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Office of the Design & Construction

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This version of the "GSA Building Information Modeling Guide Series 04 - 4D Phasing" is identified as Version 1.0 to indicate its provisional status. As its provisional status denotes, however, it will continue to serve as the basis for further development, pilot validation, and professional editing. All readers of this provisional guide are encouraged to submit feedback to the National 3D-4D-BIM Program. Updated versions will continue to be issued to address and incorporate on-going feedback in an open, collaborative process.

Currently, the following Series

- GSA Building Information Modeling Guide Series 01 - Overview, version 0.60
- GSA Building Information Modeling Guide Series 02 - Spatial Program Validation, version 0.96
- GSA Building Information Modeling Guide Series 03 - 3D Laser Scanning, version 1.0
- GSA Building Information Modeling Guide Series 05 - Energy Performance, version 1.0

are available for download, review, and comment.

For further information about GSA's National 3D-4D-BIM Program or to submit comments or questions, please visit <http://www.gsa.gov/bim>

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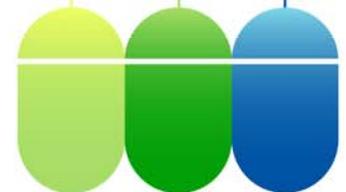


GSA

BIM Guide For 4D Phasing

GSA BIM Guide Series 04

www.gsa.gov/bim





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executive summary: 4D phasing

In 2003, U.S. General Services Administration (GSA) Public Buildings Service (PBS) Former Office of Design and Construction (ODC) established the National 3D-4D-BIM Program (<http://www.gsa.gov/bim>). As part of this program, ODC has evaluated an array of 3D-4D-BIM applications on a number of capital projects. The National 3D-4D-BIM program's work in 4D phasing has been used to understand spatial and temporal relationships of the construction phase. 4D models visually communicate aspects of a phasing or construction schedule through the use of 3D (isometric or BIM) models and schedules.

About 4D Modeling

4D modeling combines a 3D model with time (via a schedule). The models combine building elements with construction activities to display the progression of construction over time; 3D objects are linked to specific activities, which can appear or disappear at specified times according to the schedule. Permanent building elements that are to be constructed appear during the time of construction, and remain throughout the rest of the schedule. Temporary spaces/objects such as swing space or construction supports appear only for a specified duration, and then disappear.

Objective of 4D models

"While it's possible to create an image of a building in your mind, to see it take shape on screen, in sequence, creates much more effective shared understanding with the entire delivery team (Seliga 2007)." CPM scheduling has been the accepted method of choice for construction project scheduling since 1950s but CPM has downfalls stemming out of inability in coping with non-precedence constraints, difficulty in evaluating and communicating activity interdependencies, and inadequacy in work-face planning situations (Sriprasert and Dawood 2002; Wang 2007). Traditionally, phasing plans have been communicated through 2D snapshots showing each phase. This requires reviewers to visualize, in their minds, what activities will be occurring at a particular time and space on the project. Many stakeholders may not have the ability to see the entire big picture based solely on the Gantt chart. The Gantt chart (used to show the CPM schedule) only provides the sequence of events, not physical objects, which can be more difficult to validate and evaluate (Retik 1993). The overall purpose for 4D models is to visually communicate the construction plan, scope of work, affected areas by the project and/or tenant's movements in renovation projects to the stakeholders. 4D models provide a way to visually show an animated process to describe the phasing and construction plan. ODC anticipates this will allow of clearer communication and feedback between the GSA project teams and customers.

Benefits and Limitations of 4D Modeling

The private sector has seen many benefits of 4D modeling in all different phases of the project schedule. Projects on very tight construction schedules have incorporated 4D modeling to proactively coordinate subcontractors and manage the schedule and cost better. 4D modeling has been implemented by owners, designers, engineers and contractors alike.

The benefits of 4D modeling include increased coordination and visualization of the schedule. Stakeholders can work with the 4D model in renovation projects to see how tenants will be moved, what construction that is occurring around them, and to evaluate different alternatives. In new projects 4D models can be used to show the construction processes sequence and verify the space availability in addition to the logic and soundness of construction schedule. At present, 4D models are able to reflect the schedule, identify physical conflicts, improve the design team synchronization and help the constructors manage the flow of data and work better. In addition these models can help the developers to identify potentially unsafe activities due to time or location. However, 4D models are neither intelligent nor automated. These models cannot modify or optimize the schedule automatically. 4D models require intimate interaction with the project team to fully realize its benefits. Developing the models can be very time consuming and errors cannot be identified by the software.

Major points regarding modeling for 4D Phasing

- BIM modelers are responsible for managing and updating the 3D model, schedule, and 4D model. These may all originate from the 4D modeler, or from different sources. This task requires a **constant and clear communication** between the modelers and the owner, designers, engineers, and contractors responsible for the project.
- 3D models should have a layering scheme based on area and/or construction sequence and time which supports 4D models. This layering scheme may differ from the default layer scheme found in many 3D modeling applications which is typically based on building elements and location. This could also be achieved via a unique identifier, group or property definition that is used with rules because of the required level of detail in the model and the schedule.
- The construction scheduler or the modeler should ensure that all activities and activity types are represented in the schedule. Often, this may mean adding “non-constructional activities” for use by the 4D model. The schedule needs to include an exclusive activity for every physical object or space that is created or every movement that takes place during the construction phase. The vice-versa can be true where some activities such as commissioning or review meetings are not related directly to any 3D objects and these tasks do not need to be linked. As often the schedule is modified, it is important to constantly update the schedule in the model.
- If the 3D model and construction schedule are coordinated correctly, the process of creating the 4D model is simplified. It is recommended to optimize the schedule using a line-of-balance optimization process, before linking it to 3D model.

introduction

GSA's mission is to "help federal agencies better serve the public by offering, at best value, superior workplaces, expert solutions, acquisition services and management policies." Within GSA, PBS manages over 352 million square feet of workspace for the civilian federal government. GSA PBS Office of the Design & Construction (ODC) provides leadership and policy direction to all 11 GSA regions in the areas of architecture, engineering, urban development, construction services, and project management.

This "BIM Guide Series 04: 4D Phasing" guide has been developed to assist GSA associates and technical consultants on developing 4D phasing models for GSA capital projects. This Series will describe how aspects of project phasing, from the feasibility study through construction, can be incorporated into a 4D model. This Series will also describe how 4D models fit into GSA's capital program delivery process. The objective of this series is not to cover the details of different projects and how BIM tools can be applied to each project specifically but to provide a generic guideline for 3D-4D-BIM implementation in construction projects. Examples used in the project are for illustration purposes and may not directly apply to every type of construction project.

4D models typically refer to any presentations of a project that includes the timeline and shows the progress through graphics with respect to the timeline. Figure 1 shows an example of development of a 4D model from Laser Scanned images to a tenant phasing model.

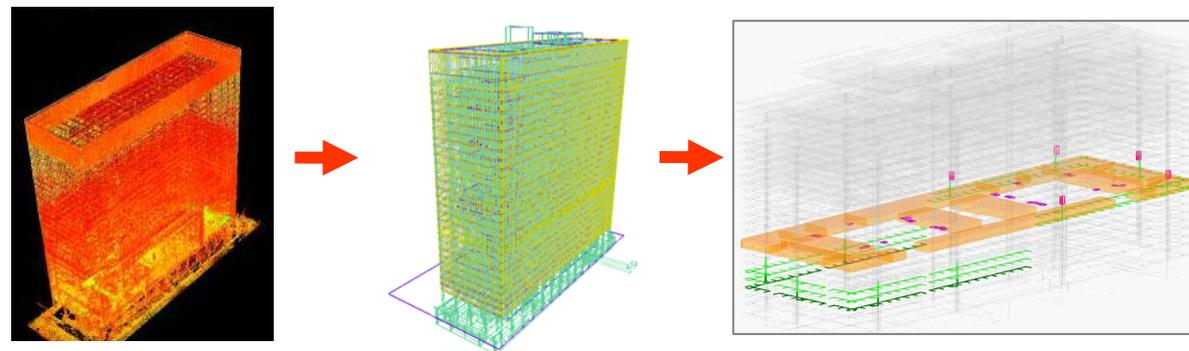


Figure 1 Dirksen Courthouse - 4D model generated from laser scanned 3D model

This BIM Guide Series 04 is also part of a collection of GSA BIM Guides from the National 3D-4D-BIM Program. The BIM Guide Series 01 - Overview provides an overview of the National 3D-4D-BIM Program, and is intended for both GSA associates and the wider AEC community. Topic specific guides provide best practices and guidance on a wide array of activities within the National 3D-4D-BIM Program. The following topic-specific guides are available:



- BIM Guide Series 02 - Spatial Program Validation
- BIM Guide Series 03 - 3D Laser Scanning
- BIM Guide Series 04 - 4D Phasing
- BIM Guide Series 05 - Energy Performance and Operations
- BIM Guide Series 06 - Circulation and Security Validation

Please visit <http://www.gsa.gov/bim> for the latest BIM Guides.

DISCLAIMER:

This Series is considered a living document that is constantly changing and being updated as the technology matures. While GSA has tried to highlight the major points of spatial program validation, GSA cannot take into account all the special cases and changing technology. Therefore, if you have any questions or comments regarding the content of this Series, please contact OCA for the most up-to-date information.

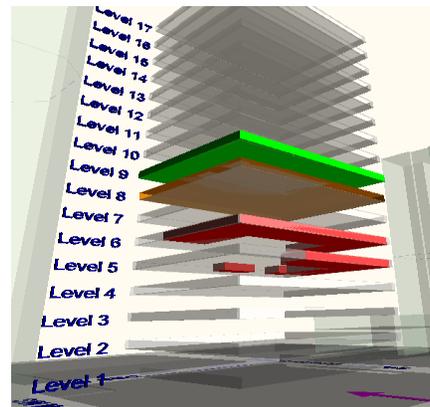
About this Guide

This Series is divided into three sections.

- **4D Phasing - The Basics:** This section of the Series is to assist GSA associates in determining whether or not to use 4D models on their projects. This section describes the situations in which 4D models may assist the project team, and what factors to consider before contracting 4D modeling services. This section describes the “Process for adopting 3D, 4D, and BIM technologies” diagram (from Series 01 - Overview) with respect to 4D phasing in particular.
- **Defining 4D Phasing Scope:** This portion of the Series is to assist GSA associates in analyzing the feasibility of implementing 4D phasing on their projects. This section describes the “Feasibility of Implementation” diagram (from Series 01 - Overview) in detail with respect to 4D phasing.
- **Technical Guidance for 4D phasing:** This portion of the Series is to assist 4D modelers and consultants on best practices in creating and maintaining 4D models.

Status of OCA-initiated 4D modeling activities

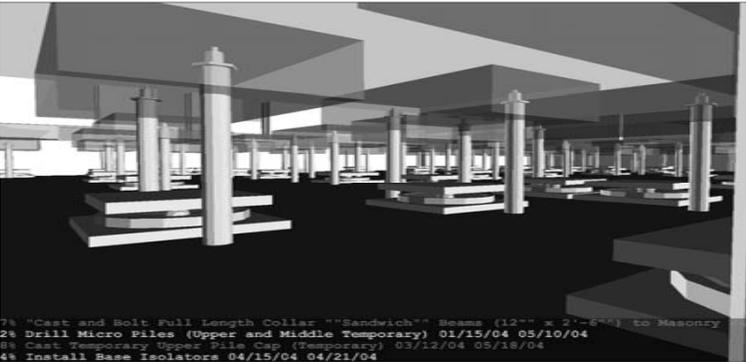
OCA has currently initiated eight projects across the nation. These projects have been in different phases, from early feasibility through construction documentation. The following table highlights these projects:



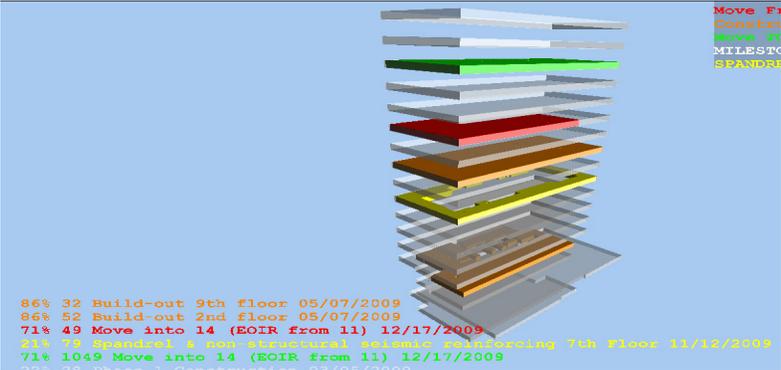
Edith Green/Wendell Wyatt Federal Building - This federal building modernization required a detailed phasing plan to understand how tenant would move throughout the top-down construction process. A 4D model was constructed and snapshots of the model were taken and presented to the tenants to show their specific tenant movement.



300 NLA - The 4D model of this federal building modernization helped to reduce the construction schedule by 19%. In addition it enabled the owner to keep the building operational and saved moving costs and extra rent on swing space. Created in the design development phase, this 4D model was also used and updated during construction. The use of 4D model enabled the project team to transfer information much faster and more efficiently and gave all the stakeholders a better understanding of the process. The model was essential for building trust between the design team and contractors as well as tenants.

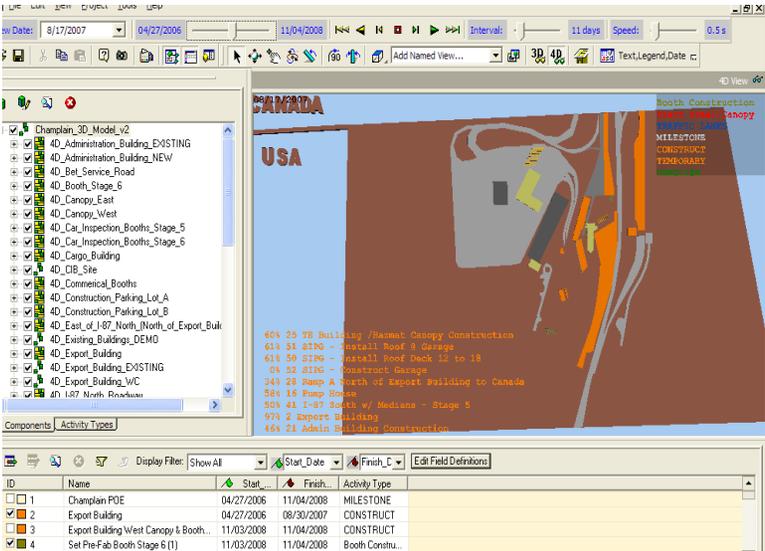


Pioneer Courthouse - The 4D model of the seismic upgrade of the Pioneer Courthouse allowed GSA to better communicate the scope of the project with the public, tenants, and GC bidders. The model was shown during a pre-bid meeting to allow bidders to better understand the project context. The extra information helped the contractors to lower their leverage and the bid spread was much narrower than bid spread for similar projects without 4D model.



Rodino Federal Building - The 4D model helped the project team to visualize the construction schedule and to determine impacts of changes/additions in scope on the construction schedule. The schedule was used to provide feedback on swing space usage and conflicts in tenant phasing and construction.

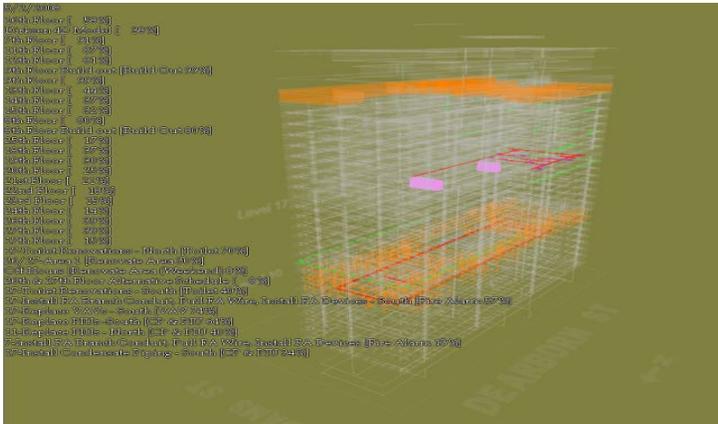




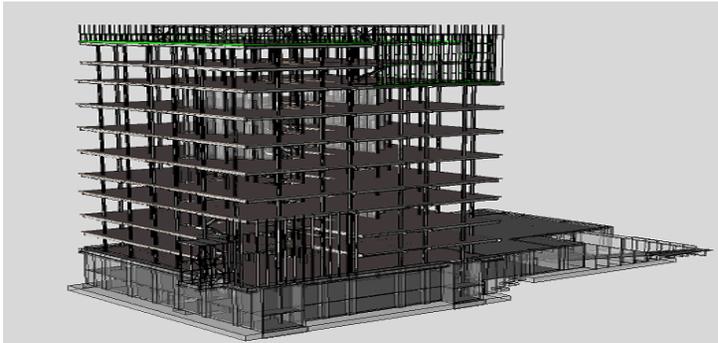
Champlain Port of Entry - The 4D model was used to better understand the coordination between installing new passenger inspection booths and demolishing existing booths. Since a minimum of seven booths must be open throughout the construction process, 4D was used to visualize the baseline schedule, as well as various alternatives.



Madawaska port of Entry - The 4D model was used to better understand the coordination between installing new passenger inspection booths and demolishing existing booths. In addition the model was used to demonstrate the process to the local residents and officials and reassure them that the project would not interfere with their local business. Also a minimum number of booths must be open throughout the construction process and 4D was used to visualize the baseline schedule, as well as various alternatives and test the “what if” scenarios



Dirksen - To visualize the construction schedule and to study the impacts of the construction activities on the 30 story tall building, a 4D model was developed. The 4D model is also intended to be used to study the swing space usage and conflicts in tenant phasing and construction.



Salt Lake City Courthouse - The 4D model was used to understand and improve the construction schedule. The completed construction schedule was used for the model and the construction sequence was captured. The interesting part of this process was the fact that the project team built the model only a week after their first software training. As part of GSA's effort in BIM implementation, general and specific trainings are provided for regions and project teams.

Jan 2009		Jan 2010		Jan 2011		Jan 2									
Jul	Oct	Apr	Jul	Oct	Apr	Jul	Oct	Jan 2							
3	26	40	53	66	79	92	10	11	13	14	15	17	18	19	20
3	26	40	53	66	79	92	10	11	13	14	15	17	18	19	20

We have also provided project-specific contract language regarding 4D modeling services for several on-going projects.



section 01:

4d phasing - the basics

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section 1: 4d phasing - the basics

This section is intended for GSA associates to evaluate the potential use of 4D modeling on their projects. It describes what types of business needs and goals are supported by 4D models, how these models can be used throughout the project lifecycle, and what main factors should be considered.

1.1 What is 4D Modeling?

4D modeling is the integration of a 3D (or BIM) model with a construction schedule in order to visualize the sequence of construction (Figure 2). 4D models can be created to various levels of detail, from high-level zone analysis during the design phase, to detailed sub-contractor coordination during construction. The same model can be updated and maintained throughout the project based on the updated schedule and 3D model.

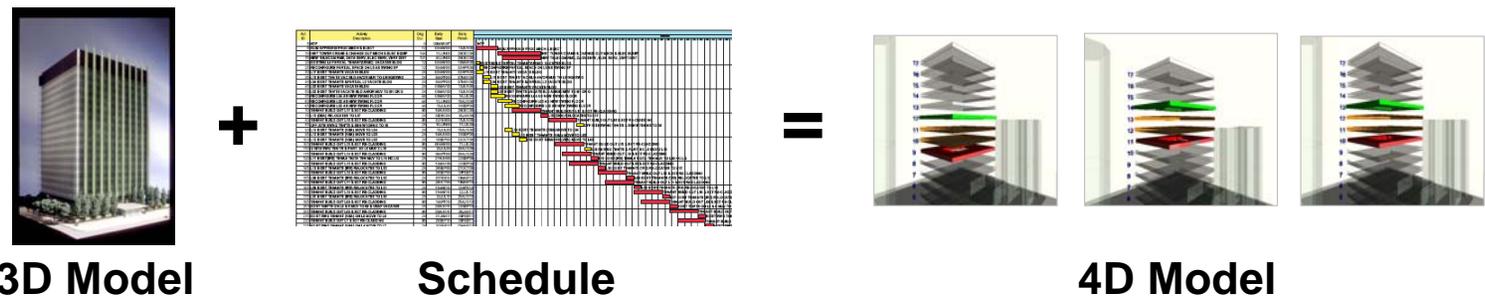


Figure 2 4D models link 3D components with activities in the phasing schedule



4D elements are created by linking 3D components to an activity in the schedule. For example, Figure 3 depicts the high-level construction of a port of entry site.

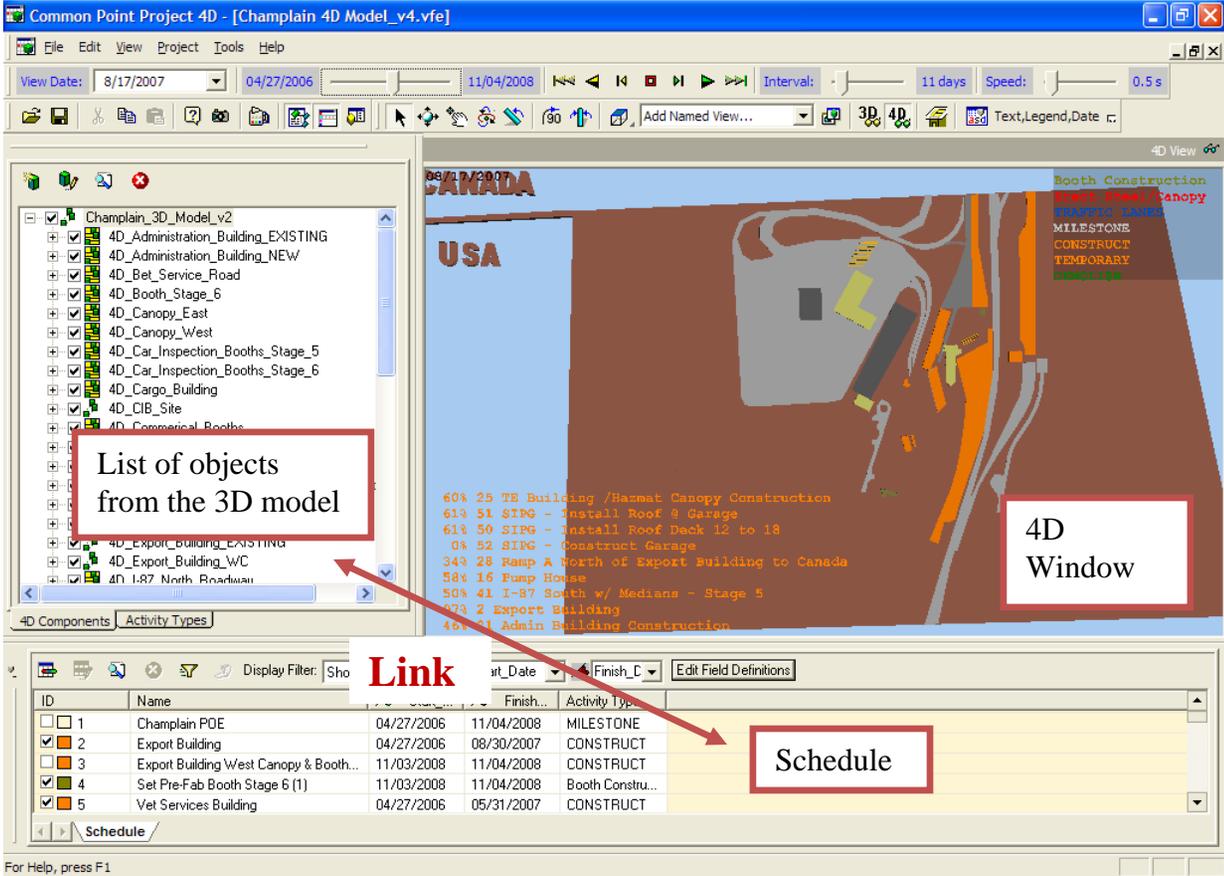


Figure 3 Snapshot of a 4D software interface showing how schedule is connected to objects

1.2 Thinking the “4D Way”

4D modeling enables project planners to visualize related activities of the construction process (e.g. changing locations of traffic lanes, locations of swing space). These other aspects, however, require specific start and end dates, similar to regular construction activities. All construction and related activities must have specific start and end dates linked to specific 3D components in order to be visualized in the 4D model. Often times, these start and end dates are within the planner’s thinking, but not explicitly stated. This explicit statement of attaching *specific start and end dates to specific locations and components* is “thinking the 4D way”.

1.3 Using 4D modeling on GSA Projects: Process Overview

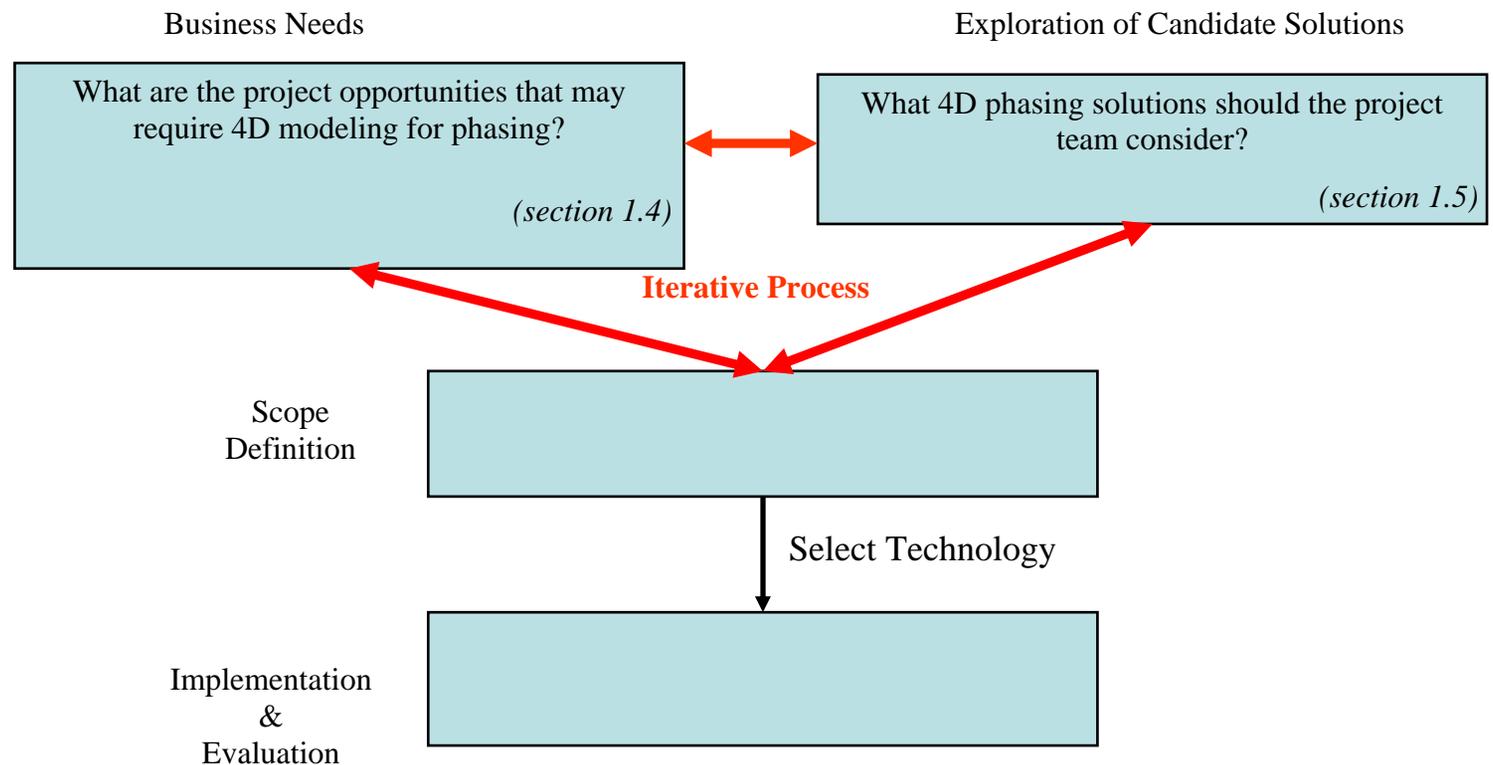


Figure 4 Process for adopting 4D phasing

1.4 Understanding Business Needs: Project Opportunities for 4D Phasing

4D modeling can be utilized both in new construction projects as well as renovation projects. In renovation and modernization projects, one of the typical project challenges is where and how to utilize swing space and how to move tenants during construction. Often times, tenants will want to know exactly where they will be moving to, the duration, and how the construction within the building will affect them. 4D models allow project teams to explain these aspects of the project to each tenant. For new construction projects, project teams can use 4D models for managing the construction schedule, matching the schedule timeline with the location based schedule, predicting and avoiding interruptions between different crews and activities, as well as verifying the soundness and correct sequence of the activities. Engineers and superintendents can use snapshots of 4D model to communicate the short term objectives to the crew and evaluate the daily progress.

The following table shows highlights of some project challenges that may be improved using 4D modeling:

Project Phase	Project Challenge	Goal
Pre-Design & Design Development	<ul style="list-style-type: none"> • How to best use swing space and optimize tenant phasing? • How to communicate phasing plan to tenants? • How to visualize construction alternatives? • What are the limitations factors? 	Better understand swing space use; save time in schedule Better communication to tenants Visual analysis of construction alternatives and activities
Design	<ul style="list-style-type: none"> • How to integrate the design intent, structural specifications and construction schedule? • How to communicate schedule to potential bidders? • How to satisfy all potential tenants? 	Better communication to project stakeholders about the construction process, duration and design intents
GC Selection & Construction	<ul style="list-style-type: none"> • How to manage the construction schedule and coordinate subcontractors? • How to maintain traffic flows during construction? • How to communicate the scope of each activity with stakeholders and workers during the process? • How to implement lean and efficient process? 	Better coordination of subcontractors as well as activities and other occupants during construction Show the 4D model and snapshots of it to the appropriate group at the right time.

4D models can help with enabling stakeholders to visualize the construction process and to optimize the schedule and save time. Although it is very difficult to quantitatively measure whether or not there is better communication between stakeholders, GSA associates can evaluate the success of the 4D model by understanding what the typical amount of questions or change orders there are using traditional phasing and coordination means, and compare those to the number using 4D modeling. Other metrics used to measure the success of 4D models can be: time saved on project, number of coordination detection, budget for 4D



model, number of activities, objects and linkages, time spent to do the 4D model, number of revisions, time spent to revise the 4D model, overall project’s duration and budget in comparison to similar projects and stakeholder’s satisfaction.

4D models in the project lifecycle

4D models can be used throughout the project lifecycle. While numerous industry cases have been documented on the use of 4D models throughout the project lifecycle, GSA can benefit from using 4D models in three specific stages:

Pre-design:

4D models have been used for strategic project planning during the feasibility phase. For example the model can be used to determine different phasing sequences and swing space configurations or to optimize the construction schedule. These models allow comparison of different alternatives with detailed assessment at a relatively low cost to the team and the owner. In the following federal building project (Figure 5), 4D models were used to analyze different alternatives based upon whether or not a major tenant would move out of the building.



Figure 5 Snapshots of the 4D model to analyze different phasing and swing space alternatives

Design Development:

4D models can be used to improve constructability of the design and to determine advantages of different construction processes. These models can be used to optimize the construction schedule, phasing, and/or tenant sequencing. In addition, the models can be used to communicate the phasing plan to the tenants as shown in Figures 6 and 7.

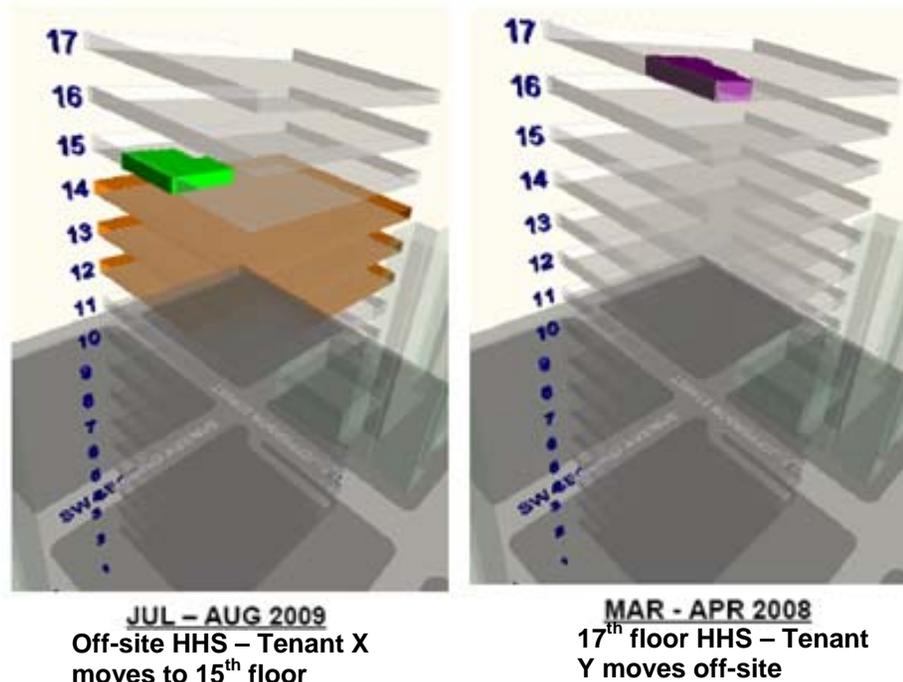


Figure 6 Snapshots of 4D model to show proposed top-down construction sequence and tenant phasing



Figure 7 4D model is used to communicate the scope of work and construction sequence

GC Selection/Construction Bidding:

4D models can also be required in the RFP to show the contractor's ability and direction to execute the work. If work is complicated, 4D models can be used to understand tenant phasing and/or construction activities sequence during bidding. If the contractors understand the space and the constraints better, the bids may be more accurate.

On a GSA courthouse project, a 4D model was created by GSA and used at a pre-bid conference (Figure 8) to allow the bidders to understand the project constraints and expectations better for a seismic upgrade project.

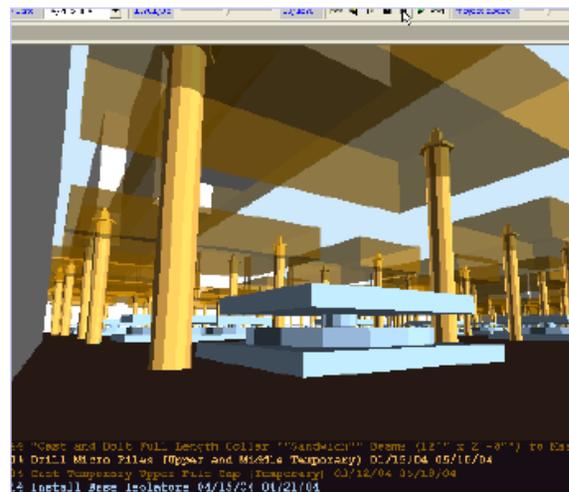


Figure 8 Snapshot of 4D model to show proposed construction sequence of seismic upgrade

Construction:

4D models can be used for the temporal aspects of construction coordination and constructability review. These include understanding where and how trades will work over a period of time and understanding traffic and site flow processes. On-site, these models can be used for bi-weekly construction progress reviews and to compare as-built with as-planned schedules for management and claims purposes. 4D models can also be used to communicate with tenants during the construction process. In addition 4D models can be used to communicate the utility and control system changes required during specific periods and their impacts, especially for renovation projects. Since 4D models are based upon 3D models, 3D construction coordination (this is different from clash detection, for example coordination of different trades' work-schedule in the same space and on the same objects or close-by objects) can be a by-product of 4D modeling; of course this varies depending on the level of detail and may not be true in all cases.

1.5 Exploring 4D Phasing Solutions

4D modeling software typically come within a suite of applications or as a stand-alone third party application. 4D modeling applications that are within a suite of applications allow the project team to create the 3D and 4D model all within one application family. 3D components are linked with time by either specifying specific phases within the modeling application, or importing a project schedule into the application.

Stand-alone 4D modeling applications will import both the 3D model and project schedule. The linkages are then created in these applications. Project teams should ensure that their 3D modeling and project scheduling applications are compatible with the 4D modeling application chosen.

1.6 Summary of Benefits

In summary, the benefits of 4D modeling may include:

In design:

- Increased stakeholder communication through visualization and better understanding
- Preliminary analysis of traffic flows, tenant phasing, construction activities
- Support development of construction sequencing alternatives

In construction:

- Improved sub-contractor coordination
- Reduced number of RFIs and COs
- Detailed analysis of constructions sequencing





section 02: defining 4d phasing scope

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section 2: defining 4d phasing scope

This section is intended for GSA associates to understand the process and the management requirements to develop a scope of work for specific projects. It describes the different concerns regarding 4D models, the required personnel, available software for modeling and a generic process of how to prepare for a 4D model.

2.1 Overview

Defining the appropriate scope for a 4D phasing project is essential for the success of the project. Figure 9 (modified from the Series 01 - Overview) shows the general process for analyzing and determining the scope of the 4D modeling. This section describes and defines the best practices for determining the scope, based upon this figure.

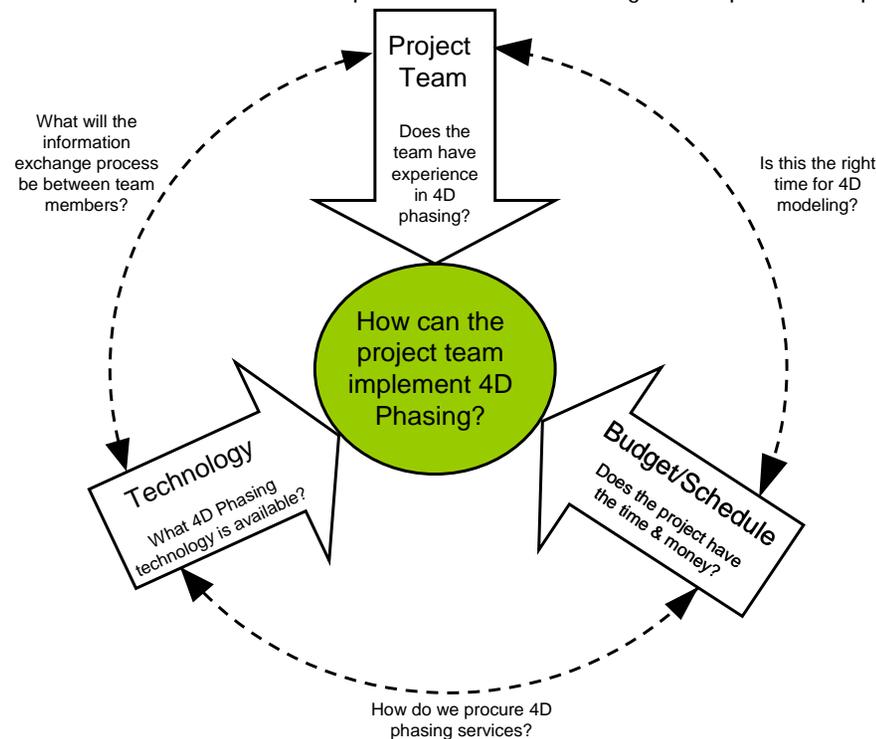


Figure 9 Feasibility of Implementing 4D Phasing

Often times, project teams may have more project opportunities for 4D modeling than available resources. Project teams, therefore, should prioritize the scope of the 4D work. This section is designed to help project teams understand the strengths and weaknesses of possible 4D scopes and to prioritize the scope.

2.2 Factors Affecting the Feasibility of 4D Phasing Implementation

2.2.1 Project team

Since 4D modeling combines both the design and schedule together, it is important to have various members of the project team on board. First, project teams must decide **who** will create the 4D model and **who** will provide the inputs. The following are examples, of who the project team consisted of, and in which phase the modeling occurred. This table is just a stereotype and the number of parties involved as well as the role of the participants can vary depending on the type of project and type of contract. Modified versions of this implementation process should be applied to fit the specific project requirements.

Role	Responsibility	Project Participants
3D Modeler	Provide 3D model and updates per design	Architect
Scheduler	Provide construction schedule and updates	GC
4D Modeler	Link 4D model, provide guidance to 3D modeler and scheduler for updates	CM Subcontractors
Other Stakeholders (e.g., occupants)	Provide input into phasing requirements and constraints	Owner Occupants

2.2.2 Budget/Schedule

The majority of the time to create a 4D model is spent on creating the 3D model itself. This is a good example of synergies between multiple uses of a BIM model. If projects are already going through the spatial BIM validation process, a 3D model will already be created; thus, already contributing towards the cost of creating the 4D model. Project teams should discuss what additional detail and corresponding elements need to be modeled for the 4D model (e.g., MEP elements, temporary equipment, work zones, etc).

Since every project has a construction schedule, the only task remaining to achieve a 4D model is linking the objects to the schedule. However it is important to realize that the 4D model schedule may be different than the construction schedule. In most cases there are some activities that need to be added to the model to enable the correct visualization of the construction sequence. Since the models are not intelligent, removal of temporary objects or movement of tenants also need to be included in the schedule. For example in a 4D model to communicate the swing space schedule, the actual schedule will only state "tenant A

moves to swing space” but in the model there should be two different tasks for this process: 1. removing tenant A from original location and 2. placing tenant A in swing space. It is important to realize that the 3D model requires a higher level of detail and more components than the model used for spatial validation; however having the framework, simplifies achieving such model in a short period of time in most cases.

Based upon the project challenges, technology and available information, project teams must ensure that the timing of the 4D model creation is correct. 4D models created too early or too late yield less benefits than those created during the ideal time. Although BIM based projects encourage developing a 3D model early on the project, 4D models created too early are generally too superficial and cannot provide insight into the project challenges. During programming and schematic design phases, when objectives and elements will constantly change, a 4D model can convey little useful information. 4D models created too late usually do not allow for changes to be made on the project from new insights or cost more to do so.

2.2.3 Finding the Appropriate Scope and Level of Detail

First, the scope and level of detail (LOD) depend upon the minimum common information provided by the schedule and 3D model. Thus, even though a detailed 3D model is available, it is not even possible to create a detailed 4D model if the schedule is not at that level of detail. The vice-versa is also true and usually it is more time/effort consuming to increase the LOD in 3D model.

Project teams also need to understand what the scope and LOD should be. Typically, the LOD increases as more design and construction information becomes available throughout the project lifecycle. The following table can be used as a guideline to manage the level of detail but it may vary from project to project.

Phase	3D Model Level of Detail	Construction Schedule Level of Detail
Feasibility Study	Project	Construction project
Concept Design	Buildings / Major Project Elements	Construction areas
Design Development	Systems / Components	Sub areas / Building Units / Disciplines
Construction Documents	Parts	Activities

The scope of the project should also be discussed. Often times, only specific aspects of the project need to be studied. For example, if one were to use a 4D model for MEP coordination, one would not need to model tenant moves.

2.2.4 Information Exchange

The main areas project managers should be aware of regarding the 4D technology are:

Software Integration Issues

What kinds of inputs can be put into the 4D model?

Some 4D software can only accept certain types of proprietary schedule and modeling formats. Members of the project team should make sure that the 3D model and schedule can be imported into the 4D software.

User Interface Issues

Are viewers available for outside users to see the model?

Not all stakeholders need create and edit the 4D model; however, it may be useful for all stakeholders (e.g., tenants) to be able to see the 4D model. Project managers should check to see how the model can be viewed by outside stakeholders. Viewers also allow GSA associates to view and track the 4D model without needing the entire 4D modeling software package. Some software offer the ability to create a video file or an animation of the 4D model that can be viewed by basic media players.

How easy is it to navigate during a meeting?

Coordination and communication of the schedule is usually accomplished in project meetings where navigation of the 4D model is required. Depending upon the level of usage during project meetings, project managers should decide how much control should be required by the presenter. In some meetings, model will be used only to communicate the objectives and/or building elements, without any model changes. In other meetings, the presenter may require extensive use and editing of the model for which the model may not be in the same format as the viewing model.

4D Technical Process Issues

GSA project managers should be aware of and discuss the following 4D technical process issues when procuring 4D modeling services. Please see section 3: technical guidance for 4D modeling for specific guidance on these topics.

How can the model accommodate different LOD?

If project managers would like to re-use the model in later stages of the project, the model needs to be able to accommodate increasing LOD, i.e. even at a low LOD the modeler must use individual objects for different building elements rather than creating a mass model.

How easy is it to update the model?

Since changes will occur during the lifetime of the model, it is important to understand how to update the model and the time requirements. It is also important to document the modeling process and the assumptions while the model is being created.

Project managers should understand and discuss solutions to these issues.



2.2.5 Scope of Work (SOW) Development and Procurement

GSA project teams can contact OCA to discuss the context of 4D modeling for their specific project. OCA can provide scope of services and contract language for 4D modeling services, as well as a consultant list.





Section 03:

Technical Guidance on 4D Modeling

GSA BIM Guide Series 04

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section 3: technical guidance on 4d modeling

This section is intended for GSA associates to understand the process of developing a 4D model. The process is broken down into steps with guidelines and tips on how to accomplish each step. The section identifies the elements needed for different types of 4D and walks through validating process of the material. At the end of the section the process of making a 4D model using the BIM model and the schedule is explained.

3.1 Overview

The set-up of the 3D model, schedule, and 4D model is critical in effectively using a 4D model. Often times, if these three core components to the model are not set up correctly, it is very difficult to manage and update the model, reducing its effectiveness. The following sections give best practice guidance on creating and managing these core components effectively.

At a minimum, 4D models require 3D isometric object data and a schedule with a start date and finish date. While a BIM is not required for a 4D model, project teams should consider creating a BIM to enable the project team to have more opportunities to use 3D, 4D, BIM technologies later. The general tasks required for modeling are shown in Figure 10.

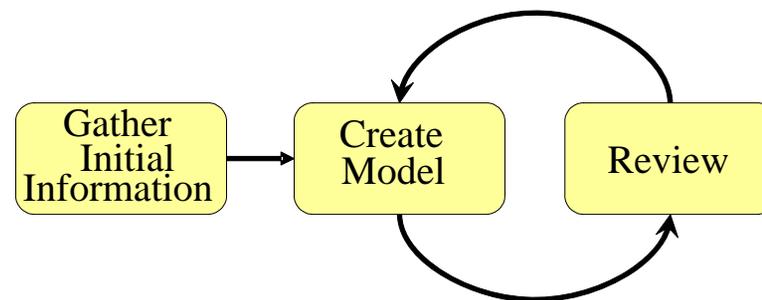


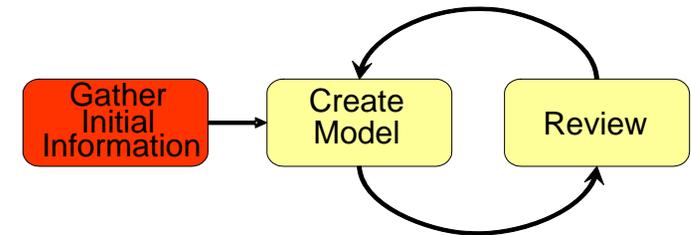
Figure 10 4D Modeling Process

3.2 Gather Initial Information

The first step in the 4D modeling process is to gather all necessary information to build the model as shown in Figure 11.

Step 1. Gather Initial Information	
Key Team Members	All
Key Activities	Project Kickoff Meeting (<i>Section 3.2.1</i>) Information Checklist (<i>Section 3.2.2</i>)

Figure 11 Process to create 4D model



3.2.1 Project Kickoff Meeting

A project kickoff meeting should be set up in order to coordinate information exchange and to develop a common understanding of the use of the 4D model. The agenda for the project kickoff meeting should include:

- Introduction of Stakeholders
- Status of GSA Project
- Intended use of 4D model on GSA Project
- Schedule of integration between 4D model and GSA Project
- Coordination of Information Exchange (Section 3.2.2)
- Follow-up Responsibilities and Next Steps

3.2.2 Information Checklist

The 4D modeler should ensure the following information is available:

- 2D drawings (if 3D models are not available)
- 3D models (if available)
- 3D renderings
- Construction schedule
- Other project metrics and schedule for analysis (e.g., tenant information, traffic lane schedule, etc.)
- Critical operations and major concerns during the construction process

The 4D modeler should also understand the LOD of each piece of information. In some cases, the LOD of each piece of information differs from the rest. The 4D model will only be as detailed as the minimum level of detail represented by the 3D model or schedule.

3.3 Create Model

Once the initial information is gathered, the 4D modeler can begin to create the model. The modeler should first examine all of the information gathered and develop a plan to create the model. Often times, this requires multiple iterations between the 3D model, schedule, and 4D model (Figure 12). Initial high level 4D models should be created first (Figure 13), such that any parts of the model can then be further developed based on the project team review of the model (Section 3.4).

	Step 2. Create Model	
Key Team Members	3D Modeler	
	Scheduler	
	4D Modeler	
Key Activities	Create 3D model	(Section 3.5)
	Create Schedule	(Section 3.6)
	Create 4D model	(Section 3.7)

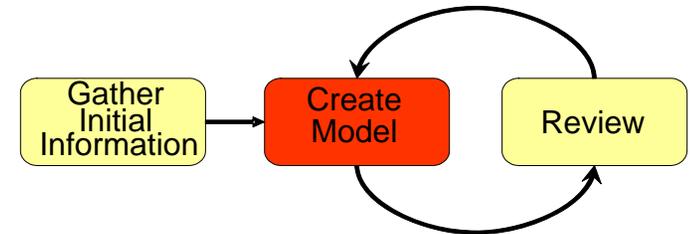


Figure 12 Process to create 4D model

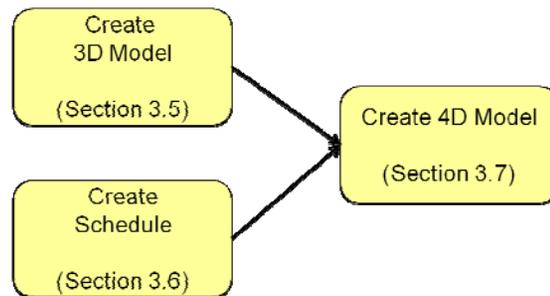


Figure 13 Integration of 3D model and the schedule

3.4 Review Model

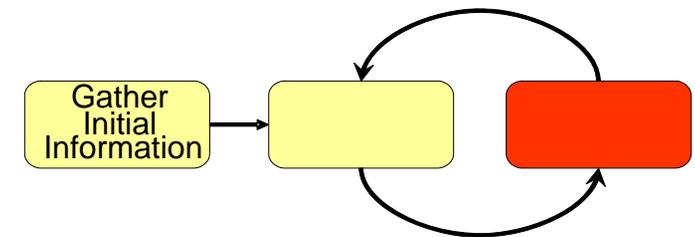
The project team should periodically review the model (Figure 14). The review of the model should ensure that:

- The modeling is on schedule with integration to the GSA Project
- The model can be used for its intended purpose
- The model is at the correct LOD
- The model visualizes the necessary components of the schedule
- The model is easy to understand (must consider the audience and provide the appropriate model)

Step 3. Verify and Update Model

Key Team Members	3D Modeler Scheduler 4D Modeler Project Stakeholders
Key Activities	Updating <i>(Section 3.4.2)</i> Refinement and Presentation <i>(Section 3.5)</i>

Figure 14 Process to create 4D model



Guidelines on Updating the Model

The 4D modeler should also incorporate any insights or changes to the 3D model or schedule into the next revision of the model. The 4D modeler should also be responsible for managing and coordinating the 3D modeler and scheduler for updates to the 4D model. The 4D model should be updated as often as necessary. The schedule for updating depends upon the model usage and phase. For example, during feasibility, the model may be used for visualization and marketing purposes only, which requires little updating. However, during design development, the 4D model may be used to determine constructability and influence design changes. In this case, the 4D model, 3D model, and schedule may be updated frequently. During construction, the design is finished and managing the construction schedule becomes the main use for the 4D model. Therefore updates to the 4D model and schedule are frequent, while changes to the 3D model are limited.

3.5 3D modeling for 4D Phasing

3D models (isometric or BIM) have a specific layering scheme within the 3D modeling application. Objects are typically layered based on building elements (e.g., all slabs are on one layer, interior walls on another layer, etc). However, in the actual construction of the project (and the 4D model representation), building elements are never constructed all at once. Therefore, it

is essential for model management to have a 3D model layering scheme which supports the 4D modeling activities. Figure 15 describes how a 3D model can be transformed from a layering scheme by building elements to a layering scheme by schedule. However there are other methods to make the 3D model and schedule correspond to each other. These methods are using a unique identifier of elements and tasks such as their RSMean code, and using a consistent naming convention recognized by the modeling and scheduling software.

If the 4D modeling application is within a suite of applications, including the 3D modeling software, this is usually not a problem because the software will link elements with activities without changing the layering scheme. However, if third-party software is used, it is important to establish a layering scheme to support the 4D model. Otherwise, it is very difficult to manage and update the 4D model. In addition some elements in the 3D model might have to be divided into segments to correspond to the schedule, for example a large slab might have to be in 2 or more pieces to correspond to different pour schedules.

The 4D modeler must also understand how the model will be used and how often it will be updated. If the model will be updated frequently, an information exchange process must be set up. If the 4D modeler is also the designer (i.e., A/E) the process will be in-house. However, if the 4D modeler is different than the 3D modeler, an information exchange process must be established where one party must update the 3D model *per the construction schedule layers*. This updated model can then be incorporated into the 4D model. If the model is not updated frequently (e.g., it is used for marketing purposes or pre-bid meeting only), then the information exchange process is not as critical.

3.5.1 Specifying Layering Standards in 3D Models

For some third party 4D-modeling software, 3D models are imported based on the layering standards in the 3D model. Therefore, to save time and organize the model, it is important to have a specific layering scheme, which may be different from the traditional PBS CAD Standard. While the layering standards required for 4D models do not replace the layering standards of the PBS CAD Standard, it is important to realize that additional layers may be created to manage the 4D model. While the PBS CAD Standard is organized by object type, 4D models need to be organized by construction. Therefore, it may be applicable to group objects in terms of construction area location, not just construction material.

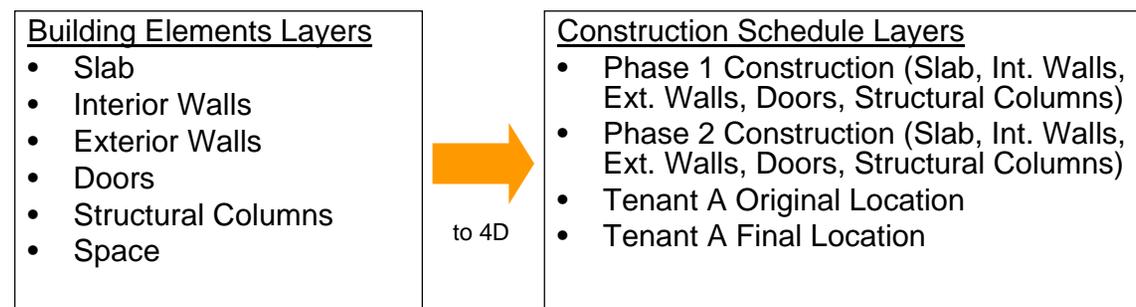


Figure 15 Feasibility of Implementing 4D Phasing

3.5.2 Additional Building Elements and Activities which Support Visualization

When building elements in the 3D model are not sufficient to describe the construction or phasing process, supporting building elements and activities need to be created.

For example, a project team may want to examine the use of traffic lanes during construction. If the traffic lanes are not present in the 3D model, additional building elements representing traffic lanes need to be created. Additional activities need to be created that represent traffic movements. Often times, these activities are correlated with existing construction activities.

3.5.3 Orienting the Model

Model orientation is important for outside stakeholders to understand the 4D model. Without orienting the model, project stakeholders may be confused at what they are seeing. Model orientation can include adding 3D text to locate street names or building levels or adding a high level site model. In addition when the model is used as a coordination tool for different trades, micro details (e.g. grid lines, room names) can be used to orient the model as well.

3.5.4 Required Building Elements

While building elements should be customized for each 4D modeling project, the following building elements should be required in the model:

3.5.5 Required for Phasing Schedules

- Walls
- Slabs
- Spaces
- Site Model

3.5.6 Required for Construction Schedules

- Building elements broken down to the same LOD as schedule (e.g., individual AHU units, columns, beams)

3.5.7 Optional (depending on project objectives)

- Traffic flows
- Temporary structures
- Workspace requirements
- Equipments

3.6 Scheduling for 4D Phasing

During feasibility through design development, the activities in the construction schedule are typically at the phase level, describing work areas.

3.6.1 Generic Activity Categories

Each activity in the schedule is assigned to one of three categories: Construct, Temporary, Demolish. These categories describe how components will be visualized during the activity dates in the 4D model. Elements attached to construct activities appear at the start of the activity and remain visible through the end of the schedule. Elements attached to temporary activities appear at the start of the activity and disappear sometime before end of the project. The temporary activities could be in two different line-items, such as erecting and removing shoring. Finally, elements attached to demolish activities are visible from the start of the schedule and disappear at the end of the activity.

3.6.2 Project-Specific Activity Types

The schedule should be broken down by different types of activities. For example, in a renovation project, where tenants are moving to swing space, the following activity types may appear: tenants move from original location, construction activity, moving to swing space, tenants move off-site. In the 4D model, these different activity types would appear in different colors.

Many times, a construction schedule will combine different activity types into one activity. Therefore, non-construction activities need to be created to visualize the schedule correctly. For example, the activity "Move tenants to swing space" is actually composed of two parts: 1) Highlighting where the tenants are moving from (i.e. tenant original location) and 2) Highlighting where the tenants are moving to (i.e. swing space). Since these represent two different *types* of activities, two separate activities are required in the 4D model. Figure 16 shows these different types of activities highlighted.

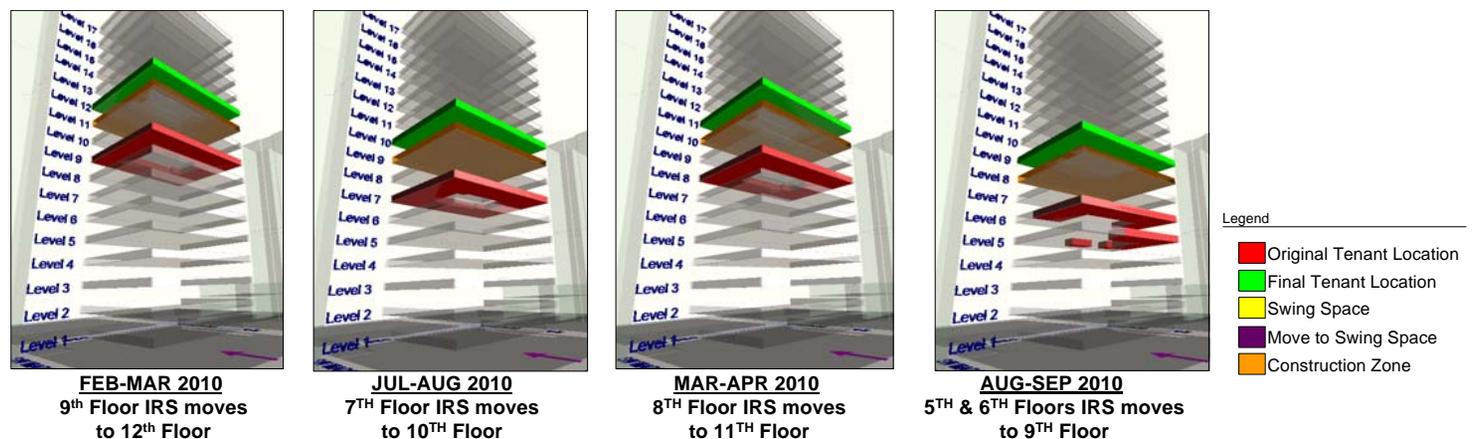


Figure 16 Tenant snapshots taken from 4D model describe tenant moves during construction

3.6.3 Activity Attributes

Activities in the schedule can also be loaded with information to be visualized in the 4D model (e.g., cost, resources, and spatial attributes). These attributes must be broken down into a “per activity LOD” (e.g., cost per activity).

3.7 Linking the 3D model and schedule

If the 3D model and schedule are set up correctly, the linking of the two components together to create the 4D model should be a straight-forward process; however depending on the complexity of the model, the task can become very tedious and time consuming. During this task, attention to details is required to ensure that the links are correct. Some software even offer an automated linking process based on the unique identifiers defined in both 3D modeling and 4D modeling software but a human check and verification is always necessary.

3.7.1 Dealing with Different Levels of Detail

In some cases, the LOD of the 3D model may be different from the LOD of the schedule. The 4D model will only be as detailed as the minimum detail represented by the 3D model or schedule.

3.7.2 Creating Groups within the 4D model

Objects within the 4D model can be arranged in groups, such that stakeholders can focus on specific parts of the model. Typically, these groups should include: per tenant, per floor, permanent objects, and site model. Grouping can be done either for components or activities that will later be detailed out separately.

These groups allow different stakeholders to focus on pertinent details related to each stakeholder. For example, if this were shown to a specific tenant, only that tenant’s movement should be shown. However, for overall phase planning, all tenants and construction activities should be shown. By setting up the model with these specific groups, OCA is better able to use the model for a variety of needs. Another benefit of grouping and naming convention is to take advantage of automated linking. Although Navisworks is not an intelligent modeling tool, still activities and objects can be automatically linked together when they have matching names.

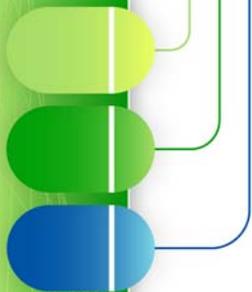


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