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Teaching Project Planning and 4D Scheduling in a Project Planning and Scheduling Course

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Abstract

Planning is the first part of project planning and scheduling and yet not much is found in most textbooks and research papers on the aspects of project planning. This paper reviewed the end result of project planning and the aspects of project planning that are key to effective project scheduling and control. Today's methods of planning and coordinating projects have benefited from virtual design and construction (VDC). Incorporating VDC in project planning and coordination helps in identifying potential site logistics and sequencing issues that might affect construction, and it does help in optimizing construction methods and resources. To that end, this paper explored the implementation of 4D scheduling in today's project planning and scheduling course. The research sought to improve construction planning and scheduling course with focus on how to implement project planning and 4D scheduling. The research collected and evaluated the course content covered in typical project planning and scheduling courses to better understand the state of practice. This evaluation showed that project planning and scheduling as taught by most programs do not properly cover the topic of project planning, and most of the programs do not cover the topic on 4D scheduling. This paper is written with those gaps in mind and includes what could be covered in both areas to fill the gaps. This paper presents a description and discussion of the approach in teaching project planning and 4D scheduling within the context of project planning and scheduling course. It is hoped that such improvement will help to better prepare the students for today's complex projects. It is hoped that other faculty members in the construction-related programs could benefit from the description and discussion presented in this paper and aid them in implementing hands-on and real-life project planning and scheduling courses that cover the areas of project planning and 4D scheduling.

Keywords: Project Planning, 4D Scheduling, Virtual Design and Construction, Building Information Modeling, MS Project, Primavera P6.

Introduction

Project planning, scheduling, and control course introduces the techniques for planning, scheduling, and controlling construction projects. As taught at the University of Cincinnati, the topics include a refresher on the characteristics of the construction industry, a refresher on construction materials and methods, aspects of construction planning and the need for planning. The course also covers scheduling techniques and analysis of critical path, and it also exposes students to the project specifications that define how to develop and use project schedule. Other area that are covered in the course include hands-on exercises in the use of software for developing project schedule as well as for developing 4D scheduling. The course also covers the topics on time-cost tradeoff, and schedule update. The scheduling software that are taught in the course include Microsoft (MS) Project, and Primavera P6. For 4D scheduling, Navisworks is used. Construction management programs are increasingly teaching students how to use advanced digital technologies such as Building Information Modeling (BIM) and 4D scheduling [1, 2]. 4D scheduling provides a virtual simulation of the construction process. It integrates 3D BIM objects (representing project components) with the corresponding construction work tasks (activities) to help simulate the sequence in which the project components are constructed. 4D scheduling helps students to gain a better perspective, and understanding of the construction sequence of a project.

After the first half of the semester, students are exposed to scheduling techniques and the use of MS Project and Primavera P6 to create a project schedule. This implementation focuses on a hands-on learning approach through lecture and lab sessions. Various aspects of project planning and scheduling are reinforced during the weekly class meetings. The lecture provides examples of scheduling techniques implemented across the project stages – schematic design, design development, and construction stage. The chart in Figure 1 illustrates the typical course format.

This paper explored the approach to teaching project planning and the aspects of project planning that are key to effective project scheduling and control. The paper further explored the approach to teaching 4D scheduling within the context of the project planning and scheduling course.

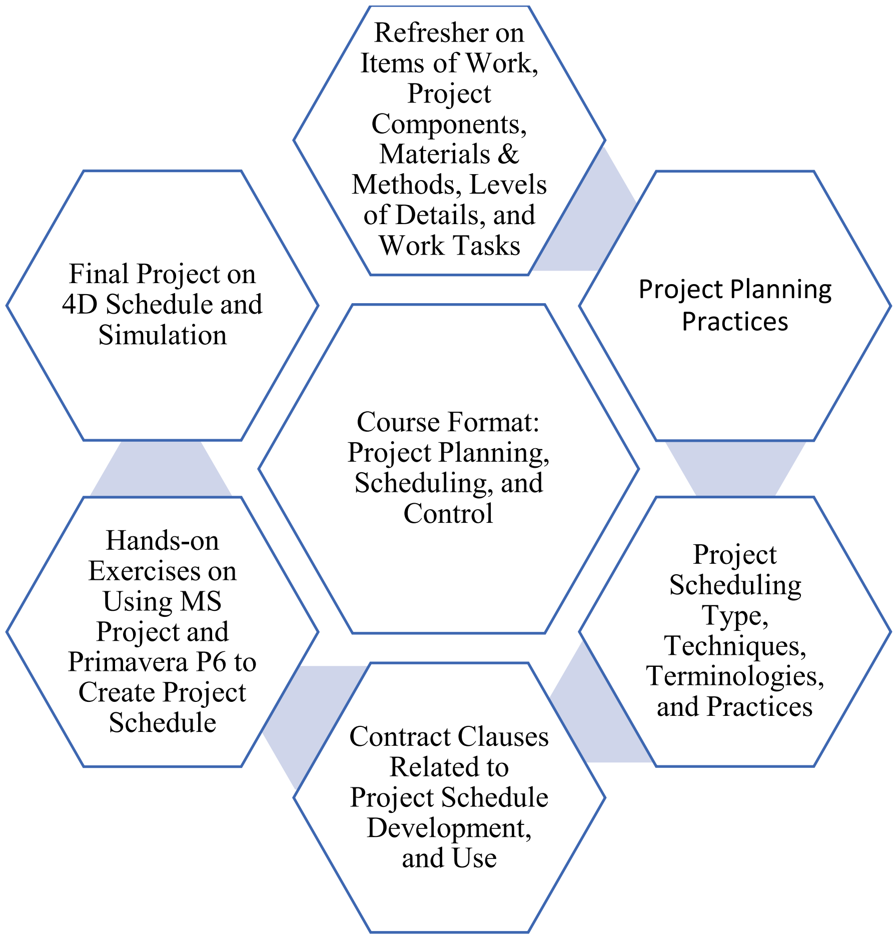


Figure 1. *The typical format of project planning, scheduling, and control course*

Project Planning

Difference Between Planning and Scheduling

Planning and scheduling are two critical steps in project development that allow project managers to achieve a project's goals and deliver the required results. While the two share similarities, each serves an essential, unique purpose in the project process. Planning is focused on coming up with strategies to get the work done, and scheduling is focused on graphically depicting the strategies in a format that allows all parties to visually see how the plan will be accomplished. The process of planning and scheduling is an iterative (back and forth) process.

Aspects of Planning

Planning happens before scheduling, and the practice is to start with the plan first. With so many options in every aspect of constructing construction project, planning helps to uncover specifically which one from the list of options must be selected so as to meet contract requirements, as well as optimize usage of resources. Planning is about planning for the following items as they relate to what, when, where, and how:

a. The scope of work,
b. Required materials (permanent and temporary materials), and permanent equipment,
c. Required labor,
d. Required construction equipment,
e. Applicable permits,
f. Applicable work tasks (activities), and their duration,
g. The alternative construction methods,
h. Applicable submittals,
i. Required shop drawings,
j. Coordination of people and work
k. Subcontract and/or material contract items of work,
l. Items of work that are self-performed by the prime contractor,
m. Related utilities connect, tie-ins, and conflicts,
n. Applicable underground and overhead utility protections,
o. Field sampling and testing,
p. Field inspections,
q. Applicable work constraints and restrictions,
r. Sequence or order of constructing the work tasks, and
s. Others.

Factors that Affect Contract Completion Time

Project delays happen for several reasons, and some of which may depend on the scope of work and the complexity of the project. Other reasons may relate to the construction methods chosen. Figure 2 details some of the factors that could drive contract completion time.

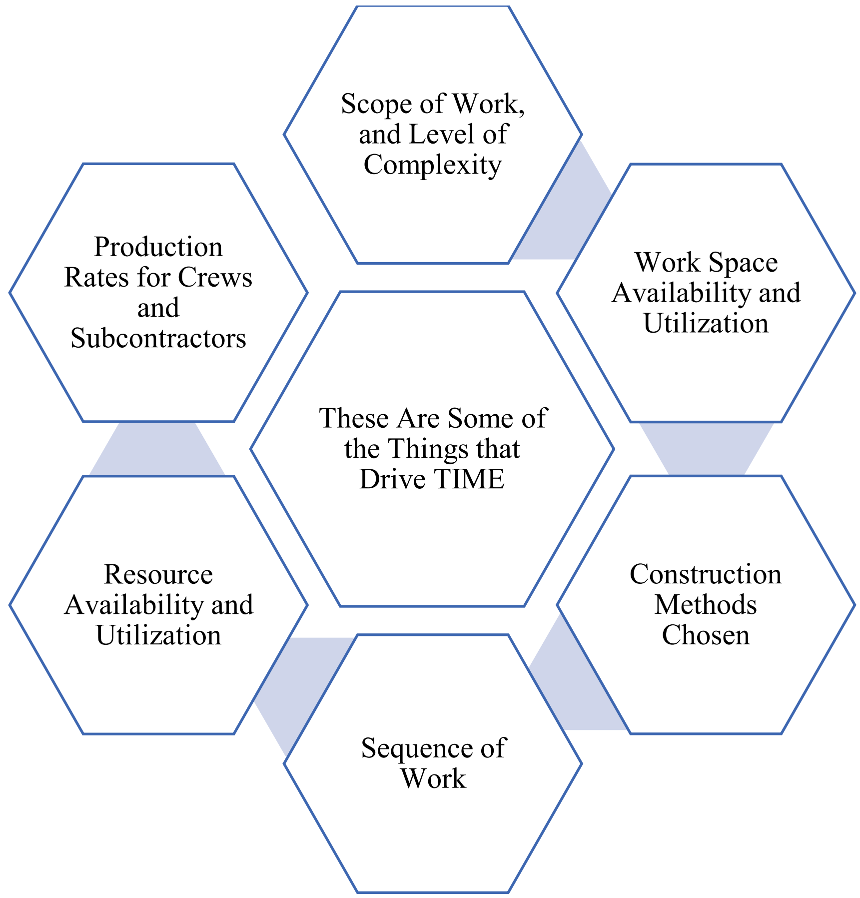


Figure 2. *Factors that are found to have impact on project duration and completion time.*

Factors that Affect Construction Productivity

Coelli et al. (2005) [3] define productivity as the ratio of the produced outputs to the inputs used to create the outputs. In the construction context, labor productivity has been described as the ratio between the units of work accomplished (i.e., output quantity) and the hours of work (i.e., inputs for labor) [4, 5]. Different factors influenced construction labor productivity, and Table 1 details some of the factors that affect construction productivity on construction projects [6].

Table 1. Factors that are found to affect construction productivity on construction projects, Adapted from [6]

Poor labor supervision	Poor construction methodology
Delay in payments	Unsafe working conditions
Poor work environment	Inspection delays
Lowly skilled labor	Lack of rest time(s) during the workday, fatigue
Bad weather conditions	Excessive overtime
Low employee satisfaction	Unclear technical specifications
Design errors and changes during construction	Delay in responding to "requests for information"
Reworks	Higher ratio of subcontracted work
Poor site logistics and management	Not following the safety precautions and rules
Poor communication between project team	High level of noise
Lack of training sessions	Lack of labor recognition programs
Poor material/equipment management	Client's intervention
Frequent change orders	Lack of periodical meetings
Crew size and composition	Unforeseen ground conditions
Lack of job security	Unsuitability of storage location
Delay in approvals by authorities	Unstable local economy
Poor communication with labor	Labor absenteeism
Shortage of labor	Lack of safety officer on the construction site
	Frequent changes in regulations

End Result of Project Planning

The end result of project planning is a detailed understanding of what work must be completed, when the work will be completed, where the work will be completed, and how the work will be constructed. The output or end result of a well-planned out project include:

- Detailed understanding of the project scope of work.
- Detailed understanding of the contractual requirements for developing and maintaining the project schedule.
- A work breakdown structure (WBS) of the scope of work for scheduling purposes.
- Detailed listing of the work tasks.
- An understanding of work constraints and their impact on the work tasks.
- Detailed list of work tasks and their respective duration.
- An understanding of the sequence or order of construction of the work tasks.
- Detailed list of construction resources (materials, labor, construction equipment) and the corresponding work that that will utilize them.
- An understanding of the alternative construction methods that could be used to construct each work task – there is always more than one option.

The Need to Teach Project Planning to Construction Students

Project planning for construction is an essential tool enabling project managers to break down large and complex projects into smaller and manageable phases. Project managers must thoroughly understand project planning, what it takes to deliver projects in a timely manner and the steps needed to accomplish the desired result. Knowledge of project planning prepares students for management positions in the construction industry by providing them with the required skills. This allows them to effectively and confidently lead planning efforts and help deliver project on time and on budget. Knowledge of project planning exposes the students to play a significant role in the industry and understand the universally accepted principles of project planning and practices used by industry experts to determine how much time is required to construct a project.

How Project Planning is Taught in Today's Planning and Scheduling Course – A Look at the Syllabi.

The course syllabus details the course content – what should be covered. Course syllabus generally includes an overview, learning outcomes, pre-& co-requisites, delivery method, resources, classroom procedures/policies, course materials, assessment and grading policies, and course calendar & schedule (workload). Construction project planning and scheduling courses are based on a well-developed syllabus that is aligned with how project planning and scheduling are practiced in the construction industry. This research evaluated the course content in planning and scheduling courses as taught in different construction-related programs, and compared them to the University of Cincinnati's (UC's) planning, scheduling, and control course. This paper reviewed 21 syllabi from different programs across the United States to gauge the project planning content. Table 2 shows what is being taught. It also shows the gaps in the content as they relate to planning aspects of the course. In addition, the table also shows how many of the programs have content that relates to 4D scheduling.

Table 2. Typical course content of project planning, scheduling and control, as collected from 21 construction programs in United States.

TYPICAL COURSE CONTENT INCLUDED IN THE COURSE FOR PROJECT PLANNING, SCHEDULING AND CONTROL OF 21 CONSTRUCTION PROGRAMS TAUGHT IN UNITED STATES	CE482/CE582 - Construction Project Planning, Scheduling and Control - University of Arizona	CE 5386 – Construction Planning and Scheduling - The University of Texas at Arlington	CE566 – Project Controls / Planning and Scheduling - University of Southern California	CNET3190 - Construction Scheduling - University of North Texas at Dallas	CMP 311 – Construction Project Scheduling - Michigan State University	BCN 4720 - Construction Planning & Control - University of Florida	CMGT 457 – Project Controls and Scheduling - California State University, Chico	CMT 244 - Construction Project Management II - Delaware Technical Community College	TMGT 455 - Project Planning and Scheduling -Texas A & M University, Commerce	CM27 - Planning, Scheduling & Control - Sacramento State University	CMT 257 - Construction Planning and Scheduling - Southwestern Illinois College	CMGT 324 - Construction Scheduling - Northern Kentucky University	CE 4387/5387 - Construction Scheduling - The University of Texas at El Paso	CMGT 275 - Construction Planning and Scheduling - Montgomery College	CVEEN 5820 (6820) - Project Scheduling - The University of Utah	CIV_ENV 336 - Project Scheduling - Northwestern University	CEM 653 - Construction Scheduling and Resource Optimization - University of Nevada, Las Vegas	BCT 550 - Construction Scheduling and Project Control - University of Massachusetts	CE 611-850 - Project Planning & Control - New Jersey Institute of Technology	ONST 420 - Construction Scheduling - Brigham Young University -Idaho	CE 134 - Project Management for Construction - San Jose State University
Refresher on Construction Industry Characteristics	NO	YES	NO	NO	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO
The Need for Planning, Scheduling and Control	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Refresher on Construction Materials and Methods	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Exercise on Planning Project	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Breaking Down and Aggregating the Items of Work Using Work Breakdown Structure (WBS)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Breaking Out the Items of Work and Defining Activity list, Cost, and Duration	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Introduction to Scheduling Techniques	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Activity Network, CPM and Activity Network Diagramming Methods	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
CPM Computation Using Zero Method and One Method	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	YES	NO	NO
Baseline Schedule and Scheduling Specifications	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO
Hands-on with Microsoft Project	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO
Hands on with Primavera P6.18	YES	YES	NO	YES	YES	NO	NO	NO	NO	NO	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES	NO
Introduction to 4D Scheduling (Simulation)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Final Project, Hands-on with 4D Scheduling (Simulation)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Schedule Control Techniques	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time-Cost Trade	YES	YES	YES	NO	YES	YES	YES	NO	NO	NO	NO	NO	YES	YES	YES	NO	YES	YES	YES	NO	NO
Final Group Project (4D Scheduling)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Implementing Planning Exercise Using Real-World Project, Based on 26 Checklist Items

The students had an opportunity to demonstrate the knowledge from the planning lectures & exercises. The students were given a scenario and a list of 26 deliverables to complete as a group exercise. Each group comprised of three (3) students tasked to accomplish the deliverables by the end of the 5th week of the semester, allowing students time to apply the planning knowledge to the scheduling and controlling aspect of the course. The description of the case study and the list of 26 deliverables are indicated below.

The Case Study – Planning Scenario Example

You recently came off a project similar in scope to the UC Lindner Hall building project, and you have just settled in to start capturing lesson learned. Just a few days after, a call came in from the chief estimator requesting a meeting immediately. The chief estimator has set up series of brainstorming and planning meetings to help develop the project schedule for the new project that the company is about to construct. The project is the UC Lindner Hall building shown below, and you have been asked to help with the planning aspect of this project. You have been asked to focus on specific portion of the project scope of work, and to compile the 26 project planning deliverables itemized. You are to compile the information in a digital binder (feel free to use Excel Spreadsheet). The chief estimator has provided all the reference documents that you will need for this assignment and will be available for further clarification or additional information if needed.

The Deliverables

The project planning deliverables required the students to prepare and submit the items listed below to demonstrate their understanding of what is required to effectively plan out a portion of the structural framing work on the UC Lindner Hall building Project. The following are the list of items:

1. Per assignment, detail the extent and limit of the construction scope of work – *refer to the scope of work listed in the previous slide, see construction specifications.*
2. Per the scope of work, prepare an org chart (construction phase) showing key positions of team members, their roles and responsibilities.
3. Per the scope of work, prepare a location breakdown structure (LBS) of workspace – chart per three or more of: substructure, superstructure, levels, areas, zones, bays, functional space such as rooms.
4. Per the scope of work, prepare a list of distinctive structural components (structural framing members only) – *based on building levels, building areas at each level, type of component, component material type, quality of material, quality of workmanship, level of complexity of work, dimension (shape, size) of component, component method of construction - refer to the construction drawings,3d pdf model, and the typical list of structural component parts provided for this assignment.*
5. Per the components listed in no. 4, for each level and area, group together similar named structural components typically constructed using the same construction techniques. Provide a general sequence (must meet physical structural support dependency) of construction by group of similar components in a descriptive or graphic format showing the order with which the grouped structural components at each level will be constructed.

6. Per the scope of work, list all applicable inspection and testing requirements – *refer to the construction specifications provided for this assignment.*
7. Per the scope of work, list all applicable permits – *refer to the list of potential permits provided for this assignment.*
8. Per the scope of work, list all applicable submittals – *refer to the construction specifications provided for this assignment.*
9. Per the scope of work, list of all applicable shop drawings required – *refer to the construction specifications provided for this assignment.*
10. Per the scope of work, list items of work by others that require coordination and hand over/sign-off – interface with other work.
11. Per the soils report, research and provide data on type of soil, water table, water content, and bearing capacity of soil (if available) – *refer to the geotechnical report provided for this assignment.*
12. Per the components listed in no.4, list what level and what group of structural components require survey, layout, and staking.
13. Per the components listed in no. 4, list typical construction materials required, and for what tasks – *refer to construction drawings, construction specifications and MasterFormat provided for this assignment.*
14. Per the six (6) specific components highlighted in the last two slides of the PowerPoint provided for this assignment, prepare a list of work tasks applicable to each of the structural components – *as a guide, refer to potential list of tasks provided.*
15. Per the tasks listed in no. 14, list crews (skilled labor only of skilled labor and construction equipment) required for each task– *refer to RSMeans crew list provided for this assignment.*
16. Per the tasks listed in no. 14, list applicable crew production rate (crew daily output) for each task – *refer to RSMeans cost data for division 3 and 5 provided for this assignment.*
17. Per the concrete pour tasks listed in no. 14, compute duration for each task as a function of quantity of work/production rate – *refer to 3D PDF file for component data, and RSMeans cost data for division 3 and 5 provided for this assignment.*
18. Per the tasks listed in no. 14, list all temporary structures' packages for the scope of work that requires structural design by a registered engineer - *must be designed by design consultants.*
19. Per the tasks listed in no. 14, list self-performed items of work that your team (working as the general contractor) will perform.
20. Per the tasks listed in no. 14, list subcontracted items of work.
21. Create a site logistics plan (per work phases) to show vehicular traffic route, road closures, detours, site security perimeter fence, material storage area, material staging area, fabrication area, construction work zone/area, public/pedestrian foot traffic path, temporary facilities placement areas, noise control path, tower crane swing zone – *refer to example logistic plan provided for this assignment.*
22. Per the tasks listed in no. 14, list all applicable offsite fabrications and/or precast required, and applicable lead time for deliveries.
23. Per the scope of work, list utility tie-ins and shutdowns applicable to the scope of work
24. Per the scope of work, list potential opportunities and project risks that need to be considered/mitigated.
25. Per the tasks listed in no. 14, list constructability issues (based on completeness of instructions presented in the contract drawings and specifications) related to division 3 and division 5 that need to be sorted out before construction starts – should include issues that may affect construction such as, environmental considerations, economic, availability of materials, site restrictions, local conditions, errors, omission, ambiguity in scope, ability to make proper system connections, system interface/conflicts (between structural, architectural, and MEP systems), ability to obtain specified tolerance, etc.
26. Based on the factors that affect productivity, you are to indicate which of the above listed 25 planning efforts could mitigate the negative impact of poor productivity.

Understanding 4D Scheduling

Research has shown that 4D scheduling can solve many of the deficiencies of current planning practices [7]. Enriching a 3D BIM model with scheduling data has increasingly improved the quality of the construction planning process through the development and integration of several use cases. For example, simulating the progress of work over time is an efficient communication tool for explaining to a client the progress of a project and the construction methods used. Indeed, 4D scheduling visualizations provide an intuitive comprehension of the construction process, enabling more effective communication and better collaboration between all project stakeholders [8,9].

The next section covers the concepts of BIM, VDC, and 4D scheduling and their significant contribution to maximizing efficiency in planning for construction projects.

What is BIM, VDC, and 4D Scheduling.

The National Building Information Standards defines BIM as a digital depiction of the physical characteristics of a construction facility. As such, BIM serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward. At the same time, Virtual design, and construction (VDC) combines state-of-the-art digital models across the building construction disciplines with traditional project planning and management techniques to build a project digitally before it is built physically. VDC allows stakeholders to view plans and designs through virtual reality software or portals during the design phase of a project. The process can lead to more efficient planning and better communication between all parties involved in a project. As with any new technology, some risks are associated with using VDC, such as data security and potentially higher costs for implementation. However, these risks are outweighed by the benefits of this innovative approach to project management. 4D scheduling is a digital construction project representation incorporating the three-dimensional physical elements and the fourth dimension of time. It allows stakeholders to visualize the construction execution process from beginning to end, considering the sequence and duration of activities and their dependencies. By associating the project schedule with the 3D model, 4D scheduling provides a comprehensive overview of the construction project's timeline and progress.

The Need to Teach 4D Scheduling to Construction Students

The primary benefit of 4D scheduling is enhancing project visualization. By combining the spatial and temporal dimensions, students can understand and visualize the construction process in a highly realistic and interactive manner. The visual representation enables better understanding and communication among project teams, clients, and other stakeholders.

How 4D Scheduling is Taught in Today's Planning and Scheduling Course – A Look at the Syllabi.

A 21-syllabus survey across different programs as shown in Table 2 indicates a diverse trend in how project planning and scheduling are taught in those programs. Most programs teach the course without including 4D scheduling. Most of the course description and content differs from how UC's construction management program teaches 4D scheduling as part of its project planning, scheduling, and control course.

For teaching the 4D scheduling at UC, a detailed lab manual is written and provided to the students to guide them in developing 4D scheduling. The high-level overview of the 4D scheduling instructions includes:

1. Obtain the 3D Revit model – a concrete framed structure.
2. Develop the corresponding CPM schedule activities, copy the required activities and columns to an Excel file, and then convert the Excel file to a CSV file.
3. Identify the 3D Revit model elements corresponding to the construction activities.
4. Add a 3D Revit model element identifier field and enter the Task ID associated with each particular element in the model.
5. Export the 3D Revit model file as nwc file and import the 3D model elements into Navisworks Manage.
6. In Navisworks Manage, create sets for each element linked with an activity (task) imported from the schedule.
7. Import the activity (task) data from the CSV file.
8. Link the tasks to the sets in the simulation platform.
9. Run the simulation and make the necessary changes to reflect the proposed work order correctly.

The implementation section below further goes in detail on the process of developing 4D scheduling.

Implementing 4D Scheduling Exercise Using Real-World Project

The steps below outline the steps for developing 4D scheduling. In general, the steps start with creating a project schedule with either MS Project or Primavera P6, and exporting the data for the activities into MS Excel, and then the file is converted to CSV file format. The 3D Revit model contains the corresponding model elements related to each of the activities in the schedule created using MS Project or Primavera P6. To use the 3D model elements for simulation purposes, the elements are tagged with the corresponding activity ID. The data for the activities from the CSV file and the corresponding data of the elements tagged in the 3D Revit model are then brought into Navisworks. In Navisworks, with the help of the TimeLiner feature, the model elements from 3D Revit model are linked to the activities from the CSV file to produce the 4D scheduling simulation.

1. Obtain the 3D Revit model-

The model used for the implementation exercise is a reinforced concrete framed structure that captured deep foundation work (piles and pile caps), slab-on grade, columns and beams supporting elevated slabs and roof system. The model also includes wall systems on one end of *the structure. It is also easy to see that the project could be organized to reflect different bays and phases as shown in Figure 3.*

2. Prepare the Project schedule-

Schedules are developed to reflect and meet construction requirements, and in this case, the CPM schedule that was developed for this exercise was designed to reflect the construction sequence of all the model elements. In order to integrate the schedule in Navisworks, the project schedule needs to be in CSV format. This is accomplished by first creating a copy of the schedule in Excel spreadsheet (XLS) format, and then converting the XLS file to CSV file. The easiest method is to copy the required columns and rows into Excel, and then save the file as .csv file. You only need to copy the columns below out of your project schedule:

ID	Task Name	Task Duration	Start Date	Finish Date

The Task Duration format should be just the number of days and should not include the "days" as part of the number. In addition, the Date format should be month/day/year (for example 3/14/2024) without the day of the week as part of the date. Add this extra column below to the above listed five columns in your spreadsheet and populate the corresponding cell for each task with "Construct."

Task Type
Construct

3. Identify, name, breakup the 3D Revit model elements-

In order to relate the schedule activities to the model elements in Revit, it is important to review the model elements and identify which one relates to which activity. In some cases, it might be necessary to break component parts in order to align and relate them to the scheduled activities.

4. Add the 3D Revit model element identifier field and enter Task ID number (adding activity attributes to each model element)-

With the activities defined and scheduled, and the model elements identified, the next step is to add a model attribute that will be used to capture and identify which model element relates to which activity.

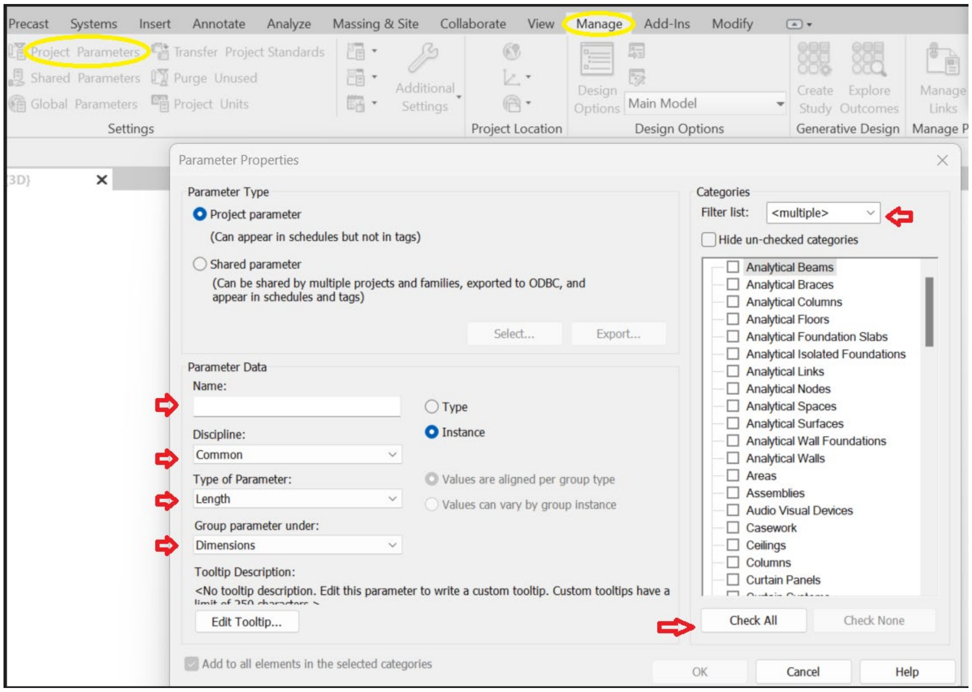


Figure 3. *The project setting in Revit for defining the project parameters.*

This is accomplished in two steps. The first step is to define the project parameter in Revit. Refer to Figure 3 above. To do this, open the Revit model, and add project parameter as follows:

a. *Click on Manage.*
b. *Click on Project Parameters under the settings group.*
c. *When the dialogue box comes up, click on Add.*
d. *Under Name, enter Task ID.*
e. *Under Categories, click on the filter List drop down arrow, and check only "Structure" and Check All at the bottom.*
f. *Under Discipline, choose Common.*
g. *Under Type of Parameter, choose Text.*
h. *Under Group Parameter, choose Construction.*
i. *Click OK at the bottom to finish creating the parameter.*

The second step is to enter the corresponding Task ID for each 3D element based on which Task ID it represents. It is important to accurately enter the data here, because it will make it easy to search and find those elements when creating sets in Navisworks. Refer to Figure 4 below.

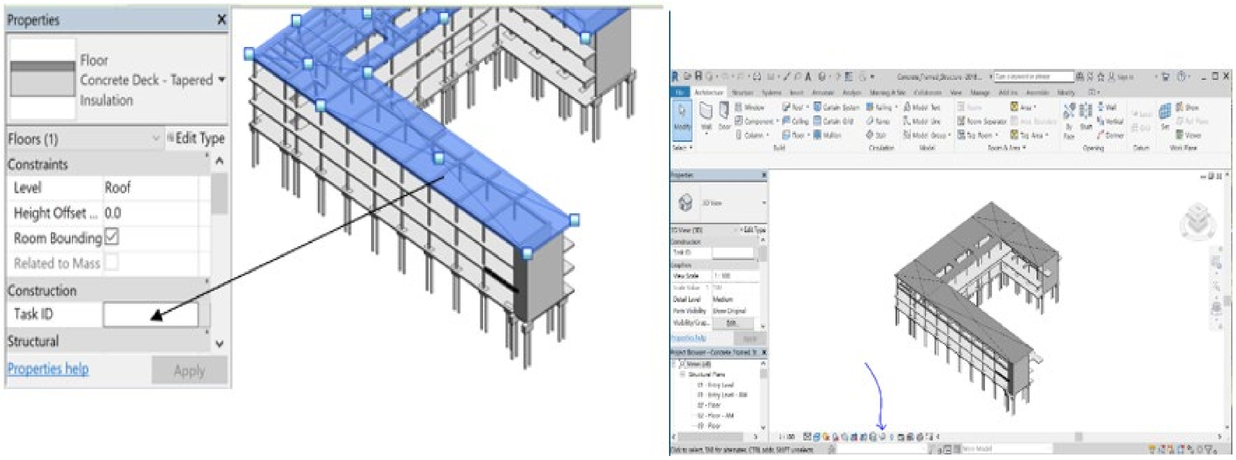
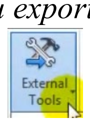


Figure 4. *In Revit, the command icon shown on the right-side with a blue arrow allows users to isolate and hide different elements and tag them.*

5. ***Export the 3D Revit model file as a .nwc file and import the 3D model into the Navisworks Manage***

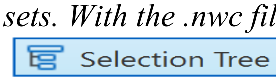
At this point that the 3D model elements in Revit have been associated with corresponding Task IDs, the model should be exported as a Navisworks (NWC) file. Make sure that the model is in 3D view before you export it, in that way all the model elements will be included in the exported file. Go to Add-ins, 

External Tools, and click on corresponding Navisworks year (latest version) installed on your computer to export to Navisworks file.

Note that if the model is not exported as Navisworks file, some of the elements and data (such as the previously entered data on Task ID) may not show up when the model is imported into Navisworks. With the model exported as a Navisworks file, the next step is to import the data into Navisworks so that the model elements can be linked with the schedule activities or tasks that have already been exported as XLS file and converted to CSV file.

To import the 3D model into Navisworks, first open Navisworks  *Manage software, and then go to the home tab and click on Append under Project to find and append the .nwc file that you exported from Revit.*

6. ***Create the sets in Navisworks Manage-***

Now that the model and accompanying data have been imported into Navisworks, the model elements need to be isolated and tagged appropriately. This is accomplished by creating sets in Navisworks Manage. In Navisworks the two items that are used for building and running simulations are the sets and tasks (activities). Using the Task ID entered while in Revit, it is easy to search and find those elements and tag them properly as sets. With the .nwc file appended and the model visible in Navisworks, click on the Selection Tree 

, to and dock it

to the side. Then click on the down arrow under the selection tree, choose ***Properties****, click on* ***Custom****, then click on "****Task ID****" properties that you created in Revit. At this point you should see all the corresponding Task IDs that you assigned in Revit.*

To open the set window and start creating the sets, click on the home tab, and click on

icon to open the set creation window. From the selection tree, select each model element ID that you want to create a set for, then click on "save selection" in the set creation window, and enter the corresponding task (activity) ID number for that model element. Repeat this for each model element ID until you have created all the corresponding sets.

7. Import the activity (task) data from the CSV file-

In Navisworks, the feature for importing schedule tasks becomes activated as soon as there is a model to work with. Navisworks defines three types of tasks that include: construct, demolish, and temporary. Navisworks runs the simulation based on the task type definition, which can be defined with the CSV file before the tasks are imported or in Navisworks after the tasks are imported. The best practice would be to add a column within the CSV file, name the column "Task Type" and fill the corresponding cells with "Construct" as the task type. This is the preferred option instead of picking them individually within Navisworks TimeLiner tool.

Also, note that in order to import the schedule tasks correctly, the columns in the CSV file and the columns in Navisworks have to be mapped so that the right data are imported to the right column in Navisworks.

So, from Navisworks TimeLiner go to Data Source tab and click on Add. Find and choose the CSV file. As soon as you choose the CSV file, the field selector dialog window will open up for you to map the Task TimeLiner Fields to the corresponding fields in your CSV file.

The first column is preset in Task TimeLiner, and the next column reflects the mapping fields in the CSV file being brought in. Make sure to map User 1 to TaskID, which is the same as ActivityID. This is the field that will be used to map the task ID in the schedule to the "Sets" task ID that was entered in Navisworks. When you have completed the mapping of the fields, click OK, and select NO to the prompt asking you to specify a column mapping for synchronization ID. Then go back to TimeLiner and click Refresh, choose All Data Sources, and say OK on Rebuild Task Hierarchy, and click OK on Problem on Imported Data. Now when you return to TimeLiner and click on Task tab, you will see all the task from the CSV file in TimeLiner.

8. Link the tasks to the sets-

The sets have been defined and the tasks have been imported into Navisworks, the next step is to link each set to corresponding task. This can be done individually, or by configuring auto-attach. The auto-attach is the preferred method but requires a few configuration steps that allow the application to properly link the sets to tasks. For example, the auto rule will only work when the task and the sets have the same ID number. Click on the Auto-Attach Using Rules icon next to Attach icon in the TimeLiner window indicated in Figure 4. This window opens up, then select the second option as shown and then click New and the next window opens up.

To use automatic attachment rule without attaching the sets to task individually. Make sure to indicate the **User1** field as the field to use for mapping.

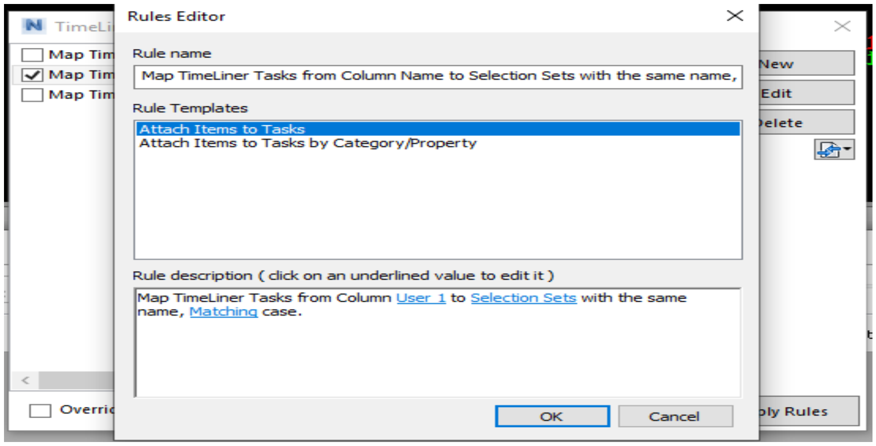


Figure 5. The Auto-attach rules setting.

9. Run the simulation-

The final step in the process is to turn the switch and run the simulation, and to show a time lapse of each element, where it fits, and when construction starts and finishes.

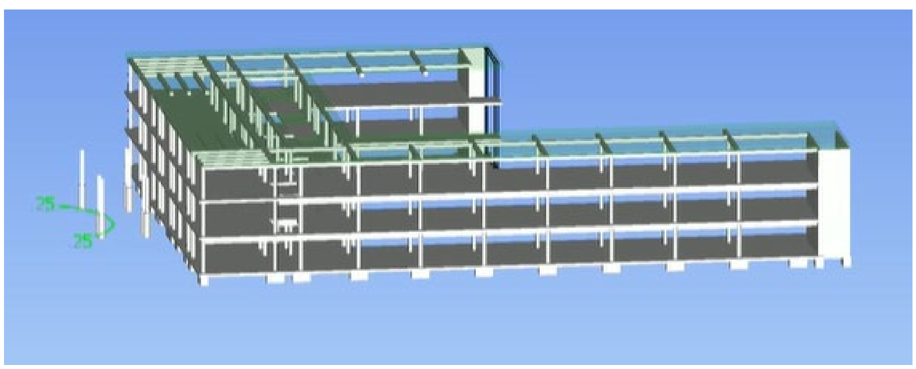


***Figure 6**. Snapshot of the simulation*

Discussion and Results

The study introduced a description and discussion of the approach in teaching project planning and 4D scheduling within the context of project planning and scheduling courses to improve construction planning and scheduling courses. The study focused on implementing project planning and 4D scheduling in solving complex construction projects.

The discussion focuses on what was accomplished or the results of incorporating the planning exercise into the course, as well as the 4D scheduling.

By incorporating the planning exercise, students understand what goes into planning a project - the strategies. They understand that there are various options and approaches that can be taken to construct a project, and part of planning is trying to figure out which one to take. In addition, the planning exercise highlights the need to fully understand the scope of work without which the plan falls apart. The plan must be grounded in an understanding of what must be constructed, where it will be constructed, when it will be constructed, and how it will be constructed. The work submitted by the teams at the end of the assignment showed that the students understand what is required in planning and the application of all 26 deliverables when it comes to effective planning. The exercise also allowed the students to see the dependency between project planning and scheduling.

The implementation of 4D scheduling is informed by today’s contract requirements and practices. The use of 4D scheduling can never be overemphasized. Teaching students how to create 4D scheduling helps prepare them for the VDC related assignments when they graduate. The result of the assignment is evident in the materials submitted by the groups. With 4D scheduling, the students were able to review the construction sequence of their project and analyze the simulation for issues that may have come from bad planning and/or scheduling.

Conclusion and Recommendation

The paper explored the implementation of 4D scheduling in today's project planning and scheduling course and further sought to improve construction planning and scheduling courses with a focus on how to implement project planning and 4D scheduling. The use of real-world case study in the project planning exercise, coupled with assignments, CPM schedule development, and 4D simulation, helped highlight the innovative use of VDC, BIM, and 4D scheduling, and enhanced the learning experience of the students. Exposing the students to aspects of project planning helps to prepare them for the real-world. In addition, exposing the students to 4D scheduling aligns closely with current VDC practices.

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