Express 4d Simulation Scheduling and Construction Management with Dynamo

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Learning Objectives

- Learn how to create in minutes a 4D simulation from model information and construction workflows
- Solve time scheduling for a model-related structure, and get a Microsoft Project output.
- Learn how to integrate Dynamo player routines as a model quality checkup process for construction management.
- Learn how to use time information on Revit software’s model to create comparatives and different types of analysis.

Description

4D time simulation in Navisworks software for construction projects are often complicated BIM (Building Information Modeling) services to be used on a daily basis. Reasons can include problems in model coordination, time and element mismatches, time model execution availability, and more. With this approach, we will use the Dynamo player and Dynamo workflows over Revit 2021 software to clean, manage, label, and even create a time schedule so 4D simulation can be easily created and the communication proposal facilitates model coordination and execution. We will cover several routine workflows so that all elements for any type of intelligent model are aligned clean and useful for project management, enabling us to link the model and time schedules with Navisworks in record time. This instructional demo is the synthesis of 13 years of simulations from different projects to make 4D simulation a required task for all projects.

Speaker(s)

Enrique Galicia is a BIM Specialist which works as a Consultant to several International Firms, He provides real construction solutions to common problems while implementing and using BIM, using Autodesk Revit, Autodesk Navisworks, Autocad Civil 3d and Dynamo. He has 13 years of experience with workflows of BIM, interoperability and developments.

Worked over more than 110 projects with BIM, and worked deeply on research to enhance future workflows for BIM uses. Awarded Excelence Professor of Architecture on 2019 by the Tecnologico de Monterrey giving BIM Courses and Seminars, Has developed 81 online courses on Udemy’s Platform to spread the word using BIM true potential with more than 15000 students over 154 Countries, and its always happy to help.
Introduction to 4d Simulation

4d Simulation it’s the process of linking time schedule with construction elements, so that it can easily give us an idea of how construction would be performed, tracked and reported.

Samples of 4d Simulations.

To create a 4D Simulation, Construction Tasks and Elements in the Model need to be connected and that’s the main problem when doing it so, time schedule needs to have Revit Elements and the Model requires to have elements for all time schedule tasks.

My First 4d Simulation Project was a hospital with more than 300 hundred tasks and it became really complicated to link all elements, mostly because mismatch between them and the required time execution.

After several 4d Simulation projects, a lot of practice and improvements on efficiency methods, and the use of Dynamo on the workflow its much more easy to create 4d simulation that hold the characteristics required and can be created faster than ever before.

So lets review the Basics.

Revit Introduction

Revit it’s a BIM Modeling Software that allow us to create construction elements with parameters, so that elements can have properties such as measurements, categories, level, materials, and coding capabilities such as assembly code and keynote code.

By its elements models can follow construction processes and can to linked to tasks.

Best approach its to create selections and save those values as tasks themselves, using a Shared Parameter.

A Shared Parameter it’s a custom created parameter that can be assigned to any Revit element so that information on it can be retrieved later on.
Navisworks Introduction

Navisworks it’s a BIM Platform Software that allow us to coordinate multiple models with multiple data values and create interactions with them. It uses a selector by properties to create search sets and selection sets. Search Sets are property driven selections that in this case can select elements by category, by parameter property value, level. On the other hand Selection Sets are user defined selections for objects to be picked up.

Basic Simulation WorkFlow

The main problem its that elements are separated by multiple circumstances so that their requirements are specific and so on the planning.

Step 1 - First Simulation Workflow

We need to Export properly our Model from Revit to Navisworks. For this we need to have installed the Navisworks Exporter we can get from https://www.autodesk.co.uk/products/navisworks/autodesk-navisworks-nwc-export-utility

It oftenly installs the exporter once you install Navisworks but there are cases and depending on the version that you might need an spetial one.
Open the Exporter

Important options to be selected are
- Convert Element Ids
- Convert Construction Parts
- Convert Element Properties
- Convert Linked Files.

Elements Ids would be useful if we want to find elements by the unique identifier.
Construction Parts can help us to get much more detail on the elements.
Element Properties are required since we want to know about elements for selection.
Linked Files just in case we want all files coordinated to be in a single file.
Create Selections of Elements.
Once Exported we can open it on Navisworks by Append we can use the selection tree and the selection sets to create selections.

We can select elements from the selection tree and create selection sets or we can select from the model and create selection sets.

And so on until the model is completely selected.
Create Tasks of Elements.
Once we have all tasks

We can work with the TimeLiner

And we can right Click on the Task from the Time liner to create task from every set.

So that would Create Tasks already linked wit a single time.
Manage Those Tasks
We can modify time from those elements to fit our requirement.

Create Simulation.
Jumping to the Simulate Tab we can directly use play to review the element creation.

So the previous workflow get into a simulation but it would require a lot of selections, tasks and other things difficult to manage on Navisworks, so let go deeper with the Revit Management.
Simulation with Revit Management

Getting better in simulation values we need to set properties on a shared parameter we will call SIMULATION.

So we will start by adding a parameter and Making it Shared.

https://youtu.be/CAfxvtyf4gQ
On a new Tab Group Called Simulation and Called it SIMULATION set as Text.

And we will add them to elements in the model.
On this Sample we are using just Floors, Structural Columns, Structural Framings and Structural Foundations.
And then the difficult part is to set their values. So that all elements are using at least the Category and the Level they Belong. Once the Model its ready next step its to create a time schedule of all tasks. We can use the Same Method of creation used before just by using the selection tree properties to create the search sets and then create the timeliner. 
https://youtu.be/jrJUiVzytjI
And then Create the Tasks on the TimeLiner Same as Before

And Manage the Tasks so that the time properly corresponds with the expected result of creation.
Create a 4d Simulation in Minutes.

Dynamo as a game Changer.

Dynamo it’s a Playground application that runs over Revit, and on recent versions over Civil 3d, Advanced Steel and Autocad. It allows you to easily create by connections simple routines that can be tested and used to enhance several elements.

- Improve Complex Modeling
- Automate Repetitive Tasks
- Set Model Management
- Transform Model Information
- Create interoperability between different files.

So it enables workflows that can be nurtured by the requirements and the company standards. And in our case it would transform completely the 4d simulation possibilities.

Dynamo may become overwhelming in some circumstances for new audiences, so just relax and start pulling strings and connectors so confidence can be built.

Dynamo requires a lot of resilience, but the benefits are incredible.

Have realized that there’s three types of audiences.
   - Raw Users – That would pull all nodes from scratch and link with normal coding
   - Medium Users - That would use workflow scripts and custom nodes to complete their requirements
   - Low Users – That would just use the Dynamo Player, as their working tool.

We will set the workflows for Medium and Low Users, but all scripts would be shared.

Dynamo SetUp

For Dynamo to work we need to set up some libraries. So we need to click on packages on the dynamo window.
Open Search for a Packages and Add Data Shapes PracticalBIM Rhythm

Once we have it we can create a New Script.

Using Dynamo for Writing the SIMULATION Parameter

There's going to be a left side of nodes and a right side with a 3d Screen. On the top right there are two icons to change from geometry to nodes just ensure you are using the nodes selected.
Creating the Script
For the Script creation we need to understand the logic of Dynamo that its pulling the elements from one side to another 1 input multiple outputs.
So its pulling information from Revit to processes it and to write it back.
First two nodes are Selecting all elements of category of the category we are requiring.

Categories is selecting a Category and All Elements of Category its getting all elements.
Elements in Dynamo have multiple characteristics and each element its linked with an object in revit.
Then we need to extract all elements on the Model

And Join them with a List Create, the List Create would set all values on a single list and by that we have control of all elements selected.
Next we need to have the level properties value and it will depend on the element we are selecting. Structural Foundations and Floors use Level property but Structural Framings and Structural Columns use Reference Level and Base Level.

The Get Parameter Value by Name is actually extracting information from the elements. The Information Extracted in this case it's a Level element hence it need to be extracted the property of Name.
With that transaction we get a text (String) value that can be easily used to write our label. So we need to compress it to change Level 1 to L1. We are going to use the node GetCompressedStringF_N that changes names like that the only requirement is to have a space before the number to be used.

For the Category Names we can create a list with the same order as the categories selected.

Do the same list create with the level values and use a code block called a"_"+b to add the Category Text to the Level Name to a single String.
And finally that result we will use it on the Model Elements with the node `Element.SetParameterByName`.
So it may seem little complicated if you are new to Dynamo but at this point we already have one labeling script that can pull information to the exact spot that it's required and we can used it with the player for any type of file as long as it is using the SIMULATION parameter.

Call the Script 01_Simulation Parameter.  
https://youtu.be/9gjykckxZMs

Creating a Time Schedule from Model Information
Next process it's to create as easy as possible a time schedule with all simulation activities. So we need to start by pulling all categories on proper order so that they can get proper timing.

And from there get the new SIMULATION parameters values so that we can find how many tasks are there, using a Get ParameterValueByName a Unique Items and a Sort so they are sorted by their values.
Ant then by counting the number of elements will give them each field a duration value in days such as 2 for foundation tasks, 2 for framing tasks, 3 for Columns Tasks, and 2 For Floors. And mix them with the TimeDurationProgression node that would give us time separation for each particular task adding to the end a progression of days for each group to start.

With those numbers now it's easy to work with time creating a starting date by numbers, and using the values of the progression as time spans that can be added to the start date, and with the duration of those tasks.
Because we want to read properties directly to Navisworks we will export the time to Navisworks Time with the node FlattentoNavisworkstime
And arrange data so we can have a list of simulation parameters, a task type of Construct, and Start date and end data formatted for Navisworks import, finally once its already created we can export the file to csv

Called the Script 02_Simulation Time Schedule.dyn
https://youtu.be/wPPqU66jBNU

Exporting the File to Navisworks with the csv file now can be linked so that the simulation can be created quite easily, just need to append the nwc file to Navisworks and on the Timeliner use the option of Data Sources and Add the csv produced file

With this configuration so that values can be pulled to create a time schedule.
And without selecting the Row 1 contains headings, once selected then we need to select the Rebuilt task hierarchy from Link.

And the Time schedule its been created just need to map the property of Element SIMULATION with the Name of the Task by selecting .
Autoattached assigning Rules with the Property.

With that we can now test the simulation and it would run as config, probably not perfect on time planning but still pretty fast and usefull.

https://youtu.be/uPdK0qP-vJs
Creating a CSV Structure for Ms Project

So simulation works well but still we can improve if data can be used for MS Project workflow so dependencies can work with the data displayed. We can start that script by using the previous one. We are going to read the csv file to separate and format information properly.

Once Extracted we need to detail the task name so need to separate the categories from the levels so we can use the string split function and then group the values on different lists so the category name can be inserted as a first task to be used.

With those values a List.groupbykey node would simplify the management by separating information in groups, that can be labeled later on as the name we will like to see on MS Project.
Using the same grouping convention the other values would be separated and added to the same list so values are complete. The only different ones to be display are the Dates cause we need to use the ParseCSVDateToDateTime so the string can become a date, and with proper DateTime.Format now values are on the configuration required by MS Project.

Need to change the end date for duration using a TimeSpan.Differsence and timespan.totalDays, and once everything its configure its time to create a new csv for MSProject Import.
With the new file we can open Microsoft project and finish configuring it.

And follow the wizard to create the MS Project.

Final Result can be a really close type of simulation file that need to be indented, and grouped so it can follow all settings.
Change all tasks to be auto-scheduled, as soon as possible as method and create task that would cover every category and start linking tasks so that time progression can be reviewed.

<table>
<thead>
<tr>
<th>Task Mode</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start Date</th>
<th>Finish Date</th>
<th>Predecessor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foundations</td>
<td>2 days</td>
<td>Tue 20/10/20</td>
<td>Wed 21/10/20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>3 days</td>
<td>Tue 20/10/20</td>
<td>Fri 23/10/20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>2 days</td>
<td>Thu 22/10/20</td>
<td>Fri 23/10/20</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>2 days</td>
<td>Wed 28/10/20</td>
<td>Thu 29/10/20</td>
<td>4,18</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>2 days</td>
<td>Tue 03/11/20</td>
<td>Wed 04/11/20</td>
<td>5,19</td>
</tr>
<tr>
<td></td>
<td>L5</td>
<td>2 days</td>
<td>Mon 09/11/20</td>
<td>Tue 10/11/20</td>
<td>6,20</td>
</tr>
<tr>
<td></td>
<td>L6</td>
<td>2 days</td>
<td>Fri 13/11/20</td>
<td>Mon 16/11/20</td>
<td>7,21</td>
</tr>
<tr>
<td></td>
<td>L7</td>
<td>2 days</td>
<td>Thu 15/11/20</td>
<td>Fri 16/11/20</td>
<td>8,22</td>
</tr>
<tr>
<td></td>
<td>Floors</td>
<td>23 days</td>
<td>Mon 26/10/20</td>
<td>Wed 27/10/20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>3 days</td>
<td>Mon 26/10/20</td>
<td>Wed 28/10/20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>3 days</td>
<td>Fri 30/10/20</td>
<td>Tue 03/11/20</td>
<td>11,5</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>3 days</td>
<td>Thu 03/11/20</td>
<td>Mon 04/11/20</td>
<td>12,6</td>
</tr>
<tr>
<td></td>
<td>L4</td>
<td>3 days</td>
<td>Wed 11/11/20</td>
<td>Fri 13/11/20</td>
<td>13,7</td>
</tr>
<tr>
<td></td>
<td>L5</td>
<td>3 days</td>
<td>Tue 17/11/20</td>
<td>Thu 19/11/20</td>
<td>14,8</td>
</tr>
<tr>
<td></td>
<td>L6</td>
<td>3 days</td>
<td>Mon 23/11/20</td>
<td>Wed 25/11/20</td>
<td>15,9</td>
</tr>
<tr>
<td></td>
<td>Columns</td>
<td>18 days</td>
<td>Mon 26/10/20</td>
<td>Wed 18/11/20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L1</td>
<td>2 days</td>
<td>Mon 26/10/20</td>
<td>Tue 27/10/20</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>L2</td>
<td>2 days</td>
<td>Fri 30/10/20</td>
<td>Mon 02/11/20</td>
<td>16,5</td>
</tr>
<tr>
<td></td>
<td>L3</td>
<td>2 days</td>
<td>Thu 03/11/20</td>
<td>Fri 05/11/20</td>
<td>19,6</td>
</tr>
</tbody>
</table>

With the final result, now we can import it to Navisworks and link. Important notation is that Text Nine needs to be linked with the Element Parameter Simulation and Text 10 would be used as task type. Called the Script 03_Time Schedule to Project.dyn

https://youtu.be/dt7AF1msvN8
https://youtu.be/0Aet2lbVJwM
https://youtu.be/1w59O4I5mWM
Integrate Dynamo Player Routines for Construction Management.

Now for improving performance and quality there are several routines and samples that can be achieved with dynamo player and dynamo. Some samples are as follows.

**Coloring by Parameter or Value**
Function starts by opening the categories tab as an input so that user can change the values on dynamo player then with the elements user can call the parameter he wants and create a group by key sorting list that would modify active view by setting override colors.

Really Simple but powerful because once running with dynamo player.
And result can be deploy by play button.

So very easily you can use colors to understand if elements are on proper place. Called the Script 04. Coloring by Parameter or value.dyn
https://youtu.be/fN4WGogSWRE
Splitting Floors and other elements

Considering the geometrical capabilities of dynamo we sill need to be able to splits elements with the dynamo player so for doing it so we need to make elements intersect, recreate the resultant geometry and finally get rid of the previous one. For than the easiest way is to use the Transactions, Transaction Start and end would enable the script to create elements and once finish discard the unusefull ones. So the Script need to follow this structure.

Two elements selected the floor and the line so that they can intersect, they are inside of the list create and then go on the transaction, in which the lines are separated to create an outline curve a surface and then the split of that surface so that new outlines can appear.

And using that same structure there are the FloorbyNewGeometry Function that would create the new floors. With the new floors need to create a new list.create so they can go out of transaction and the original element can be then eliminated.
Renaming Levels

Multiple functions can be used so another sample would be the Levels Element Types Rename by Elevation order. This case uses the Element Types all Elements of Type to then read from the level Values the Elevation, being sure that values are sorted creates a new counter from 1 to the total count that can write with an open string input.

Simple but powerful to change names on Levels.

Called the Script Renaming Levels.dyn
https://youtu.be/aKsLWRveWik

Use time Information on Revit for Comparatives and Analysis.

Inserting Time Information into the Model

So now let's get back to Time Management with the simulation. We have the Simulation Parameter but we want also to have the time on Revit elements, so we need to imported, so first need to call all element that should be written.
And the file that its going to be used to link values, with the information of the SIMULATION parameter by one side we can link the tasks on the time schedule with the elements, with that relation established.
We need to Parse Dates with the ParsingDated\_mm\_yyyytoDateandString and that would pull dates as String Inputs. So because they are numbers we need to create two parameters “TI\_START” and “TI\_END” so that elements can have the information of their timings.

Called the Script 07\_Inserting Time values.dyn
https://youtu.be/Ttkqy4TdHfo

Creating the Comparison and Analysis views of a Specific Time Period. Last Script of these class its about of reading the properties and selecting a period of time to be selected and copied on a view so can it be completely visible to which elements it corresponds.

So we will start by the Selection of elements to be manage and a view by the node AllElementsInView.
Wnd with those we need to set two string inputs with the minimum and maximum values so that elements in between can be checked.

If values are in between those numbers they would be selected and therefore the copy of the view would have the time lapse and the selected elements.
So with that its possible to create multiple views with just selected elements.
Called the Script 08_Time Analysis.dyn

https://youtu.be/woO2zAm0ow

Hope this class help you a lot with simulation, management and Dynamo, if interested in more content follow my youtube channel and keep in touch through linked in would be more than happy to help.