4D CONSTRUCTION PLANNING

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ABSTRACT

Linear, 2-Dimensional and now 3-Dimensional visualization are the current tools used in the construction planning area. It is time for a new dimension to be added - the dimension in which Planning Engineers are more interested. The dimension is TIME, which is now appropriate to add as the 4th dimension in construction planning.

Current planning processes in the construction industry are still mainly based on two dimensional (2D) drawings. On the other hand model based planning methods can improve communication among project stakeholders and help to avoid planning failures. They also enable continuous optimisation of the construction project during early design phases by investigation of different design alternatives. Thus building models enable the project team to make a qualified choice from a range of possibilities.

4D construction planning is a process which enables clear visualisation of a construction programme as an animated sequence. 4D models are created by linking 3D Computer Aided Design (CAD) data with one or more programmes. This visualisation is then automatically updated any time the programme is updated. In particular, construction sequence planning as one of the key processes in a construction project, can benefit from model based working. Since the time schedule defines sequences of activities and allocates resources such as material and labour, it plays an important role in optimising and managing a construction project. In this respect, model based working can offer more to construction sequence planning than just a visualisation of the construction sequences, in which the term ‘4D simulation’ is today commonly understood.

4D simulation of construction sequences is an adequate tool for visualizing inherently abstract and complex time scheduling data which are otherwise buried in deeply nested Gantt charts. 4D simulation software is, in principle, capable of generating visualisations which illustrate construction processes along the timeline. By linking the objects of a three dimensional model to the tasks in a time schedule, this assists in reducing major scheduling errors just by inspection and thus communication within the project team is improved.

This paper discusses 4D simulation of construction sequences used in the construction industry and the potential benefits.
INTRODUCTION
In project management, construction planning is defined as a fundamental activity involving the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks. It also includes the identification of any interactions among the different work tasks. It can be stated that amongst other factors, thorough planning and efficient site utilization are of the utmost significance in any construction project. In practice, this technique is the reflection of a planner’s mental process for problem solving.

Firstly, it is represented by the planner’s workplace identification based on the design illustration. Secondly, the planner decides the tasks and time associated with the identified workplace and finally a logical task sequence is developed. This mental process of the task definition is related to spatial information for workplace identification, temporal information for task time control, and logical information for sequence generation. In most cases, construction projects are a collaborative effort, and the development of a construction plan is no exception to this approach. This requires social creativity including contributions from multiple planners. At present the composition of projects is becoming increasingly complex, involving more and more parties. The planners have to consider the resource requirements including human, material, and plant as well as site facilities incurred under the project. They have to incorporate the appropriate workspace logistics, a logical construction sequence, and economic resource allocation within a spatial and time domain.

Quite often the engineering drawings fail to reflect this dynamism on site. As such, they are virtually separated from the planning and scheduling system. On the other hand, construction plans generated mainly by computer-based tools are usually represented as bar charts or critical path method (CPM) network charts. These types of tools are not capable of displaying the spatial construction features as well as the pertinent resource and workspace requirements, which are envisioned only in the mind of the planners. They do not furnish data integration or visual representation of the project versus time, such as project progress and the status of site space usage. As such, planners can only glean information from design documents to adopt the appropriate construction scheme and site facility layout on the basis of their intuition, experience, and judgement. It can be said that the potential assistance they can receive from the computer has not been fully exploited.

HISTORICAL DEVELOPMENT
In order to develop advanced planning techniques, many researchers have devoted efforts to the concept of 4-dimensional modelling, which incorporates the time dimension into the concept of 3D visualization. Retik et al. explored the potential application of computer graphics to construction scheduling and outlined the possible features of the tool (1). McKinney et al. developed a 4D-CAD tool, which provides visual and communicative usage on the construction design process (2). Collier and Fischer used the 4D modeling of the San Mateo County Hospital as an example of visual-based scheduling (3). Williams represented the construction plan graphically with a 4D-Planner in response to project visualisation, simulation, and communication needs (4). Adjei-Kumi and Retik reported a library-based 4D model PROVISYS for planning and visualizing the construction plan in a virtual reality environment (5). McKinney and Fischer presented and evaluated a 4D application integrating the use of AutoCAD, Primavera, Jacobus Simulation Toolkit and Walkthru (6).
McKinney et al. delineated a construction example to illustrate how feature extraction of 4D-CAD models can help identify construction problems (7). Kamat and Martinez described a general purpose 3D visualization system for construction operations (8).

**OBJECTIVE**

This paper presents the implementation of a system that visualizes the construction process by combining 3D modelling data and schedule data to control the work flow.

Bechtel Corporation has been at the forefront of 4D construction sequencing implementation. They have evolved an in-house system in the early 1980s. Today, many major construction companies profess that they use 4D technology for Construction Planning and management. Most of these tools have been developed in-house and utilise a 3D-CAD model and a separately developed schedule.

There are a number of software tools now available in the market-place that achieve the same result. For the purpose of this paper Autodesk’s Navisworks Manage is used to demonstrate 4D visualization planning.

**DEVELOPING THE 4D MODEL**

Developing the 4D visualization plan for a construction project involves a number of interrelated steps, first obviously to have a 3D geometric model of the Plant, then the Schedule, and then these two are synchronised. (Figure 1)

**Representation of 3D Geometrical Model**

Based on the geometrical data input together with the graphical user interface (GUI), 4D Simulation is able to produce the 3D model of the building project and permit the visualization of almost all 3D model components from different viewing angles.

**Conventional Construction Planning**

The conventional site management procedure, construction schedule and graphical site facility layout, which are already used by site planners, are included in the 4D Simulation as far as practicable. In the prototype system, the bar chart representing the project schedule and the graphical site plan drawing can be generated, modified and displayed in a convenient fashion.
4D Visualization
The 4D simulation for a specific construction project can be generated by integrating the 3D geometrical model with the associated activity schedule. This is achieved by associating elements within the model to specific construction tasks in the schedule. Under the model, the visualization of building construction at the activity level together with 3D site space utilization at any specific instant can be displayed through playing forward or backward within the time period.

The Model
One of the greatest advantages of the Navisworks software is that it is able to accept most 3D Models, such as PDMS, Bentley, Revit and obviously AutoCAD. The Model is developed by conventional methods using any of the 3D modelling environments. Figure 2 is an example of a 3D model of a bleach plant. It is then imported into Navisworks. It is important that the modeller has a clear understanding of the construction methodology and uses elements in the model no larger than the tasks in the schedule. For example, if a floor slab is constructed in multiple phases, the model needs to segregate the floor slab in definite segments that mirror how the construction is planned.

The Schedule
It is imperative that at any phase of a project, the schedule is developed when the engineering and design is nearing completion.

The model should be at 70-80% completion (or at the least tender stage) for the planners to effectively design the construction planning. The Schedule can be developed in MS Project, Primavera or some other accredited software (Figure 3). Once the schedule is developed to the satisfaction of the planner and the project manager, it is imported into the Navisworks “Timeliner” environment of the model.
Assigning the 4th Dimension to the Model

Once both the model and the schedule are within the Navisworks environment, individual tasks are assigned to a set of elements in the model (Figure 4 and 5). If ten columns belong to a single task (meaning these are being constructed at the same time), these columns are grouped together in the model to form a set and the task is assigned to the set. In the schedule the task has a start and end date, and when the model is simulated, the set of elements in the model will be visible during that period of time. Usually Navisworks can show the elements at the start date with a designated colour for ‘Construction’. At the completion date, the colour changes as can be seen in the built portion of the model (Figures 6, 7 and 8).

In the same way, temporary works can be defined at the beginning by shading and at completion by using a different shade. Demolition works can also be shown in a similar way. Figures 9 and 10 illustrate building construction with colours being used to show the completed ground floor and the 1st floor under construction.

CONCLUSIONS

4D Modelling is a modern approach to design and management of the building construction process. It allows effective utilization of critical resources such as labour, materials and time during the building construction life cycle.

Construction projects are scheduled according to the availability of resources and depend on many external factors. As time progresses these parameters also change and hence it is important to keep a check on important activities to finish the project without any significant delays. The popular 3D building information model does not help in establishing the relationship between the schedule and sequence of construction activities to be carried out during the project execution. A 4D model incorporates time as the added 4th dimension and hence improves the quality and accuracy of the entire building life cycle management.

The major benefits of using 4D model during construction planning are:

- Improved reliability and scheduling efficiency: 4D modelling enables a project team to easily visualize time constraints and opportunities to improve the project schedule, as well as recognising where the major challenges will occur.
- Optimum use of critical resources: 4D modelling allows the team to understand the scope of work more easily and access to various resources over a period of time. It also allows the team to visually review and evaluate the complete construction plan and to optimise the resources and labour accordingly.
- Improved communication: During the construction phase potential spatial conflicts may arise between building components. These conflicts are very difficult to identify when
coordination is performed using 2D or 3D layouts. The use of a 4D model greatly enhances this coordination process. In addition, the overall communication of project scope and sequencing is greatly improved.

A 4D Model provides a graphically rich and animated illustration of the construction sequence against time. Also, once a 3D model is prepared, the 4D model can be generated relatively cheaply giving additional benefits from the investment made in producing a 3D model. 4D modeling has found its use not only for residential projects but also for commercial and industrial facilities such as theatres, museums, hospitals and technology parks.

Our aim is to make 4D construction planning the method of choice for pulp and paper projects.
Figure 6  Screen shot of 4D simulation – Columns under construction, on top left hand corner, is the time stamp and also the tasks (activities in progress with % progress)

Figure 7 - Screen shot of 4D simulation – 2nd sets of Columns under construction, the first lot completed.
Figure 8 - Screen shot of 4D simulation – Beams under construction, the first lot beams and all columns completed

Figure 9 – A building Ground level complete
REFERENCES