DEVELOPMENT OF A 4-D MODEL FOR APPLICATION IN CONSTRUCTION MANAGEMENT

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ABSTRACT

Planning for construction projects faces challenges due to complexity in design and short deadlines. Further, very limited tools are available to planners for integrating the visual representations of site with the progress of time, which results into their relying on experience and imagination to decide the appropriate sequence of construction plan. In the study, the 4D Model has been developed with the hope that it will allow the planners to visualize the construction with the passage of time at the planning stage itself without even starting the work in reality and thereby removing the flaws that might have been left out in the construction project plan. The model has been tested for a simple construction due to paucity of time. However the results obtained are encouraging. It has the potential to show potential conflicts in a construction site and is capable to perform what-if analysis which may finally lead to the improvement in project planning and project executing strategy.

KEYWORDS

4D Model, Project Planning, Progress Tracking, AutoCAD, MS Project

1. INTRODUCTION

The position of a point in space is defined by the coordinates (x, y, z). When all the elements of a structure are defined in space with the help of their 3d coordinates, the result is a 3D model of the structure. When the position of the point with respect to time is not fixed or in case the point is changing its position with time, then we need to consider another dimension, the fourth dimension 'time' and the resulting model is known as 4-D model.

During the past decades, advances in three-dimensional (3D) computer-aided design (CAD) technologies have furnished the opportunity for planners to apply 3D models to manage construction information in projects, by way of viewing their static realistic images. However, these 3D models by themselves, without the ability to display the exact status of a project at a specified period, furnish little assistance in progress control. There are no data integration and interaction between the 3D model, schedule information and other data. In order to produce a construction schedule from 3D drawings, planners have to envision the sequence of construction in their mind.

Construction projects are dynamic in nature and as the time progresses the status of construction progress also changes. However, most managers plan their projects based on the preliminary site layout and utilization drawings which frequently gets updated during the execution of project. A 3D model for such situations generally does not capture the reality and the need for a 4-D model which can incorporate 'time' also into account would be very much desirable. The 4D model not only provides the visual aid in depicting the structure as the time progresses, it also poses numerous other advantages, such as capability of

performing what-if analysis, viewing the structure from different angles etc.

In this paper, the authors have linked 3D model of the structure and construction schedule of the project, so that the status of the project can be reviewed in the form of 3D model of the structure at any instance of time. For developing this program AutoCAD has been used for generating the 3D model and Visual Basics has been used for providing interface and generating the user friendly input window.

The model so developed could assist the planning managers in visualization of the details of the prospective work at any specified time. This could further lead them to take better decisions both during the planning and construction stages.

As mentioned above 4-D model has wide applicability in construction industry, the present study however focuses on developing the model which allows project stakeholders to view the planned construction of a facility over time on a computer screen and to review the planned or actual status of a project in the context of a 3D CAD model for any day, week, or month of the project.

The paper has been organized in number of sections. In the next section we review the literature relevant to the study area and then present the research methodology adopted to achieve the stated objectives. The description of the model with an illustration follows next. At the end summary and conclusions are provided.

2. LITERATURE REVIEW

During the past decade, research efforts have been made towards advanced four-dimensional (4D) planning models by integrating three-dimensional (3D) visualization with the time attribute.

Koo and Fischer [1] showed that 4D models are effective in evaluating the executability of a construction schedule and highlighted the need for improvements to 4D tools through a case study. They concluded that 4D models are a useful alternative to project scheduling tools like CPM networks and bar charts. The case study also highlighted the need for improvements to 4D tools.

Dawood et al. [2] presented the report on the development of an integrated database to act as an information resource base for 4D/VR construction process simulation. A comprehensive database was designed, implemented and populated with the School of Health Construction Project. The database is composed of a core database of building components which is in turn integrated with AUTOCAD 2000, MS Project and Graphical User Interfaces. The core database was designed using Standard Classification Methods. Integrated interfaces between MS Access database, AutoCAD drawings and MS Project Schedules were developed and implemented.

Chau et al. [3] discussed a 4D visualization model that is intended both to help construction managers plan day-to-day activities more efficiently in a broader and more practical site management context. Mallasi and Dawood [4] reported on the development of site –PECASO model as part of their ongoing project. The Site-PECASO model provides project planners with a product-oriented simulation tool that highlights spatial clashes and interference between construction operations in real-time 4D environment. Chau et al. [5] discussed some insight and experience on the on-site use of a prototype 4D site management software system for a warehouse superstructure in Hong Kong. The system links a three-dimensional model and a construction schedule to furnish visualization of the state of a site at any user-specified date. Through site trial, some limitations of the software are also spotted which consequently lead to enhancement to the system. Sadeghpour et al. [6] presented an interactive computer-aided site layout model to support site planning in a computer-aided design (CAD) environment. The model offers three tiers of objects: (1) site objects, (2) construction objects, and (3) constraint objects. The structure facilitates the creation of new objects and reuse of domain knowledge, which allows for the gradual expansion and enrichment of the model's knowledge base. The model is structured in three main modules: Database, Project Module, and Layout Control Module. The functionality of each module, along with their interconnectivity is described. The model is implemented using Visual Basic for applications in AutoCAD environment and

Microsoft Access. Chau et al. [7] delineate the development and implementation of a prototype four-dimensional site management model (4DSMM), with the objectives to address the requirement for linking scheduling data to a three-dimensional computer graphics building model and to furnish the capability for planners to view graphic simulations of the construction process at any prospective specified date.

Lena and Osama [8] discussed the utilization of CAD technologies to establish effective integration in a number of construction management functions. A CAD-based project management methodology is achieved by making use of the AutoCAD features that allow the designer to associate graphic objects with extended data stored in a central database. The system further integrates the database with commercial project management software that becomes the interface for construction management functions including, planning, scheduling, and cost estimating. Arun et al. [9] developed a methodology for integrating computer aided design with construction scheduling using standard software application packages namely AutoCAD and MS-Project along with MS-Access database. The integration was achieved by developing suitable interfacing modules.

In the present study, a 4D visualization model for construction planning and site utilization has been developed. The research methodology adopted for the development of model is presented in the next section.

3. RESEARCH METHODOLOGY

The 4D model developed for the study comprises mainly a 3D model of the structure and a construction schedule. In the development of model for the study, the 3D geometrical model of the structure has been prepared using AutoCAD and VBA representing all elements floor by floor, based on the construction method and program proposed by the contractor. Microsoft Project has been used in this model to display a bar chart scheduling environment, and for developing the interface Visual Basic application tool available in AutoCAD has been used. The model developed has been tested on a hostel building.

4. DESCRIPTION OF THE MODEL

The 4D-model provides an information platform that couples the project schedule and dynamic site plan with the structure 3D model to serve the purpose of site management, covering construction planning.

The 4D model program is developed and tested for a two-storeyed concrete framed hostel building for illustration in the paper. The building has been divided into eight grids numbered 1 to 8 in X-direction, and four grids numbered A to D in Y-direction. At each of the grid intersection a reinforced concrete column is there, thus a total of 32 columns exist at each of the floors of the building which adds to 64 column elements for the hostel building. The slab and beam at each floor has been divided into seven elements, thus a total of 14 slab and beam elements for the building. Similarly walls in x-direction and y direction for both the floors combined together add to 108 elements. Thus, the entire hostel building is split into a total of 186 individual elements. These elements are numbered separately, so that after inputting the values, the program calls the element with the same number. The numbering pattern can be seen from Fig 1 also which is the input form of the program and appears after running the program. For ground floor column, the symbols ColF1A to ColF8D have been used while for first floor columns the symbols ColS1A to ColS8D have been used. Similarly the symbols have been kept for wall and slab-beam elements for ground and first floor.

For developing the interface the coding has been done in Visual Basic editor which appears in AutoCAD screen after invoking | Tools | Macro | Visual Basic editor in that order. In the input form shown in Fig 1, the user has to input the tentative date of completion of each activity separately. The user also has to specify the progress period at which the user wants to view the progress. This input form is linked with VB code, to develop the 3D model for different options.

The flowchart of the coding shown in Fig. 2 describes the working of the software. For working on program first the user has to run the program. When the program runs, it generates a window which appears as shown in Fig. 1, then the user has

to input the planning schedule (based on the construction schedule prepared in the M.S. project) and the time at which the user wants to see the progress and the 3D model of the structure.

Then for each element the program checks the planned completion date as per the planned schedule and the date for which progress is required. If the date for the planned completion date of the individual elements is less than or equal to the later one that is the date of monitoring , then the program calls that particular element and generates 3D drawing of that particular element. Similarly the program checks for each element separately and finally the program generates the 3 D model of the structure showing the progress up to that particular date. Hence this way the user can see the 3D model of the structure planned to be completed up to that particular time. At this stage if the user wants to compare the different planning options, then it can also be done by this program just by changing the inputs. For example if the user wants to see the progress on n[th] day, he inputs the value of 'n' in the space provided in the input form along with the planned date of completion of each of the elements shown in the input form.

Once the program is run, it compares the planned input values with 'n' and generates the 3D model of the structure showing planned progress on that date. Some outputs of the program for different values of 'n' and planned completion dates of each of the elements are shown in Figures 3 and 4.

The 4D Model allows what-if analysis to compare the different planning options. In other words, if the user had filled all the inputs based on the initial planning and after seeing the 3D models which the software develops or due to some other reason, the user wants to change the planning, then just by changing the values against that particular elements for which the user want to change the planning, the software again generates the new 3D model based on that new planning.

Another advantage of such models is that images could be rotated for viewing from any desired angle, zoomed as required and shared on the computer network, which is impossible by other available techniques. The 4D model can also assist site personnel during brainstorming sessions on access to site, storage at sites and sequencing of construction activities.
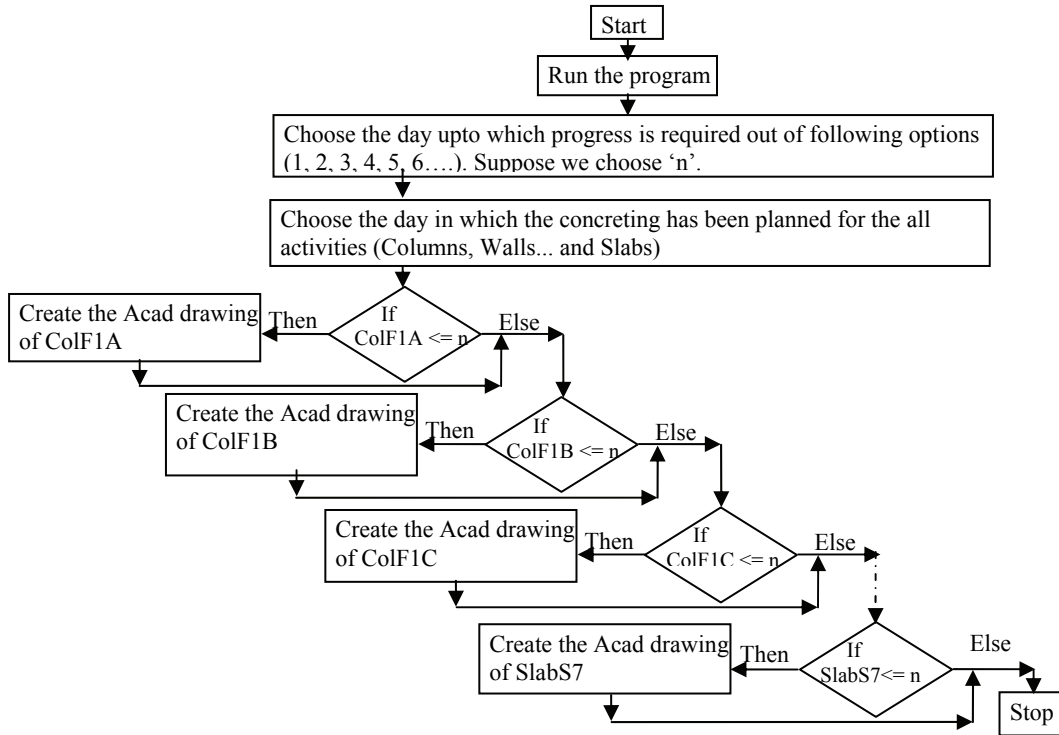

Figure 1 The Input Form
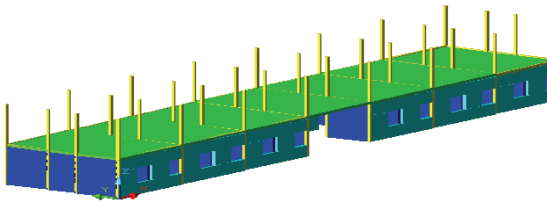
Figure 2 Flow Chart of the Coding

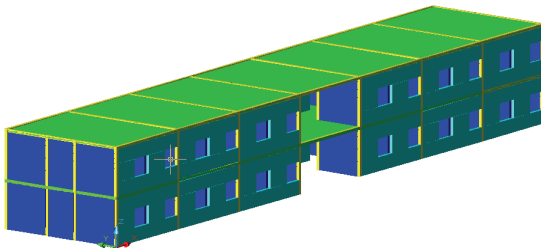**Figure 3 Output at Intermediate Stage**

Figure 4 Output at Final Stage

For implementing this software at site, the architect/designer prepares the 3D model and the planning department of contractor is responsible for the preparation of the construction schedule. If there is early collaboration between the two parties, good results can be obtained. However, in actual practice, designers and planners usually work independently with a low degree of co-ordination which may impede the successful implementation of the model. Indeed, the 4D model applications would be assisted by close co-ordination between designers and site planners.

The model described in the paper is the output of an ongoing study and is in preliminary stage. A number of improvements can be made to make it more users friendly. The current model requires a large number of input to be given by the user since it is not compatible with the scheduling software. Further, the model does not provide any information on percent completion of the project currently.

5. CONCLUSIONS

In this paper, a prototype 4D model has been developed and implemented with a view to overcoming problems incurred in conventional construction planning methods and in incorporating practical site management features. This 4D model, which links the 3D geometrical model with scheduling data, comprises the activity schedule and 3D model of site facilities at any projected instant. There are many potential benefits of the 4D model system, including facilitating site planning and management, predicting the occurrence of any potential site problems, and streamlining the site management practices. Moreover, the advancements in computing technology have assisted in this work, resulting in a user-friendly, comprehensive, and integrated site management tool. It is believed that 4D visualization will have strong potential in construction planning and management processes.

Further for successful implementation of the model, close coordination between designer and planner is required. The present weak level of co-ordination can either hinder the application of such software, or else such software itself could, perhaps a bit optimistically, become the means of promoting future co-ordination between designers and site planners.

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