Using 4D in a new “2D + time” Conceptualization

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ABSTRACT: This paper describes a system that combines a 2D digital board that shows dynamically in rows and columns arranged in a special layout, starting and finishing dates of subcontractors work linked to the fourth dimension, time, coming from construction schedules. The system is the result of a research project whose objective is to improve planning, scheduling, and controlling the work of subcontractors of finishings in building projects. The system will be tested on case studies projects for planning, scheduling and controlling the work of subcontractors. It is expected that the systems will act as a powerful real time Visualization, Planning, Analysis and Communication Tool in the case studies. Despite the 3D case studies models were very useful for constructability and other purposes, the traditional 4D approach that combines 3D + time was not very useful when dealing with construction works that remained mainly “hidden” within the project 3D model. Applied to the case studies, the digital board shall provide different ways to display, communicate and understand information about resources, costs, dates and relationships coming from a traditional CPM network using 4D in a new 2D + time conceptualization.

1 INTRODUCTION

1.1 4D Modeling

4D models have traditionally been conceived like adding the temporal dimension to 3D CAD models, i.e. linking a 3D graphical model to a construction schedule, through a third party application (Collier and Fischer, 1996, McKinney et al., 1996), providing the ability to represent construction plans graphically (Williams, 1996). Recently the definition of a 4D model has expanded its scope to include activities from the design and procurement also linked to the components in 3D CAD models (Fischer and Kunz, 2004).

1.2 A new conceptualization of 4D

In this paper it will be presented a conceptualization of 4D models that does not include a 3D CAD model as an obligatory requirement, but considers a 2D digital board that shows dynamically in rows and columns arranged in a special layout, starting and finishing dates of subcontractors work linked to the fourth dimension –time– coming from construction schedules.

The system aroused from the application of “typical” 4D models to three case study projects (two building repetitive project and a subway station), in which components in the 3D CAD models related to certain finishing construction works carried out by subcontractors remained “hidden” once the main structure of the project was displayed as a 3D model.

The system combines commercially available software tools, that allows different ways to display, communicate, understand and mainly update in “real-time” information about resources, costs, dates and relationships coming from a traditional CPM network using 4D in a new “2D + time” conceptualization. The new approach has led to the creation of prototypes of the proposed system that will be validated in two of the case studies where research about “typical” 4D is carried out. It is expected that planning, scheduling and controlling the work of subcontractors will become improved using the proposed system as a powerful real time Visualization, Planning, Analysis and Communication Tool.

2 HIDDEN 3D CAD ELEMENTS

2.1 4D-PS applied to non-industrial projects

In collaboration with two construction contractors in Chile, research projects to adapt the 4D Planning and Scheduling (4D-PS) work process (Rischmoller et al, 2000) to be used in building repetitive projects and in a subway station are currently underway.

The main change respect to the original 4D-PS approach is related with the responsibility for the 3D model development and the stage of the project in which the 3D modeling and construction schedule development efforts are carried out. The original 4D-PS work process was designed considering that the 3D modeling effort is carried out by the project engineering department in parallel with the construction schedule development during the project design stage.

2.2 *Adapting 4D-PS*

The current 4D-PS adaptation, considers that the design of the project is finished before starting the 3D modeling and construction schedule developing efforts. The design of the project is received by the construction contractor as 2D drawings developed using AutoCAD software.

The research team using Architectural Desktop (ADT) software develops 3D models of the projects divided in "pieces" according to the construction plans and schedules developed by the contractors using MS Project software based in the 2D drawings project design. A new construction schedule is developed using Primavera Project Planner (P3) software ensuring that the "pieces" in the 3D models will match with the activities names in the P3 schedule. The new P3 schedule is also loaded with the material quantities take off coming from the ADT 3D model. Finally 4D models are produced linking de ADT 3D models and the P3 schedules using the SmartPlant Review software, which is also used review the 4D model as well as navigating through the 3D model before starting the 4D modeling efforts.

2.3 *Building repetitive projects*

4D models have been developed for a contractor specialized in low income building repetitive projects. The floors of these building projects are repetitive and sometimes the projects include several similar buildings. Based on the project 2D drawings, once one type of floor has been modeled in 3D, it is copied as needed to assemble one or more 3D building models. The level of detail for the 3D model of every typical floor is high (e.g. including wall paper, paved floor, interior doors, stuccowork, etc.) (Figure 1).

The visualization of the 3D model led to a better understanding and communication of the needed construction works for every typical floor.

A construction schedule was developed in parallel to the 3D modeling effort taking into account the expected match between construction activities with the 3D CAD model elements in order to expedite the 4D model development process. In this way 4D models of some building projects were developed expeditely.

When revising the 4D models it was realized that once the main concrete structure (i.e. walls and slab) of every floor was finished, the 3D elements inside the building became hidden. In every project executed by the contractor composed of five to twenty five stories buildings, the ability to visualize the construction sequence associated to the hidden objects in the 3D/4D model was null in every 4D model developed. The same occurred for an individual building seventeen stories tall.

The 3D models developed during the research were very useful to obtain the material quantity take-off of the projects and to support planning of mainly finishing construction works in individual typical floors. However, the elements in the 3D model mainly related to finishing construction works –the hidden 3D elements– were not very useful to review and analyze the complete construction schedule when included into 4D models.

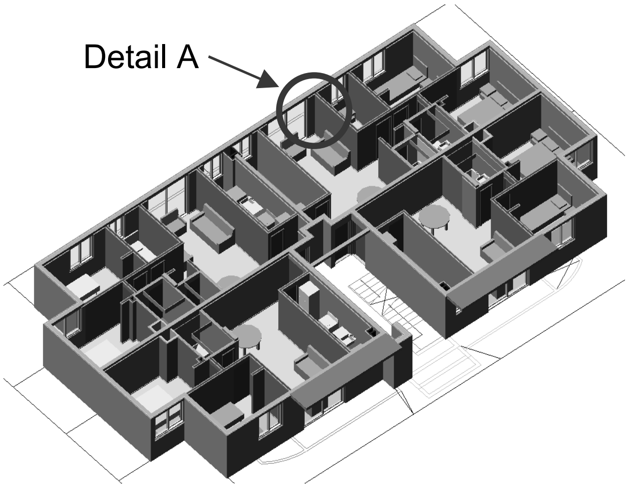

Figure 1. Detailed 3D model of a typical floor

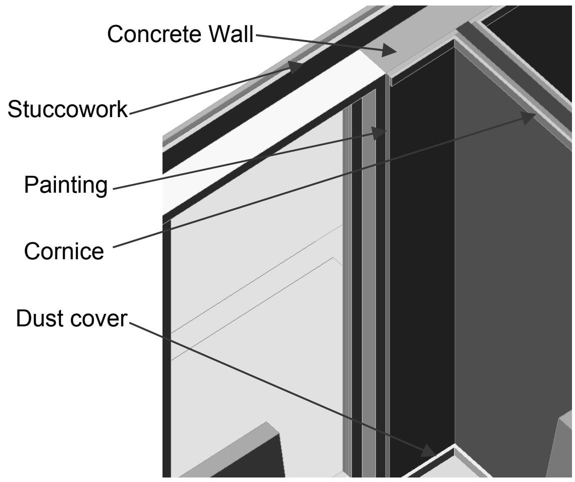

Figure 2. Detailed of a typical floor (Detail A Figure 1)

2.4 *Subway station*

In another research project a similar approach to that used in building repetitive projects was applied. The project consisted in 4D modeling a subway sta-tion in which the scope of the 4D models did not in-clude finishing works, but it was limited to the con-crete walls and slabs of the subway station. Even finishing construction works of the subway station were not 3D modeled, it was corroborated that once the main structure of the project is complete, there are several construction works that would have be-come hidden if they would have been 3D/4D mod-eled (Figures 3 and 4).

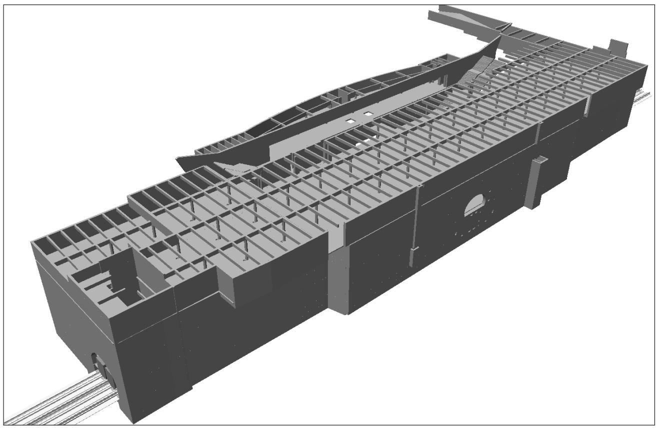

Figure 3. Subway Station, finishing construction works be-come "hidden" by the walls and slabs

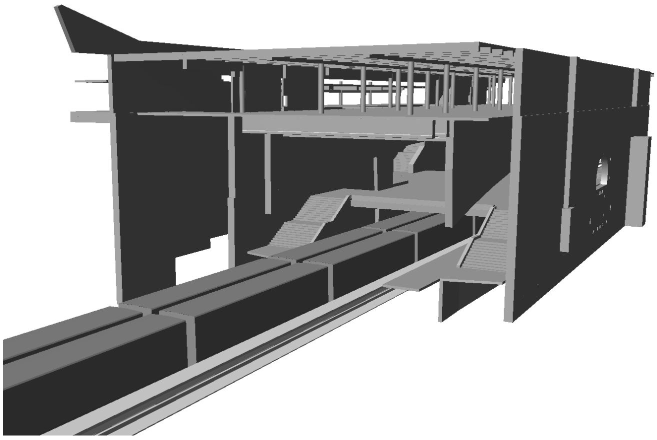

Figure 4. Subway Station, finishing construction works be-come "hidden" by the walls and slabs

3 TRADITIONAL JOBSITE BOARDS

3.1 *Jobsite boards*

Using black or white boards or panels at the jobsite to try to support construction plans and schedules communication and control is not uncommon. These boards are sometimes very good structured showing a good relationship between the construction activities, the dates these activities must be executed, and the location in the project where these activities must be carried out (i.e. the horizontal as well as the vertical division of the project). Maintaining these boards however demands manual intervention which makes it difficult to keep them with updated information as the project progresses. These boards are also stationary and it is the people who has to get near the board in order read its information rather than moving the board (i.e. a printed copy) where the people is, as needed.

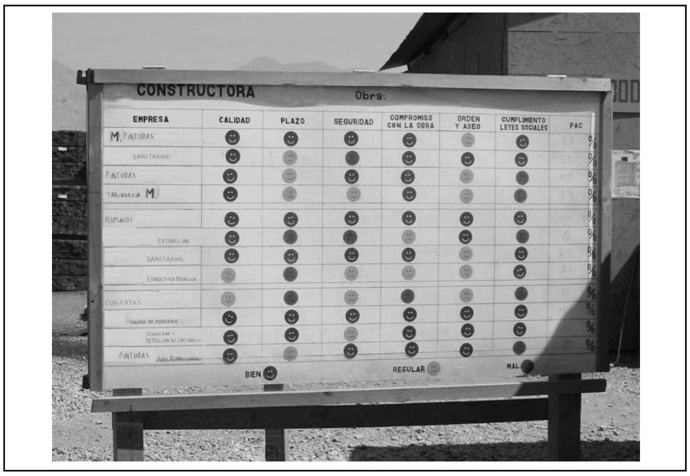

Figure 5. Board at the jobsite

4 THE DIGITAL PLANNING AND SCHEDULING BOARD

4.1 *Temporal dimension of 3D hidden objects*

According to the experience with the application of 4D modeling to the case studies, it was concluded that the temporal dimension of some "3D hidden elements" was not being effectively useful to consider 4D models as the powerful Visualization, Planning, Analysis and Communication Tool it promises to be. Since 4D modeling benefits are not in doubt, in order to solve this "problem" the new approach –the digital planning and scheduling board (DPS Board)– presented in this paper was developed.

4.2 *Finishing construction schedule*

The repetitive nature of the finishing construction works in building repetitive projects led to presume that a typical gannt chart would be easy to develop, understand and used to control the finishing works in the project. Construction schedules using MS project software had previously been developed by the case studies contractor intending to support planning communication, reporting of advance and construction execution improvements. These schedules contained several 100 activities for a typical project with hundreds of arrows trying to depict the relationships among the different activities (Figure 6). These schedules proved to be pretty long to be rapidly understood, communicated and even printed to be useful to the rest of the projects participants. Furthermore, trying to maintain the schedule updated once the project begins and reschedule the project when needed, proved to be a task so tedious that using these schedules was soon disregarded.

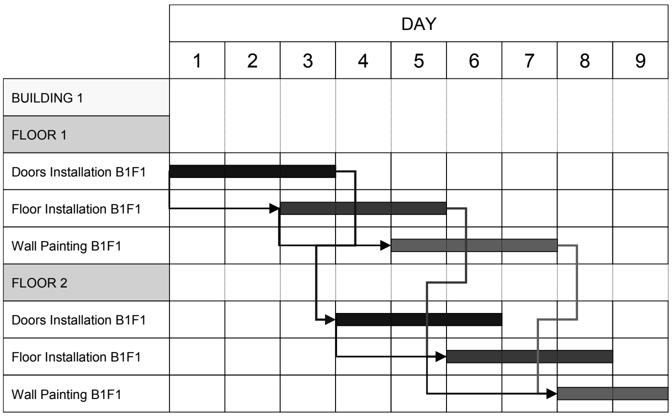

Figure 6. Fragment of a long finishing construction works schedule

4.3 *Replacing 3D elements with cells*

Based in the idea of typical white boards used at the jobsite of several construction projects, the information about the finishing construction works of the building repetitive case studies was structured in a matrix whose rows contained cells representing repetitive construction activities grouped by the different project elevations (i.e. floors). The columns of this matrix reflected the horizontal division of the projects, in some case by buildings (i.e five buildings of five stories each building) while in other case by floors (i.e. the seventeen stories unique building)

This matrix was drawn using ADT software considering that each cell of the matrix shall be linked to one or more construction activities in the construction schedule. Different layers, colors and files combined with the Xref manger feature from AutoCAD were used to achieve this goal. Figure 7 shows an outline of the matrix: the DPS Board.

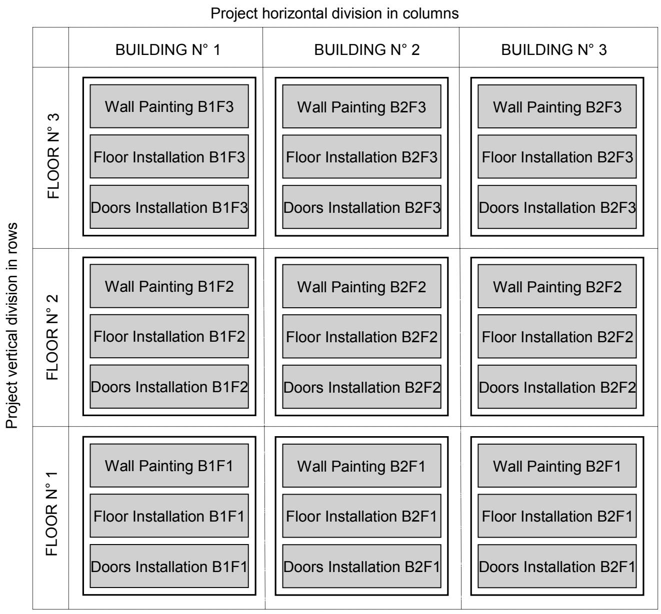

Figure 7. Outline of part of the digital planning and scheduling board (DPS Board)

4.4 *Linking the construction schedule with the 2D elements*

Once the DPS Board is constructed, the activities in the construction schedule are linked to the cells in the DPS Board in the same way that 3D elements in a 3D model are linked to construction activities. In this way, and despite the third geometrical dimension is not considered, since the 4th dimension of time coming from the construction schedule is included, we consider the result as a 4D model.

Several prototypes of 4D models using the DPS Board have been constructed proving its functionality from the software tools perspective. The cells in the DPS Board are turned on or off controlled by the activities in the construction schedule. Each cell has a color code associated, and equal activities executed in different location are the same color. A different color tonality is also used according if an activity has not started, is in progress or it is finished.

In collaboration with a building repetitive projects contractor in Chile, these prototypes are being prepared to be validated as Visualization, Planning, Analysis and Communication Tools in two case studies, from the construction management perspective.

5 BENEFITS

5.1 *Expected benefits*

The expected benefits of the application of the DPS Board shall be to some extent similar to those obtained from a "typical" 4D modeling application (Fischer & Kunz, 2004; Rischmoller et al, 2002; Heesom & Mahdjoubi, 2003). The geometry of the elements considered in the DPS Board is simplified to cells instead of the accurate representation provided by 3D model elements. However, for elements that become "hidden" into 3D models, the DPS Board offers different ways to display, communicate and understand information about resources, costs, dates and relationships com-ing from a traditional CPM network using 4D in a new 2D + time conceptualization. In this way the DPS Board provides an alternative to consider the relationship between the spatial and temporal aspects of some construction project elements which otherwise would be very difficult to take into account (i.e. "typical" 4D modeling).

The quantitative as well as the qualitative benefits of the application of the DPS Board will be measured and contrasted with the expected benefits at the case studies currently underway briefly presented in this paper.

5.2 *Further research*

Further research applying the DPS Board to other kind of projects shall contribute to validate the approach presented in this paper. A customized arrangement of cells structuring a suitable horizontal and vertical division for other kind of projects shall be carried out in further research. The cells in the board could represent repetitive or non-repetitive activities grouped in work packages. Defining a work package as a group of activities which have in common either location, tools required, execution processes or other characteristic of similarity (e.g. doors installation, painting, etc…). Figure 7 shows a general representation of the DPS Board that could be adapted to other kind of projects during further research.

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