STRATEGIC REVIEW OF THE PRODUCTION OF A 4D CONSTRUCTION SEQUENCING MODEL – THE LESSONS LEARNT

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ABSTRACT: Construction project losses can often be associated to information failures caused by poor coordination between the multi-disciplinary organisations that deliver them. Information failure could include late, inaccurate, inadequate and inconsistent information. 4D Construction Sequencing Models (CSM) seek to improve the coordination of design, plant, equipment and labour through the visual representation of the construction process by linking project programmes with 3D design information.

This paper reports on the experiences of a major UK contractor during the development of a 4D CSM, with a focus on the lessons learnt and the recommendations made. Team problem solving workshops, semi-structured interviews and a lean study review were conducted to establish these findings.

The concluding recommendations not only highlighted the importance of establishing a standard method and procedure, but also identified several software limitations that have subsequently been reported to the developers and will be incorporated as future enhancements. The challenge of maximising the value of 4D CSM for clients and change management also form key topics within the paper.

KEYWORDS: 4D, construction, sequencing, process, lean.

1 INTRODUCTION

Building design has been the main driving force for the application of virtual prototyping to various stages of construction projects from conceptual design to construction on site. By allowing architects to visualize and present their designs, a much clearer understanding is gained of both the qualitative and quantitative nature of the space (Nimeroff et al 1995). 3D modelling also enables designers to evaluate proportion and scale using intuitive interactive modelling environments (Kurmann 1995) and simulate various performance aspects such as lighting, ventilation and acoustics within internal environments (Shinomiya, et al. 1994). Visualization can also be used to better communicate design intent to clients by generating walkthrough models giving users a feel of the design in a more direct manner (Ormerod & Aouad, 1997).

Another useful application of Virtual prototyping is in the modelling of the construction sequence in order to simulate and monitor site progress. This can be done by linking 3D models to construction programme information to be able to visualise stages of the construction sequence at any given time of the process (Barrett, 2000; Hu et al, 2005; Lee and Pena-Mora, 2006).

At present the benefits that virtual prototyping can bring to the construction industry are fully appreciated by the majority of practitioners. However despite the continually falling costs associated with the hardware and software, there remains a big obstacle to its full uptake, this is the low compatibility between systems and tools making its implementation costly due to the resource intensive tasks of creating the models.

2 PRACTICAL APPLICATIONS

The 4D CSM this paper reports on was produced for the £250 million private finance initiative (PFI) Whiston Hospital contract. The New Hospitals Consortium of Taylor Woodrow Construction and Innisfree has achieved financial closure which now secures one of the largest private finance initiative (PFI) contracts in ten years to provide two hospitals in Merseyside for the St Helens and Knowsley Hospitals NHS Trust. Total financing raised for the project is approximately £430 million, £338 million of which is construction works. The design and build contract includes the construction of new In Patient facilities, including Accident and Emergency, Diagnostic, theatres and 823 beds to replace the existing facility at Whiston in Merseyside, along with the construction of a Diagnostic Treatment Centre (DTC) at St Helens Hospital. Main construction work is planned to commence on 3 July 2006. Construction at St Helens is scheduled for completion in Autumn 2008, with Whiston Hospital construction completion following in Spring 2010. TWC are working with Innisfree to develop the infrastructure and services of St Helens and Knowsley Hospitals NHS Trust.

In addition to the construction contract, Planned Preventative Maintenance and Life Cycle Replacement works worth in excess of £100 million will be undertaken by TW's Facilities Management business as part of the PFI contract and extend over a 30 year period.

The 4D CSM of Whiston Hospital has been commissioned by the TWC led project team to improve the communication of the sequence of the complex project and to identify the potential risks of installing over 600 prefabricated bathroom and toilet pods, and over 2500 prefabricated building services modules.

The project was in the early stages of construction when the project modelling team were approached to carry out this 4D CSM project. The product would represent one of the largest 4D CSM produced to date in the UK, see Figure 1.

The TWC led project team required the 4D CSM to assist in the coordination of numerous subcontractors on site, to clearly and visually identify logistical restraints on site and to effectively communicate the integrated design and programme to relevant project stakeholders.

The 3D object information was created by the TWC Technology Centre Collaborative Working group using Autodesk Architectural Desktop 2006 software. These 3D CAD model files were stored in DWG format in a predetermined folder hierarchy on the group's local server. The 4D CSM model was produced by referencing the 3D CAD model files into Navisworks Jetstream V5 (herein referred to as Navis). Any changes in the original source of DWG files were automatically reflected in the Navis 4D CSM. The construction programme information was originally created in Microsoft Project and was manually imported into the Navis 4D CSM.

Production of the 4D model began in August 2006 with an expectation of 7 man weeks worth of work. Final completion and delivery of the 4D CSM exceeded this estimate. A lean study investigation, two team problem solving workshops and several semi-structured interviews were conducted to identify the lessons learnt during production of the 4D CSM and to provide recommendations for future projects of a similar nature. This paper reports on these findings.

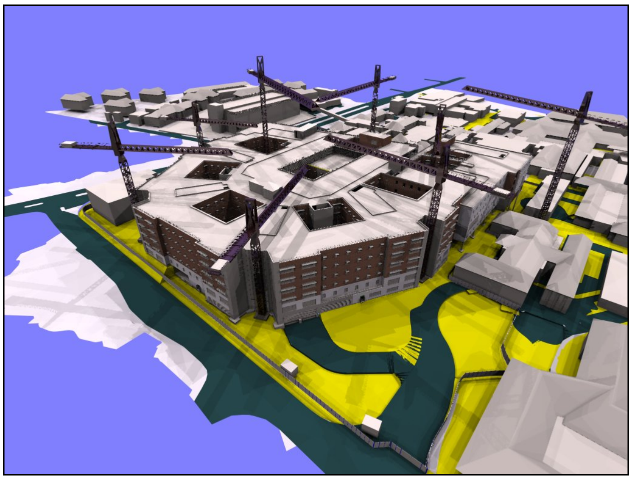

Figure 1. A Static image of the 4D CSM of Whiston Hospital.

3 PROBLEMS AND SOLUTIONS

3.1 *Synchronisation*

The team experienced difficulty with managing changes in the source 3D object information and the synchronisation of this with the 4D CSM software (Navis). In the early stages of the project review this issue was thought to be due to technical limitations of the software application. However, it was later established that the approach towards linking the 3D object information to the programme information was not the appropriate method. The team manually created selection sets within the 4D CSM software (Navis). Each selection set contained a group of objects in the model relating to a certain task in the programme. The appropriate selection sets where then attributed to the relevant programme tasks. The problem occurred when changes were made in the source 3D CAD model DWG file information, as new objects introduced to the 4D CSM would not be assigned to a selection set and therefore a task. The generic cause of the problem was the absolute linkage of 3D objects to a selection set and selection set to a task.

An alternative approach would have been the use of task rules. For each task in the project programme a rule can be created to search and select particular object types in the 4D CSM. The search criterion includes object type, location, and material. In this case, if a new object is created in the 3D modelling environment, upon opening the 4D CSM the new object will automatically be added to the 3D visualisation and to the relevant task through the rule definition. Great care has to be taken in both configuring the selection set rules and in creating the 3D CAD model files with respect to the construction programme.

3.2 *Change management*

Synchronisation was further complicated as the 4D CSM was being created by multiple users in separate geographical locations and changes to the 3D model information were automatically incorporated into the 4D CSM but were not automatically flagged by the software to the user. It is possible to identify changes through a manual process, but the team regularly forgot to check. It was indicated that even if the task rule method was adopted that automatically synchronises objects with tasks, clear indication of changes in the 3D model information needed to be clearly communicated by the software. This could be accomplished through a visual indication (for example a red coloured wall could indicate that it has been added since the last update) or the generation of an audit log. This suggestion has subsequently reported to the software developers and will be considered as a possible future enhancement.

3.3 *Process*

It is important to distinguish between NWF (Navisworks Files) and NWD (Navisworks Document) formats. The NWF format is the file type used for the active model that incorporates dynamic links to the referenced 3D CAD model file design information. The NWD format is the file type used for publication of the model at a particular point in time, as it is a self-contained file with no linkage to external DWG files. An NWD file type should only be published to provide the client with an off-line published 4D CSM or an archive file for auditing. The basic system architecture that was adopted is illustrated in Figure 2. A simple improvement to this architecture would be the provision of a link between the client interface environment and the central shared server. Another approach would be the use of a web based viewer where the client could access a secure site to view the 4D CSM. In a situation where multiple users are involved in the development of a 4D CSM it is essential that the team understand the purposes and interface of each file type. The distinction between model files and published files are fundamental to this. In the 4D CSM under review, errors relating to this issue had a significant impact on time.

The most apparent error occurred when work on the 4D CSM needed to be carried out off-line from the server that contained the source DWG files. The team generated a NWD file (publication file) from the 4D CSM to capture all the 3D object information and worked on the model off-line to the server. Any changes in the source DWG data would now not be reflected in the 4D CSM. The only readily available solution to this problem would be to relocate all the referenced DWG files from the server location onto the local machine, but due to the size and number of files this was not practical. Since this research, the team has developed a standard method and procedure to reduce the risk of a reoccurrence of this error.

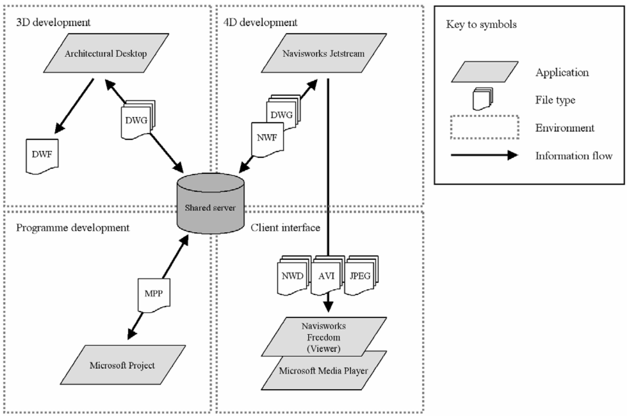

Figure 2. Simple system architecture.

3.4 *Delivery*

The 4D CSM was produced for a project in the construction phase. To maximise the value of such information, it should be produced and available as early in the project lifecycle as practically possible. With the correct processes in place, a very early stage 4D CSM could evolve over the project lifecycle increasing in complexity and detail as the design develops. From the contractor's perspective, the earliest realistic stage of involvement is during the initial tender stage. A 4D CSM at this stage would deliver many benefits to all project stakeholders:

- Provide a clear, accurate and shared visualisation of the project.
- A platform to test different construction scenarios and perform what if analysis.
- Identify and communicate value-engineering exercises.
- Provide the opportunity to perform further analysis such as quantity take-off for estimating.
- Improve design coordination, reducing project risk.
- Test and evaluate project programmes and make necessary adjustments.

Deploying a 4D CSM at a later stage of a project still provides project teams with a valuable tool. However, as project time elapses, the cost of change increases, reducing the value of many of the benefits indicated above. In this case study, the 4D CSM is only being utilised to assist visualisation of the project in comparison to programme and to aid communication at sub-contractor coordination meetings.

3.5 *End user interface*

The client was using Navisworks Freedom, a freely available viewer from the Navisworks suite to allow a limited level of interaction with the 4D CSM. This version allows the user to open a Navis model file and perform standard 3D view functions such as orbit, zoom, look around, walk. It also allows playback of the construction sequence, but is limited to play, pause, fast forward and rewind. No functionality for viewing step-by-step or specific dates/times is provided. The full functionality of the 4D CSM was only available to the client when a member of the modelling team was demonstrating the model on a PC with the full 4D CSM software package installed (Navisworks Jetstream). Instead, numerous static images were produced of the 4D CSM on different dates of the programme from different views. Although this satisfied the client and their requirements, the true value of the 4D CSM had been missed. Images should only be by-products of the 4D CSM and the client should have the ability to manipulate not only the views of the model, but also the time properties.

To enable the full functionality of the 4D CSM, a copy of Navisworks Roamer software would need to be purchased. This application would allow the end-user to fully interact with the 4D CSM, ideally from a central shared server or web-based project extranet, manipulating the views and time properties of the 4D CSM but without editing rights. As espousal of this type of technology is still relatively low on live projects, a few roaming software licenses would suffice at this point in time. Discussion around this issue was taken up directly with the software vendors and it has been since reported that the next freeware version of Navisworks Freedom will indeed incorporate the timeline function, solving the issue of achieving maximum functionality for the end-user (although this still only provides viewing capability with no editing rights).

3.6 *Smart tags*

Smart Tags in Navis are information lists that appear in the viewer when the cursor is hovering over an object with a Smart Tag enabled. The information displayed in the list can be user defined and usually would refer to the attribute information relating the object in question. Currently, the software allows users to define the Smart Tag information display. However, these options are user specific and not transferable. It was suggested that a global command that allows different sets of information to be set-up and displayed depending on with Smart Tag group is selected. For example, one Smart Tag group might be concerned with quantity and cost information, whereas another may be concerned with material type and manufacturer information.

This sort of functionality would be highly beneficial in a scenario where different end-users are utilising the 4D CSM for different purposes, one such example being a planning versus estimating team. Although Smart Tags were not used in the case study project, the team indicated a desire to incorporate them in future models.

4 CONCLUSION

The 4D CSM reported in this paper was well received by the client. However, the research findings have highlighted a number of lessons leant and opportunities for future improvements, both technical and process driven. These can be summarised as follows:

- Deploy the 4D CSM as early as possible in the project lifecycle to maximise value.
- Establish a standard method and procedure to ensure compliance with a process.
- Ensure that the end-user interface provides the level of functionality required.
- Adopt a method that allows dynamic and automated synchronisation of objects to task.
- Ensure that a strategy to highlight and track changes in the model is present.
- Clearly distinguish between reference models files and publications files.
- Utilise Smart Tags to take advantage of object information inherent in the model.
- Avoid absolute links between information sets.

A second paper is intended in the near future that would aim to capture the resulting effects of the recommendations proposed in this paper.

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