project.

Table 1 - Schedule of the VisiLean demonstration and implementation sessions

Date	Session Details	Persons involved
6 March 2012	Initial discussions related to selection of the project and “selling the idea”	Business Improvement Manager (main contractor)
26 April 2012	Initial demonstration meeting with the project team	Business Improvement Manager, Lean Planner, BIM Technology Support Engineer, and a Senior Design Consultant
5 Sep 2012	Demonstration meeting to the design team to identify the best way forward for the pilot project and also to outline the changes required to the project BIM model	Project’s BIM Designer, Senior Design Manager and Senior Design Consultant
21 November, 20 December 2012, 17 January 2013	Demonstration of VisiLean and simulating the collaborative planning session to project team members	Project lean planner, Business Improvement Manager, Assistant Lean Planner, Section Engineer, BIM Technology Support Engineer

Figure 4. Final Feedback Meeting at the main contractor's Office

Figure 5. VisiLean research team demonstrating the system

2.3. Feedback from the implementation sessions

Feedback was documented during each of the sessions on what worked and what didn't work. The feedback and the resulting outcome have been set out in Table 2 below.

Table 2 - Feedback from the pilot sessions

Session	Feedback	Outcome
05/9/12	In this first session the BIM model was imported to VisiLean and tasks related to installation of ducts were discussed. As the project involved laying communication infrastructure through ducts on two major motorways, it also passed through the intersection. Due to the added complexity of the intersection, it was identified that the tasks around the intersection are the most difficult to visualise, especially when they are interconnected. It was suggested that the VisiLean system would be especially useful in such complex situations. Upon demonstration of the system, the section engineer in charge of the ducting tasks highlighted the current problem of having to "chase" different systems to get production related information. Especially, the information related to task management, i.e. status of tasks in production (started, stopped, completed, etc.) and also reasons for deviation from the schedule. The section engineer highlighted that a system such as VisiLean will help overcome that problem by having all information in one place. It was recommended that a feature should be added whereby notes can be added to tasks and stored for future auditing. The section engineer also highlighted the usefulness of a system such as VisiLean during daily planning sessions, where they occasionally use a large touch screen and project the plan (in Excel) and the BIM model. A number of issues with the model were identified at this meeting, which are discussed above. These were due to the model not having full parametric capabilities.	1. A feature was added in the task management window where notes can be added to tasks and stored for future reference. 2. Changes needed with the model were noted so that it can be imported in VisiLean.
21/11/12	When the model was imported in VisiLean and a custom selection tree was built, in the next demonstration a	It was decided to edit the model import file in VisiLean

	look-ahead plan was imported and the model was displayed in the BIM window. It was found that due to the lack of hierarchy in the model, there were over 1700 elements just in the ducting work package. Further details about this can be found under section 2.4.1.3. Two suggestions were made to overcome this problem. First suggestion was to only include model elements, which had matching tasks in the look-ahead plan. This was a temporary short-term fix and didn't solve the problem going forward. The second suggestion was to provide a search box, which would enable searching for elements by name (identity). This was a preferable long-term solution; however, it would need significant changes to the VisiLean system.	so that only those elements with matching tasks in VisiLean would be displayed in the selection tree. This made it easier to link them to the planning window.
20/12/2012	Once the model was updated to include the limited amount of ducting elements, the planning tasks were linked to the model and their respective constraints were added. At this stage the VisiLean system had the two-week look-ahead plan and two weekly plans added to the system and all the tasks were linked to the BIM model. During this session, the Business Improvement Manager asked if it would be possible to get an "overview" of task statuses in the BIM window. At this stage the VisiLean system only has a "one-to-one" mapping, i.e. only one task/subtask can be selected and respective BIM elements viewed in the BIM window. However, to get a quick overview of the current production status, this would not be very efficient. This requirement was recorded, however due to significant amount of work needed, it was not considered for implementation. The Business Improvement Director also highlighted the benefit of using VisiLean as it can potentially be used as a system that helps "aggregate" all relevant production related information. Although, currently in the VisiLean system this information has to be input manually, going forward the idea is to dynamically link information such as procurement and cost estimating and quantities through relevant information systems.	The main outcome of this session was to evaluate if all the major issues regarding the model functionality and navigation had been resolved and that the collaborative planning workflow was corresponding to the model appropriately. The Business Improvement Manager agreed that all major pending issues have been resolved and a final implementation session should be organised. The features highlighted during the feedback sessions as "good to have" in VisiLean have been taken in consideration for future development.
17/1/2013	During this final session the VisiLean system included the complete two-week look-ahead plan and two weekly plans, along with the links with the BIM model elements. Detailed discussions took place during this session and significant feedback was received relating to the VisiLean system and also what measures should be taken to implement a system such as VisiLean on future projects. The most important discussion revolved around how to create a "common language" across the transport infrastructure industry so that synchronising the planning tasks and model elements would be a relatively efficient process. As witnessed in VisiLean, almost 30-40% of the effort during the pilot project was dedicated to making changes to the model, first to import it in VisiLean and secondly to link it to the project plan. By creating a commonly accepted method of structuring the model	The feedback received from this final session was used to draft recommendations and document the perception of the project of VisiLean, which were then submitted to the Highways Agency. Due to the limitation of time, it was not possible to make further changes to the VisiLean system and re-implement it to this project. However, some of the features, which were deemed important, have been considered for future implementation in 5.8.

	and also preparing the project plan, it would make it easier to link tasks to model elements. Also, the importance of having a fully parametric model, where a well-defined hierarchy of objects is available, was emphasised. The need to involve main contractor during the design process was also highlighted. The members present during the session felt that at least the project planner and engineering manager should be involved during design to provide knowledge of constructability aspects and to ensure the model is developed to a sufficient level of detail so that it can be used properly during the production stage. From a VisiLean system point of view, a number of issues were raised. In the current iteration, the VisiLean system did not have any notifications for pending tasks or "unresolved" constraints. The site team suggested that the relevant members should be sent a notification at a set time prior to the weekly planning meeting, reminding them if any of their tasks have constraints, which are not yet resolved. It was also highlighted that an overview "heatmap" in the BIM window, showing the status of the project at a glance should be provided. This means a colour-coded model showing the relevant production status of the tasks. The Engineering Manager also highlighted the need to have cost and quantity related information linked to the tasks, as this information is very regularly needed and if linked, could help with automated generation of a number of reports. The project team reported a current problem with the planning process in VisiLean, which was related to the weekly planning module. In the current iteration, the VisiLean system would not let the user select a task for execution if it has a predecessor, which is not yet complete. However, the team highlighted a scenario, whereby sequences of interrelated tasks, which are all scheduled for execution for the same week (and otherwise free of constraints), are there in the look-ahead plan. This was identified, and it was decided that the VisiLean systems should allow releasing such tasks to the weekly plan. The project team found the VisiLean feature of flagging "conflicting resources (constraints)" very useful. As on the current project, one of the formwork subcontractor regularly assigned the same resource to multiple tasks (which are managed by different section engineers), ultimately leading to non-execution of at least some of the tasks. As the current planning is done using Excel spreadsheets which are not linked with each other, this is not detected (unless discussed directly during a meeting). It was mentioned that by clearly showing a conflict between the allocated resources before execution starts would prevent such conflicts and improve the PPC.	

	Overall the feedback was positive and it was recognised that VisiLean bridges a distinct gap in the market, by providing a production management system for the project. It was also suggested that the VisiLean interface should be as simple as possible for it to be used by site personnel and consistent with the collaborative planning process. It was also mentioned that the VisiLean system has a potential to reduce the amount of rework needed while maintaining separate systems for Lean and BIM, and also separate systems to manage the production processes (such as planning spread sheets).	

2.4. Major Issues identified

2.4.1. Model related

During the initial discussions and preparation for the trial a number of issues arose with respect to the BIM model for the project. These issues required a considerable degree of up-front effort to resolve on the part of several parties and included:

2.4.1.1. Model element identity

The project model as it was initially presented had an internal structure that offered little in the way of properties to uniquely identify elements in the model. Such properties are required in order to form a link between model elements and activities in the project, plan that can be relied upon to identify the model elements for selection and display in the viewer window. As changing the data structure of the model was not an avenue open to the project team, we had to design an alternative means of identifying model elements of interest in the context of the VisiLean trial. This meant the representative from Balfour Beatty responsible for preparation of the model had to add unique identifying names to elements in the model as the value of an existing property. The VisiLean team then had to design a means to access that property and make its value (per-element) available to the linking mechanism within the software. This entailed some custom development work that tied the software to the specific structure of the M4/M5 model - a situation that is far from ideal but which was necessary for any progress to be made.

2.4.1.2. Model size and linearity

In contrast to a building model, which represents a relatively compact entity and is generally easily navigable, the M4/M5 model represents a large geographical area which is quite sparsely populated with elements of interest to the project. The nature of the project work is largely linear, being organised by chainage or by linear run in network structures such as drainage or power and signalling ducts. This presented a problem for the VisiLean application's model viewing window in that the navigation functions were not adequate to move around the model and find items of interest without extensive zooming, panning and orbiting. During such navigation operations it became clear that it was easy to "lose one's place" in the model and not be able to find the element sought. As such the VisiLean team needed to implement a new navigation feature which allowed the user to zoom directly to (or focus on) a particular element as identified through the model element selection tree (see figure 4). This in tandem with the features already available to hide other elements makes finding relevant model items significantly easier.

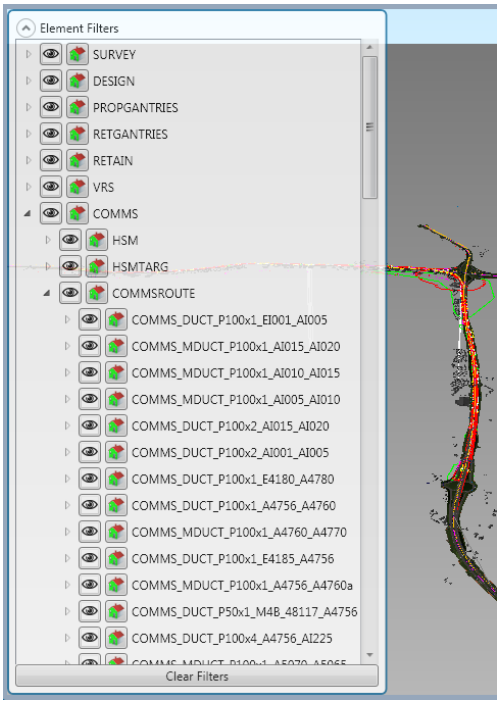


Figure 1 - The VisiLean Model Element Selection Tree

2.4.1.3. Volume of model components

Somewhat related to both of the previous issues was the problem of the number of elements presented in the model element selection tree, which is shown in Figure 1 above. In the first iteration of the dedicated data provider for the M4/M5 model, there were approximately 1700 elements in the one sub-category of the tree we were most interested in. This made it near impossible to find specific elements of interest without much time consuming scanning of the tree. The remedy to this problem was to modify the data provider such that it presented only those model elements which were relevant to the tasks in the project plan for the trial, along with section headers for other categories of element whilst filtering out all other detail. Again this meant extra development work on the part of the VisiLean team.

2.4.1.4. Model sectioning

The chosen work package for the trial involved power and signalling duct run installation, which resulted in extra work for the modelling team at Balfour Beatty. This was because in the design phase, duct runs were not modelled in the lengths they were to be installed in, but typically between access chambers, which could be a length equivalent to several days work. As the project plan had duct installation broken down into single day activities with lengths of duct commensurate with the average daily capacity for installation, the model needed to be modified to reflect this breakdown structure.

2.4.2. Process related

Other issues not directly related to the model that was raised during the trial period included:

2.4.2.1. Look-ahead to weekly workflow

The current workflow within VisiLean for transitioning activities from Look-ahead to weekly plan requires that candidate activities have no outstanding unsatisfied constraints. Such constraints would render the activity's status as 'Not Ready', which prevents the activity from being released from a Look-ahead plan to a weekly plan ready for work. The rationale behind this rule is that all activities scheduled into a weekly plan should be constraint free and actionable at the time they are released to the weekly plan, thereby improving the accuracy and reliability of the weekly plan. This however fails to take into account chains of dependent activities of short duration (say 1 day), all of which might conceivably be scheduled into a single week's work. For example a chain of five activities, each of 1 day duration starting on a Monday morning and each with a 'finish before start' type dependency on the previous activity could not be scheduled into a single weekly plan because activities 2 through 5 would have an outstanding unsatisfied constraint on the previous activity. This was regarded as an undesirable side effect of the rule, which would need to be worked around if VisiLean was to be of general utility in the type of process embodied by the M4/M5 project.

3. Conclusions and The Way Forward

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.

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.

All the project team members unanimously agreed that for a system such as VisiLean to succeed and being used on the project, the user interface has to be very simple and intuitive. It was also suggested that providing a user interface, where it can be navigated using touch gestures would be better. Also, the proposed mobile interfaces (for smart phones and tablets) were welcomed.

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).

3.1. Standardised process

It is important to standardise the collaborative planning process as far as possible to minimise the amount of setup work required per-project. This makes the tools easier to implement also. The lack of integrated lean planning and control tools/software was responsible for considerable amounts of rework and inconvenience. Apart from the master planning, which was carried out using Oracle Primavera P6, all the subsequent lean planning was carried out using Excel spread-sheets. These spread-sheets are not connected with each other or any other information systems that the project uses, hence their functionality becomes limited and a significant amount of manual work and data re-entry are required.

3.2. Early involvement of downstream supply chain

Get downstream supply chain members involved in design activity to ensure a 'design for construction' mentality and process. This is one of the most important aspects of a lean and BIM project, and is strongly recommended on all future projects where the HA wants to implement lean and BIM in an integrated way. Involving the downstream stakeholders will help identify constructability related issues early on, and also help develop the structure and level of detail of the BIM model to the required specifications, so that issues such as those raised in section 2.3 are minimised.

3.3. Structure and section models according to process

Realise the importance of having a model that is structured in such a way that it reflects the process by which the building or facility will be constructed. As outlined in section 2.3, many issues were identified related to the way the BIM model was structured and organised, and also the level of detail available in the model. For example, if the construction team wants to have a 2 week look-ahead planning window, a weekly planning session and a daily progress meeting, and would like to visualise the tasks in BIM simultaneously, the model should be developed to the level of detail so that BIM elements can be directly linked to tasks in the schedule. Also, the “model element tree” should be structured in a way that the navigation during collaborative planning sessions becomes efficient. Also, for HA projects, most models will be of linear nature, spanning over several miles with possibility of structures and intersections in-between. It is recommended that the BIM model is developed using standard naming conventions, which can be used across all projects, making it easier to identify and link objects with construction plans. Using standard naming conventions would also make it easier to automate certain tasks such as quantity take off and linking other project related information to the model.

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