A CRITICAL REVIEW OF DECISION SUPPORT SYSTEMS FOR CONSTRUCTION PROJECT PLANNING

Lamine Mahdjoubi, David Heesom+

+*School of Engineering and the Built Environment, Wulfruna Street, University of Wolverhampton, Wolverhampton, WV1 1SB, UK*

Graham Winch, Alan Penn, John Kelsey, Andrew Edkins, Steve North

▪ *Bartlett School of Graduate Studies, UCL, Gower Street, London, WC1E 6BT, UK*

Nash Dawood, Brian Hobbs, Abi Akinsola, Zaki Malassi*

**School of Science and Technology, University of Teesside, Middlesbrough TS1 3BA, UK*

ABSRACT

The scheduling of activities is of vital importance for the delivery of a successful construction project. Traditionally experienced construction planners, with in-depth knowledge of potential conflict between various construction tasks, generate the project plan. This information is then communicated to other members of the project team by means of a Gant chart showing the critical path for the completion of the various tasks. The use of Virtual Reality is becoming increasingly acknowledged as a potential benefit in this area. This paper discusses various research being undertaken to investigate the use of virtual reality and visualisation techniques to assist in the area of construction project planning. These methods range from providing a visualisation of a completed project to planners to assist with the logic of constructing the project schedule to linking a virtual reality model with the tasks defined on the Gant chart to highlight potential space-time conflicts.

Keywords
Construction Planning, Visualisation, Virtual Reality

1.0 INTRODUCTION

The time – space conflict of activities on the construction site have been identified as a major cause of productivity loss (Howell and Ballard, 1995), therefore the ability to rehearse construction processes prior to construction commencing on site is of vital importance. There is increasing pressure on the construction industry to perform more efficiently and reduce construction programme times. The task of construction planning is extremely complex and entails both spatial and temporal decisions to be made at strategic, tactical and operational levels. There is however, increasing concern throughout the industry that a skills gap is emerging in the area of project management and construction planning.

The Construction Task Force (1998), outlined targets for the improvement of the construction industry and in order to achieve these targets the operation of planning construction projects has to be improved. Various initiatives are being carried out in an attempt to improve process planning with the integration of visualisation techniques.

2.0 REVIEW OF RECENT INITIATIVES

2.1 4D CAD

The area of 4 dimensional CAD is currently being researched at Stanford University. 4D CAD combines the standard Gant chart method of project planning to a three dimensional visualisation of the objects being constructed.

The effect of 4D-CAD facilitates planning efforts by introducing a higher level of communication i.e. visualisation using VR, between the client and other project team members. Timed construction animation sequences provides a 'clip' of construction activity proposed, which informs viewers of specific project intent and allows evaluation by a more informed project team (McKinney & Fischer, 1998)

4D-CAD is an efficient method of linking the temporal and spatial aspects of a project program that can then provide the user with a 3 dimensional visualisation of the construction process over time. It has the ability to provide a visualisation of the construction site at a snapshot in time and provide 3D animations of the construction process. However the 4D-CAD approach does not highlight potential problems and conflicts between tasks for example clashes between the space usage of tasks.

2.2 3D visualisation to optimise operational level planning

Work in the area of using 3D modelling and animation to optimise strategic and operational level planning of construction projects was recently investigated by Songer at the University of Colorado. This work aimed to:

- Establish whether 3D visualisation technology has benefits over traditional 2D paper drawings when creating a construction schedule;
- Ascertain if 3D technology is more effective for planning specific construction processes;
- Determine whether 3D animation of construction sequences facilitates clear evaluation of schedules;

This work focused on how the provision of 3 dimensional information to construction project planners could assist with the pre-construction programming process. The project provided 50 project planners, both experienced and inexperienced, with either 2 dimensional hard copy drawings, 3 dimensional hard copy drawings or a 3 dimensional VR walk through of a pipe rack for a power plant. Each planner then provided a list of construction activities and a CPM schedule based on their interpretation of the project using the media provided.

The results showed that using the walk through visualisation during the planning stage enhances the scheduling process by:

1. Reducing missing activities from the schedule;
2. Reducing missing relationships between activities;
3. Reducing invalid relationships in the schedule;
4. Reducing resource fluctuation for complex construction processes;

The use of the walk through technology allowed planners to improve the quality of their schedules i.e. there were fewer critical activities, smoother workflow and shorter overall schedule durations. In addition to this, it appeared to minimise the differences between the quality of the programs produced by the experienced and inexperienced planners (Songer, 1997).

Although this work concluded that the use of a 3D real time visualisation was beneficial in providing a sound spatial comprehension of the construction process, this method is most suited to the planning of more complex tasks. For straightforward activities such as structural steel and concrete footings it made little contribution to the comprehension of the tasks required and therefore there were minimal differences in the schedules. The prepared schedules were linked to the 3D model using a 4D CAD tool to provide an animation of the construction tasks for each schedule. Although this highlighted logic errors and safety problems within each schedule it did not provide information into any time space-conflicts that occurred.

2.3 Space planning on construction sites

Tommelein and her team have carried out various research at the University of Michigan to investigate the planning and scheduling of space use on construction sites. This work has developed two systems to assist with the visualisation of site layout changes over time (MovePlan) and the optimisation of space-time scheduling of site layout (MoveSchedule).

The aim of the MovePlan system was to provide a model, which aids in planning the reuse of site space over time. The available space is described by the site boundaries in which the work must be conducted and the required space is described by the dimensions of resources present on site at various times. The user provides MovePlan with a CPM schedule of activities along with resources and a time frame for which the site layout is to be generated. The system then formulates a layout showing previously positioned resources and the ones that remain to be located (Tommelein, 1995).

The MovePlan system provides the user with a visualisation of the site layout. This can be used to inform suppliers of the unloading location for materials on site and to inform workers where material can be found. The system can also be linked with a portable surveying station to provide real time positions of materials around the site. Whilst the software identifies areas where work is being undertaken, the identification of conflicts between resources is left to the operator.

The MoveSchedule system is an integrated scheduler and space planner that adjust the project schedule to comply with the variation of site space limitations and resource space needs as they change over time. The objective of the system is to minimize resource transportation and relocation costs by solving constrained dynamic layout problems using geometric constraints along with timings inferred from the activity schedule. The solution is a sequence of layouts that describe changes in resource positions at discrete points in time corresponding to arrival and departure times of resources to and from site (Zouein, 1995).

The system improves on the concept of MovePlan as when no solution is found, i.e., when the resources needed in a given time period cannot be accommodated on site without violating constraints on their positions, MoveSchedule adjusts durations or start dates of activities to lower the total space need over the problematic time period.

2.4 Formalisation and automation of time space conflict analysis

Work undertaken by Akinci and Fischer at Stanford University aimed to build on the work currently being undertaken into the use and applications of 4D CAD within the construction industry.

The ultimate aim of the research was to formalize time space conflict analysis as a classification task. In order to achieve this the research had three main goals:

i) To detect conflicts in four dimensions (i.e. x, y, z, and time dimensions);
ii) To categorise the conflict according to a taxonomy of time-space conflicts developed (i.e. Design conflict, Congestion, Safety hazard, Damage);
iii) To prioritise the multiple types of conflicts between the same pair of conflicting activities;

A prototype system was developed, the 4D Workplanner Time-Space Conflict Analyser (4D TSConAn), which was linked to another system, the 4D Workplanner Space Generator that automates the generation of workspace required by construction activities. Using the spatial information required for each task, the 4D TSConAn first detects spatial conflicts between activities by simulating the construction process. When time space conflicts are detected the system categorizes them according to the derived taxonomy. An outline of the stages for the 4D TSConAn can be seen if Figure 1.

The output of the 4D TSConAn is a list of categorised and prioritised time-space conflicts which can be viewed either within a 4D CAD simulation (implemented in VRML in which the various types of conflict are highlighted) or within an Excel spreadsheet that documents all of the information about the conflicts detected e.g. conflict type, volume, duration etc. (Akinci, 2000).

The system is able to detect time space conflicts in 4 dimensions, display the conflicts as a virtual reality model and categorise conflicts in order to prioritise conflicts according to the problems they can create on site. It does however have various limitations.

The detection of conflicts is limited to rectangular prisms located to orthogonal planes, the time-space taxonomy includes only micro level activity space requirements and not macro level spaces (i.e. the spaces required within the proximity of components being installed and not large scale spaces located across the site) and the prioritisation of time space conflicts only ranks conflicts between pairs of conflicting activities and not between non related activities. In addition to this the system does not take into account movement of resources between spaces. Also the micro level spaces modelled remain constant for the duration of the whole activity whereas in reality the space requirements may change as the activity is undertaken. For example when painting a wall the system schedules a space for the entire wall for the entire duration of the activity, however in reality once a section is completed, that space will become ‘free’ and could be utilised by another activity.

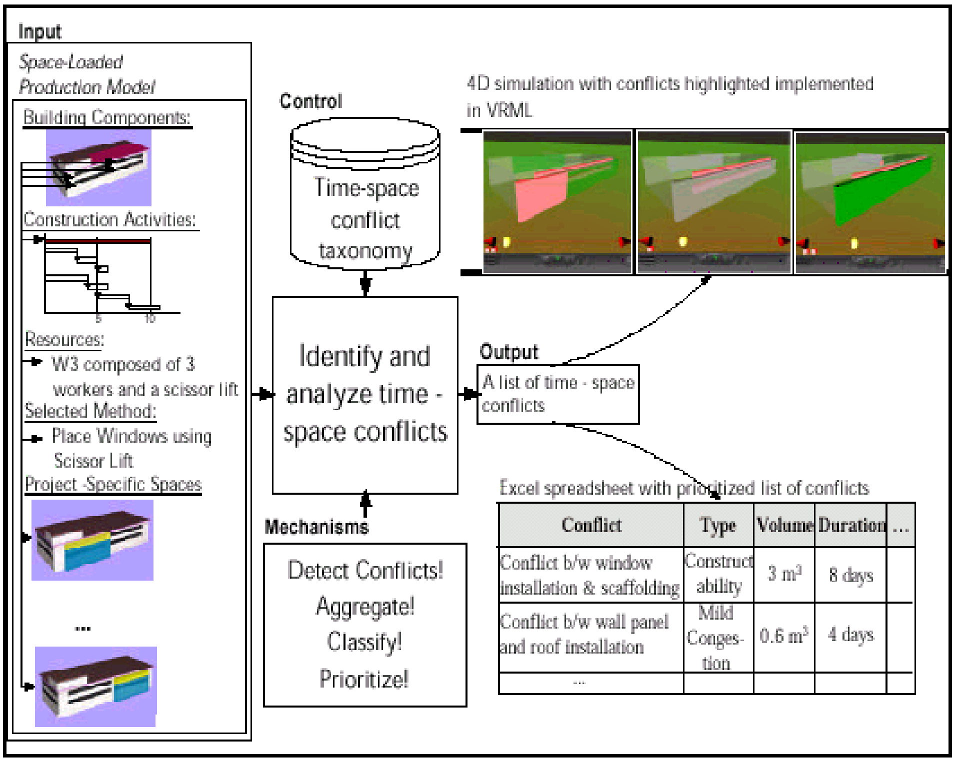

Figure 1: 4D Workplanner and Time-Space Conflict Analyser. (Source: Akinci et al. 2000)

3.0 VIRCON: A NEW APPROACH TO PROJECT PLANNING

3.1 Background

The Virtual Construction Site (VIRCON) is a decision support system for construction planning currently being developed by University College London, University of Wolverhampton, University of Teeside and various industrial collaborators. The system is envisaged to be a decision support tool for construction planners to assist with the planning process.

3.2 Aims and objectives

The aim of the project is to build on the work reviewed in this paper and elsewhere that has succeeded in advancing the visualisation of construction tasks beyond the Gant chart. It is envisaged that the VIRCON system will combine task schedule information in the form of CPM along with a developed Critical Space Analysis (CSA) tool to provide a space-time broker. The key components of the VIRCON are shown in Figure 2.

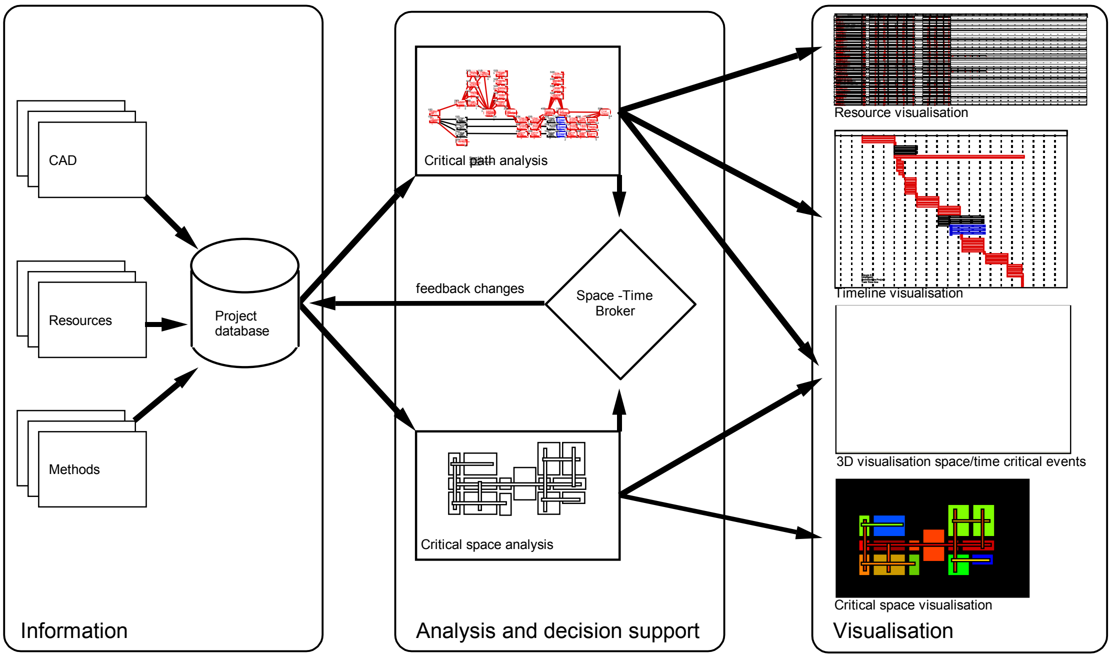

Figure 2: Outline of The Virtual Construction Site.
(Source: Dawood et al., 2000)

The developed Critical space analysis tool, which is to be developed, is envisaged to add a new kind of functionality to construction planning decision support software. This tool will allow a network of spaces, which comprise the construction site and the partially constructed building to be represented and analysed stage by stage throughout the construction process. Visualisations will be developed that link the Critical space Analysis and the Critical Path Analysis so that both can be tracked. Using the information stored in the project database and the CPS and CSA information a prototype Space-Time broker will be developed. This will use multi-criteria optimisation and constraint techniques to evaluate possible solution strategies for the spatial and temporal process of construction planning.

This decision support tool, will allow project planners to trade off the temporal sequencing of tasks with their spatial distribution, allowing the provision of a more rehearsed project schedule (Dawood et al. 2000).

4.0 CONCLUSIONS

This paper has presented various initiatives, which utilise virtual reality and real time visualisations to assist in the area of construction project planning. These have shown that the use of visualisation techniques can greatly assist in all aspects of this area. The work undertaken at Colorado established that visualisation of a completed construction project can assist with the process of compiling a construction schedule. Work elsewhere at Stanford and Michigan have shown that using visualisation and 4D-CAD principles to model the space requirements of construction tasks relative to time potential time-space conflicts can be highlighted.

In addition to this the current VIRCON project attempts to provide a decision support system that performs both a critical path and critical space analysis of the project program to produce a 3D visualisation of space/time critical events. The future process of project planning will benefit increasingly from the acceptance of virtual reality as a design tool. The use of virtual reality will not only assist with the initial preparation of a project schedule it will also enable the schedule to be updated in real time during the duration of the project to identify potential conflicts.

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