The Effects of Comparative 4D Models on Schedule Development and Controls

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Abstract

In this paper the argument is made that the use of comparative 4D models, which involve the simultaneous review of multiple project schedules, improves a project’s schedule development and control process. Traditional project planning and scheduling lacks the detail for efficient process, planning, and comparative schedule analysis. 4D models integrate product and process information into a visual format for the effective evaluation of potential scheduling issues, such as activity sequencing and a project’s resource constraints. This paper supports the fact that the use of comparative 4D models allows scheduling personnel the ability to efficiently explore multiple schedule alternatives and contributes to the effective management of project change requests and time impacts. This paper describes the process by which a project team can utilize comparative 4D models effectively during design and construction. The paper also describes the benefits and shortcomings of the use of comparative 4D models, their effect on a project’s outcome, and additional research issues.
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### Acronyms

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<th>Acronym</th>
<th>Description</th>
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<tr>
<td>AEC</td>
<td>Architecture, Engineering, and Construction</td>
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<td>CPM</td>
<td>Critical Path Method</td>
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<td>IAI</td>
<td>International Alliance for Interoperability</td>
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<td>IFC</td>
<td>Industry Foundation Classes</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>MEP</td>
<td>Mechanical, Electrical, and Plumbing</td>
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<td>RFI</td>
<td>Request for Information</td>
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1 Introduction

The Architecture, Engineering, and Construction (“AEC”) industry has made significant improvements in productivity through the use of new Information Technology (“IT”) applications. The result of these changes has been increased profitability and reduced risk exposure for those firms (or project stakeholders) utilizing these new tools.

Many in the AEC industry believe that significant efforts expended on construction administration could be eliminated through early project-team coordination. This early coordination can lead to the early resolution of problems such as field conditions that were impossible to describe fully in traditional 2D drawings; unanticipated physical interferences among mechanical, electrical, and plumbing (“MEP”) designs; and constructability issues as a result of project phasing issues encountered during the construction process. Schedules alone are not detailed enough for performing certain process analyses. Some parameters used for planning are lost once a schedule is created and some schedules are not conducive to considering “what-if” scenarios. Building projects in virtual reality during planning, pre-construction, and construction phases of a project can assist in the resolution of problems before the project is built, when the solutions have a higher cost and risk.

1.1 4D Modeling Overview

Figure 1 depicts the components of a 4D model. These components include a 3D model of the project design, representative of the product, and the project schedule, representative of the process and plan. “Virtual” project models can also incorporate other parameters, such as cost and resources, and are referred to as XD models, where X represents the number of additional parameters included beyond the product and process.

Figure 1 - 4D Model Components

1.1.1 Users

Users that have benefited from 4D modeling include:

- Architects
- Construction Litigators
- Construction Managers
- Design/Build Firms
- Developers
1.1.2 Project Types

The use of 4D modeling is not limited to a particular type of construction project or contract value. This technology can and has been used successfully on project types such as transportation, general commercial, office and retail complexes, biotechnology, new and retrofitted hospitals, theaters and museums, industrial, manufacturing, heavy civil, and financial facility asset modeling. Additionally, 4D modeling can and has been used in master planning applications.

While all of the above project types can benefit from 4D modeling, the key to creating benefits from this technology is in understanding the best uses for the 4D modeling for different project types.

For example, one of the best uses of 4D modeling on renovation projects is in creating high-level 4D models to be used for move management and the communication of issues and logistics to the existing tenants and the owner’s team. Project types that involve complex MEP systems, such as biotechnology projects, benefit from the production of a more detailed 4D model. This detailed model can then be used for communicating, planning, analyzing, and optimizing project scope and schedule issues during an early phase of the project when risk and cost impact are at their lowest level.

1.1.3 Benefits

It has been documented that the use of 4D modeling has contributed to projects completing on time and within budget, as compared to similar projects (Fischer, 2002). The following list shows some of the typical benefits resulting from the use of 4D models:

- **Increase Scheduling Efficiency**: The use of a 4D model enables a project team to visualize schedule constraints and opportunities for improving the project schedule. It allows for a much faster consensus on planning and scheduling issues. As a result, the schedule resulting from the 4D planning process is much better than normally possible in an equivalent time period.

- **Increase Schedule Reliability**: Many more people are able to understand the flow of work and provide constructive input, which allows the project team to consider many more aspects of a schedule. For example, over a much shorter time period than with traditional means, a scheduler is able to rapidly compare alternative “what-if” scenarios. In addition, 4D models greatly assist a project team in recognizing where the major project risks will manifest themselves.

- **Optimize Site and Space Use**: The use of a 4D model allows the user to understand and improve the use of work, access, and staging areas over time. 4D models also allow users to understand the relationship between construction activities and facility operation for retrofit projects.

- **Increase Constructability**: 4D models assist in analyzing the schedule and visualizing conflicts that are not apparent in Gantt charts and Critical Path Method (“CPM”) diagrams.
• **Improve Subcontractor Coordination:** Subcontractors have reported increased field productivity, less rework, and fewer change orders and Requests for Information (“RFI”) when using 4D models as coordination tools (Schwegler, Fischer & Liston, 1999). The work of related subcontractors is typically coordinated through 2D overlays, which allow a project team to identify some spatial conflicts in the design. However, the construction phase can introduce entirely new spatial conflicts that are very difficult to identify with 2D overlays. This issue is resolved through the use of 3D and 4D models by subcontractors.

• **Optimize Resource Utilization:** The use of a 4D model allows for the optimization of labor and equipment utilization through the analysis of spatial conflicts among crews and other production elements.

• **Increase Site Safety:** The use of a 4D model allows the user to visually assess and review safety plans, erection plans, traffic rerouting plans, testing plans, etc.

• **Shorten Project Duration:** The use of 4D models provides the opportunity to shorten the design and construction period as a result of improved project planning and analysis techniques.

• **Improve Communication:** 4D models are effective tools for communicating project scope and related phasing, sequencing, and construction scenarios to project stakeholders during all project phases. Time-based project data, such as cash flow, quantities-to-date, financial assets, etc. can be easily communicated using a 4D model.

• **Improve Team Building:** 4D modeling is important in constructing a team atmosphere in which team members solve problems jointly. The 4D model provides a shared, visual model to externalize and share project issues.

• **Improve Portability of Design:** The project manager or a subcontractor’s superintendent can have a laptop on site and use the 4D models for daily planning of construction activities. He or she can filter the 4D model for the specific work activities that would be performed for each day and print them out for the field crews.

• **Increase Learning and Feedback for Future Projects:** Each 4D model documents the design and construction of a project very clearly, which allows future project teams to understand the approach taken on past projects.

• **Gain New Projects:** Creating a project-specific 4D model, to be included with a project team’s proposal to an owner, can provide the project team with a competitive edge during the bidding process. In addition, as-built 4D models from previously completed projects can be utilized for marketing presentations, external website graphics, etc.

• **Provide Operations and Maintenance Support:** An as-built 4D model provides the operations and maintenance team with a tool to manage office layouts, storage requirements, and tenancy change requirements. In addition, the 3D and 4D models can be coupled with additional software packages and used as a training platform for facility management and maintenance personnel.

• **Communicate Findings in Dispute Resolution:** A 4D model is an effective tool for presenting information during alternative dispute resolution or litigation in a way that can be easily understood and retained. 4D models can be used as demonstrative aids and trial graphics and are extremely effective for use in as-planned versus as-built schedule comparisons.
1.1.4 Process

The process associated with creating 4D models can range from simplistic to complex, depending upon the user, project type, and software applications utilized. Figure 2 shows an example of the flow of modeling information between parties and software applications on a typical Design/Build project.

Figure 2 - Typical Modeling Information Flow

![Diagram of typical modeling information flow between parties and software applications on a Design/Build project.]

1.2 Comparative 4D Modeling Overview

This paper addresses the use of comparative 4D models, which involve the simultaneous review of multiple, yet related, 4D models in adjacent computer screen “windows.” The playback of such 4D models is synchronized through the use of internal or external software links. For the most part, the current use of 4D modeling is limited to the review of a single 4D model, incorporating a single 3D model and its associated project schedule in a single window. This method of 4D modeling does not allow the user to efficiently and effectively review and compare multiple 4D models related to the same project. This paper explores some of the technical issues related to the use of comparative 4D models during all phases of a project and supports the fact that the use of comparative 4D models allows scheduling personnel the ability to efficiently explore multiple schedule alternatives and contributes to the effective management of project change requests and time impacts. This paper also describes the benefits and shortcomings of the use of comparative 4D models, their effect on a project’s outcome, and additional research issues, including the use of comparative 4D models in construction claims and dispute resolution.

Figure 3 depicts the components related to a comparative 4D modeling scenario that allows the user to perform a visual comparison of a single 3D model and multiple schedules. This scenario utilizes one 3D model that is linked to two schedules. This type of comparative 4D model is best suited for performing “what-if” schedule comparisons during the pre-construction and construction phases. It is equally beneficial for use as an as-planned schedule versus an as-built schedule comparison tool and to effectively manage project change requests and time impacts through the visualization and comparison of impacted versus unimpacted schedules. These uses highlight the...
usefulness of such a tool during all project phases and as a demonstrative aid or graphic in alternative dispute resolution or litigation.

Figure 3 - Comparative 4D Model Components: Scenario #1 (1 3D Model/2 Schedules)

Figure 4 depicts the components related to a comparative 4D modeling scenario that allows the user to perform a visual comparison of multiple 3D models and respective schedules. This scenario utilizes two 3D models that are linked to separate schedules. This type of comparative 4D model is best suited for performing "what-if" schedule comparisons during the pre-construction and construction phases, especially when substantiating time entitlement for potential scope growth. Conversely, this scenario can be utilized for analyzing means in which impacts can be mitigated through work-arounds. Similar to the first scenario, this scenario is beneficial for use as an as-planned schedule versus an as-built schedule comparison tool.
Figure 4 - Comparative 4D Model Components: Scenario #2 (2 3D Models/2 Schedules)

Figure 5 depicts the components related to a comparative 4D modeling scenario that allows the user to perform a visual comparison of multiple 3D models and a single schedule. This scenario utilizes two 3D models that are both linked to the same schedule. This type of comparative 4D model is best suited for performing comparisons of work scope and scope growth.

Figure 5 - Comparative 4D Model Components: Scenario #3 (2 3D Models/1 Schedule)
2 Pre-Construction

4D modeling has proven to be a beneficial tool when used during the pre-construction phases of a project. Different project delivery methods offer differing results for the use of the technology during the planning phases, but all delivery methods can benefit. Design/Build projects are good delivery methods for 4D modeling use, due to the fact that this type of project necessitates that the designers and constructors work closely through different design iterations. With this type of project, especially if the project is being “fast-tracked” and the design and construction is being performed concurrently, it is important for project teams to have the ability to build a project “virtually” and to create “what-if” scenarios in a virtual reality environment. For other project delivery methods, such as Design/Bid/Build, the use of the 4D models is also extremely important during the pre-construction planning phase. Whereas Design/Build projects foster early communications amongst the project team members, the earlier that project teams interact and communicate on Design/Bid/Build projects, the greater the influence the 4D modeling will have on the project. Figure 6 shows typical cost and influence curves for utilizing 4D modeling during the different phases of a construction project.

Figure 6 - Cost and Influence Curves: 4D Models

The following is a list of some of the methods in which comparative 4D models can be utilized during the pre-construction planning phase of a project:

- **Marketing Presentations**: Incorporating a 4D model into a proposal package can provide the project team with a competitive edge during the bidding process and is a powerful tool for communicating ideas with the owner’s organization. A comparative 4D model allows the project team to demonstrate to the owner the differences between design options and their subsequent sequencing and construction durations. In the competitive construction market, the benefits of using new technologies as part of an overall project strategy can often mean the difference between winning and losing a contract. However, gaining the release of design drawings from an owner during a project’s proposal stage in order to assist in creating a 4D model can be difficult, especially from a liability standpoint.

- **Schedule Assessment/Validation**: Comparative 4D models can be used during coordination meetings to assist the project team in recognizing where the major project risks will manifest themselves, increasing scheduling efficiency and reliability, and visualizing conflicts that are not apparent in Gantt charts or CPM diagrams. The use of comparative 4D models provides the opportunity to shorten the design and construction period by allowing for the rapid comparison of alternative “what-if” scenarios and the effect
of schedule changes. Section 2.1 provides further details on the use of comparative 4D models during the schedule assessment and validation process.

- **Site Logistics and Sequencing:** Comparative 4D modeling can support site logistics, the visualization of concurrent activities at a high or low level, and it can greatly improve the ability to predict outcomes by simulating multiple construction scenarios. Comparative 4D models allow for the alignment of work and the prevention of rework.

- **Resource Management:** A good project plan accounts for the right number of resources at the right times throughout the project. Resource analysis is greatly simplified through the use of a comparative 4D model. A comparative 4D model allows the project team to visualize multiple resource allocation scenarios, thus helping to create reliable sequences of work.

### 2.1 Schedule Assessment and Validation

Assessing and validating a preliminary schedule during pre-construction is key to the successful implementation of that schedule during the construction phase. Many planning parameters are lost when developing a CPM schedule. The use of a standalone 4D model to assess and validate a preliminary schedule’s durations, sequencing, critical path, etc. has proven successful, due in large part because the 4D model allows the user to visualize many of the parameters that are not easily discernible when reviewing a Gantt chart or CPM diagram. However, the use of a comparative 4D model improves upon the benefits realized during the review of a standalone 4D model by allowing the user to synchronize and compare multiple “what-if” schedules concurrently.

Comparative 4D models can be used during pre-construction coordination meetings to increase scheduling efficiency and reliability by allowing the project team to do the following:

- Assess the pros and cons, as well as the schedule ramifications, of utilizing different construction means and methods.

- Shorten the design and construction period by allowing for the rapid comparison of alternative “what-if” scenarios.

- Analyze the effect of schedule changes on completion dates, critical path shifts, changes in float values, and availability of resources.

- Recognize where the major project risks will manifest themselves by assessing the risk associated with the critical path in different schedule alternatives.

Figure 7 shows a theoretical example of a comparative 4D model incorporating one 3D model and two preliminary project schedule alternatives. This comparative 4D model allows the user to compare the pros and cons, as well as the schedule ramifications, of the two schedule alternatives in an effective and efficient manner. The user has the opportunity to compare and visually filter many parameters, such as specific work groups, critical paths, or resource allocation variances, between the two schedule alternatives.
2.2 Comparative 5D Models and Project Cost Analysis

A 5D model is a 4D model that incorporates an additional parameter, such as cost, resources, etc. Many construction contracts require that the contractor’s project schedule be cost-loaded and that the contractor’s payment applications be based on a cost report generated from this cost-loaded schedule. If such a schedule is incorporated into a 4D model, the cost component of the schedule can be visualized in the 4D model, making it a 5D model. This type of 5D model allows the user to visualize cost information such as monthly cash flow, budgeted cost-to-date, and cost-to-complete values in relation to a particular date, project phase, or the volume of work-in-place. The use of this type of comparative 5D model allows the user to visually compare and assess multiple schedule cost-loading scenarios concurrently.

3 Construction

4D modeling has also proven to be a beneficial tool when used during the construction phases (or “phase”) of a project. The following is a list of some of the methods in which comparative 4D models can be utilized during the construction phase of a project:

- **Site Coordination/Overview**: Comparative 4D models allow for the creation and comparison of “views” of site areas, which can be used for the discussion of site coordination, staging areas, access restraints, erection plans, traffic management, and safety issues.

- **Workflow Coordination and Site Logistics**: Comparative 4D models can be used to coordinate the workflow of subcontractors and site logistics over time. During a commercial building project that utilized 4D modeling, the project’s general superintendent stated that the ratio of time spent communicating the project schedule to the time spent preparing the project schedule was 6 to 1. Utilizing
a 4D model provided a reduction in that time, while at the same time increasing the amount of subcontractor schedule input (Common Point Technologies, Inc., 2003). During construction, the comparative 4D model can be used to compare and review the scope of work for the upcoming 90 days (or any other time period), under different scenarios, in subcontractor coordination meetings.

- **Coordinating with the Owner:** Comparative 4D models allow for improved communication between the contractor and owner. A comparative 4D model provides a means for communicating different project scenarios, in an easy to understand visual format, to the owner.

- **Zone/Move Management:** A comparative 4D model can be used to support complex move management tasks and to complete ongoing “what-if” scenarios. A 4D model also allows users to understand the relationship between construction activities and facility operation for retrofit projects.

- **Monthly Schedule Updates:** On many projects, the 4D model is updated in conjunction with the maintenance of the project’s schedule updates. This process is a simple one, involving the import of the updated project schedule into the 4D model as often as the project schedule is updated. The 4D model can be converted to a video file for easy submission with the project schedule update to the owner. This submission allows the owner to easily understand the progress of the project to-date and the project’s future planned progress, including visualization of the project’s critical path. Section 3.1 provides further details on the use of comparative 4D models during the schedule update process.

- **Change Orders and Contract Modifications:** A comparative 4D model is an excellent tool for substantiating critical path delays and contract time extension requests. The project’s critical path and any new work, in the form of ‘fragnets,’ can be incorporated into the 4D model to allow all parties to better understand the cause of delays or the impact of changes to the project’s completion date. Section 3.2 provides further details on the use of comparative 4D models in change management.

### 3.1 Progress Schedules and Payment Applications

A 4D model can be updated throughout the course of construction using a process similar to the one used in developing progress schedules. As a project schedule is updated, a dynamic link between the schedule and the 3D model can automatically update the 4D model. This allows the 4D model to accurately depict updates to the project schedule that pertain to actual progress, scope, logic, activity durations, resource allocation, etc. In addition, any and all design changes are incorporated through revisions to the 3D model.

A typical schedule update process involves the following steps:

- Gather progress information from the field or through the review of daily reports.
- Input progress information into current progress schedule update.
- Recalculate schedule and review schedule status, including critical and near-critical paths.
- Run cost and/or resource reports as applicable.
- Make necessary revisions to activity durations, logic, etc., based on schedule review and the current project plan.
- Compile 2-week (or applicable time period) look-ahead schedule.
- Compile narrative report outlining work progress, issues, and potential issues.
- Submit schedule, payment application, and required documentation to owner or owner’s representative.

The use of a comparative 4D model in conjunction with the above process provides the potential for multiple benefits to both the contractor and the owner. These benefits include utilizing the comparative 4D model for analyzing multiple “what-if” acceleration/mitigation strategies during the schedule update process, tracking and monitoring project progress and performance by comparing the baseline 4D model to the current progress 4D model, improving communication of monthly project progress to future tenants (specifically if the owner is the
developer), and supporting payment applications by providing a visual comparison of work-in-place for the current payment period versus the previous payment period.

Figure 8 shows a theoretical example of a comparative 4D model incorporating one 3D model and two project schedules, the baseline schedule and a progress schedule update. This comparative 4D model allows the user to compare the original baseline plan to the project status depicted in the current project schedule update, or any other progress schedule update. In Figure 8, the user can see that on January 19, 2006 the actual progress of the building’s core is ahead of the baseline plan, but that the actual parking garage concrete deck work is lagging behind the baseline plan.

Figure 8 - Progress Schedule Comparative 4D Model

3.2 Change Management and Time Impact Analyses

Change management and impact and delay analyses are an important component of project management and controls and are often a point of contention between the contractor and owner. Often, this contention is the result of a lack of a common communication tool that can be understood by all parties. The use of a comparative 4D model solves this communication gap by allowing all parties access to a useful tool for the visualization of project impacts and delays. Such impacts can include scope changes, disruptions, production inefficiencies, force majeure, and unforeseen conditions.

If a contractor encounters a delay or one of the above impacts, not through its own fault, and resulting in a delay to the completion of the work on the project’s critical path, as shown in the approved contractor’s schedule, the contractor is entitled to a time extension equal to the delay to the project’s critical path, as defined above. This delay is often assessed contemporaneously through the use of a Time Impact Analysis (“TIA”).

A typical TIA performed by or for a contractor involves the following steps:

- Define impact, delay, or new scope of work.
• Insert new fragment of activities into the applicable progress schedule update.
• Insert or delete logical relationship(s).
• Modify existing activity duration(s) and/or logical relationship(s).
• Recalculate impacted schedule and identify and quantify the resulting impact to the project’s critical path.
• Submit time extension request, with TIA and required documentation as support, to the owner or owner’s representative.

The use of a comparative 4D model in conjunction with the above TIA process and when communicating the findings of the above TIA process provides the potential for multiple benefits to both the contractor and the owner. These benefits include utilizing the comparative 4D model for reviewing the results of the TIA process by comparing the unimpacted 4D model to the impacted 4D model, supporting time extension requests by providing a visual comparison of the unimpacted critical path versus the impacted critical path and the subsequent extension to the Contract completion date, and developing and testing means by which to mitigate impact and recover delay by analyzing multiple “what-if” scenarios.

Figure 9 shows a theoretical example of a comparative 4D model incorporating one 3D model and two project schedules, the baseline schedule (unimpacted schedule) and a progress schedule update (impacted schedule). This comparative 4D model allows the user to visually compare the original baseline critical path to the impacted critical path depicted in the progress schedule update that incorporates the impacts. This type of comparative 4D model allows the user the option to make visible only the critical path activities, thus focusing on only those activities and 3D model components affected by the impact or impacts.

**Figure 9 - TIA Comparative 4D Model**
4  Post-Construction

For many projects, a 4D model can be utilized very effectively in the post-construction phase. While this project phase has not seen widespread use of 4D modeling, this will change as new technology applications are created. The following is a list of some of the methods in which 4D modeling and comparative 4D modeling can be utilized during the post-construction phase of a project:

- **As-Built Documentation:** The 4D model can be effectively utilized as an as-built document, especially when dealing with facilities that anticipate future upgrades and/or expansions. It can also be used to increase learning and feedback for future projects by allowing project teams to understand the approach taken on past projects.

- **Operations and Maintenance:** An as-built 4D model allows the operations and maintenance team to manage office layouts, storage requirements, and tenancy change requirements. In addition, the 3D and 4D models can be coupled with additional software packages and used as a training platform for facility management and maintenance personnel.

- **Dispute Resolution:** A comparative 4D model is an effective tool for presenting information during alternative dispute resolution or litigation in a way that can be easily understood and retained. Comparative 4D models can be used as demonstrative aids and trial graphics and are extremely effective for use in as-planned versus as-built schedule comparisons. Section 4.1 provides further details on the use of comparative 4D models during alternative dispute resolution and litigation.

4.1  Alternative Dispute Resolution and Litigation

Alternative dispute resolution and litigation are areas that have seen little use of 4D modeling, yet this is an area that can reap significant benefits from the use of 4D models, especially the use of comparative 4D models. Comparative 4D models can be used as impact and delay analysis tools and/or as demonstrative graphics and visual aids.

Figure 10 depicts the components incorporated in a comparative 4D model that provides a visual comparison of an as-planned schedule and an as-built schedule. This scenario utilizes one 3D model that is linked to the two schedules. This type of comparative 4D model is best suited for analyzing and reviewing delays and impacts encountered during a project.
Figure 10 - As-Planned versus As-Built Comparative 4D Model Components

Figure 11 shows a theoretical example of a comparative 4D model that incorporates an as-planned or baseline schedule and an as-built schedule. In this particular example, the user is able to clearly visualize a critical delay to one of the project’s main concrete foundation pours.

Figure 11 - As-Planned versus As-Built Comparative 4D Model: Example #1

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Figure 12 shows a second theoretical example of a comparative 4D model that incorporates an as-planned or baseline schedule and an as-built schedule. In this particular example, the user is able to clearly visualize a critical delay to a section of the project’s structural steel erection.

Figure 12 - As-Planned versus As-Built Comparative 4D Model: Example #2
5 Conclusions

5.1 Effects of Comparative 4D Modeling on Schedule Development

While the use of 4D models is gaining momentum in the AEC industry, the use of comparative 4D modeling has not seen widespread use. Comparative 4D models have the potential to provide users with benefits greater than those achieved through the use of standalone 4D models.

It has been documented that the use of 4D modeling has contributed to projects completing on time and within budget, as compared to similar projects (Fischer, 2002). The following is a list of some of the potential benefits that can be found through the use of comparative 4D models:

- Increase scheduling efficiency and reliability.
- Optimize cost-loading of schedules.
- Optimize site and space use.
- Increase constructability and site safety.
- Improve subcontractor coordination.
- Optimize resource utilization.
- Shorten project duration.
- Improve current schedule update process.
- Assist in communication and substantiation of TIA findings.
- Improve communication and team building.
- Increase learning and feedback for future projects.
- Increase efficiency of delay and impact analyses.
- Increase effectiveness of delay and impact analyses through visual communication of findings.

5.2 Research and Improvements Needed

The use of comparative 4D models is not problem-free. While multiple software firms provide 4D modeling applications, only a small percentage of these applications provide the capability to perform comparative 4D modeling in an efficient and effective manner. In addition to the availability of comparative 4D modeling software, the cost to implement 4D models and comparative 4D models can be a limiting factor, although the average cost to develop a 4D model is decreasing as improvements are made to the interoperability and the functionality of existing 3D and 4D software applications. The International Alliance for Interoperability’s (“IAI”) Industry Foundation Classes (“IFC”) are an example of an area of development in the field of software application interoperability. In the area of construction litigation, the use of comparative 4D models has seen very little use, mainly due to the relative immaturity of 4D modeling, but also as a result of some reluctance to use high-technology tools in dispute resolution or trial settings. As more 4D software applications include a comparative 4D modeling functionality, the ease and efficiency of developing a comparative 4D model will undoubtedly improve and will be met with more widespread use.
6 References

