A Comparative Analysis of US Departments of Transportation Scheduling Specifications and Industry Recommended Scheduling Practices

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Abstract

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Scheduling is a key process in delivering construction projects in time and within budget. States departments of transportation (DOTs) rely on scheduling to achieve such objectives. However, a review the standard specifications of most states reveals considerable inconsistencies in those specifications. For example, some states require CPM schedules some simply require Gant Charts. This research work investigates the scheduling practices adopted by states DOTs by conducting a full content review of standard specifications of all 50 states and the special provisions of a number of projects in various states. The content review is followed by a comparative analysis of the scheduling practices of State DOTs and industry best practices presented by the Project Management Institute (PMI), the Association for the Advancement of Cost Engineering International (AACEI), Unified Facility Guide Specifications (UFGS), and the National Aeronautics and Space Administration (NASA). A survey questionnaire of a 110 of various DOT scheduling personnel was also administered to get their perception about the inconsistencies. The results of the research work contributed by proposing new recommended standard scheduling specification that mainly reflect the scheduling needs of the DOTs.

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I'm both lucky and blessed to have a wonderful family that supports me relentlessly.

1 INTRODUCTION

Scheduling is a key process in delivering construction projects. Whether it's called a baseline schedule, a project schedule or a progress schedule, it serves the same purpose: the completion of the project on time without exceeding the budget. Schedules can take many forms, from a simple bar chart (Gant Chart) to a more complex Critical Path Method (CPM). Schedules can also vary in the level of detail and number of constraints. Departments of Transportation (DOTs) around the U.S establish specifications and best practices to ensure the standardization of Construction Schedules in their projects within state boundaries and ensure some level of control. When reviewing DOT Standard Specifications in various states, one will find variances in the characteristics of the construction schedules demanded by these DOTs. For example Colorado DOT limit the activities duration to 15 days[1], while Texas DOT limits activities duration to 20 days[2]. On the other hand, states like Washington and California do not force any limitation on activity duration. Also, the complexity of Schedule Specifications can vary between states; for example Kansas DOT dedicates two paragraphs for scheduling in the Standard Specifications while Colorado DOT Standard Specifications contains almost 7 pages specifying the characteristics of the construction schedule and submittal procedures (KDOT, 2007) (CDOT, 2011).

The inconsistencies between state DOT scheduling standard specifications are evident. When each of these specifications is compared to industry best practices discrepancies are also evident. For example, the Project Management Institute (PMI) recommends substituting activity constraints with activities when possible, on the other hand the state of Montana scheduling specification include the following provision: "Do not use any other schedule restraints such as activity mandatory start and finish dates or mandatory zero float constraints" (MDT, 2006).

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[1] Colorado Standard Specifications for Highway Construction 2005, page 62
[2] Texas Standard Specifications For Bridge and Highway Construction 2004, page 102

In general, the contractor is responsible for drafting the construction schedule; the specifications for such schedule can be found in the standard specifications of each state DOT. The scheduling specifications can vary significantly depending on the state and project complexity. DOTs and contractors have different opinions when dealing with schedules. Contractors prefer more loose general provisions that give them the flexibility of doing what they desire (e.g. front load the schedule), while most state DOTs try to control the contractor with more detailed specifications (Warhoe, 2009). But that's not the only problem; some of the scheduling specification provisions can also be vague or contradictory creating disputes at the very beginning of the project.

A number of researchers agree that the current scheduling specifications need to be enhanced in order to achieve better project control and fulfill the aspirations of both owners and contractors (Galloway, 2006) (Mattila, 2004) (Elnagar & Yates, 1997) (Li, 2003) (Levin, 2006) (Ballast & Popescu, 2001). Little research addressed state DOT scheduling specifications, but since State DOTs are responsible for billions of dollars' worth of infrastructure projects each year, a glance at their scheduling specifications can prove to be beneficial.

Many questions arise while reviewing the Scheduling Specifications of state DOTs. Are the Standard Scheduling Specifications sufficient in all 50 states? How do these specifications compare to industry best practices? What are the recommended states DOT Standard Scheduling Specifications?

This research paper investigates the scheduling practices adopted by state DOTs by conducting a full content review of standard specifications of all 50 states and the special provisions of a number of projects in various states. The content review is followed by a comparative analysis of the scheduling practices of State DOTs and industry best practices presented by the Project Management Institute (PMI), the Association for the Advancement of Cost Engineering

International (AACEI), Unified Facility Guide Specifications (UFGS), and the National Aeronautics and Space Administration (NASA). In order to triangulate the results of the analysis, a survey questionnaire was drafted and sent to a number of DOT scheduling personnel in State DOTs nationwide. The content analysis, the comparative analysis, and the survey questionnaire are then used to formulate new recommended DOT standard scheduling specification. Since the survey questionnaire was tailored toward DOT personnel only, the newly developed specifications reflect the scheduling needs of the DOTs and do not take into consideration the contractors' opinion.

The following chapter investigates scheduling specifications in existing literature. Chapter 3 will explain the research methods used: content review, comparative analysis, and survey questionnaire. The analysis starts with chapter 5 addressing the basic scheduling components followed by chapters 6 and 7 for an in depth look into schedule development and management components. Chapter 8 investigates the level of DOT schedule conformance. Finally, Chapter 9 presents the recommended DOT scheduling specifications and conclusion.

2 LITERATURE REVIEW

2.1 Importance of a Construction Schedule

Many researchers focus on the importance of detailed construction schedules (Galloway, 2006) (Mattila, 2004) (Elnagar & Yates, 1997) (Li, 2003) (Levin, 2006) (Ballast & Popescu, 2001). For example, one study conducted by Janet K. Yates and Hala Elnagar (1997) investigated the main causes of construction delays and delay indicators in various business sectors (Governmental, Commercial Building, Process, Institutional Building, Heavy Industry, and Light Industry, and Infrastructure and Power). The study concluded that project schedules are the number one delay indicators in all sectors (except for Infrastructure and Power) (Elnagar & Yates, 1997). Project schedules can also be the direct cause for delays (not just an indicator), for example an overly optimistic project schedule can cause a delay (Elnagar & Yates, 1997).

2.2 Issues in Scheduling Specifications

Industry professionals have voiced concerns regarding scheduling specifications. In an article published by the Cost Engineering Journal, Stephen P Warhoe indicated that the main reasons behind schedule frustration –from the contractors' side- were the inconsistent requirements and performance metrics between owners in the same industry, the poorly written specification documents, and the lack of experience on the owner's side (Warhoe, 2009). In a paper titled "Scheduling Specifications for the 21st Century" Paul Levin identifies a number of provisions in schedule specification that are often inconsistent as follows (Levin, 2006):

- Who develops the schedule? (Contractor or Owner)
- Type of schedule required: CPM? Bar Chart? Etc…
- Schedule updating procedures
- Review and approval requirements
- Scheduling software requirements
- What type of information to be added to the schedule? Resource loaded? Cost loaded?
- Progress payment relationship to schedule updates
- Schedule Recovery Requirements
- Risk management requirements

Scheduling Specifications of State DOTs provide a rich example of inconsistency: "For progress updates, one state required resource loading to include the tracking of cost, labor hours, equipment, and materials in addition to the traditional time related schedule progress updates. Other specifications request only that the schedule be cost loaded. Yet, there was at least one state that specifically stipulated that schedules not be resource loaded" (Warhoe, 2009). Another example of specification inconsistency has to do with scheduling software. Some states specified that Primavera should be used, while others include general scheduling software provisions and most states do not include any software provisions (Warhoe, 2009). Through the content review and comparative analysis of all 50 State DOTs scheduling specifications, this research will reveal more inconsistencies.

2.3 Open vs. Closed Specifications

Open scheduling specifications are general specifications that simply require the contractor to provide a project schedule, leaving the details (such as software selection, number of activities, resource loading etc.) to be decided by the contractor, therefore giving the contractor complete freedom. Open specifications are best for small, short duration projects (Levin, 2006). "It may also work on larger projects in which the contractor and owner are knowledgeable professionals and when the owner has significant trust in the contractor's scheduling and project management abilities." (Levin, 2006). On the other hand, a closed specification restricts the contractor to certain scheduling details (such as the type of schedules to be submitted, approval processes, and schedule methods required for time extension requests).

The literature explains some of the reasons behind choosing open or closed specifications. Contractors prefer less detailed schedules because they are cheaper to produce, give contractors flexibility in scheduling, and it's easier to hide proprietary information (Krone, 1997) (Levin, 2006). On the other hand, closed specifications "standardize administrative procedures and reduce heated debates resulting from unplanned events" (Krone, 1997), minimizes the owner's risks, and provides a good reference in case of a time-related claim (Levin, 2006).

In a survey conducted in 1995 titled "Construction Scheduling Specifications" 85% of contractors supported specifications for an original schedule (open specifications). When asked about their support for progress payment provisions, updating procedures, software, and cost loading, the result came as follows: "There is little support for specifications requiring a schedule with progress payments (22.5%) or specified updating procedures (17.5%), and virtually no support for specifying the type of schedule (2.5%) or cost loading the schedule (2.5%)" (Krone, 1997). Although research shows that contractors prefer open specifications, "History has shown that contractor's preference can be changed by adopting closed specifications that direct implementation of better business practices" (Krone, 1997).

Well defined scheduling specifications helps schedulers develop and manage baseline project schedules effectively (Li, 2003). Dr. Win suggests that if the specifications are too strict, it might confine the contractor; on the other hand, if the specifications are too general, it can result in an unrealistic schedule that might create problems (Li, 2003). Therefore, "A balance has to be found on the level of detail of the planning and scheduling specification system. Planning and scheduling specifications that are too brief are likely to cause problems as well as specifications that are too cumbersome or too detailed" (Ballast & Popescu, 2001).

2.4 Project Complexity

Leaf A. Ballast, PE, and Dr. Calin M. Popescu, PE studied a number of planning and scheduling specifications and their relationship with project complexity and contract type. Project complexity was determined based on five factors (Ballast & Popescu, 2001):

- Number of construction activities
- Number of subcontractor
- Number of CSI divisions

- Cost of installed equipment
- Project priority

Two types of contracts were studied: Lump Sum and Cost Reimbursable. The survey results demonstrated a relationship between the complexity of the project and the desirability of planning and scheduling specifications; the more complex the project, owners and contractors lean towards more detailed specifications (Ballast & Popescu, 2001). One of the survey findings is a list of scheduling clauses that "is essential to a well-run project and meets the basic requirements needed for a good planning and scheduling system" (Ballast & Popescu, 2001) See Table 2.4.1.

Lump-Sum Projects		**Cost-Reimbursable Projects**	
1.2	Scheduling Responsibility	1.2	Scheduling Responsibility
1.6	Detailed Network Submission	1.6	Detailed Network Submission
2.1	Network Analysis Technique	2.1	Network Analysis Technique
2.2	CPM Software (or equal) to be Used	2.2	CPM Software (or equal) to be Used
2.3.1	Activity Description	2.3.1	Activity Description
2.3.2	Activity Duration (Time Units)	2.3.2	Activity Duration (Time Units)
2.3.3	Activity Coding System	2.3.3	Activity Coding System
		2.3.4	Responsibility Codes
2.3.8	Work Calendars	2.3.8	Work Calendars
2.5.3	Detailed Network	2.5.3	Detailed Network
3.1	Updating Frequency		

Table 2.4.1: Basic Requirements for a Good P&S Specification

2.5 Scheduling Specifications

Schedule specifications consist of a number of clauses; Leaf A. Ballast, PE, and Dr. Calin M. Popescu developed an extensive list of scheduling specifications divided into three sections: general organization and responsibility, scope and product, and progress monitoring and updating. The clauses are listed in Table 2.5.1 (Popescu, 2001).

Clauses
1. General Organization and Responsibility
1.1 Description, References, Standards

Clauses
1.2 Scheduling Responsibility
1.3 Minimum Qualifications of Planning and Scheduling Staff
1.4 Training Requirement for Contractor, Subcontractor, Owner
1.5 Preliminary Network Submission Deadline
1.6 Detailed Network Submission Deadline
1.7 Review and Approval Process
1.8 Cost of Planning/Scheduling and Monitoring
1.9 Progress Payments for Planning/Scheduling and Monitoring
1.10 Subcontractor Input
1.11 Contractor's Scheduling Plan
1.12 Planning/Scheduling and Monitoring Audits
1.13 Confidentiality/Schedule Ownership
1.14 Computer Access and Security
2. Scope and Products
2.1 Network Analysis Technique
2.2 CPM Software (or equal) to be Used
2.3 Activity Related Information
2.3.1 Activity Description
2.3.2 Activity Duration (Time Units)
2.3.3 Activity Coding System
2.3.4 Responsibility Codes
2.3.5 Activity Level Resources
2.3.6 Project Level Resources
2.3.7 Activity Costs
2.3.8 Work Calendars
2.4 Required Level of Network Detail
2.4.1 Maximum Activity Duration
2.4.2 Maximum Activity Costs
2.4.3 Minimum Number of Activities in the Completed Network
2.4.4 Minimum Number of Activities in the Preliminary Network
2.5 Network Diagram Scope
2.5.1 Summary Schedule
2.5.2 Preliminary Network
2.5.3 Detailed Network
2.6 Project Breakdown Structure
2.7 Milestones and Imposed Dates
2.8 Activity Sorting Requirements
2.9 Drafting Requirements
2.10Required Reports for Initial Submittal of Completed Network

Clauses
2.11Specialized Network Analysis
2.11.1 Resource Aggregation
2.11.2 Resource Leveling
2.11.3 Resource Allocation Optimization
3. Progress Monitoring and Updating
3.1 Updating Frequency
3.2 Updating Participation
3.3 Updated Network Approval
3.4 Updating Turnover Time
3.5 Updating Records and Reporting
3.6 Float Management
3.7 Change Orders
3.7.1 Change Order Representation
3.7.2 Change Order Summary/Documentation
3.7.3 Timing of Change Order Incorporation
3.8 Required Reports at Each Update

Table 2.5.1: Planning and Scheduling Specification Clauses

Dr. Win suggested two levels of scheduling requirements: Level one represents general requirements and Level two represents specific requirements for task by their discipline (Li, 2003). Paul Levin recommended 4 sections in a schedule specification: General, Administrative, Technical, and Time Analysis (Levin, 2006). Figure 2.5-1summarizes these sections.

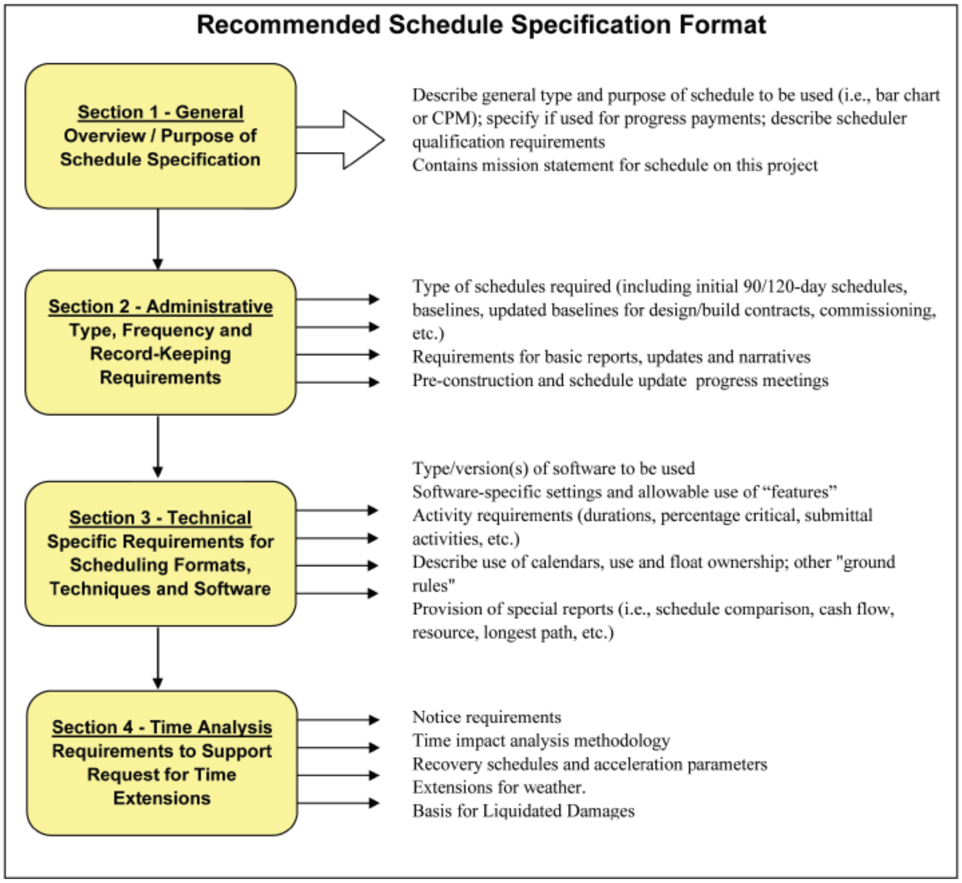


Figure 2.5-1: Recommended Schedule Specification Format

Patricia D. Galloway, Ph.D. drafted a questionnaire surveying owners and contractors (alongside other stakeholders) in the construction industry; a total of 430 responses. The survey revealed that there is an immediate need for CPM scheduling standards. Over 92% of the respondents expressed the need for a best practices guide developed by any agency to help all parties develop CPM schedules (Galloway, 2006). The survey also showed that 47.6% of the owners required CPM scheduling on all projects. Of those requiring CPM scheduling, 72.5% include CPM provisions in their contracts, "Owners were split on whether the CPM specification in their contracts was a standard specification or was customized for a particular project" (Galloway, 2006). 50% of contractors noted that CPM schedules have been requested in their contracts. 67% of contractors indicated that they would develop a CPM schedule even if it wasn't required .The same survey showed that 80% of contractors indicated that they rely on CPM schedules for making execution decisions on the project execution. The main reason for using CPM schedules, from the contractors' perspective, is shown in Figure 2.5-2 (Galloway, 2006):

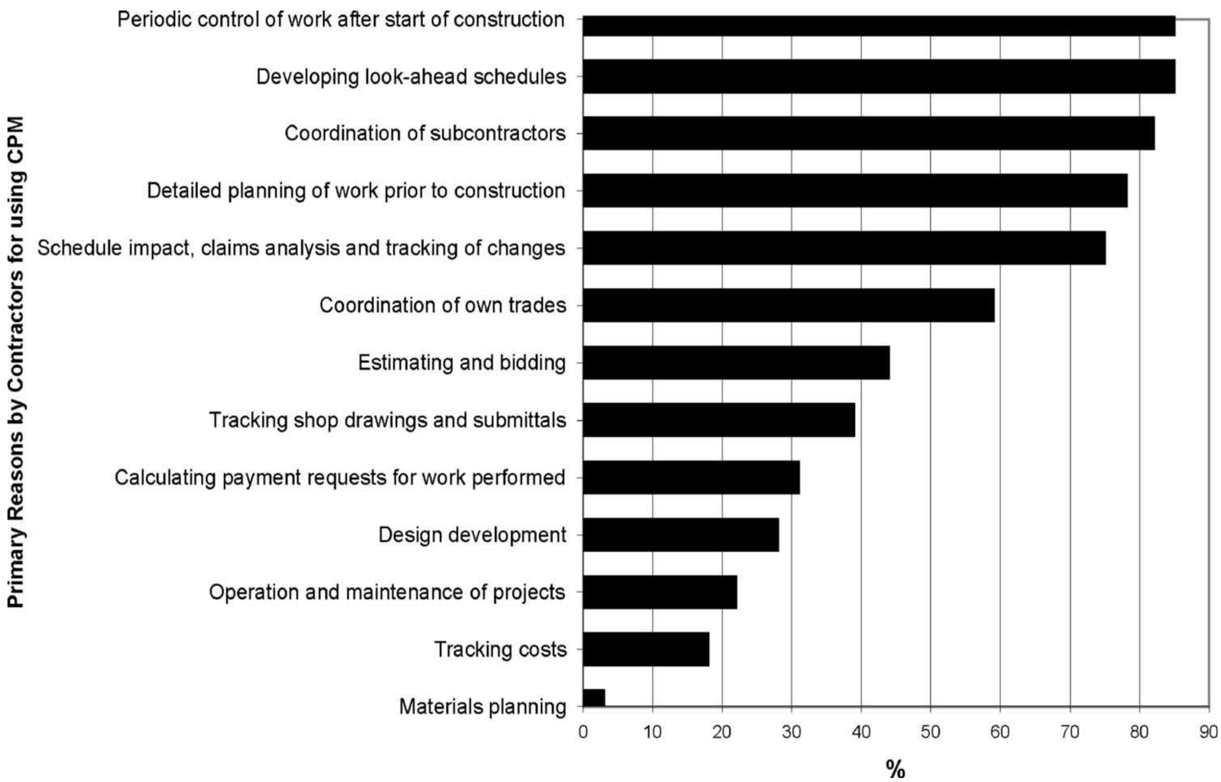


Figure 2.5-2: Primary Reasons for Contractors Use of CPM

The survey conducted by Patricia D. Galloway, Ph.D. found many advantages and disadvantages for CPM schedules from the point of view of owners and contractors as follows (Galloway, 2006):

Owner CPM advantages:

- Owners can try different scenarios in case of change orders or delays (If submitted digitally)

- CPM can be summarized into a Gantt chart which makes it easier to manage and understand

Owner CPM disadvantages:

- Construction managers and project managers lack the experience in CPM software which limits their ability in understanding the schedule.
- The contractor can easily manipulate the logic in the schedule.
- Owners felt that CPM schedules can be costly for small projects.

Contractor CPM advantages:

- Improves planning, scheduling, and controls
- Improves communication
- Improves project understanding

Contractor CPM disadvantages:

- Schedule logic abuse is a main concern
- Requires a lot of effort to implement
- Requires scheduling specialists
- Does not reflect what is implemented on site.

In another study, the accuracy of schedules was the main point. Many progress schedules are inaccurate due to the lack of updating and detail (Mattila, 2004). Schedules should specify the frequency of schedule updates, the use of computers software in updating, and what variables need to be updated (Mattila, 2004). The specifications should also state the events that trigger schedule revisions and the modifications needed when revisions are requested (Bradley, 2005). Galloway's survey showed that almost all owners required schedule updating, with 77% requiring monthly updates. 84% of owners required schedule revisions in the event of schedule delays or change orders (Galloway, 2006).

Galloway's survey revealed that approximately 50% percent of the Owners require resource loading. 70% of owners were concerned with manpower loading on activity, while only 50% of the owners required cost loading. On the other hand 40% of the contractors did not find either manpower or cost loading useful. 30% of contractors believed that resource loading is useful; other contractors felt it was too much work and still others believed it was project specific (Galloway, 2006). Bradley suggests that as a minimum a schedule should be loaded with labors hours and equipment. Bradley also argued that the main reason owners request cost loading is that it prevents contractors from exaggerated front loading (Bradley, 2005).

The technological advances in schedule software and computer hardware directly influences schedule specification therefore schedule specifications have to be flexible (Levin, 2006). Over 64% of owners used Primavera as their scheduling software while 22% used MS project (Galloway, 2006). Owners were concerned that "while their preference was to use Primavera as the required software specified, that their experience was that many contractors still use MS Project which has limitations and does not allow the owner to perform the monitoring that it desires throughout project execution" (Galloway, 2006). The survey concluded by stating "While Primavera software is the number one choice among the stakeholders, it is believed to be complex and difficult to understand, thus increasing the cost to the project" (Galloway, 2006).

2.6 Conclusion

The inconsistencies in scheduling standard specifications in the same industry have frustrated contractors; which is evident in state DOT scheduling specifications. Contractors lean towards open specifications while owners prefer closed specifications. Literature shows that what the construction industry needs is a balanced specification that is neither too closed nor too open, satisfying both owners and contractors. This triggered organizations such as the PMI and AACEI to develop scheduling best practices; the PMI went further by defining parameters and components for a minimally acceptable schedule. Since schedules are the number one indicator of construction delays (Elnagar & Yates, 1997), many entities have realized that scheduling specifications need to be enhanced and updated. This research will review the scheduling specifications drafted by DOTs around the United States, compare them with the available best practices, and then try to fill the gaps with the results of a questionnaire aimed at industry professionals.

3 RESEARCH METHODOLOGY

3.1 Content Review

The first step of this research effort was a full (all states in the United States) content review of state DOT Standard Specifications, Construction Manuals, Contract Administration Manuals, Supplemental Specifications, and standard special provisions (hereafter referred to as scheduling documents). The documents were obtained through the DOTs' websites. All states published their standard specifications online; however, not all states published construction manuals, contract administration manuals, supplemental specifications, or standard special provisions. Appendix A lists all the publications used from each state.

The scheduling documents contain provisions concerning scheduling specifications- for example, the scheduling method (e.g. simple bar chart, CPM, etc...), the maximum activity duration, the allowed logical relationships, the type of software used (Primavera, MS project), etc.- The content review included organizing, categorizing, and quantifying the data using Microsoft Excel.

Two types of specifications were encountered: open and closed. In the case of open specifications, little or no details were included in the scheduling provisions. In order to further investigate the scheduling practices of such specifications, this research acquired the special provisions of 90 projects in 20 different states. DOT websites rarely provide project documents, so in order to acquire these documents some DOTs had to be contacted by e-mail and phone. Another method was Bid Express, which is a website that some DOTs use to announce bid information (e.g. project documents) and accept online bids.

DOTs are responsible for many different types of projects (e.g. resurfacing, bridges, highway construction etc.). This research confined the sample to paving, resurfacing, rehabilitation, highway construction, bridge construction, grading, and widening projects. Four projects were selected in each state. Two projects were selected with a cost of less than $10 million and the other two were selected with a total cost of more than $10 million. The project costs ranged from $1 million to $160 million. Appendix B summarizes the name, cost, and a brief description of the project sample selected for this research.

3.2 Comparative Analysis

Many organizations have realized the inefficiencies in scheduling specifications in the construction industry; the Association for the Advancement of Cost Engineers International (AACEI) and the Project Management Institute College of Scheduling (PMICOS) have published scheduling best practices that aim at enhancing project schedules in the industry. The Unified Facilities Guide Specifications (UFGS), one of the better closed specifications, as used by the U.S. Army Corp of Engineers (USACE), Naval Facilities Engineering Command (NAVFAC) and the Air Force Civil Engineer Support Agency (AFCESA), has also been involved in updating their scheduling best practices (Levin, 2006).

The PMIs “Practice Standard for Scheduling”, published in 2007 divided the schedule model components (e.g. start date, relationships, float etc.) into Pre-development, Development, and Maintenance and Status Reporting (PMI, 2007). Every schedule component is individually assessed and a “good practice” is developed accordingly. The result of the PMI effort is a list of schedule components that are either required or optional; a “minimally acceptable schedule” (a term used by the PMI), should include all required components listed in Appendix D The PMI also developed a Conformance Index which identifies the level of compliance of a schedule to the PMI standards (PMI, 2007).

Appendix D developed by PMI, can be used to manually assess a schedule’s level of conformance by calculating the Conformance Index. The first and second columns define the components and sub-elements. The third column categorizes the components into required (R) or optional (O). A minimally acceptable schedule should cover all required components; once that is achieved, the Conformance Index can be calculated. When a component is present in the schedule, a point is earned. The ratio of the earned points to the total possible point is the Conformance Index of the evaluated schedule (PMI, 2007). Section 8 of this research assesses the Conformance Index of all state Scheduling Standard Specifications.

The AACEI published a number of recommended practices addressing various cost engineering topics. These standards or guidelines are developed as part of a collective effort by a number of industry professionals. Some of these recommendations have been utilized in this research as follows:

1- 23R-02-Identification of Activities
2- 24R-03-Developing Activity Logic
3- 27R-03-Schedule Classification System

4- 32R-04-Determining Activity Durations

5- 37R-06-Schedule Levels of Detail

6- 49R-06-Identifying the Critical Path

7- 53R-06-Schedule Update Review

8- 54R-07-Recovery Scheduling

9- 61R-10-Schedule Design

10- 64R-11-CPM Schedule Risk Modeling and Analysis Special Considerations

11- 83R-13-Organizational Breakdown Structure and Responsibility Assignment Matrix

The UFGS standard specifications include eleven sections as shown in Appendix E As mentioned above, the UFGS is one of the better closed specifications. "The UFGS has been continually updated and refined since 1999 by a task force led by AACEI member Steven D. Madsen….. This specification is used as the case study for the Wickwire-Groff series of articles on drafting schedule specifications" (Levin, 2006). Wickwire and Groff concluded in their article that: "at the very least, the UFGS is an important reference point for parties faced with the task of drafting an appropriate schedule specification for their project" (Wickwire & Groff , 2003).

The last reference is the "NASA Schedule Management Handbook" published in 2010. The purpose of this guide is "To provide the framework for time-phasing, resource planning, coordination, and communicating the necessary tasks within a work effort. The intent is to improve schedule management by providing recommended concepts, processes, and techniques used within the Agency and private industry" (NASA, 2010).

The content review yielded a number of the scheduling provisions in question. These provisions are then isolated and compared to the industry best practices (AACEI, PMI, UFGS, NASA).

3.3 Survey Questionnaire

The comparative analysis revealed some discrepancies between the best practices and the DOT scheduling documents. State DOT documents also have discrepancies in them; in order to fill this gap and triangulate the conclusions, a survey questionnaire was drafted and sent out to a number of scheduling professionals in state DOTs. The practitioners were selected from different states through DOT websites and project documents. 110 state DOT engineers responded to the survey from 35 different states (including Washington DC) as shown in Table 3.3.1. Approximately 30% of the respondents came from Texas and Michigan. The complete survey is attached in Appendix C Overall percentages were calculated for each question. The survey was voluntary, so it is not possible to assume that the results represent the opinion of all DOT scheduling personnel. Some DOTs refused to comment on the survey and even referred us to their legal departments.

State	# of Respondents
Alabama	1
Alaska	2
Arizona	1
Arkansas	1
California	3
Connecticut	3
Delaware	3
District of Columbia	2
Florida	1
Illinois	8
Iowa	2
Kentucky	1
Louisiana	1
Maine	1
Michigan	13
Minnesota	5
Montana	1
Nebraska	1
Nevada	1
New Hampshire	1
New Mexico	8

New York	1
North Carolina	2
North Dakota	1
Ohio	1
Oregon	1
South Dakota	3
Tennessee	3
Texas	21
Vermont	1
Virginia	2
Washington state	6
West Virginia	1
Wisconsin	5
Wyoming	2

Table 3.3.1: Survey Respondents by State

3.4 Analysis Format

The research divided the schedule components into three sections: Basic Schedule Components, Schedule Development, and Schedule Management. Each component is then evaluated in four different sections; all of which are explained in the following chapters:

1- ***Common Practices***: this section discusses the recommended industry scheduling standards (AACEI, PMI, UFGS, NASA)

2- ***State Standard Specification***: this section investigates and quantifies DOT Standard Specifications regarding each component.

3- ***State Special Provisions***: this section investigates and quantifies DOT Standard Special Provisions and Project Special Provisions regarding each component.

4- ***Schedule Specification Survey***: this section discusses the findings of the survey

5- ***Summary of Recommendations***: Based on sections 1-4 a recommended practice is developed in this section.

4 Schedule Significance and Use

In order to gauge the general attitude towards DOT scheduling practices, the first part of the survey asked DOT personnel general questions regarding the importance of project schedules and the shortcomings of current construction schedules.

Table 3.4.1 summarizes the survey results on the importance of project schedules. It is evident that the surveyed DOT personnel value construction schedules and their importance to establish deliverables, monitor and measure progress, and manage change conditions. One interesting result is item#4 in the matrix; when the respondents were asked if they believe that construction schedules can help pressure the contractor to finish on time and under budget, approximately 51% agreed, 16% disagreed, and 33% were neutral. From these results, one can conclude that DOTs value construction schedules but have some doubts on the schedules role to pressure contractors.

	Question: Some managers consider construction schedules as valuable management tools. Your perception about construction schedules could be explained as follows, they ...	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Help establish deliverable goals (milestones)	0.91%	0.91%	3.64%	49.09%	45.45%
2	Help monitor and measure progress	0.91%	0.00%	4.55%	47.27%	47.27%
3	Help manage change conditions	0.91%	8.18%	11.82%	50.91%	28.18%
4	Help pressure the contractor to finish on time and under budget	2.73%	13.64%	32.73%	36.36%	14.55%
5	Are not needed; a project can be managed without them	39.09%	45.45%	10.00%	3.64%	1.82%
6	Are not needed because construction sequence changes frequently	38.18%	48.18%	10.91%	1.82%	0.91%
7	Are not needed; stakeholders' timeline questions can be answered in a different way	36.36%	47.27%	10.91%	4.55%	0.91%

Table 3.4.1: Survey Results: Importance of Project Scheduling

Table 3.4.2 summarizes the survey results on DOT scheduling shortcomings. The results are sorted by the most agreed upon scheduling shortcoming. The top five shortcomings are: missing activities, unreasonable activity durations, missing critical paths/activities, inadequate activity groupings, and inadequate activity detail. Most of these items will be discussed in detail in following sections.

Priority	Question: The list of shortcomings that I usually encounter in the contractor's construction schedules include:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Missing activities required by the contract (e.g. procurement, submittals, etc...)	2.73%	10.91%	13.64%	59.09%	13.64%
2	Unreasonable activity duration.	0.91%	12.73%	25.45%	46.36%	14.55%
3	Missing critical activities or critical path.	1.82%	20.00%	20.00%	46.36%	11.82%
4	Inadequate grouping of activities (e.g. into phases, WBS, etc...)	1.82%	16.36%	26.36%	50.91%	4.55%
5	Inadequate activity detail (e.g. "footing" instead of "footing formwork")	1.82%	18.18%	24.55%	48.18%	7.27%
6	Not accounting for contract restrictions (e.g. holidays, traffic control restrictions, etc.)	0.91%	25.45%	26.36%	37.27%	10.00%
7	Incomplete network logic (e.g. open ends, no successors, etc.)	0.91%	15.45%	37.27%	35.45%	10.91%
8	Wrong construction sequencing for the construction tasks.	1.82%	24.55%	35.45%	35.45%	2.73%
9	Unreasonable number of activities.	0.91%	23.46%	42.73%	28.18%	4.55%
10	Inadequate sorting based on early start.	1.82%	18.18%	52.73%	23.64%	3.64%
11	Inadequate formatting of the bar colors and the font and size of the activity information.	5.45%	26.36%	43.64%	23.64%	0.91%
12	Illegible printed copies of the schedule submittals.	14.55%	50.00%	24.55%	9.09%	1.82%

Table 3.4.2: Survey Results: DOT Scheduling Shortcomings

5 BASIC SCHEDULE COMPONENTS

This section analyses the scheduling components that are deemed as required activity components in a minimally acceptable schedule by the PMI. Table 3.4.1 lists these components.

Component	Sub-Component
Pre-development	
Activity ID	
Project Name	
Project Schedule ID	
Project Version	
Calendar	
Data Date	
Milestone	
Development	
Activity label	
Unit of Measure	
Duration	
	Activity Original Duration
	Activity Remaining Duration
	Activity Actual Duration
	Activity Baseline Original Duration
	Project Original Duration
	Project Remaining Duration
	Project Actual Duration
	Project Baseline Duration
Relationships	
	Finish to Start
Start Date	
	Activity Early Start Date
	Activity Late Start Date
	Activity Baseline Start Date
	Activity Actual Start Date
	Project Early Start Date
	Project Baseline Start Date
	Project Late Start Date
	Project Actual Start Date
Finish Date	
	Activity Early Finish Date
	Activity Late Finish Date
	Activity Baseline Finish
	Activity Actual Finish Date
	Project Early Finish Date
	Project Late Finish Date
	Project Baseline Finish Date
	Project Actual Finish Date

Component	Sub-Component
Float	
	Total Float
	Free Float
Critical Path	
Baseline Data Date	
Maintenance & Status	
Percent Complete	
	Activity Physical Percent Complete
	Project Physical Percent Complete
Update Cycle	

Table 3.4.1: Required Activity Components in a Minimally Accepted Schedule. (PMI, 2007)

The content review of the DOT Standard Specifications targeting the components listed in Table 3.4.1 yielded in a matrix presented in Appendix F. It should be noted that the matrix does not include all the states because a number of states does not include any activity component requirements in their standard specifications. Similarly, the content review of the project special provision identified in Appendix E, resulted in a matrix shown in Appendix G.

5.1 Activity ID

5.1.1 Common Practices

Activity ID is defined as: "A short unique numeric or text identification assigned to each schedule activity to differentiate that project activity from other activities. The Activity ID is "typically unique within any one project schedule network diagram" (PMI, 2007). As a good practice, it is helpful to have structured activity IDs similar to activity code (PMI, 2007). AACEI recommends as a best practice that each activity should have "A unique alpha/numeric identifier. Should be capable of "smart" or "intelligent" activity identification in which unique activity identifiers are systematically organized to relate to various groupings of schedule activities. Such intelligence allows for enhanced sorting and reporting abilities" (AACEI, 2007). The AACEI also recommended that in the case that an activity is deleted through the schedule update process; the ID should not be reused for any other activity (AACEI, 2008). The UFGS require activity IDs (UFGS, 2008).

5.1.2 State Standard Specifications

A total of 18 states require using activity IDs in a project schedule. Rhode Island Standard Specification includes a very detailed approach to activity IDs. 10 characters have to be included in an activity ID: the first 2 characters are project specific, the following 4 characters refer to the WBS code, and last 4 characters are contractor specific (RIDOT, 2004).

5.1.3 State Special Provision

Twenty one projects included Activity ID provision. Kentucky Pike-Virginia State Line Road (US 460) Grade and Drain (Contract ID – 111307) and Ohio's USR 50 Improvements Project 110255 and USR 20 Resurfacing Project 113003 provided detailed provisions for Activity ID: "Assign each activity a unique identification number. Activity ID length shall not exceed 10 characters. Once accepted, the Activity ID shall be used for the duration of the project." (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011).

5.1.4 Schedule Specifications Survey

The survey results show that approximately 62.73% of the respondents encouraged the use of Activity IDs as shown below

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Activity ID	69	62.73%

Table 5.1.1: Survey Results: Activity ID

5.1.5 Summary and Recommendations

Activities shall be coded with a unique alphanumerical identifier; it is recommended that the Activity ID correlates with activity codes.

5.2 Project Name

5.2.1 Common Practices

A short phrase or label for each project, used in conjunction with the project identifier to differentiate a particular project from other projects in a program. Sometimes known as project title" (PMI, 2007).

5.2.2 State Standard Specifications

Although it seems like a basic thing to have in a project schedule, only 13 states specifically require the inclusion of the project name on a project schedule. Rhode Island Standard Specifications include a standard for naming the project as follows (RIDOT, 2004):

- Preliminary Project Schedule: PS00
- Baseline Schedule: BL00
- Bi-Weekly Status Schedules: Uxxx
- Recovery Schedule: Rxxx

5.2.3 State Special Provision

Seventeen projects require the contractor to include the project name on the submitted schedule. Kentucky Pike Project required the contractor to include the following: Project Number, County, and Route Number (Kentucky DOT, 2011). See Appendix G for a complete list of projects requiring project names included in the schedule submittal.

5.2.4 Summary and Recommendations

Schedule shall clearly show the Project Name.

5.3 Project Schedule ID

5.3.1 Common Practices

Project Schedule ID is defined as: "A short unique numeric or text identification assigned to each schedule model to differentiate that schedule model from others" (PMI, 2007).

5.3.2 State Standard Specifications

Twelve states require including Schedule IDs. See Appendix F for a complete list of State Standard Specifications requiring Schedule IDs.

5.3.3 State Special Provision

Seventeen projects require the contractor to include the project ID on the submitted schedule. South Carolina Standard Special Provision includes the following provision: "When submitting schedules to the SCDOT, the Contractor shall assign file names to each schedule file (baseline and updates) according to the following conventions (dates are YYMMDD)" (SCDOT, 2007):

Type of Schedule Submitted	Baseline	Update
File Name Convention	[File Number]b[Data Date]	[File Number]u[Data Date]
File Name Example	32.82571b060201	32.82571u060201

Table 5.3.1: South Carolina Standard Special Provisions 2007: Project ID

5.3.4 Summary and Recommendations

The project schedule shall have a unique Identification number. At a minimum the ID shall include the DOT contract number and the data date.

5.4 Project Version

5.4.1 Common Practices

Project version is defined as "A designation of the instance of a schedule. Examples include; as of date, revision number, agreed versioning codes, among others" (PMI, 2007).

5.4.2 State Standard Specifications

Nine states require including project version. See Appendix F for a complete list of State Standard Specifications requiring Project Version to be included in the schedule title block.

5.4.3 State Special Provision

Eleven projects require the contractor to include the project version on the submitted schedule. See Appendix G for a complete list of projects requiring project version included in the schedule submittal.

5.4.4 Summary and Recommendations

The Project Version should be part of the Project ID. A good example is South Carolinas Standard Special Provisions approach as shown in Table 5.3.1.

5.5 Calendar

5.5.1 Common Practices

A Project Calendar is defined as "A calendar of working days or shifts that establishes those dates on which schedule activities are worked and nonworking days that determine those dates on which schedule activities are idle. Typically defines holidays, weekends, and shift hours. The calendar initially assigned to schedule activities and resources" (PMI, 2007). A Project Calendar constitutes the default calendar assigned to all activities. Project Calendars can be replaced by activity specific calendars. Major scheduling software offer activity calendar assignment options; each activity can be assigned a different schedule. For example, concrete pour activities can be assigned a "5 day week" calendar while the concrete cure activity is assigned a "7 day week" calendar (curing doesn't stop on weekends). The scheduler should pay attention when using multiple activity calendars because it can negatively impact the critical path calculation (AACEI, 2010).

Resource Calendars are defined as: "A calendar of working days and nonworking days that determines those dates on which each specific resource is idle or can be active" (PMI, 2007). NASA requires the use of both activity and Resource Calendars where appropriate and emphasizes the importance of calendars in estimating realistic activity/project duration (NASA, 2010). The UFGS require the use of activity calendars that reflect weekends, federal holidays, and adverse weather days as non-working days (UFGS, 2008).

5.5.2 State Standard Specifications

Eighteen states include calendar provisions in their standard specifications. Some states capture the intent of the project calendar; for example, the state of Hawaii include the following provision: "The schedule shall account for normal inclement weather, unusual soil or other conditions that may influence the progress of the work, schedules, and coordination required by any utility, off or on site fabrications, and other pertinent factors that relate to progress" (HDOT, 2005). The state of Montana includes similar specifications as follows: "[project schedule shall account for] Work days per week, holidays, and number of shifts per day, hours per shift and major equipment to be used" (MDT, 2006). Rhode Island includes the most detailed schedule calendar specification, defining a number of calendars as follows (RIDOT, 2004):

- Calendar 1- 5-day workweek (includes Holidays and Winter Shut Down)
- Calendar 2- Procurement
- Calendar 3- 6-day workweek (includes Holidays and Winter Shut Down)
- Calendar 4- 7-day workweek (includes Holidays and Winter Shut Down)
- Calendar 5- 5-day workweek (includes Holidays and No Winter Shut Down)
- Calendar 6- 6-day workweek (includes Holidays and No Winter Shut Down)
- Calendar 7- 7-day workweek (includes Holidays and No Winter Shut Down)
- Calendar 8- Interstate 5-day workweek (includes Holidays & Winter Shut Down)
- Calendar 9- Interstate 6-day workweek (includes Holidays & Winter Shut Down)
- Calendar A- Seeding
- Calendar B- Wetland Seeding
- Calendar C- Plants B&B

5.5.3 State Special Provision

Twenty projects require the utilization of calendars in the project schedule. Indiana project # 33049 and # 33045-A require that "Each activity shall be assigned to an activity calendar. A CPM schedule may utilize more than one activity calendar, but only one activity calendar shall be assigned to each activity. All activity calendars shall be project calendars as classified by Primavera." (Indiana DOT, 2011) (Indiana DOT, 2010). Both projects also require that "Activity calendars associated with construction activities shall include a minimum number of non-work days for the months of April through November, inclusive, equal to the number of above normal inclement weather days shown in 101.02. However, the number of non-work days included in calendars associated with bridge, traffic, and road construction activities shall be equal to or greater than the tabulated value related to B, T, or R contracts respectively, regardless of the type of contract involved" (Indiana DOT, 2011) (Indiana DOT, 2010). Similarly, a number of projects in Florida - T1322, T2376, and T4299- require that "All activities shall be assigned to a specific calendar within the software. Specific calendars will be defined within the software to include planned work days. These calendars will include both Contractor and Contract defined holidays and suspension days as non-workdays" (FDOT.a, 2010) (FDOT.c, 2010) (FDOT, 2010).

State of Washington project # 7936 gave the contractor freedom in choosing activity calendars, but "If multiple calendars are applied to the progress schedule, the contractor shall submit a written narrative describing each ones purpose" (WSDOT, 2010).

5.5.4 Summary and Recommendations

Calendars shall be assigned to each activity. All calendars shall account for holidays, weather, and state specific shutdowns. As a minimum, the contractor shall utilize the following calendars:

- 5-day week calendar including holidays
- 6-day week calendar including holidays
- 7-day week calendar including holidays
- 7-days week calendar without holidays (used for activities such as concrete cure)

5.6 Data Date

5.6.1 Common Practices

Data Date is defined as "The date (including time of day) through which the project status and progress were last determined and reported for analyses, such as scheduling and performance measurements. It is the last past historical date" (PMI, 2007). As a good practice the Data date has to be advanced at equal intervals (PMI, 2007).

5.6.2 State Standard Specifications

Nine states include data date provisions in their standard specifications. A number of states include simple provisions; the State of Washington specification simply requires the contractor to display the data date (WSDOT, 2010). New Jersey Standard Specifications require the contractor to "Use a vertical line to indicate the data date" (NJDOT, 2007). Kentucky limits the data date to "not less than one week prior to the submission date" (KDOT, 2007).The state of Rhode Island defined three types of data dates based on schedule type (RIDOT, 2004):

- Preliminary CPM Schedule –Date of Bid Opening
- Baseline CPM Schedule –Date of Bid Opening
- Status Update Schedules –TBD at Schedule Development Meeting

5.6.3 State Special Provision

Twenty projects require contractors to include the data date in the project schedule. California projects defined the data date as "The day after the date through which a schedule is current. Everything occurring earlier than the data date is "as-built" and everything on or after the data date is "planned." (Caltrans, 2010) (Caltrans, 2011) (Caltrans b, 2011) (Caltrans.C, 2011) (Caltrans.D, 2011) (Caltrans.b, 2011).

5.6.4 Summary and Recommendations

Project schedules shall include the Data Date. In Baseline Schedules the Data Date shall be the Notice to Proceed date. In Updated Schedules the Data Date shall be decided by the DOT Engineer.

5.7 Milestone

5.7.1 Common Practices

A schedule Milestone is a significant point or event in the project. At a minimum, schedules must have Start and Finish Milestones. Milestones must not have any duration or resources (PMI, 2007).

The UFGS requires contractors to show start of project, projected completion, and contract completion Milestones as follows (UFGS, 2008):

a. Project Start Date Milestone: the first milestone (no predecessors) in the schedule; must have a mandatory start constraint equal to the contract award date.
b. Projected Completion Milestone: An unconstrained milestone that indicates the completion of the project.
c. Contract Completion Date Milestone (CCD): The last milestone in the schedule with the projected completion milestone as its only successor. A mandatory finish constraint equal to the current contract completion date shall be applied. "Calculation of schedule updates shall be such that if the finish of the "Projected Completion" milestone falls after the contract completion date, then negative float will be calculated on the longest path and if the finish of the "Projected Completion" milestone falls before the contract completion date, the float calculation shall reflect positive float on the longest path" (UFGS, 2008).

5.7.2 State Standard Specifications

Twenty four states require the use of milestones in the submitted project schedule. New Hampshire requires, as a minimum, the following milestones: "…start date of the project, winter suspensions if planned, project intermediate, and final project completion dates." (NHDOT, 2010). Similarly, Maine Standard Specifications included the following: "Milestones to be included in the schedule include: (A) start of Work, (B) beginning and ending of planned Work suspensions, (C) Completion of Physical Work, and (D) Completion" (Maine DOT, 2002). Rhode Island Standard Specification constrained the contractor to only use "Milestones that are defined in the Contract's Special Provisions" (RIDOT, 2004).

5.7.3 State Special Provision

Twenty two projects require contractors to include milestones in the schedule. Florida projects- T1322, T2376, T4299- included milestone provisions as follows: "At a minimum, the start and finish of each Maintenance of Traffic phase or subphase shall be represented by a milestone activity". (FDOT.a, 2010) (FDOT.c, 2010) (FDOT, 2010).

Kentucky Pike project, Ohio Project 110255 and 113003 included the following detailed milestone provision (Kentucky DOT, 2011) (Ohio DOT.b, 2011) (Ohio DOT, 2011):

- Start Project: The Contractor shall include as the first milestone in the schedule, a milestone named "Start Project". The date used for this milestone is the date the contract is executed and signed by the Department.
- End Project Milestone: The Contractor shall include as the last activity in the project schedule, a milestone named "End Project". The date used for this milestone is considered the project completion date.
- Start Phase Milestone: The Contractor shall include as the first activity for a project phase, an activity named "Start Phase X", where "X" identifies the phase of work.

The Contractor may include additional milestones but, as a minimum, must include all contractual milestones.

- End Phase Milestone: The Contractor shall include as the last activity in a project phase, an activity named "End Phase X" where "X" identifies the phase of work. The Contractor may include additional milestones, but at a minimum contractual milestones.

5.7.4 Summary and Recommendations

At a minimum the schedule shall have a "Start Project" milestone, and a "Finish Project" milestone. No activity shall precede the Start Project milestone, and no activity shall succeed the Finish Project milestone. Other milestones can be used to highlight major project events such the start of phase or the end of a phase.

5.8 Activity Label/Description

5.8.1 Common Practices

Activity Label/Description is defined as "a short phrase or label for each schedule activity used in conjunction with an activity identifier to differentiate that project schedule activity from other schedule activities. The activity description normally describes the scope of work of the schedule activity." (PMI, 2007). The PMI suggests, as a best practice, activity descriptions start with a verb and a unique subject (noun) (PMI, 2007).

NASA requires that "Task descriptions should be concise yet complete. The task description should be complete enough to stand on its own, but concise enough to facilitate ease of use. Acronyms and abbreviations are acceptable as long as they are standardized and used consistently throughout all project documentation" (NASA, 2010).

5.8.2 State Standard Specifications

Twenty nine states require activity descriptions in the project schedule. Idaho Standard Specifications require that "The activity descriptions and durations shall be such that the work is readily identifiable and the progress on each activity can be readily measured." (ITD, 2004). New Jersey further explains the requirement of an acceptable activity description as follows: "Provide activity descriptions to ensure that the start, completion, and intermediate status of the Work is readily identifiable. Do not use nonspecific activity descriptions like "Start," "Continue," "Complete," "X percent," "Y percent," "Z percent," or similar." (NJDOT, 2007).

5.8.3 State Special Provision

Twenty four projects include activity description provisions in their special provisions. Kentucky Pike Project and Ohio Project 110255 and 113003 include the following provision: "Each activity shall have a narrative description consisting of a verb or work function (e.g.; form, pour, excavate) and an object (e.g.; slab, footing, underdrain)" (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011).

Indiana projects # 33045-A and # 33049 include the following provision: "Each activity description shall generally describe the work type and location and shall be associated with only one operation" (Indiana DOT, 2010) (Indiana DOT, 2011).

5.8.4 Schedule Specifications Survey

99.09% of the survey respondents encourage the use of Activity Descriptions.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Activity Description	109	99.09%

Table 5.8.1: Survey Results: Activity Description

5.8.5 Summary and Recommendations

Activity descriptions shall be clear and concise; it is suggested to use a verb and noun to describe the activity (example: install scaffold)

5.9 Activity Original Duration

5.9.1 Common Practices

Activity Original Duration is defined as "The activity duration originally assigned to a schedule activity and not updated as progress is reported on the activity. Typically used for comparison with activity actual duration and activity remaining duration when reporting schedule progress. The activity original duration is normally developed with a reliance on historic data, specialists, resource availability, financial considerations, and volume of work to be performed" (PMI, 2007).

5.9.2 State Standard Specifications

Twenty five states require contractors to define activity durations in their standard specifications. Some states included Maximum and Minimum activity duration provisions; this will be discussed in depth section 6.4 Activity Duration.

5.9.3 State Special Provision

Twenty five state projects require including the activity duration in the schedule submission. Indiana projects # 33045-A and # 33049 define original duration as: "The estimated time, expressed in activity calendar days, required to perform an activity." (Indiana DOT, 2010) (Indiana DOT, 2011)

5.9.4 Schedule Specifications Survey

96.36% of the survey respondents encouraged the inclusion of Activity Durations in the project schedule as shown below.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Activity Duration	106	96.36%

Table 5.9.1: Survey Results: Activity Duration

5.9.5 Summary and Recommendations

The project schedule shall clearly show Activity Original Durations.

5.10 Activity Actual Duration

5.10.1 Common Practices

Activity Actual Duration is defined as "The total number of work periods in calendar units between the activities actual start date of the schedule activity and either the data date of the project schedule, if the schedule activity is in progress, or the activity actual finish date, if the schedule activity is complete" (PMI, 2007).

5.10.2 State Standard Specifications

Only 2 states specifically require contractors to show the actual duration in the project schedule. For states that require reporting actual start and finish dates, calculating the actual duration is easy - but these states (a total of 15) do not specifically require reporting actual durations, therefore they are excluded.

5.10.3 State Special Provision

Nine projects require contractor to report activity actual durations in the Updated Schedule. Washington state project 7936 states that schedule update shall reflect the actual duration of activities (WSDOT, 2010).

5.10.4 Summary and Recommendations

The updated project schedule shall clearly show the Activity Actual Duration

5.11 Activity Baseline Original Duration

5.11.1 Common Practices

Activity Baseline Original Duration is defined as "the total number of work periods in calendar units between the activity baseline start date and activity baseline finish date of a schedule activity as determined by its approved project schedule baseline." (PMI, 2007).

5.11.2 State Standard Specifications

None of the states specifically require activity baseline durations, but it is assumed that if a state's Standard Specification requires the submittal of a baseline schedule and the baseline schedule includes activity durations, then the Standard Specification meets the PMIs "minimally acceptable schedule". A total of 14 states include baseline activity durations provisions in their specifications.

5.11.3 State Special Provision

None of the projects specifically require activity baseline durations. But it is assumed that if a project's Special Provision requires the submittal of a baseline schedule, and the baseline schedule includes activity durations, then the Special Provisions meets the PMI's minimally acceptable schedule. A total of 5 projects included baseline activity durations provisions in their specifications.

5.12 Remaining Activity Duration

5.12.1 Common Practices

Remaining Activity Duration is defined as "The total number of work periods in calendar units, (a) equal to the Original Duration for an activity that has not started or (b) between the Data Date of the project schedule and the Early Finish date of a schedule activity that has an activity Actual Start Date. This represents the time needed to complete a schedule activity where the work is in progress" (PMI, 2007). NASA encourages the use of Remaining Duration as the primary method for updating activities because "This will keep projected finish dates accurate, as well as succeeding linked tasks/milestones properly time phased" (NASA, 2010). The UFGS also requires that activity progress to be shown using remaining duration (UFGS, 2008).

5.12.2 State Standard Specifications

eighteen states require including remaining activity duration in schedule updates.

5.12.3 State Special Provision

Fifteen state projects require the contractor to include the remaining activity duration in the schedule. Indiana projects # 33045-A and # 33049 defined the remaining activity duration as "The estimated time, expressed in activity calendar days, required to complete an activity" (Indiana DOT, 2010) (Indiana DOT, 2011).

5.12.4 Schedule Specifications Survey

56.36% of the survey respondents recommend including Remaining Activity Durations in the project schedule as shown below.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Remaining Activity Duration	62	56.36%

Table 5.12.1: Survey Results: Remaining Activity Duration

5.12.5 Summary and Recommendations

The project schedule shall show the remaining activity duration for each active activity. Remaining Activity Durations shall be used to update the schedule

5.13 Project Duration

5.13.1 Common Practices

The PMI defines four types of durations: Original Duration, Project Remaining Duration, Project Actual Duration and Project Baseline Duration (PMI, 2007). The definitions are the same as the activity durations defined above but applied for the entire project.

5.13.2 State Standard Specifications

Since this is a basic contractual requirement, it is assumed that all DOTs address the project duration; therefore this component is not evaluated.

5.14 Relationships

5.14.1 Common Practices

A Relationship is defined as "a dependency between two project schedule activities, or between a project schedule activity and a schedule milestone. The four possible types of logical relationships are: Finish-to-Start; Finish-to-Finish; Start-to-Start; and Start-to-Finish" (PMI, 2007). NASA recommends including all relationships in the schedule (NASA, 2010). Relationships are discussed in detail in section 6.6 Logical Relationships.

5.14.2 State Standard Specifications

Twenty seven states require that the submitted schedule show activity relationships (Logic, inter-dependencies, or predecessors/successors).

5.14.3 State Special Provision

Twenty one projects include activity relationships provisions in their Special Provisions. Kentucky Pike Project and Ohio Projects 110255 and 113003 include a detailed activity relationship provision as follows (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011):

- All activities, except the first activity, shall have a predecessor(s).
- All activities, except the final activity, shall have a successor(s).
- Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
- Use of finish-to-finish relationship is permitted when both activities are already linked with a start-to-start relationship.

5.14.4 Summary and Recommendations

The project schedule shall show all Activity Relationships.

5.15 Activity Early Start/ Finish Dates

5.15.1 Common Practices

Activity Early Start/Finish Dates is defined as the earliest possible point in time when the schedule activity can begin / be completed (PMI, 2007). The UFGS requires the inclusion of Early Start/Finish Dates in the schedule submission (UFGS, 2008).

5.15.2 State Standard Specifications

Twenty six state standard specifications require the contractor to include activity Early Start/Finish dates in the project schedule.

5.15.3 State Special Provision

Twenty two projects include Early Start/Finish dates provisions.

5.15.4 Schedule Specifications Survey

84.55% and 80.91%of the respondents encourage the use of Early Start and Early Finish dates respectively.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Early start	93	84.55%
2	Early finish	89	80.91%

Table 5.15.1: Survey Results: Early Start/Finish Dates

5.15.5 Summary and Recommendations

The schedule shall clearly show the Early Start/Finish dates.

5.16 Activity Late Start/ Finish Dates

5.16.1 Common Practices

Activity Late Start/Finish dates are defined as the latest possible point in time when the schedule activity can Start/Finish without violating a schedule constraint or delaying the project end date (PMI, 2007). The UFGS requires the inclusion of Late Start/Finish Dates in the schedule submission (UFGS, 2008).

5.16.2 State Standard Specifications

Twenty six states require the contractor to include Activity Late Start/Finish dates in the project schedule.

5.16.3 State Special Provision

Twenty one projects included Late Start/Finish dates provisions.

5.16.4 Schedule Specifications Survey

71.82% and 75.45%of the respondents encourage the use of Late Start and Late Finish dates respectively.

	For schedule submission, i would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Late start	79	71.82%
2	Late finish	83	75.45%

Table 5.16.1: Survey Results: Late Start/Finish Dates

5.16.5 Summary and Recommendations

The schedule shall clearly show the Late Start/Finish dates.

5.17 Activity Actual Start/ Finish Dates

5.17.1 Common Practices

Activity Actual Start/Finish is the point in time at which work actually started/finished on the schedule activity (PMI, 2007). The UFGS requires the inclusion of actual Start/Finish Dates in the schedule submission (UFGS, 2008).

5.17.2 State Standard Specifications

Fifteen states require reporting actual start dates and 20 states require reporting the actual finish dates in the submitted schedule.

5.17.3 State Special Provision

Sixteen projects include actual start provisions and 21 projects required including actual activity finish in the schedule update submission. Indiana projects # 33045-A" and # 33049 include the following provision: "The CPM shall not include any actual start or actual finish dates later than the data date for any activity" (Indiana DOT, 2010) (Indiana DOT, 2011).

Some projects require the submission of an as-built schedule. California projects include this provision: "Submit a final update, as-built schedule with actual start and finish dates for the activities" (Caltrans b, 2011) (Caltrans, 2011) (Caltrans, 2010) (Caltrans b, 2011). Florida and South Carolina projects listed in Appendix G also included as-built schedule provisions.

5.17.4 Summary and Recommendations
The schedule shall clearly show the activity Actual Start/Finish dates.

5.18 Activity Baseline Start/Finish Dates

5.18.1 Common Practices
Activity Baseline Start/Finish dates are the points in time associated with the beginning/completion of the schedule activity in an approved project schedule baseline (PMI, 2007).

5.18.2 State Standard Specifications
Following the same logic as the activity baseline duration, none of the states specifically require activity baseline start/finish dates. But it is assumed that if a state's Standard Specification requires the submittal of a baseline schedule and the baseline schedule includes activity start/finish, then the Standard Specification meets the PMIs minimally acceptable schedule. A total of 14 state's specifications require baseline start/finish dates in the project schedule.

5.18.3 State Special Provision
A total of 11 projects special provisions require baseline start/finish dates in the project schedule submission.

5.19 Project Dates

5.19.1 Common Practices
The PMI defines a number of dates that are required in a minimally accepted schedule: Project Early Start/Finish Dates, Project Late Start/Finish Dates, Project Actual Start/Finish, and Project Baseline Start/Finish Dates (PMI, 2007). The definitions are similar to activity dates but targeting the project as a whole.

5.19.2 State Standard Specifications
Since this is a basic contractual requirement, it is assumed that all DOTs address the project duration; therefore this component is not evaluated.

5.20 Float

5.20.1 Common Practices

There are two types of float: free float and total float. Total float is defined as the amount of time that an activity or milestone can be delayed without affecting the project end date. Free float is defined as the amount of time that an activity or milestone can be delayed without delaying the immediate successor (NASA, 2010).The PMI defines Free Float as "the amount of time that a schedule activity can be delayed without delaying the Early Start of any immediately following schedule activities" (PMI, 2007), and the total float as "The total amount of time that a schedule activity may be delayed from its activity Early Start date or activity Early Finish date without delaying the project end date, or violating a schedule constraint" (PMI, 2007). NASA suggests that no credible schedule management can be achieved without evaluating float times (NASA, 2010). The AACEI defines three additional types of float -Independent float, Junior float, and As-built float- as follows (AACEI, 2010):

- Independent Float – The amount of time that an activity may be delayed without affecting the early start or early finish of any succeeding activities.
- Junior Float – The lowest free float of all preceding activities.
- As-built float is a time estimate of the activity's float at the time the work actually occurred.

Total float is essential when evaluating the critical path (see section 5.21Critical Path). Free float may be used as an indicator of missing relationships (high free float can mean that the activity is not tied to logic) (AACEI, 2010).

The UFGS requires the contractor to include total float values for each activity. The UFGS also requires the submission of a total float report, which is a report of all unfinished activities sorted in ascending order of total float (UFGS, 2008). This type of report is intended to give the engineer a quick understanding of all critical and near critical activities. It should be noted that the UFGS restricts the use of artificial float constraints such as "zero free float" or "zero total float" (UFGS, 2008). The UFGS also addresses float ownership as follows: "Float available in the schedule, at any time, shall not be considered for the exclusive use of either the Government or the Contractor" (UFGS, 2008).

The UFGS allowed the presence of Negative Float due to the specific application of project completion constraints as follows: "Constrain completion of the last activity in the schedule by the contract completion date. Schedule calculations shall result in a Negative Float when the calculated early finish date of the last activity is later than the contract completion date" (UFGS, 2008). The AACEI suggest that negative float shall not be permitted in a baseline schedule. However, negative float may not be avoided in updated schedules especially if the project is late. In this case, the negative float should be properly documented (AACEI, 2008).

5.20.2 State Standard Specifications

Ninteen states require showing total float values and 5 states require showing free float value on the submitted schedule. Almost all states that mention float include a provision stating that float is a shared commodity between the department and contractor and is not for the exclusive use or benefit of either party. Float is available for use by either party as needed to meet contract milestones, intermediate contract completion dates, or the contract completion date. (DelDOT, 2004) (ODOT, 2008) (ITD, 2011) (NMDOT, 2007) (NDOT, 2010) (RIDOT, 2004) (WIDOT, 2011) (NDDOT, 2008) (NJDOT, 2001) (HDOT, 2005).

5.20.3 State Special Provision

Twenty four projects include total float provisions and only 7 include free float provisions.

California introduced a type of float called "state-owned" defined as follows: "State-owned float is considered a resource for the exclusive use of the State. The Engineer may accrue State-owned float by the early completion of review of any type of required submittal when it saves time on the critical path." (Caltrans b, 2011) (Caltrans, 2011) (Caltrans, 2010) (Caltrans.D, 2011) (Caltrans.b, 2011)

Negative float is generally generated when activity start or finish times are constrained or when the float is constrained. Negative float can also be generated when updating a schedule that is behind. The states of Ohio, Kentucky, and Indiana projects specify that any generated negative float will not be a basis for requesting any time extensions (FDOT.a, 2010) (FDOT.c, 2010) (FDOT, 2010) (Indiana DOT, 2011) (Indiana DOT, 2010) (Kentucky DOT, 2011) (Ohio DOT.b, 2011) (Ohio DOT, 2011). 9 projects stated that negative floats will not be allowed, and that any schedule with negative floats will be rejected (Caltrans, 2010) (Caltrans, 2011) (Caltrans b, 2011) (Caltrans.C, 2011) (SCDOT.a, 2011) (SCDOT, 2011) (SCDOT, 2010) (SCDOT.c, 2011) (Kentucky DOT, 2011)(see Appendix G).

Florida, Ohio, and Kentucky include an identical provision concerning float suppression techniques as follows:

"Use of float suppression techniques, such as preferential sequencing (arranging critical path through activities more susceptible to Department caused delay), special lead/lag logic restraints, zero total or free float constraints, extended activity times, or imposing constraint dates other than as required by the contract, shall be cause for rejection of the project schedule or its updates. The use of Resource Leveling (or similar software features) used for the purpose of artificially adjusting activity durations to consume float and influence the critical path is expressly prohibited" (FDOT.a, 2010) (FDOT.c, 2010) (Kentucky DOT, 2011) (Ohio DOT, 2011) (Ohio DOT.b, 2011) (FDOT, 2010) (Ohio DOT, 2010) (Ohio DOT.b, 2010).

5.20.4 Schedule Specifications Survey

78.18% and 54.55% of the respondents encourage the use of Total Float and Free Float respectively.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Total float	86	78.18%
2	Free float	60	54.55%

Table 5.20.1: Survey Results: Activity Components

5.20.5 Summary and Recommendations

The project schedule shall clearly show the Free and Total Floats for each activity. Negative float is not allowed in the baseline schedule. It is acceptable for Schedule updates to have negative float but shall be documented in the schedule narrative. Float shall be considered a shared commodity between the Owner and Contractor.

5.21 Critical Path

5.21.1 Common Practices

The Critical Path is defined as "the sequence of schedule activities determines the duration of the project. Generally, it is the longest path through the project" (PMI, 2007). The AACEI suggests that there is no absolute standard for calculating CPM schedules; it all depends on understating the algorithm of the software used. Some of the most frequently used methods to calculate the critical path are listed below (AACEI, 2010):

- Lowest Total Float: The activities with the lowest total floats.
- Negative Total Float: Any activity with a negative total is considered critical.
- Longest Path: This is the main stream method of calculating the critical path and is recommended for multiple calendar schedules.

Sometimes the critical path is influenced by a schedule milestone or a date constraint. In order to establish a meaningful critical path, schedulers should pay attention to the following (PMI, 2007):

- Activity relationships and logic.
- Open ends; No open ends are allowed other than project start and finish milestones.
- Logic constraints; constraints must be restricted to only those that represent external or internal events that cannot be effectively addressed with activity logic.

NASA recommends that "after each update cycle of the IMS, the critical path shall be identified and compared to the previous month's critical path. In making this comparison, it is important to clearly understand what has changed, why it has changed, and again validate that the sequence of tasks passes the common sense test" (NASA, 2010). Schedule updates can lead to out-of-sequence activities, which occur when the actual progress of an activity starts before the logic is met; for example, two activities, A & B, have a finish-to-start relationship, and the work on activity B actually started before activity A is complete. It is essential that the scheduling software is capable of capturing the critical path implications of out of sequence activities (AACEI, 2010). The UFGS requires schedule calculations to retain the logic between predecessors and successors and therefore prohibit progress override (UFGS, 2008). The AACEI on the other hand recommended the following methods to override schedule logic with actual progress (AACEI, 2010):

- Retained Logic – The data date and all logical relationships are considered and out-of-sequence work is automatically suspended until all logically preceding work is complete.
- Progress Override – The data date is considered but any predecessor relationship to the out of sequence activity is completely ignored by the CPM calculations. Note that this does not prevent the software from displaying such relationships as if they were still was in effect.

- Actual Dates – This is a hybrid of the above two methods that retains the predecessor logic if the activity has started out of sequence but ignores it if the out of sequence activity finishes.
- Constraining All Early Activities – Microsoft Project optionally allows the scheduler to set a status date and then change the CPM calculation options to assign start no earlier than the status date constraints to all unfinished activities that would otherwise show planned work before this date.
- Ignoring the Data Date – By default Microsoft Project ignores status date considerations, thus ignoring the ramifications of out of sequence progress. This RP recommends against using any CPM calculations for analysis that do not take into consideration of the effects of the status date to planned work

Another important consideration is near-critical activities: "While critical path activities require elevated management attention to ensure timely project completion exclusively concentrating only on critical activities is unwise" (AACEI, 2010). Near critical activities are defined as activities close to being critical but are not; for example activities with a total float of 1. These activities should be monitored similarly to critical activities. The following are two methods for identifying near critical activities (AACEI, 2010):

- Near critical float: define a total float range above the critical path float.
- Near longest path: activities with float values close to the longest path.

Multiple critical paths can occur in project schedules; some of the reasons for this are (AACEI, 2010):

- Having two paths in the schedule with exactly the same overall duration

- The use of Activity Constraints
- Combining multiple schedules into one master schedule. This causes the master schedule to show each of the sub-schedules critical paths, along with the master schedule's critical path.

5.21.2 State Standard Specifications

Twenty two states require the contractor to show the critical path on the submitted schedule and/or identify the critical activities. Idaho Standard Specifications define the critical path as follows: "The critical path will be the path with the least amount of total float. The critical path does not have to follow the same logic path from start to finish and does not have to have zero total float." (ITD, 2004). Hawaii Standard Specifications require the contractor to clearly show the Critical Path as follows: "The critical path clearly marked in red or marked in a manner that makes it clearly distinguishable from other paths and is acceptable to the Engineer" (HDOT, 2005). The state of Rhode Island, in addition to showing the critical path, requires identifying the near critical activities (within 10 days of the critical path) (RIDOT, 2004).

The state of Delaware restricts the contractor from submitting a schedule with multiple critical paths: "The submitted activity sequence and durations must generate a CPM schedule having only one critical path; a schedule with multiple critical paths will not be allowed" (DelDOT, 2004). The state of Washington, on the other hand, allows it: "It is not unusual to see dual critical paths on a CPM schedule, nor is it prohibited. Multiple critical paths are generally very short in duration. Lengthy occurrences of parallel critical activities should be cause for careful scrutiny of activity durations and sequencing" (WSDOT, 2010).

5.21.3 Schedule Specifications Survey

The survey included a question regarding multiple critical paths as shown in Table 5.21.1. Approximately 63% of the respondents approve of multiple critical paths while half of 63% suggested informing the engineer when multiple critical paths occur.

	The best policy for contractors using multiple critical paths.	Percentage
1	Contractor should be allowed to use them	30%
2	Contractor should avoid them but inform the engineer if used	32.73%
3	Contractor should be prohibited from using them	37.27%

Table 5.21.1: Survey Results: Multiple Critical Paths

5.21.4 State Special Provision

24 projects require the contractor to identify the critical path on the submitted schedule. California projects include the following provision: "Clearly show the primary paths of criticality using graphical presentation" (Caltrans b, 2011) (Caltrans, 2011) (Caltrans, 2010) (Caltrans.D, 2011) (Caltrans.b, 2011). Kentucky Pike Project and Ohio Projects 110255 and 113003 include the following provision: "Identify the critical path of the project on the bar chart in red" (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011). Similarly, Washington projects included the following provision: "Regardless of which format used, the schedule shall identify the critical path" (WSDOT, 2007) (WSDOT.e, 2009) (WSDOT, 2007).

5.21.5 Summary and Recommendations

The project schedule shall clearly identify critical activities and the critical path. The critical path shall be calculated using the longest path. Multiple critical paths are allowed and shall be documented in the schedule narrative.

5.22 Percent Complete

5.22.1 Common Practices

Based on PMI, there are two ways for reporting and calculating percent completion for a certain activity: activity duration percent complete and activity physical percent complete. Activity duration percent complete is defined as "An estimate, expressed as the percentage that the activity actual duration represents, of the activity total duration for a schedule activity that has work in progress" (PMI, 2007). Activity duration percent complete does not give an actual representation of the amount of work done. If Earned Value Management is not adopted, activity duration percent complete serves as a rough approximation (PMI, 2007). The AACEI also advises against using the duration percent completion for the same reasons stated above. Instead, the AACEI recommends the use of "remaining duration" to report activity status (AACEI, 2008).

Activity physical percent complete is defined as "An estimate, expressed as a percent, of the amount of work that has been completed on a schedule activity, measured in terms of either physical work progress or via the earning rules of earned value management" (PMI, 2007). The project scheduler should determine the method used to report percent completion (such as 50/50 rule, actual quantities, by milestone etc.). The PMI recommends the use of earned value based percent completion methods because it's less subjective (PMI, 2007).

The UFGS allows the contractor to report an activity as complete even if it's not at 100% completion (punch list, inspection etc…)in order to allow the flow of successor activities (UFGS, 2008).

5.22.2 State Standard Specifications

Ninteen states require contractors to include the percent completion in their updated schedules.

5.22.3 State Special Provision

Twenty one projects require contractors to show activity percent completion on the project schedule.

5.22.4 Schedule Specifications Survey

71.82% of the respondents recommend identifying the activity percent completion in the project schedule.

	For schedule submission, I would encourage following activity information to be available:	Frequency (out of 110 respondents)	Percentage
1	Percent completion (by quantity or cost)	79	71.82%

Table 5.22.1: Survey Results: Percent Completion

5.22.5 Summary and Recommendations

The project schedule shall clearly show the percent complete for each activity. Activity percent completion shall reflect the physical percent completion not the duration percent completion.

5.23 Update Cycle

5.23.1 Common Practices

Update Cycle is defined as "The regular interval at which the project activities have their status reported to the current known state" (PMI, 2007). As a best practice, the PMI suggests that update cycles shall not exceed one month. The PMI also suggests that the frequency of the updates shall be influenced by the rate of change in the project; if the project at hand is low-risk in nature a monthly or bimonthly cycle is appropriate, whereas high-risk project updates may be required hourly (PMI, 2007). In general, the project management team, using the expertise of the scheduler, should determine the appropriate frequency for performing updates and at what point these updates should occur; these decisions can be affected by many factors such as the timing of review meeting and payment cycles (PMI, 2007).

The NASA Scheduling Management Handbook mentions that when prime contractors are involved in a process they usually provide monthly schedule updates, which "limit the capability of providing management with a fully integrated and updated IMS to a monthly cycle" (NASA, 2010). So NASA suggests that the adoption of weekly or bi-weekly updates can be more beneficial to the project (NASA, 2010).

The UFGS requires that the contractor submit schedule updates on a monthly basis, but the contracting officer can request the issuance of an update at any point depending on the progress of work (UFGS, 2008).

Schedule Updates are discussed in depth in section 7.6.

5.23.2 State Standard Specifications

Thirty states require a specific update cycle. Different states require different updating cycles, ranging from 1 week to 90 days. Alaska specifies that the contractor should report the progress on each pay item weekly (AKDOT, 2010), whereas Tennessee requires the contractor to submit schedule updates at least every three months (90 days) (TDOT, 2006). Most states adopt monthly schedule updates and some adopt two month update cycles. The submittal frequency is summarized in Table 5.23.1.

<table>
<tr><th>State</th><th>Update Cycle</th></tr>
<tr><td>Alaska</td><td>1 week</td></tr>
<tr><td>Delaware</td><td rowspan="5">2 weeks</td></tr>
<tr><td>District of Columbia</td></tr>
<tr><td>Hawaii</td></tr>
<tr><td>Iowa</td></tr>
<tr><td>Rhode Island</td></tr>
<tr><td>California</td><td rowspan="22">1 month</td></tr>
<tr><td>Colorado</td></tr>
<tr><td>Florida</td></tr>
<tr><td>Idaho</td></tr>
<tr><td>Indiana</td></tr>
<tr><td>Kansas</td></tr>
<tr><td>Kentucky</td></tr>
<tr><td>Maryland</td></tr>
<tr><td>Montana</td></tr>
<tr><td>Nebraska</td></tr>
<tr><td>Nevada</td></tr>
<tr><td>New Hampshire</td></tr>
<tr><td>New Jersey</td></tr>
<tr><td>New Mexico</td></tr>
<tr><td>New York</td></tr>
<tr><td>Oklahoma</td></tr>
<tr><td>Oregon</td></tr>
<tr><td>Utah</td></tr>
<tr><td>Washington</td></tr>
<tr><td>West Virginia</td></tr>
<tr><td>Wisconsin</td></tr>
<tr><td>Wyoming</td></tr>
<tr><td>Arizona</td><td>2 months</td></tr>
<tr><td>Tennessee</td><td>3 months</td></tr>
</table>

Table 5.23.1: DOT Standard Specifications: Schedule Update Cycles

5.23.3 State Special Provision

Twenty three state projects include schedule update provisions. Schedule updates cycles ranged from one week to one month as shown in Table 5.23.2. In general, the special provisions of the reviewed projects do not offer anything different than what is mentioned in the Standard Specifications. Some states, such as California, expanded the schedule update provisions and added more details in the Special Provisions. For example the state of Indiana includes the following provision:

"The first monthly update CPM schedule shall be submitted by the 7^{th} of the month following acceptance of the baseline CPM schedule. Each succeeding monthly update CPM schedule shall be submitted by the 7^{th} of each succeeding month. The CPM schedule data date shall be the last date of the month prior to submittal. The CPM shall not include any actual start or actual finish dates later than the data date for any activity. If the 7^{th} day of an individual month is a Saturday, Sunday, or a holiday on which work has been suspended, the monthly update CPM schedule shall be submitted by the first business day following the 7^{th}" (Indiana DOT, 2010).

State	**Provision / Project**	**Update Cycle**
California	Contract No. 07-138204	1M
California	Contract No. 03-3797U4	1M
California	Contract No. 12-0G3304	1M
California	Contract No. 07-241304	1M
California	Contract No. 05-0T3604	1M
Florida	Contract T2376	1M
Florida	Contract T1322	1M
Florida	Contract T4299	1M
Indiana	Contract # 33045-A	1M
Indiana	Contract # 33049	1M

Kentucky	109-PIKE, CONTRACT ID - 111307	2W
Ohio	Project Number: 110255	1M
Ohio	Project Number: 113003	1M
Oregon	SPS09350	1M
Oregon	SPS 12076	1M
South Carolina	Project Number: BR26(012), 08 February	1M
South Carolina	Project Number: BR88(066), 09 November	1M
South Carolina	Project Number: MR11(071),14 December	1M
South Carolina	Project Number: RS10(087), 08 march	1M
Washington	CONTRACT NO :007936 (Type C)	1W
Washington	CONTRACT NO :007417 (Type A or B)	2W
Washington	CONTRACT NO :007660 (Type A or B)	2W
Washington	CONTRACT NO : 007276	2W
Total		23

Table 5.23.2: DOT Project Special Provisions: Schedule Update Cycles

5.23.4 Summary and Recommendations

Contractor shall submit a schedule update monthly on a specific date approved by the engineer.

6 SCHEDULE DEVELOPMENT

6.1 Scheduling Software

6.1.1 Common Practices

The PMI does not recommend a specific scheduling tool (software), but the selected scheduling tool has to have the following capabilities (PMI, 2007):

- Select the type of relationship (such as finish-to-start or finish-to-finish)
- Add lags and leads between activities
- Apply resources and use that information along with resource availability to adjust the scheduling of activities
- Add constraints where logic (precedence relationships with other activities) alone is not adequate to meet the project requirements
- Capture a specific schedule as a baseline or target schedule

- Change various parameters within the schedule model such as imposing a different project completion date in an attempt to shorten the overall project duration to analyze the impact that these changes would have on the project schedule
- Compare the most recent schedule against the previous one or against a target or baseline to identify and quantify trends or variances.

The AACEI delineates a process for schedule selection as follows (AACEI, 2013):

- Hardware and software platforms
- Versions
- Compatibility/integration
- Identification of users and levels of access
- Data sources for import and export
- Scheduling requirements (use of master schedule and sub-schedules, level of detail, methods for validation, establishing the common data date for updates, etc.)
- Ability to produce reports in desired format

The NASA Schedule Management Handbook requires external partners (e.g. contractors) to routinely and electronically submit their project schedule database in its native file format (e.g., MS Project, Primavera, Open Plan, and other) (NASA, 2010). NASA suggests that accessing the scheduling database in its native file format makes it possible for the government scheduler to "monitor, assess, and evaluate, at any level of detail, the quality and integrity of its task sequencing, projected dates, primary and secondary critical paths, assigned constraints, resources, coding, structure, and current status" (NASA, 2010).

According to NASA the Schedule management tools should perform the following functions (NASA, 2010):

- Provide for entering and editing of baseline plan, current/forecast plan, and accomplished (actual) schedule data.
- Specify relational dependencies between tasks and milestones (including lag and lead values as needed, but kept to a minimum).
- Define project calendars that reflect the business schedule (e.g., workdays, non-workdays, holidays, and work-hours).
- Display and print project schedules in Gantt and network diagram form.
- Calculate total slack (float) and free slack for all project tasks and milestones.
- Provide user-defined code fields for filtering, grouping, summarizing, and organizing data.
- Create, view, and print basic reports such as task, cost, and resource listings.
- Provide capability for resource loading and leveling.

The UFGS requires the contractor to prepare and maintain project schedules using Primavera P3, Primavera SureTrak, or the current mandated scheduling program (UFGS, 2008). The UFGS also mandates that scheduling files be saved concentric to P3 or current mandated scheduling program file format, compatible with the Government's version of the scheduling program (UFGS, 2008). Since contractors use a variety of scheduling software, compatibility can be an issue; therefore, UFGS restricted the use of data conversion techniques or third party software to import data into P3, SureTrak, or current mandated scheduling program (UFGS, 2008).

6.1.2 State Standard Specifications

Approximately 50% of the Standard Specifications require scheduling software, but to different degrees of detail. Approximately 13 states mention the use of scheduling software without specifying any specific software to be used - for example, Wisconsin Standard Specification has a provision stating that “Hand drawn schedules are acceptable. If the contractor develops the initial schedule with scheduling software, the contractor is encouraged to provide the engineer a diskette of the schedule and the name of the scheduling software used” (WIDOT 2011). Also, Missouri states that “If an electronic computer software program is used to generate the schedule, the initial and any revised schedules shall be accompanied by a disk containing the schedule files in the native format of the software program used to create the schedule. The disk shall be labeled with the contract ID, route, county, date of revision, and the name of the software program used. The contractor will not be required to provide any copies of the software program” (MODOT 2011). Both states apparently give the contractor total freedom in choosing the software.

The most frequently mentioned software in the Standard Specifications and construction manuals, in order of occurrence, are: Primavera (P3 and P6), MS Project, and SureTrak. North Dakota, New Jersey and Florida require the contractor to use Primavera (P3) as their scheduling software (NDDOT 2008) (NJDOT 2001) (FDOT 2008). Other states such as New Hampshire, Texas, and Colorado gave the Contractors more options by approving the use of MS Project and Suretrak alongside Primavera P3 (NHDOT 2010) (CDOT 2011) (TXDOT 2004). Table 6.1.1 summarizes the scheduling software approved by the states’ Standard Specifications and construction manuals.

State	General software provisions	Primavera	MS project	Suretrak
California	x			
Colorado	x	x	x	
Connecticut	x	x		
Delaware	x			
Florida	x	x	x	x
Hawaii	x			x
Idaho	x			

Iowa	x			
Maryland		x		
Missouri	x			
Montana	x			
Nebraska	x			
Nevada		x		
New Hampshire	x	x	x	
New Jersey	x	x		x
New York	x			
North Dakota	x	x		
Oregon	x	x	x	x
Rhode Island	x	x		
Utah		x		
Washington	x	x		
West Virginia	x			
Wisconsin	x			
Wyoming	x	x		
Pennsylvania				
Rhode Island	x	x	x	x
Utah	x			
Washington	x	x	x	
West Virginia	x			
Wisconsin	x			
Wyoming		x		
Total	26	16	6	5

Table 6.1.1: DOT Standard Specifications: Scheduling Software

6.1.3 State Special Provisions

Nine states include scheduling software specifications in the special provisions. Some state projects specified general software provisions allowing the use of any scheduling software; for example, Oregon project SPS 12076, I-5: Victory Blvd. to Lombard St. Section include the following provision: "The scheduling software to be used The digital copy shall be compatible with MS Project 2003, Primavera P3, SureTrak Project Manager 3.0, or another scheduling program approved by the Engineer" (Oregon DOT, 2008). Another example is California Willow Creek Bridge project, which included a very detailed scheduling software provision as follows:

"Submit to the Engineer for review a description of proposed schedule software to be used. After the Engineer accepts the proposed software, furnish schedule software and all original software instruction manuals. All software must be compatible with the current version of the Windows operating system in use by the Engineer. The schedule software must include the latest version of Oracle Primavera P6 Professional Project Management for Windows, or equivalent. If a schedule software equivalent to P6 is proposed, it must be capable of Generating files that can be imported into P6 Comparing 2 schedules and providing reports of changes in activity ID, activity description, constraints, calendar assignments, durations, and logic ties" (Caltrans.C, 2011).

Other projects opted to limit the contractor specific software; for example, New Jersey and South Carolina projects required the use of Primavera. Table 6.1.2 lists all the studied projects that include scheduling software requirements.

It's also worthwhile to mention that all studied California projects require the contractor to provide scheduling software training for DOT engineers as follows: "Instruct the Engineer in the use of the software and provide software support until the contract is accepted. Within 15 days of contract approval, provide a commercial 8-hour training session for 2 Department employees in the use of the software at a location acceptable to the Engineer. It is recommended that you also send at least 2 employees to the same training session to facilitate development of similar knowledge and skills in the use of the software. If schedule software other than P6 is submitted, then the training session must be a total of 16-hours for each Department employee" (Caltrans.C, 2011) (Caltrans.D, 2011) (Caltrans, 2011): (Caltrans, 2010) (Caltrans b, 2011).

State	Provision / Project	Price	General software provisions	Primavera	MS project	Suretrak
California	Contract No. 07-138204	$160M	x			x
California	Contract No. 03-3797U4	$130M	x			x
California	Contract No. 12-0G3304	$ 56M	x			x
California	Contract No. 07-241304	$1.56M	x			x
California	Contract No. 05-0T3604	$1.12M	x	x		
Florida	Contract T2376	$ 19.5M	x	x		x
Florida	Contract T1322	$14.5M	x	x		x
Florida	Contract T2366	$2M				
Florida	Contract T4299	$1.6M	x	x		x
Indiana	Contract # 33045-A	$142M	x	x		
Indiana	Contract # 33049	$69M	x	x		
Indiana	Contract # IR-30850-A	$26.2M				
Indiana	Contract # 32756	$8.7M				
Indiana	Contract # IR-31879-A	$3M				
Kentucky	109-PIKE, CONTRACT ID - 111307	$53.5M	x	x		
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$17M				
Kentucky	104 various, CONTRACT ID - 111012	$8.5M				
Kentucky	35-PERRY, CONTRACT ID - 111308	$2.9M				
New Jersey	CONTRACT NO. 006048005	$3M		x		
New Jersey	CONTRACT NO. 004096470	$7.5M		x		
New Jersey	CONTRACT NO. 000950476	$13M		x		
New Jersey	Contract No. 000068087	$64M		x		
Ohio	Project Number: 110255	$55M		x		x
Ohio	Project Number: 113003	$12.2M		x		x
Ohio	Project Number: 110386	$7M				
Ohio	Project Number: 110321	$3.6M				
Oregon	SPS09350	>$50M	x	x	x	x

Oregon	SPS10694	>$50M				
Oregon	SPS 12076	>$50M	x	x	x	x
Oregon	SPS 14032	>$50M				
Oregon	SPS14197	>$50M				
Oregon	SPS14949	<$50M				
Oregon	SPS06025	<$50M				
Oregon	SPS12874	<$50M				
South Carolina	Project Number: BR26(012), 08 February	$75.7M		x		
South Carolina	Project Number: BR88(066), 09 November	$17.3M		x		
South Carolina	Project Number: MR11(071),14 December	$6.7M		x		
South Carolina	Project Number: RS10(087), 08 march	$3.4M		x		
Washington	CONTRACT NO :007936 (Type C)	$53.4M		x		
Washington	CONTRACT NO : 006933	$34M				
Washington	CONTRACT NO :007417 (Type A or B)	$14.7M				
Washington	CONTRACT NO : 007685 (Type A)	$9.8M				
Washington	CONTRACT NO :007686 (Type A)	$7.3M				
Washington	CONTRACT NO :007669 (Type A)	$6.6M				
Washington	CONTRACT NO :008086	$3.6M				
Washington	CONTRACT NO :007645 (Type A)	$2.6M				
Washington	CONTRACT NO :007897	$2.4M				
Washington	CONTRACT NO :007660 (Type A or B)	$2.3M				
Washington	CONTRACT NO : 007276	$0.4M				
Total			18	20	2	11

Table 6.1.2: DOT Project Special Provisions: Scheduling Software

6.1.4 Schedule Specifications Survey.

The survey included three questions addressing scheduling software, targeting three areas: what scheduling software should be used, preferred software, and software compatibility.

The first question tried to identify the reasoning behind a DOT's decision to use scheduling software in connection to project complexity, project cost, and project duration. The survey respondents were asked to rate each factor on a scale from one to five, one being strongly disagree, 2 disagree, 3 neutral, 4 agree and 5 completely agree. The results are summarized in Table 6.1.3. The results show that the majority of the respondents "agree" that project cost, duration, and complexity should influence the decision to use scheduling software. On the other hand, the majority were indecisive (neutral) when asked if scheduling software should be used regardless of any project factors.

	I would encourage soft copies (e.g. Primavera project file) of the schedule to be requested by the agency if:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Total project cost exceeds a particular threshold.	4.55%	14.55%	26.36%	36.36%	18.18%
2	The project is complex.	2.73%	5.45%	12.73%	46.36%	32.73%
3	The project duration exceeds a particular threshold.	4.55%	13.64%	25.45%	38.18%	18.18%
4	Regardless of the reason (e.g. cost, complexity, or duration)	4.55%	18.18%	37.27%	20.00%	20.00%

Table 6.1.3: Survey Results: Scheduling Software and Project Complexity

The survey respondents were asked to select their preferred scheduling software. The majority, at 63%, chose Primavera P3 or any newer version. 10% chose MS project and 10% chose SureTrak. 17% had no preference. Table 6.1.4 summarizes the survey results.

	The most frequently mentioned scheduling software in the standard specifications and construction manuals are Primavera (P3 and P6), Ms Project, and SureTrak respectively. I would encourage the use of the following scheduling software for transportation projects:	*Frequency*	*Percentage*
1	Primavera P3 or any newer version	69	62.73%
2	MS Project	11	10.00%
3	Primavera SureTrak	11	10.00%
4	Other:	19	17.27%

Table 6.1.4: Survey Results: Preferred Schedule Software

The survey respondents were asked a second question on software compatibility (see Table 6.1.5 below). The question targeted two areas: should the contractor be limited to certain software used by the DOT, or given the freedom to select the software? And if the contractor selected the software, should it be compatible with the DOT preferred software or simply provide training to DOT engineers on the selected software. 43% of the respondents believe that the contractor should use the same scheduling software used by the DOT in order to avoid compatibility issues. 36% suggested that the contractor should be given the freedom to choose any scheduling software capable of producing compatible file formats used by the DOT. 11% believe that the contractor should be given the freedom to choose any scheduling software under the conditions that contractor provides to DOT copies of the software and proper training. And finally 7% suggested that the contractor should be given the freedom to choose any scheduling software; compatibility issues can be solved later on in the project as a joint effort between the two parties. Some other respondents suggested the following:

- Bar Chart - Hard copy only, CPM-Primavera latest version.
- DOT should purchase scheduling software, allow access for Contractor to build and maintain schedule on DOT enterprise database.
- Contractors should be given the freedom to choose any software. The contractor bears responsibility to produce a chart that meets the DOT needs, and can provide the schedule logic that can be used to check schedule validity.

	Compatibility can be an issue when using scheduling software. My position on the issue is:	*Frequency*	*Percentage*
1	Contractor should use the same scheduling software used by the DOT in order to avoid compatibility issues.	47	42.73%
2	Contractor should be given the freedom to choose any scheduling software capable of producing compatible file formats used by the DOT.	40	36.36%

3	Contractor should be given the freedom to choose any scheduling software under the conditions that contractor provides to DOT copies of the software and proper training.	12	10.91%
4	Contractor should be given the freedom to choose any scheduling software. Compatibility issues can be solved later on in the project as a joint effort between the two parties.	8	7.27%
5	Other:	3	2.73%

Table 6.1.5: Survey Results: Scheduling Software Compatibility.

6.1.5 Summary and Recommendations

Since the 1990s, researchers have emphasized the importance of scheduling software (Krone, 1997) (Tavakoli, 1990). In a survey conducted by the AACEI, it was found that owners and contractors alike believe that CPM software provision should be added in the specifications (Popescu, 2001).

Patricia D. Galloway conducted a survey trying to gauge the use of CPM schedules and its benefits from an Owner and Contractor point of view. The survey results show that "over 64% of the owners indicated that they used Primavera as their specified software with only just over 20% requiring MS Project" (Galloway, 2006). These results coincide with the survey results in Table 6.1.4; on the other hand, Table 6.1.1 shows only 16 states adopting Primavera in their Standard Specifications.

Owners raised a number of concerns regarding utilizing Primavera as the scheduling tool; mainly the added cost to the project due to its complexity (Galloway, 2006). Also, the sophisticated nature of the scheduling tools makes it easier to produce flawed and deceptive schedules, therefore schedule specification should be flexible and adaptive (Levin, 2006). Some state DOTs noticed these deceptive techniques, and as a result they included provisions trying to limit these abuses. For example, Florida Construction Project Administration Manual (CPAM) includes a detailed step by step procedure for reviewing updated schedules developed using Primavera (FDOT, 2009):

1- Check to make sure that the actual dates (for activities either in-progress or completed) and the percents complete/days remaining are historically accurate.

2- Run the scheduling calculation in "view" mode and Primavera will itemize the "open ends" (unfortunately, this will not work with SureTrak). With SureTrak, display the predecessors and successors as columns on the left side of the bar chart. Check to make sure that all "open ends" are closed, so that all calculated float values are accurate and not inflated. All activities except the first one should have predecessors, and all activities except the last one should have successors.

3- Similarly, run the scheduling calculation in "view" mode and Primavera will itemize the "out-of-sequence progress" (unfortunately, this will not work with SureTrak).Remedy the out-of-sequence progress by making logic changes that are agreed to between the Engineer and the contractor.

4- Ensure on a continuous basis that the Contractor is pursuing the critical path work activities. The "two-week look ahead schedules" and "controlling items of work" that the Contractor submits should indicate that he is primarily working on the critical or near critical activities, as a minimum.

5- Run a comparison using "Claim Digger" between the current monthly update and the previous update and the baseline to see if the Contractor made any unauthorized changes to either the original durations or logic or, if he added any unauthorized constraints. If he did, bring it to his attention and resolve it with the Contractor.

6- In addition, the "Claim Digger" comparison will itemize the "activities that should have started this update, but did not" and the "activities that should have finished this update, but did not". Bring these to the Contractor's attention, particularly the critical or near critical activities, in order to help get him back on track.

7- Lastly, check to make sure that all holidays and weather days granted through the update are put into the schedule's calendar as "non-work" days, so that they are considered when the schedule is calculated (FDOT, 2009)

Another area of concern is software compatibility. Some states require certain software to be used to develop the schedule and other states give the contractor freedom in choosing the scheduling software. Since the contractor will be using the schedule on a day-to-day basis for planning and sequencing purposes, this research recommends that the contractor shall be allowed to choose the software, but with some restrictions. If the DOT is not familiar with the software, contractor shall be responsible for providig adequate training to DOT staff similar to the state of California's approach discussed above.

6.2 Work Breakdown Structure (WBS)

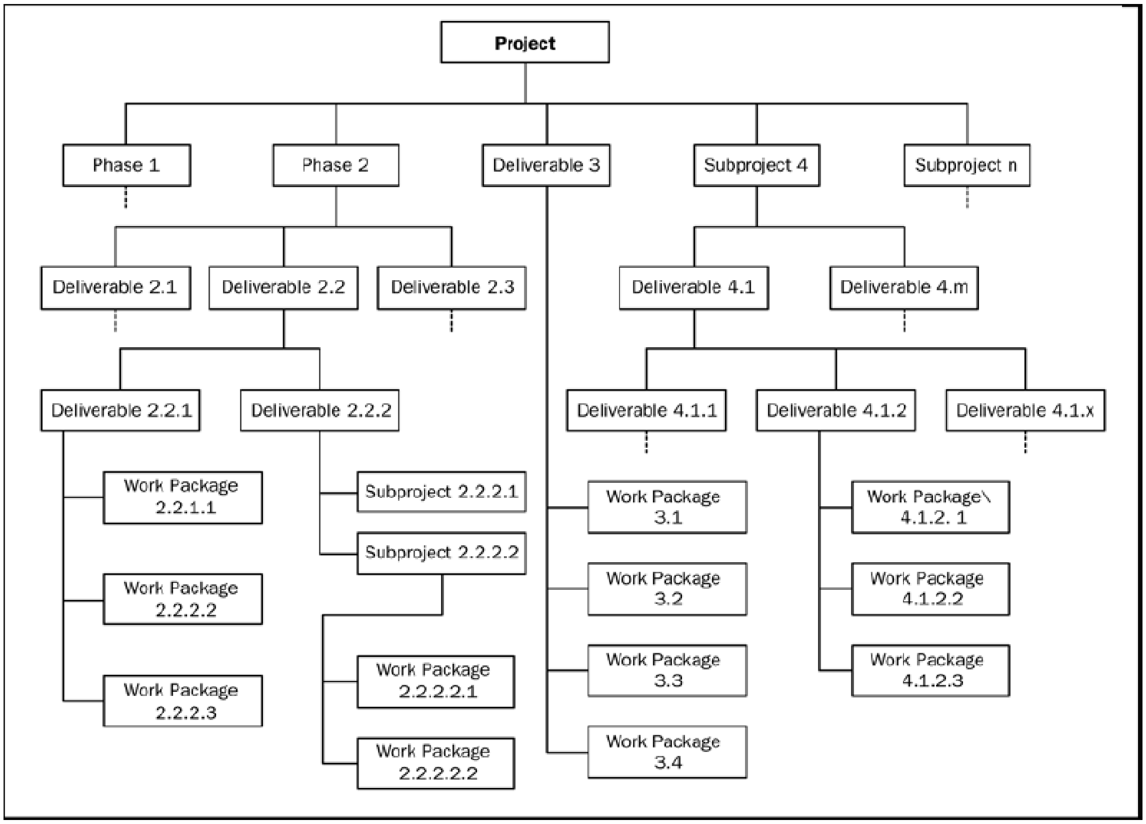
6.2.1 Common Practices

The PMI defines WBS as: "deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables. It organizes and defines the total scope of the project. Each descending level represents an increasingly detailed definition of the project work. The WBS is decomposed into work packages. The deliverable orientation of the hierarchy includes both internal and external deliverables " (PMI, 2007). NASA defines WBS as: "A product-oriented hierarchical division of the hardware, software, services, and other work tasks that organizes, displays, and defines the products to be developed and/or produced and relates the elements of the work to be accomplished to each other and the end product" (NASA, 2010). In simple terms, the WBS provides the foundation and the framework for defining and managing the project. The PMI published a "Practice Standard for Work Breakdown Structures" emphasizing the importance of WBS. Some of the benefits of a well-constructed WBS according the PMI are as follows (PMI, 2006):

- Clarifies the Project Scope
- Guarantees buy-in from all team members by reflecting their input
- Serves as a baseline for any subsequent project changes
- Organize various management functions such as: resource planning, cost estimating, schedule development, and risk identification
- Enhances communications with all project stake holders in terms of project controls, performance monitoring, and foundation communication.

Developing a project WBS occurs in planning phases following the development of the project's scope of work. The WBS has many functions such as organizing and defining the total scope of the project, and subdividing the project work into smaller, more manageable pieces of work for the purpose of project and cost controls. Although each project is unique, the WBS can be used for different projects with the proper modification. In the case of the Departments of Transportation, WBS templates can be developed and added into the standard specifications; a WBS template provided by the PMI is shown in Figure 6.2-1 (PMI, 2004).

Figure 6.2-1:Work Breakdown Structure Template



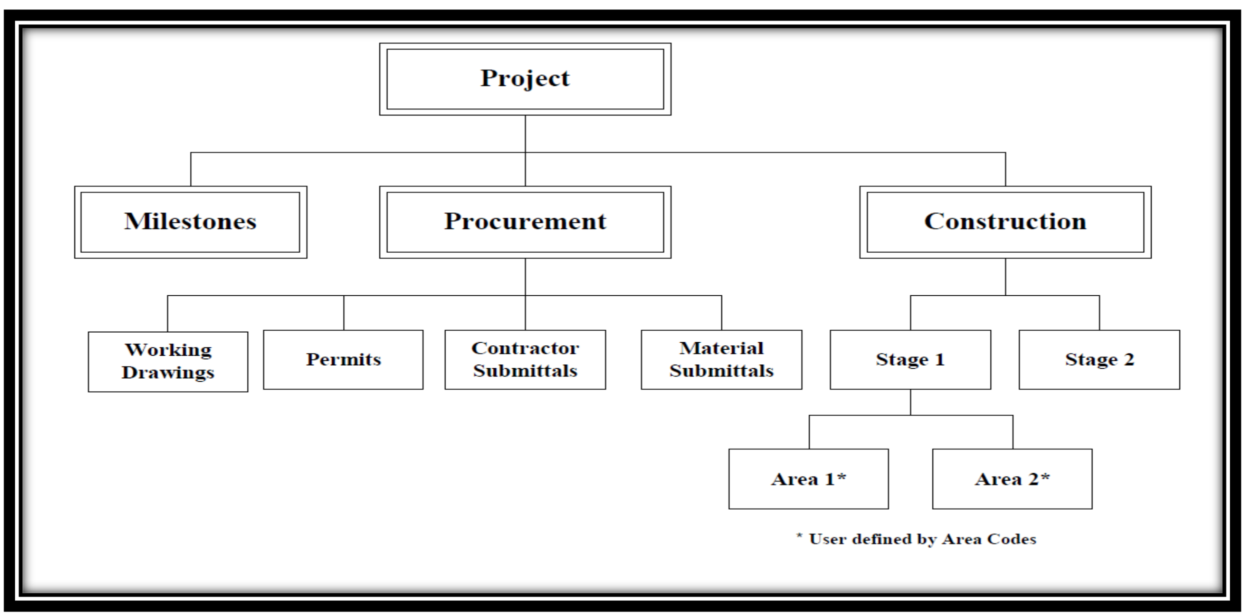
WBS elements can be assigned unique IDs/codes. The PMI defines the WBS Element Identifier as: "A short unique numeric or text identification assigned to each work breakdown structure (WBS) element or component to differentiate a particular WBS element from other WBS elements. The WBS Element Identifier is typically unique within any complete work breakdown structure" (PMI, 2007). WBS element identifiers can be utilized in the activity coding strategy discussed in depth in the following section,

It should be noted that the PMI classified the use of a WBS as "optional" in a minimally acceptable schedule (PMI, 2007).

6.2.2 State Standard Specifications

Some states might require the development of a WBS in the planning stages, but since this research is focused on the project schedule, this section investigates if WBS codes are integrated in the schedule. The Standard Specifications of four states, Hawaii, New Jersey, Rhode Island, and Utah, require the integration of WBS IDs in the project schedule. Hawaii requires that "all activities shall have work breakdown structure codes and activity codes" (HDOT 2005). Similarly, Utah requires the contractor to "Include a well-defined activity coding structure that allows project activities to be sorted by type of work, location of work, work breakdown structure (WBS)" (UDOT, 2008), and New Jersey requires the contractor to "use activity codes to identify responsibility, class, type, and WBS" (NJDOT, 2007). The New Jersey Construction Scheduling and Coding Manual offers a standard coding system and WBS structure demonstrated in Figure 6.2-2 (NJDOT, 2001).

Figure 6.2-2: New Jersey DOT Work Breakdown Structure Template



6.2.3 State Special Provisions

WSDOT SR161 SR18 Interchange Improvements project is the only project from approximately 90 projects reviewed that has WBS provisions. The Special Provisions specified that "The engineer will supply to the contractor a hierarchal work breakdown structure based upon the contract phases for the preliminary schedule, progress schedule and schedule updates. The contractor shall create a CPM schedule within the WBS provided" (WSDOT, 2010).

Rhode Island Standard Special Provisions include a useful basic structure for WBS as follows (XX are contract specific, alpha-numeric) (RIDOT, 2004):

- XX.00 Contract Name
- XX.10 Milestones
- XX.15 Summary Activities characters that will be defined by the Engineer.
- XX.30 Procurement/Shop Drawings
- XX.40 Utility/RR & Work by Others
- XX.60 Construction

6.2.4 Schedule Specifications Survey

The survey included one question addressing WBS coding as shown in Table 6.2.1. 45.55% of respondents preferred the addition of WBS code when developing Activity Codes.

	Question: The PMI defines activity codes as "one or more numerical or text values that identify characteristics of the work". I would prefer to have the construction schedule activities coded by:	Percentage
1	Project phase/stage	60.91%
2	Project work breakdown structure (WBS)	44.55%
3	Construction division (concrete, earthwork, etc)	34.55%
4	Responsibility (e.g. general contractor, subs, etc)	22.73%
5	Other:	6.36%

Table 6.2.1: Survey Results: WBS Coding

6.2.5 Summary and Recommendations

This section will investigate if the integration of WBS IDs to schedule activity codes should be required in a minimally acceptable schedule.

Only 4 state Standard Specifications (8%) require integrating the WBS IDs with project activities and only one project Special Provision required it. These results conflict with the survey results, where approximately 44% of the respondents encouraged this integration. Although the PMI lists WBS element IDs as an optional component (PMI, 2007), this research recommends that it should be required in a minimally acceptable schedule. If that is achieved, any project member can look at an activity code in a project schedule and trace it back to a work package and a responsible party, therefore increasing efficiency and enhancing communications.

The WBS can be developed in a way to help represent both planning and scheduling the project. The following are some recommendations for developing an effective WBS:

1- The upper levels of a WBS should reflect the broad physical elements of a project (e.g. substructure, superstructure). By doing so, it would be easier to delineate the physical element or system that needs to be built. UNIFORMAT II coding system top level elements is a good example.

2- The upper levels of the WBS should not reflect the Masterformat coding divisions (e.g. concrete, metals, and earthwork). Masterformat divisions' are recommended for cost estimating, not planning and scheduling.

3- The lowest level of hierarchy of the WBS should not include the project activities. For example, formwork, reinforcing rebar, concrete placement, curing and finishing should not be added to the WBS. Adding these activities will render the WBS un-necessarily detailed.

6.3 Activity Codes

6.3.1 Common Practices

An activity code is "one or more numerical or text value that identify the characteristics of the work or in some way categorize the schedule activity that allows filtering and ordering of activities within reports" (PMI, 2007). Codes shall be utilized to categorize, sort, and filter activities in order to facilitate the development and maintenance of the schedule. It should be noted that the PMI considers activity coding as an optional procedure and does not require it in a minimally accepted schedule (PMI, 2007).

The AACEI suggests that the adopted activity codes should support the types of reports anticipated on the project. The following shows the type of codes recommended by the AACEI for tracking and monitoring the work and project management (AACEI, 2013):

1- For Tracking and Monitoring Work
   - Work phase
   - Structure
   - Area
   - Floor or station
   - Location
   - Responsibility
2- For Project Management
   - Discipline
   - Work shifts
   - Costs
   - Resource

- Specification
- Change management

The UFGS requires contractors to code the activities in a construction schedule. At least six codes have to be associated with each activity: Phase, Area Code, Work Item, Category of Work Coding, Responsibility Code, and Contract Changes Code. The following is a brief description of each code as defined by the UFGS (UFGS, 2008):

- Phase: All activities shall be given a 4-digit code depending on project phase. Projects may have different phases (phase1, phase2 etc…) depending mainly on the project size and duration.
- Area: An area is defined as a **"**distinct space, function or activity category such as separate structure(s), sitework, project summary, construction quality management, material /equipment procurement, etc." (UFGS, 2008). For example area coding includes different rooms or levels in a building or even different building in a building complex. In a heavy civil project, area codes can be different locations on a highway or bridge. This type of coding may not apply to all activities for example a submittal activity has no definite area.
- Work Item: work items are basically the systems, such as walls, columns, foundations, slabs, etc… a 4-digit code shall be assigned to each activity.
- Category of Work (CATW): The categories can be: "design submittal, design reviews, review conferences, permits, construction submittals, construction submittal approvals, acceptance, procurement, fabrication, delivery, weather sensitive installation, non-weather sensitive installation, start-up, test and turnover" (UFGS, 2008). Since an activity can't fall into two categories, the UFGS specifies that each activity shall be given one digit code representing one category.

- Responsibility: All activities in the project schedule shall be identified with the party responsible for completing the task. Activities shall not belong to more than one responsible party. All activities should be assigned to the prime contractor, subcontractor, or government agency responsible for performing the activity. Governmental responsibility coding includes but is not limited to: government approvals, government design reviews, government furnished equipment, and notice to proceed.
  Examples of responsibility codes: DOR (for the designer of record), ELEC (for the electrical subcontractor), and MECH (for the mechanical subcontractor).
- Contract Changes**:** In case of a change in the schedule - as a result of a change order- the newly added activity shall be coded according to the Government's modification numbering system.

NASA argues that activity codes used vary based on project size, maturity, industry, complexity, entities involved, phase, and so on. "The appropriate number of codes to use is the number required to effectively and efficiently manage the project" (NASA, 2010). Before deciding whether or not to use a particular code and how it should be constructed, several questions should be asked and answered, such as (NASA, 2010):

- For what would this be used?
- Who are the stakeholders?
- Is there another (i.e., easier) way to get the desired results?

6.3.2 State Standard Specifications

The scheduling specifications of state DOTs barely mention activity coding. Only four states require activity coding in their Standard Specifications: Maryland, Hawaii, New Jersey, and Rhode Island. Hawaii's Standard Specifications includes the following provision: "All activities shall have work breakdown structure codes and activity codes. The activity codes shall have coding that incorporates information for phase, location, who is responsible for doing work and type of operation and activity description," (HDOT, 2005). New Jersey's Standard Specification states: "Include activity code and Area activity codes to distinguish the location of work. Activity codes including responsibility, class, area, type, and WBS." (NJDOT, 2007). On the other hand, Rhode Island's Standard Specifications specify that "The Contractor shall reserve three (3) code classifications (fields) and a minimum of six (6) characters for the Engineer's use" (RIDOT, 2004).

6.3.3 State Special Provisions

Some states mention activity coding in their special provisions. The provisions are not detailed but rather very general. For example, the state of Michigan's Special Provisions state that activities shall be coded by Stage/Phase and Area/Location (MDOT, 2011). The state of Oklahoma special provisions for scheduling required using 5 codes: milestone, work package, responsibility, hammock, and type of work (OKDOT, 2010).

Table 6.3.1 summarizes activity coding requirements in the UFGS, state Standard Specifications and state Standard Special Provisions.

	Area/ Location	Responsi bility	Class	Type	WBS	Phase/ Milestone
UFGS	x	x	x	x	x	x
Standard Specifications						
Maryland	x	x	x	x	x	
New Jersey	x	x				x
Hawaii	x	x		x	x	x
Rhode Island	x	x		x		
Standard Special Provisions						
Ohio PN107	x	x				x
Michigan 12SP102(B)	x					x
Indiana 108-C-215	x	x				x
Oklahoma 108-3(a-		x	x	x		x

c)09							

Table 6.3.1: Types of Activity Codes as Implemented in State DOTs

6.3.4 Schedule Specifications Survey

In order to capture the opinion of state DOT professionals, a simple question was included in the survey as follows (Table 6.3.2):

	Question: The PMI defines activity codes as "one or more numerical or text values that identify characteristics of the work". I would prefer to have the construction schedule activities coded	Percentage
1	Project phase/stage	60.91%
2	Project work breakdown structure (WBS)	44.55%
3	Construction division (concrete, earthwork, etc)	34.55%
4	Responsibility (e.g. general contractor, subs, etc)	22.73%
5	Other:	6.36%

Table 6.3.2: Survey Results: Activity Coding

Table 6.3.2 presents the frequency of the codes selected; about 61% of surveyed professional agreed that activities shall be phase coded, 44 % chose WBS coding, 34% chose construction division coding, 23% chose responsibility, and 6 respondents had other suggestions as follows:

1- Area of work (mentioned twice)

2- Delay

3- Time-Related Clause

4- Work Order

5- Extra-Contract Work

6- Crews (generally relates to resource loading which will be discussed in section 7.1 Resource and Cost Loading)

6.3.5 Summary and Recommendations

Construction schedules can incorporate hundreds of activities. These activities not only differ in work type (e.g. clearing and grubbing, paving, sub grading) but also differ in location, responsibility, and phase, to name a few. Coding provides an easy way to sort and categorize activities in order to highlight trends and anomalies, and to develop specialized time and cost reports that provide information for a particular code or a combination of codes (e.g. a report on concrete, in phase 1, done by subcontractor X). With the use of specialized software such as Primavera, getting all the information regarding a certain task can be accomplished in a few seconds; for example, a project manager can know which subcontractors are working on a specific day or their location in the project by using the sorting functionalities of the software. Activity codes are usually confused with activity identifiers (IDs). An ID is normally a unique numerical value given to each activity, whereas different activities can share the same code; for example, paving and compaction activities can both be coded with "project phase one" or "Subcontractor X" but each can have its own unique ID (PMI, 2007).

It is evident that activity coding is not regarded as a top priority by either state DOTs or the PMI. The PMI encourages the use of activity coding but also states that "it is not required in a minimally accepted schedule" (PMI, 2007). Moreover, only 4 states adopted activity coding in their Standards Specifications and an equal amount of states mentioned it in their Standard Special Provisions. The Standard Special Provisions mentioned earlier are mainly drafted towards bigger, more complex projects (that use CPM schedules) but still only 4 states adopted coding.

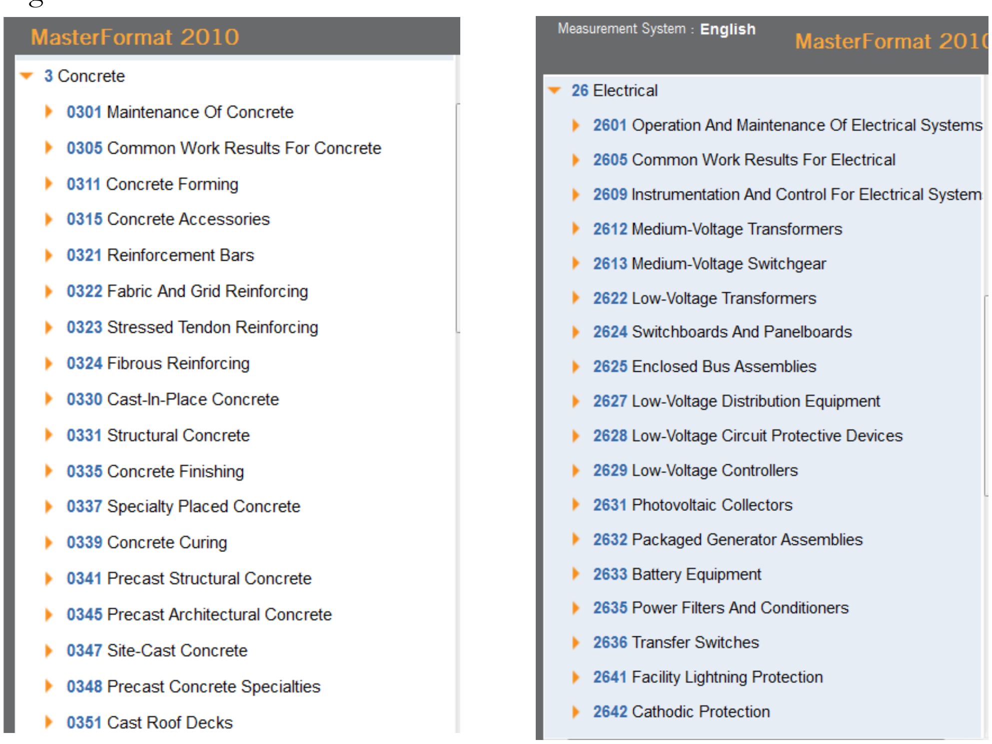
Contrary to what is implemented in most state DOTs, the survey shows that all respondents selected at least one code type (the average was 1.7 codes per respondent). This leads to the conclusion that the surveyed professionals agree that coding should be used. The question at hand now is not whether coding is to be used or not, but rather what type of coding is beneficial. One respondent commented "I don't care how schedule activities are coded; I however do want them coded so that I can sort and filter smartly".

The presumed benefit of coding - especially on complex projects - suggests that it should be a best practice. Imagine having to go through hundreds of activities looking for work done by the mechanical subcontractor; if the schedule is coded, this task can happen in a few seconds.

The survey results also suggest that professionals on the owner's side will be interested in codes that are more related to the project phases. Contractors would also be interested in the phases. However, they are more interested in the responsibility code, the work category/type (CSI Masterformat divisions – general conditions, concrete, metal, earthwork work, etc.), and which element of the project (i.e. systems, e.g. substructure, superstructure, exterior work, interior work, services).

It is recommended that the codes be subject to a structure that allows hierarchical levels in order to better code the activities. For example, using the CSI Masterformat Concrete would be coded with 03 and then further extended to one or two more levels as follows: 0311 for forming, 0321 for rebar, 0330 concrete, etc. Examples of these codes are given in Figure 6.3-1. Hierarchical coding helps schedulers develop more specialized time and cost reports.

Figure 6.3-1: Master Format Codes



In conclusion, this research recommends a modified coding structure to that of UFGS that include five coding systems, as follows:

- Phase: Most civil projects are built in phases or stages. A 2-digit code is suggested.
- Area: Used if the project has distinct subprojects, e.g. a highway subproject and a bridge subproject. Also, to be used if the contractor has multiple separate contracts for the same project, e.g. highway contract, bridge contract. A 2-digit code is suggested. Example: 00 if only one contract for the project.
- Work Items/Systems: Preferably UNIFORMAT or a modified version to include civil works. A 5-digit code for the Uniformat is suggested.
- Work Type/Masterformat: Two levels of the CSI Masterformat divisions, e.g. 03 concrete, 0322 concrete forming. A 4-digit code is suggested.
- Responsibility: A 6 digit alphanumerical code is suggested. This allows the development of different codes to different subcontractors of the same trade, e.g. MECH01, MECH02.

The codes could serve in the financial accounting of the project. For example, if the above suggested codes are combined, it would form the following integrated code:

Phase.Area.System.Division.Responsibility which is represented as
XX.XX.XXXXX.XXXX.XXXXX

For example, 02.03.A1030.0331.GC000 which represents Phase 2, Contract 3, Slab on Grade, Structural Concrete, by the General Contractor.

In software (e.g. Primavera), these codes could be built in the Global area so they could be used for all DOT projects. Further, if the company has a coding system for projects (e.g. a 2-digit code for the project number combined a 4-digit code for the year), then this code can be combined with the above suggested codes to form a unique code for the project. This could be used to record the project historical data (time and cost) for future references.

6.4 Activity Duration

6.4.1 Common Practices

The PMI establishes different definitions for activity durations depending on the purpose and the phase. Activity actual duration is the time between the actual start of the activity and either the data date (if the activity is still in progress), or the actual finish date. Activity Baseline duration is the time between the start and finish dates of an activity and normally involves the planning stage. Activity original duration is a time duration given to an activity in the planning stage, and is not updated so it can be compared with actual durations and remaining durations. Activity remaining duration is the time needed to complete an activity in progress. Total activity duration is the actual duration plus the remaining duration (PMI, 2007).

This section will not address how to determine activity durations, or how to update the activity progress, but rather focuses on maximum and minimum activity durations imposed by State DOTs in their Scheduling Documents. These restrictions are established in the planning stage, so according to PMI our focus will be on activity baseline durations and activity original durations as defined above.

Ideally, the PMI recommends that activity durations shall be less than two times the update cycle and never more than 3 times the update cycle (for example, if the update cycle is one month, then the activity duration should not exceed 2 months), with the exception of continuous activities, procurement activities, and level-of-effort activities (PMI, 2007). The AACEI recommends that activity durations shall be approximately the length of the project's status reporting period (update cycle) (AACEI, 2007).

The Unified Facilities Guide Specifications (UFGS) set restrictions on maximum activity durations as follows: "Less than 2 percent of all non-procurement activities shall have Original Duration (OD) greater than 20 work days or 30 calendar days" (UFGS, 2008). The UFGS demands a 3-week look-ahead schedule with maximum activity durations of 5 working days (UFGS, 2008). Look Ahead schedules will be discussed in detail in section 7.5 Look-Ahead Schedules. The UFGS has not defined minimum activity durations.

In a 2003 paper published by the AACE, Dr. Win G Li investigated schedule specifications in a number of projects. In a transportation project, the Standard Specifications limited the activity duration to 15 working days. Dr. Win went on to explain that "the 15 days (3 weeks) requirement is intended to eliminate potential dispute over percent complete for payment on progressing activities. It is an attempt to have most of the activities completed in one invoice cycle" (Li, 2003).

6.4.2 State Standard Specifications

Twenty states DOTs include restrictions on the maximum duration of an activity, while only 6 states include restrictions on minimum activity durations. The minimum activity durations range between 1-2 days while the maximum durations range from 10-30 days; Table 6.4.1 illustrates the maximum activity duration in different states.

State	Maximum Activity Duration	Minimum Activity Duration	Update cycle
Alaska	15 days		1week
Arizona	15 days	1 day	2 months
Colorado	15 days		1 month
Hawaii	20 days		2 weeks
Idaho	20 days		1 month
Iowa	20 days		2 weeks
Kentucky	10 days		1 month
Maryland	10 days		1 month
Montana	20 days	1 day	1 month
Nevada	10 days		1 month
New	15 days		1 month

Hampshire			
New Jersey	30 days	1 day	1 month
North Dakota	15 days		
Ohio	20 days		
Oklahoma	30 days		1 month
Oregon		1 day	1 month
Rhode Island	12 days	2 days	2 weeks
Texas	20 days		
Utah	15 days		1 month
West Virginia	15 days		
Wisconsin	15 days	1 day	1 month
Wyoming	15 days		1 month

Table 6.4.1: DOT Standard Specifications: Maximum/Minimum Activity Durations

The restrictions on the maximum activity duration are usually not absolute, and are normally followed by a clause that states that the Engineer can accept longer activity durations. For example, New Jersey Standard Specifications includes this provision: "Ensure that no construction activity has duration greater than 30 days, unless approved by the RE" (NJDOT, 2007).

Wisconsin Standard Specification defines a specific range for activity durations as follows: "Provide a duration, ranging from one to 15 working days, for each activity. Break longer activities into 2 or more activities distinguished by the addition of a location or some other description" (WIDOT, 2011). Colorado Standard Specifications requires the consolidation of short duration activities as follows: "Series of activities that have aggregate durations of five calendar days or less may be grouped in a single activity. For example, form, reinforce, and pour pier could be defined as a single activity rather than three" (CDOT, 2011).

6.4.3 State Special Provisions

Table 6.4.2 summarizes the maximum/minimum activity duration provisions for several state DOT projects. Indiana projects exclude non-construction activities from the maximum/minimum activity duration provision as follows: "Each construction related activity shall have an original duration not to exceed 20 activity calendar days unless approved by the Engineer. It is permissible for activities related to fabrication, utility relocation, permit acquisition and other non-construction activities to have longer original durations" (Indiana DOT, 2011) (Indiana DOT, 2010). Similarly, Ohio projects include the following provision: "Do not exceed a duration of 20 working days for any construction activity unless approved by the Engineer. Do not represent the maintenance of traffic, erosion control, and other similar items as single activities extending to the Completion Date. Break these Contract Items into component activities in order to meet the duration requirements of this paragraph" (Ohio DOT.b, 2011) (Ohio DOT, 2011).

State	Project	Price	Maximum Activity Duration	Minimum Activity duration
California	Contract No. 07-138204	$160,000,000.00		1 day
California	Contract No. 03-3797U4	$130,000,000.00		1 day
California	Contract No. 12-0G3304	$56,000,000.00		1 day
California	Contract No. 07-241304	$1,560,000.00		1 day
Florida	Contract T2376	$19,453,029.69	20 days	
Florida	Contract T1322	$14,667,050.00	20 days	
Florida	Contract T2366	$1,912,362.28	20 days	
Florida	Contract T4299	$1,597,956.96	20 days	
Indiana	Contract # 33045-A	$141,778,367.70	20 days	
Indiana	Contract # 33049	$69,344,417.82	20 days	
Kentucky	109-PIKE, CONTRACT ID - 111307	$53,549,206.66	20 days	
Ohio	Project Number: 110255	$54,923,975.95	20 days	
Ohio	Project Number: 113003	$12,224,208.50	20 days	
Oregon	SPS09350	> $50 million		1 day
Oregon	SPS10694	> $50 million		1 day
Oregon	SPS 12076	> $50 million		1 day
Oregon	SPS 14032	> $50 million		1 day
Oregon	SPS14197	> $50 million		1 day
Oregon	SPS06025	< $50 million		1 day
Oregon	SPS12874	< $50 million		1 day
South Carolina	Project Number: BR26(012), 08 February	$75748835.57	30 days	
South Carolina	Project Number: BR88(066), 09 November	$17346264	30 days	
South Carolina	Project Number: MR11(071),14 December	$6673974.58	30 days	
South	Project Number: RS10(087),	$3440083.5	30 days	

Carolina	08 march			
Washington	CONTRACT NO :007936	$53,398,008.88	30 days	
Washington	CONTRACT NO : 006933	$34,000,000.00	15 days	

Table 6.4.2: DOT Project Special Provisions: Maximum/Minimum Activity Duration

6.4.4 Schedule Specifications Survey

The respondents were asked to select the maximum activity duration to be used in a project schedule. Approximately 50% of the respondents selected a range between 5 and 20 days while 27.27% recommended that no restrictions should be applied to maximum activity durations. Table 6.4.3 summarizes the survey results on maximum activity durations. The survey respondents were also asked to explain the reason for selecting a certain range; their answers are summarized into 3 categories in Table 6.4.4:

- Restricting activity durations help better control and manage the project.
- Activity maximum durations should relate to update cycles.
- Maximum activity duration depends on the project/ activity.

6 respondents related the maximum activity duration to update cycles. One respondent mentioned the following: "20 days roughly represent a work month, coinciding with an update period. Allows time for activity progress to unfold (or not) and is short enough to recognize developing problems and provide time react. Potentially better control / monitoring of work progress". Another respondent suggested the following: "We update on a monthly basis therefore I use the rule of thumb one half the update duration. Also the WVDOH specifications require a maximum of 15 day activity duration (with discretion of to the engineer). I however believe that there are exceptions to this rule if the activity can be monitored easily through a production rate and it does not need further broken down for logic reasons."

13 respondents related restricting activity maximum activity durations to better schedule management. One respondent answered with the following: "There must be sufficient detail in the

schedule to coordinate successors and activity logic. Duration over a week long generally does not allow for individual work items being described and encourages grouping many activities into one item." Another respondent suggested the following: "The activities shall be detailed significantly small enough to communicate the contractor's understanding of the construction sequencing and phasing of the project. Also, it helps to monitor the duration of the major activities such as the beginning and completion dates of each activity."

	Question: From your experience, the maximum duration assigned to construction activities (excluding procurement activities, submittals, etc..) should be in the range of :	Percentage
1	Less than 5 days	2.73%
2	Between 5-10 days	15.45%
3	Between 10-15 days	15.45%
4	Between 15-20 days	19.09%
5	Between 20-25 days	5.45%
6	Between 25-30 days	4.55%
7	No restrictions	27.27%
8	Other:	10.00%

Table 6.4.3: Survey Results: Maximum Activity Duration

	Question: Reason for selecting maximum activity durations	**Percentage**
1	Better Control/Management of Project	23.64%
2	Maximum activity duration should relate to update cycles	10.90%
3	Depends on the project/activity	65.45%

Table 6.4.4: Survey Results: Reasons for Restricting Maximum Activity Duration

6.4.5 Summary and Recommendations

When developing project activities, durations are established based on production rates, available resources, restrictions, and experience. Some activities end up spanning for longer durations. For example, an activity for paving 4 miles of a highway can span for months. Long duration activities can be problematic to manage and control, especially when trying to report monthly (or bi-weekly) progress, and can also misrepresent the critical path.

In order to achieve better project management and control, long duration activities should be limited or broken up into smaller definable pieces based on other factors such as location of work. For example, The UFGS limited the amount of activities exceeding 20 days to 2% of the activities (UFGS, 2008), and the state of Wisconsin Standard Specification suggested breaking up longer activities into 2 or more activities" (WIDOT, 2011).

In general, defining maximum activity duration can help minimize long duration activities. 60% of the survey respondents agreed that some restriction should be in place and justified this by saying it can achieve better control of the project. The respondents also suggested that the maximum duration should relate to the update cycle. As a best practice, The PMI suggests that activity durations shall be less than two times the update cycles and never more than three times the update, with the exception of continuous activities, procurement activities, and level-of-effort activities (PMI, 2007). Table 6.4.2 shows the maximum activity duration by various state DOTs and the corresponding schedule update cycle; all the states fall into the PMI recommended maximum activity duration range.

6.5 Scheduling Method

6.5.1 Common Practices

PMI's Practice standard for scheduling, which is the corner stone of this study, focuses on CPM scheduling. The PMI defines the Critical Path Method (CPM) as "a schedule network analysis technique used to determine the minimum total project duration and the earliest possible finish date of the project as well as the amount of scheduling flexibility (the amount of float) in the schedule network" (PMI, 2007). Scheduling software is utilized for CPM calculations using: Precedence Diagramming Method (PDM), the Arrow Diagramming Method (ADM), or the Critical Chain Method (PMI, 2007).

NASA adopted the Critical Path Method and labeled it a "standard industry best practice." (NASA, 2010). NASA suggested that when CPM is used, the result would be "accurate task dates, future task forecasts, total slack values for all tasks and milestones, and the capability for identifying all critical paths for the project." (NASA, 2010).

The UFGS require the contractors to use CPM and PDM to generate all project schedules regardless of project size, duration, or complexity (UFGS, 2008).

6.5.2 State Standard Specifications

State Standard Specifications Provisions on CPM schedules are split into three categories:

- States that require the use of CPM schedules on all projects. For example, Iowa standard specifications mentioned: "No contract work shall be done without a CPM progress schedule approved by the Engineer" (IowaDOT, 2009);
- States that do not require the use of CPM unless the special provisions call for it. For example, California Construction Manual included the following provision: "The special provisions may require a progress schedule using the critical path method (CPM). The special provisions will contain all the requirements for such a schedule" (Caltrans, 2009).
- States that failed to include CPM provisions.

Table 6.5.1 summarizes the CPM requirement in each of the 50 states.

6.5.2.1 Schedule Complexity:

New York Construction Manual explained that CPM schedules will only be used on complex projects, without defining what "complex" means (NewYork DOT, 2009). The states of Washington and Oregon split their schedules into three types- A, B, and C-.with A being the simplest type, generally used on small projects, and C is being used on complex projects. But yet again, both specifications failed to define what complex means (It should be noted that when special provisions of several projects in Oregon were reviewed, it was found that there is a type "D" schedule used on very complex projects) (WSDOT, 2010) (ODOT, 2008). West Virginia, on the other hand, includes a Special Provision that specifies the type of schedule to be used on different projects based on project type and cost as follows:

"Activities Schedule Chart (ASC) and Critical Path Method (CPM) Schedule Schedules will not be required for projects on which the major portion of the work is resurfacing, landscaping, signing, lighting, installing signals, guardrail or bridge painting, or on which the Contract Bid Amount is $2,000,000 or less. However, on all projects not requiring an ASC or CPM schedule, the contractor will provide the Division with an Anticipated Payment Summary (APS) for the project. Activities Schedule Chart (ASC) will be required for all projects on which the Contract Bid Amount is greater than $2,000,000 but less than $7,500,000, except for project types as noted in the previous paragraph. Critical Path Method (CPM) Schedules will be required for all projects on which the Contract Bid Amount is equal to or exceeding $7,500,000 or containing an I/D Clause" (WVDOT, 2010).

Florida Contract Administration Manual and Hawaii standard specifications also specify what type of contract to use on different project based on cost, duration, and type of work (FDOT, 2009) (HDOT, 2005). Hawaii requests a time-scaled logic diagram for contracts of $2,000,000 or less, or for contract time of 100 working days or less - otherwise a CPM schedule should be used (HDOT, 2005). Florida requested that "A bar chart is allowed to be used only for the smallest projects (i.e., under $1 million), however, CPM schedules are encouraged. CPM schedules are required for large and complex projects; e.g., those over $5 million, urban projects with three (3) or more traffic phases or others deemed appropriate such as alternative contracting projects, buildings, Variable Message Sign(s), etc. CPM schedules are not required but are encouraged on simple projects such as

3R (Resurfacing, Rehabilitation, Restoration) or minor bridges, unless there are unusual conditions" (FDOT, 2009)

The state of Kentucky defines 2 levels of schedule details - or complexities - as follows (KDOT, 2007):

- Level 1. This level of detail presents a logically flowing schedule of the daily activities required to complete the project. The maximum activity length should be 10-days unless approved by the Engineer. Locations and/or stations numbers should be used to further describe activities.
- Level 2. This level of detail presents the logical progression of activities required to complete the controlling items of work, in the time limits allotted in the contract documents, to the satisfaction of the engineer.

Rhode Island Standard Specifications split project schedule into three levels as follows (RIDOT, 2004):

- Schedule Level A Projects with a high level of complexity, impact to the motoring public or community, and/or larger size Projects.
- Schedule Level B Projects of average to moderate complexity, moderate impact to the motoring public or community, and/or average size.
- Schedule Level C Smaller projects with minimal to no complexity, and minimal impact to the community. Typical examples would be resurfacing, maintenance, and landscaping projects.

State	CPM depends on special provisions	CPM required	CPM depends on Project Complexity/Size/Cost	Bar Chart required
Alabama	x			x
Alaska		x		x
Arizona		x		x
Arkansas	x			
California	x			x
Colorado		x		x
Connecticut		x		
Delaware	x			x
District of Columbia		x		
Florida	x		x	x
Georgia	x			
Hawaii			x	x
Idaho		x		x
Illinois	x			
Indiana				x
Iowa		x		x
Kansas			x	x
Kentucky			x	x
Louisiana	x			x
Maine		x		x
Maryland		x		x
Massachusetts				
Michigan	x			x
Minnesota	x			x
Mississippi				
Missouri				
Montana	x			x
Nebraska		x		x
Nevada		x		x
New Hampshire		x		x
New Jersey		x		x
New Mexico	x			x
New York	x			x
North Carolina	x			
North Dakota	x			x
Ohio	x			x
Oklahoma	x			x

Oregon	x		x	x
Pennsylvania	x			x
Rhode Island		x		
South Carolina				
South Dakota				
Tennessee	x			
Texas	x			x
Utah		x		
Vermont	x			
Virginia				
Washington	x		x	x
West Virginia	x		x	x
Wisconsin	x			x
Wyoming	x			x
Total	25	15	7	35

Table 6.5.1: DOT Standard Specification: CPM Requirement

6.5.3 State Special Provisions

The Standard Specifications of most states do not require the contractor to use CPM schedules. Some of these Standard Specifications were amended by Special Provisions that include CPM provisions. Table 6.5.2 shows a number of projects in 9 different states that require the use of CPM schedules and the price tag of each of the projects. The state of California for example require the use of CPM schedules on projects ranging from $1.12 million to $160 million, while other states such as Kentucky, Alaska, Florida and Indiana chose to include CPM provisions project with higher costs (above $14 million). It is apparent that cost is one factor in requiring a CPM schedule, but there are other factors such as project complexity and duration. For example, Grass Creek bridge project in the state of Washington (referred to as Contract No. : 007276) involves a complex special repair for the bridge. Although the cost of the repair did not exceed $500,000 a CPM schedule was required. The state of Ohio drafted a Standard Special Provision addressing CPM scheduling for short duration projects (Ohio DOT, 2010).

State	Project	Price
Alaska	Emmonak Landfill Road Project	> $5,000,000
California	Contract No. 03-3797U4	$130,000,000.00

	Contract No. 07-138204	$160,000,000.00
	Contract No. 12-0G3304	$56,000,000.00
	Contract No. 05-0T3604	$1,120,000.00
	Contract No. 07-241304	$1,560,000.00
Florida	Contract T2376	$19,453,029.69
	Contract T1322	$14,667,050.00
Indiana	Contract # 33045-A	$141,778,367.70
	Contract # 33049	$69,344,417.82
Kentucky	109-PIKE, CONTRACT ID - 111307	$53,549,206.66
	104-HENDERSON, CONTRACT ID - 111023	$17,223,036.46
North Carolina	Contract ID: C202684	$55,258,773.41
	Contract ID: C202538	$24,956,387.67
	Contract ID: C202598	$13,121,586.40
	Contract ID: C202690	$5,113,273.80
	Contract ID: C202671	$3,137,734.53
Ohio	Project Number: 110255	$54,923,975.95
	Project Number: 113003	$12,224,208.50
Oregon	SPS09350, (MLK/Grand O-Xing UPRR 02115 & 08905 Viaducts Section	> $50 million
	SPS 12076, I-5: Victory Blvd. to Lombard St. Section	> $50 million
South Carolina	Project Number: BR26(012), 08 February	$75,748,835.57
	Project Number: BR88(066), 09 November	$17,346,264.00
	Project Number: MR11(071),14 December	$6,673,974.58
	Project Number: RS10(087), 08 March	$3,440,083.50
Washington	CONTRACT NO :007936	$53,398,008.88
	CONTRACT NO : 006933	$34,000,000.00
	CONTRACT NO :007417	$14,689,000.00
	CONTRACT NO :008086	$3,569,039.50
	CONTRACT NO :007660	$2,286,623.00
	CONTRACT NO : 007276	$421,974.00
West Virginia	PROJECT NUMBER X347-H-74.85 00 ACAP-0484(246)	$82,486,513.79

Table 6.5.2: DOT Projects Utilizing CPM

6.5.4 Schedule Specifications Survey

The survey asked a question: should CPM be utilized on all projects? or does it depends on the project complexity? The results are summarized in Table 6.5.3.

	Question: For simple and short-duration projects, construction schedules could be developed based on a bar chart created by a spread sheet such as Excel. For complex (as well as simple projects) the schedules could be developed based on the Critical Path Method (CPM). From your experience, CPM should be used	Percentage
1	All the time regardless of project complexity.	26.36%
2	On complex projects; simple bar charts should be sufficient for smaller, less complex projects.	70.91%
3	Other:	2.73%

Table 6.5.3: Survey Results: CPM and Project Complexity

Approximately 70% of the respondents believe that CPM schedules should be used only on complex projects, while 26% of the respondents believe that CPM should be utilized on all projects regardless of complexity.

One of the respondents suggested the following: "CPM on complex projects; non-CPM on less complex projects, but an electronic schedule for all projects so they can be managed in one enterprise system". Another respondent suggested that CPM should be utilized on "Any project susceptible to delay/damages/risk". A third respondent responded with the following: "Bar charts may be acceptable on very short duration projects. I find that CPM can contribute to problem/delay resolution on 'simple' projects if done properly".

6.5.5 Summary and Recommendations

CPM has been developed in the 1950, but till this day it hasn't been completely accepted .A CPM schedule is crucial for a project to succeed, never the less, very few contractors use CPM to its full potential (Cole, 1991) (Levin, 2006) (Galloway, 2006).

The question posed in this section is whether CPM should be utilized on all projects regardless of complexity (size, duration, cost etc...). The PMI, NASA, and UFGS all agree that CPM should be utilized on all projects regardless of complexity. State DOT Standard Specifications are split into 3 camps: 10 states do not mention any scheduling specifications, 15 State DOT standard specifications require CPM schedules regardless of complexity, and 26 states leaves the issue to the special provisions. Some states, like Washington and West Virginia define different schedule levels based on project complexity.

The survey results somewhat align with the Standard Specifications where about 70% respondents felt that CPM should not always be utilized but rather should depend on complexity. According to PMI, NASA, and the UFGS, this is not the industry best practice; CPM should be utilized regardless of the project type, complexity, or size.

6.6 Logical Relationships

6.6.1 Common Practices

Four types of logical relationships are used in scheduling: finish-to-start (FS), start-to-start (SS), finish-to-finish (FF) or start-to-finish (SF) relationships. The PMI suggests that FS relationships shall be used when possible. Other relationships shall be used sparingly after fully understanding the impacts of these relationships in the scheduling software (PMI, 2007). PMI also suggests that "Ideally, the sequence of all activities will be defined in such a way that the start of every activity has a logic relationship to a predecessor and the finish of every activity has a logic relationship to a successor" (PMI, 2007). Table 6.6.1 lists all activity relationships and definitions.

Relationship	**Required or Optional?**	**Definition**
Finish to Start (FS)	Required	The logical relationship where initiation of work of the successor activity depends upon the completion of work of the predecessor activity.
Finish to Finish (FF)	Optional	The logical relationship where completion of work of the successor activity cannot finish until the completion of work of the predecessor activity.
Start to Start (SS)	Optional	The logical relationship where initiation of the work of the successor schedule activity depends upon the initiation of the work of the predecessor schedule activity.

Start to Finish (SF)	Optional	The logical relationship where completion of the successor schedule activity is dependent upon the initiation of the predecessor schedule activity.

Table 6.6.1: Logical Relationship Types as Defined by PMI

NASA has a similar approach towards relationships; they recommend the use of FS relationships whenever possible, claiming that FS relationships provide the most accurate calculation of total float. As for SS and FF relationships, NASA suggests that "Caution should be taken when using this type of relationship in lieu of breaking the effort down into more meaningful and discrete segments of work that can more accurately represent the task sequence. Overuse and/or improper use of start-to-start relationships will potentially hinder true critical path identification" (NASA, 2010). SF relationship, according to NASA, "is almost never used" and caution should be practiced when using such a relationship (NASA, 2010). On the other hand, the UFGS restricts the use of SF relationships (UFGS, 2008).

6.6.2 State Standard Specifications

Twenty seven state standard specifications require contractors to show logic relationships in the submitted project schedules. Only 7 states include specific logic relationship provisions in their standard specification. Most of these states allow the use of FS relationships and have some concerns when using FF and SS relationships. For example, the state of Montana restricted the use of any relationship but the FS relationship (MODOT, 2011), while the state of New Jersey include the following provision: "Ensure that all activities, except the project start milestone and project completion milestone, have predecessors and successors. The start of an activity shall have a start-to-start or finish-to-start relationship with preceding activities. The completion of an activity shall have a finish- to- start or finish-to-finish relationship with a succeeding activity. Do not use start-to-finish relationships" (NJDOT 2007). Table 6.6.2 summarizes allowable logic relationships in 7 states.

State	Schedule to show Relationships	Finish to Start Allowed	Finish to Finish Allowed	Start to Start Allowed	Start to Finish Allowed
Alaska	x				
Arizona	x				
Colorado	x				
Delaware	x				
District of Columbia	x				
Florida	x				
Hawaii	x				
Idaho	x	x	x	x	
Iowa	x				
Kansas	x				
Kentucky	x				
Maryland	x				
Missouri	x				
Montana	x	x			
Nevada	x				
New Hampshire	x	x			
New Jersey	x	x	x	x	
New Mexico	x				
North Dakota	x	x	x	x	x
Oregon	x				
Pennsylvania	x				
Rhode Island	x				
Utah	x				
Washington	x				
West Virginia	x				
Wisconsin	x	x			
Wyoming	x	x			
Total	27				

Table 6.6.2: DOT Standard Specifications: Allowed Logical Relationships

6.6.3 State Special Provisions

Twenty one projects require showing activity relationships on the project schedule. 4 projects restricted the use of SF relationships, and constricted the contractor to the use of SS, FF, and FS. Ohio and Kentucky projects approved the use of FF and SS relationships alongside FS relationships as follows:

1- "Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities" (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011).

2- "Use of finish-to-finish relationship is permitted when both activities are already linked with a start-to-start relationship" (Ohio DOT, 2011) (Ohio DOT.b, 2011) (Kentucky DOT, 2011).

Table 6.6.3 summarizes the allowable logic relationship in each of the studied project special provisions.

State	Provision / Project	Schedule to Show Relationships	Finish to Start Allowed	Finish to Finish Allowed	Start to Start Allowed	Start to Finish Allowed
Alaska	Project No. STP-0002(128)/61179	x				
California	Contract No. 07-138204	x				
California	Contract No. 03-3797U4	x				
California	Contract No. 12-0G3304	x				
California	Contract No. 07-241304	x				
California	Contract No. 05-0T3604	x				
Florida	Contract T2376	x				
Florida	Contract T1322	x				

Florida	Contract T4299	x				
Indiana	Contract # 33045-A	x				
Indiana	Contract # 33049	x	x	x	x	
Kentucky	109-PIKE, CONTRACT ID - 111307	x	x	x	x	
Ohio	Project Number: 110255	x	x	x	x	
Ohio	Project Number: 113003	x	x	x	x	
Oregon	SPS09350	x				
Oregon	SPS 12076	x				
Washington	CONTRACT NO :007936 (Type C)	x				
Washington	CONTRACT NO : 006933	x				
Washington	CONTRACT NO :007417 (Type A or B)	x				
Washington	CONTRACT NO :007660 (Type A or B)	x				
Washington	CONTRACT NO : 007276	x				
Total		21				

Table 6.6.3: DOT Project Special Provisions: Allowed Logic Relationships

6.6.4 Schedule Specifications Survey

Survey respondents were asked about the use of SS and FF relationships; results are summarized in Table 6.6.4. 59% of the respondents believe that contractors should be allowed to use SS and FF relationships. 38% of the respondents recommended that these relationships should be used sparingly after notifying the DOT engineer. Only 3% recommended prohibiting their use.

	From your experience, what would be the best policy for the contractor's use of Start-to-Start (SS) and Finish-to-Finish (FF) relationships	Frequency	Percentage
1	Contractor should be allowed to use them	65	59.09%
2	Contractor should avoid them but inform the engineer if used	42	38.18%
3	Contractor should be prohibited from using them	3	2.73%

Table 6.6.4: Survey Results: Logical Relationships.

6.6.5 Summary and Recommendations

FS relationships are the most common relationships used in project scheduling for a reason; it's easy to understand, easy to visually track, and does not change when using different scheduling software. Therefore, it's not surprising that the PMI recommends using FS relationships when possible. It is also worth mentioning that the lack of logic (relationships) can result in open-ended activities which prevent the proper calculation of the critical path (AACEI, 2010).

4 out of the 27 states that include relationship provisions prohibited the use of SS and FF relationships while only 3% of the survey respondents recommend prohibiting their use. FF and SS relationships are categorized by the PMI as "optional" and recommend using these relationships sparingly (PMI, 2007). In many occasions, schedulers cannot avoid using SS and FF in order to represent a realistic sequencing of project activities; therefore it should be allowed but avoided if possible. For example, the relationships between mechanical, electrical, and plumbing (MEP) work in most residential and commercial projects are best described by the SS and FF relationships, and should be allowed in such case. While the identification of the critical path is important, the use of such SS and FF relationships should not be problematic in identifying the critical path if the CPM calculation is done properly.

SF relationships are the least used mainly because SF relationships do not relate to construction sequencing. NASA cautioned schedulers from the use of SF relationships while the UFGS restricted it. Therefore, avoiding the use of SF relationships and replacing them with FS relationships is recommended.

6.7 Activity Constraints

6.7.1 Common Practices

NASA defines constraints as "a fixed date assigned to a task to control when it starts or finishes." (NASA, 2010). The PMI defines them as "A schedule constraint placed on the schedule activity that affects when a schedule activity can be scheduled and is usually in the form of a fixed imposed date" (PMI, 2007). Constraints can be of different types to serve particular purposes. For example, the PMI scheduling standard practice lists a number of constraints and their behavior as follows:

1- As late as possible: Allows an activity to be scheduled so that it finishes on or before its late finish date.

2- As soon as possible: Allows an activity to be scheduled so that it finishes on its early finish date

3- Expected finish: Imposes a finish date on an activity that determines the remaining duration of the activity after it has been reported as started. The behavior of Expected Finish constraints are software application-dependent.

4- Finish not earlier than: Imposes a date on the finish of an activity prior to which the activity cannot finish. The behavior of Finish Not Earlier Than is scheduling tool dependent

5- Finish not later than: Imposes a date on the finish of an activity prior to which the activity must finish. The behavior of Finish Not Earlier than is scheduling tool dependent.

6- Finish on: Imposes a date on the finish of an activity on which it must finish. Finish On constraint prevents the activity from being scheduled to finish earlier as well as later than the imposed date. Finish On constraints are a combination of a Not Earlier Than and Not Later Than constraints. These impact both the forward and the backward pass calculation and hence both early and late dates. This causes the schedule activity to have a zero *total float* while its predecessors and successors may have different total float values.

7- Mandatory finish dates: A finish date constraint placed on a schedule activity that sets both the activity early and late finish dates equal to a fixed imposed date and thereby also constrains the early start dates of the network paths logically following that schedule activity.

8- Mandatory start dates: A start date constraint placed on a schedule activity that sets both the activity early and late start dates equal to a fixed imposed date and thereby also constrains the late finish date of the network paths logically preceding that schedule activity. Schedule calculations do not override this constraint. Therefore an imposed mandatory start sets the early dates for all paths leading to and the late dates on paths leading from the activity.

9- Project start constraint: A limitation or restraint placed on the project early start date that affects when the project must start and is usually in the form of a fixed imposed date.

10- Project finish constraints: A limitation or restraint placed on the project late finish date that affects when the project must finish and is usually in the form of a fixed imposed date.

11- Start not earlier than: A schedule constraint placed on the schedule activity that affects when a schedule activity can be scheduled and is usually in the form of a fixed imposed date. A Start Not Earlier Than constraint prevents the schedule activity from being scheduled to start earlier than the imposed date.

12- Start not later than: A schedule constraint placed on the schedule activity that affects when a schedule activity can be scheduled and is usually in the form of a fixed imposed date. A Start Not Later Than constraint prevents the schedule activity from being scheduled to start later than the imposed date.

13- Start on: A schedule constraint placed on the schedule activity that affects when a schedule activity can be scheduled and is usually in the form of a fixed imposed date. A Start On constraint requires the schedule activity to start on a specific date.

Constraints can override task interdependencies, which can lead to false critical paths and float times and therefore should be used sparingly (PMI, 2007) (NASA, 2010). In some cases, logic alone might not be sufficient to express the actual sequencing. For example, if a power shut-down is scheduled in order to perform a certain activity, a "start on" and a "finish on" constraints can be utilized to restrain the activity within the power shut-down dates. As a best common practice, "Constraints must not be a replacement for schedule network logic" (PMI, 2007). The AACEI "Strongly recommends against the use of mandatory constraints as they lead to illogical results where activities are scheduled to occur even if preceding work is incomplete" (AACEI, 2010).

Some scheduling software might have an option to apply a project constraint as well as activity constraints; these kinds of constraints can be hard to identify therefore their use is not recommended (AACEI, 2010).

The UFGS included the following specification: "Activity Constraints: Date/time constraint(s), other than those required by the contract, will not be allowed unless accepted by the Contracting Officer. Identify any constraints proposed and provide an explanation for the purpose of the constraint in the Narrative Report" (UFGS, 2008).

The common planning and scheduling software(e.g. MS Project and Primavera) have provided various functionalities to work with constraints. For example, Primavera provides the following constraints: as late as possible, finish on, finish on or after, finish on or before, mandatory finish, mandatory start, and start on. Similarly, MS Project provides eight date constraints including: as soon as possible, as late as possible, start no earlier than, finish no earlier than, start no later than, finish no later than, must start on, and must finish on. The as soon as possible is the default for the activities when scheduling from the project start date, and the as late as possible is the default when scheduling from the project finish date. Some scheduling software might have an option to apply a project constraint as well as activity constraints; these kinds of constraints can be hard to identify and therefore their use is not recommended (AACEI, 2010).

6.7.2 State Standard Specifications

States varied on how to deal with constraints. Most of the states do not mention constraints in their standard specifications, and only 7 states comment on the use of constraints in a schedule. Two states, New Hampshire and Wyoming, allow the use of constraints on milestones and project completion dates. For example the state of New Hampshire included the following provision:

"Interim, milestone, and project completion dates specified in the Contract as the only constraints in the schedule logic" (NHDOT, 2010). The state of Wisconsin approves only the use of contractual constraints (MDT, 2006) (WIDOT, 2011) without any reference to those constraints. Montana included the following provision: "Do not use any other schedule restraints such as activity mandatory start and finish dates or mandatory zero float constraints" (MDT, 2006). It should be noted that Idaho was the only state that required the contractor to include the constraints on the Gantt chart (ITD, 2004).

Rhode Island had the most detailed specifications for constraints; the specifications limited the use of activity constraints to the use of Start-No-Earlier-Than and Finish-No-Later- Than for access restraints and Completion Milestone. It also allowed the contractor to request permission from the engineer for the use of constraints on other activities with the exception of "Start On, Expected Finish, Mandatory Start or Mandatory Finish (RIDOT, 2004).

State	Description
Idaho	Contractor to identify all constraints in the schedule
Montana	Use only contractual restraints in the schedule logic. Do not use any other schedule restraints such as activity mandatory start and finish dates or mandatory zero float constraints.
Nevada	Provide a mathematical analysis of the network diagram which includes Activity constraints.
New Hampshire	Interim, milestone, and project completion dates specified in the Contract as the only constraints in the schedule logic
New Jersey	Use constraint dates only for Completion and interim completion milestones, unless approved by the RE.
Rhode Island	The use of activity constraints is limited to the use of Start-No-Earlier-Than and Finish-No-Later Than, for access restraints and Completion Milestone
Wisconsin	Use only contractual constraints in the schedule logic

Table 6.7.1: DOT Standard Specification: Logic Constraints

6.7.3 State Special Provisions

While most States do not mention constraints in their Standard Specifications, the Special or Supplemental Provisions of some projects or states provide detailed information about the use of constraints. Of the states that include constraint provisions in their special provisions, all of the projects that include them were $10 million plus projects. California and Michigan Standard Special Provisions allowed the contractor to use contractual constraints. Other constraints can be allowed if approved by the engineer (MDOT, 2011) (Caltrans, 2011). The state of Ohio is more specific in the type of constraints allowed in a schedule as follows: "Use constraints sparingly in the schedule. If constraints are used, use only Early Constraints or Late Constraints" (OhioDOT, 2010). The state of Florida requires the contractor to use constraints for project start and project completion; any other constraint is not allowed unless approved by the engineer. When the contractor desires to use any other constraints, "it must be submitted to the Engineer with the rationale for the use of each desired additional constraint. If allowed by the Engineer, the rationale should be recorded in the activity's log field." (FDOT, 2010).

The state of Indiana provides the most detailed constraints provisions in their special provisions as follows: "Activities shall not be constrained unless noted herein or approved by the Engineer. The contract completion date, intermediate completion dates, and I/D dates shall be constrained using a finish on or before constraint. Delayed start dates shall be constrained using a start on or after constraint." (INDOT, 2010).

6.7.4 Schedule Specifications Survey

The participants to the schedule survey were asked: "What would be the best policy for the contractor's use of constraints?" Three options were available as shown in table 1.4.1. According to the survey, most DOT personnel do not want to restrict the contractor from using activity constraints, in fact, only 7.27% preferred the contractors not use any activity constraints.

The survey shows the majority are in favor in giving freedom to the contractor to use activity constraints (61.82%), which contradicts the industry best practices discussed above.

	Question: The use of constraint dates (e.g. start no earlier than, No later than, etc.)	Percentage
1	Contractor should be allowed to use them	61.82%
2	Contractor should avoid them but inform the engineer if used	30.91%
3	Contractor should be prohibited from using them	7.27%

Table 6.7.2: Survey Results: Logic Constraints

6.7.5 Summary and Recommendations

Constraints can be defined as user-defined dates that can alter or override the schedule-driven dates that would normally be obtained through the activity network (logic) and the CPM network calculations.

The different types of constraints can be categorized as :

- Flexible constraints: These give the same scheduling dates as are normally obtained through regular network calculations (based on sequence and CPM calculations, such as the start as soon as possible).
- Moderately flexible constraints: These give a range or window of dates to start or finish within (such as start no earlier than, start no later than, finish no earlier than, and finish no later than).
- Inflexible or hard constraints: These have absolute dates that override the schedule-driven or network dates if there is conflict (such as the must start on and must finish on).

Constraints can affect the start and finish dates of activities, which consequently would affect the float times of the activities, change the critical path of a project, and ultimately change the project milestone date and the completion date. While these effects would prove to be problematic (particularly for delay claims)only 7 states in their standard specification and 5 states in their special provisions tried to manage their use when developing schedules. It is more surprising to find that State DOTs preferred to allow the contractor to use constraints (see survey results Table 6.7.2).

Against the preference of State DOTs and the weak consideration in special provisions, the common practices of the major institutions (e.g. PMI) recommend against the use of constraints in the original baseline schedule.

It is recommended that the language of the standard specifications of the states recognize constraints as follows: "Constraints are allowed in a project schedule in as much as they would not alter the critical path of a project in a way that would be considered detrimental or harmful to the owner [e.g. highway agency, DOT, County, City] or in a way that might lead to time and/or cost effects to the owner."

6.8 Lead & Lag times

6.8.1 Common Practices

The PMI defines Lead/Lag times as: "A modification of a logical relationship that directs a delay/acceleration in the successor activity" (PMI, 2007). NASA defines lag as "the period of time applied to a relationship between two tasks that delays the defined relationship execution. For example, a task logically tied to another task with a finish-to-start relationship and a 5-day lag will result in the successor task's start being delayed until 5 days after the completion of the predecessor" (NASA, 2010). And lead as "the period of time applied to a relationship between two tasks that accelerates the defined relationship execution. The amount of lead time (acceleration time) is assigned as a negative value. For example, a task logically tied to another task with a finish-to-start relationship and a negative 5-day lead will result in the successor task's start beginning 5 days prior to the completion of the predecessor." (NASA, 2010).

The PMI places special emphasis on the impacts of lead and lag times, and cautions schedulers to have a sound understanding of these concepts. In general, the PMI advises that lead and lag time should only be used when no other logic can be used. Lead and lag times can also be replaced by activities; for example, instead of representing "document review" as lag, it can be substituted with a well coded activity (PMI, 2007).

NASA, on the other hand, allows the use of lead and lag times only when it represents a required delay/acceleration between activities (e.g. concrete cure). Lead and lag time are not very visible and can create some difficulties when analyzing the schedule. They may also corrupt the float time calculations and therefore corrupt the critical path. NASA recommends substituting the lead/lag time with well-defined activities. (NASA, 2010)

The UFGS advises that "Lag durations contained in the project schedule shall not have a negative value" (UFGS, 2008). It also restricts the contractor from using any lag times other than the ones required in the contract.

6.8.2 State Standard Specifications

Five states mention lead/lag times in their standard specifications. The states of Montana, New Hampshire, Wisconsin, New Jersey, and Wyoming prevented the use of lead and lag times. For example, New Hampshire Standard Specifications include the following provision: "Use finish-to-start relationships among activities, without leads or lags, unless otherwise approved by the Engineer" (NHDOT 2010). New Jersey Standard Specifications require substituting lead/ lag times with activities (NJDOT 2007).

6.8.3 State Special Provisions

The Standard Special Provisions of California, South Carolina, and Indiana prohibit the contractor from using negative lag values. Indiana, Ohio, and Kentucky projects allow the use of lag values only with finish to finish or start to start relationships, but these values can't exceed the original duration of the predecessor activities. The Special Provisions of the states of Florida, Ohio, and Kentucky indicate that the use of special lead/lag values will be basis for schedule rejection.

Table 6.8.1 summarizes lead and lag provisions included in state special provisions. The states of Indiana and Kentucky included lead/lag provisions on specific projects. While other states like California and Ohio included lead/lag provisions in all the projects.

State	Provision / Project	Price	Description
California	Contract No. 07-138204	$160,000,000.00	Baseline schedule should not show negative lag to any activity
California	Contract No. 03-3797U4	$130,000,000.00	Baseline schedule should not show negative lag to any activity
California	Contract No. 12-0G3304	$56,000,000.00	Baseline schedule should not show negative lag to any activity
California	Contract No. 07-241304	$1,560,000.00	
California	Contract No. 05-0T3604	$1,120,000.00	Baseline schedule should not show negative lag to any activity
Indiana	Recurring Special Provisions 108-C-215 Critical Path Method Schedule		• A statement describing the reason for the use of each lag is required • Finish-to-finish or start-to-start activity relationships may use lags that include fewer days than the original duration of the predecessor activity. • The use of lags with a negative value shall not be used for any activity relationship type.
Indiana	Contract # 33045-A	$141,778,367.70	• A statement describing the reason for the use of each lag is required • Finish-to-finish or start-to-start activity relationships may use lags that include fewer days than the original duration of the predecessor activity. • The use of lags with a negative value shall not be used for any activity relationship type.
Indiana	Contract # 33049	$69,344,417.82	• A statement describing the reason for the use of each lag is required • Finish-to-finish or start-to-start activity relationships may use lags that include fewer days than the original duration of the predecessor activity. • The use of lags with a negative value shall not be used for any activity relationship type.

Indiana	Contract # IR-30850-A	$26,200,000.00	
Indiana	Contract # 32756	$8,700,000.00	
Indiana	Contract # IR-31879-A	$2,960,000.00	
Kentucky	109-PIKE, CONTRACT ID - 111307	$53,549,206.66	• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$17,223,036.46	
Kentucky	104 various, CONTRACT ID - 111012	$8,510,265.82	
Kentucky	35-PERRY, CONTRACT ID - 111308	$2,911,145.71	
Ohio	PN 105 – Critical Path Method Progress Schedule For Short Duration Projects		• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Ohio	PN 107 - Critical Path Method Progress Schedule		• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Ohio	Project Number: 110255	$54,923,975.95	• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Ohio	Project Number: 113003	$12,224,208.50	• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Ohio	Project Number: 110386	$7,171,036.00	• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
Ohio	Project Number: 110321	$3,658,484.63	• Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities.
South Carolina	Project Number: BR26(012), 08 February	$75748835.57	• Initial baseline schedules shall not attribute negative lag to any activity • Schedule narrative should include an explanation of lag for each activity lag is associated with
South Carolina	Project Number: BR88(066), 09 November	$17346264	• Initial baseline schedules shall not attribute negative lag to any activity • Schedule narrative should include an explanation of lag for each activity lag is associated with

South Carolina	Project Number: MR11(071),14 December	$6673974.58	• Initial baseline schedules shall not attribute negative lag to any activity • Schedule narrative should include an explanation of lag for each activity lag is associated with
South Carolina	Project Number: RS10(087), 08 march	$3440083.5	• Initial baseline schedules shall not attribute negative lag to any activity • Schedule narrative should include an explanation of lag for each activity lag is associated with

Table 6.8.1: DOT Project Special Provisions: Lead and Lag Requirements

6.8.4 Schedule Specifications Survey

The respondents were asked if contractors should be allowed to use lead/lag times when developing schedule logic, and whether the engineer should be notified about it. 66% of the respondents believe that the contractor should be allowed to use Lead/Lag times without notifying the engineer, while 30% recommended informing the engineer (See Table 6.8.2).

	Question: The use of lead/lag times between activities	Percentage
1	Contractor should be allowed to use them	66.36%
2	Contractor should avoid them but inform the engineer if used	29.09%
3	Contractor should be prohibited from using them	4.55%

Table 6.8.2 Survey Results: Use of Lead/Lag Times

6.8.5 Summary and Recommendations

Adding lag/lead times can corrupt logic calculations and can affect the critical path. It is recommended by the PMI that schedulers replace lag with activities as mentioned earlier (PMI, 2007). New Jersey is the only state that recommends replacing lead/lag times with activities. State Special Provision for Indiana, Kentucky, and Ohio included the following provision "Use only finish-to-start relationships with no leads or lags to link activities, or use start-to-start relationships with lags no greater than the predecessor duration to link activities" (See Table 6.8.1).

The use of Lead and lag times should not be prohibited. They are necessary to develop a factual project schedule. But since the excessive use can impact the schedule logic, this research recommends that schedulers substitute the lead/lag times with activities when possible. This recommended provision would help maintain the integrity of the schedule logic and prevent the contractor from preferential sequencing.

6.9 Maximum Number of Activities

6.9.1 Common Practices

The AACEI, PMI, NASA, and the UFGS do not specify a limit on the number of activities used in a project schedule.

6.9.2 State Standard Specifications

The majority of the states do not restrict the contractor to a maximum or a minimum number of activities. The states of Alaska, Idaho, Maryland, and North Dakota give the engineer the right to limit the number of activities on a schedule (AKDOT, 2004) (ITD, 2004) (MarylandDOT, 2008) (NDDOT, 2008). Louisiana has a different view; the contract administration manual suggests that "The number of activities is maximized in the best CPM schedules" (LADOTD, 2005).

The states of Montana, Oklahoma, and West Virginia chose to limit the contractor to a number of activities. The state of Montana limited the number of activities to a minimum of 50 activities and a maximum of 500 (MDOT, 2003). Oklahoma also limited the maximum number of activities in the range of 50 – 500 activities (OKDOT, 2009). West Virginia standard specifications include the following provision: "The schedule shall provide a minimum of ten activities or categories, hereafter referred to as "Activities", per million dollar value of the contract and a maximum of three hundred activities or as directed by the engineer" (WVDOT, 2010).

6.9.3 State Special Provisions

The state of California is the only state that relies on the Special Provisions to limit the number of activities in a construction schedule as follows: "At least 50 but not more than 500 activities, unless authorized. The number of activities must be sufficient to assure adequate planning of the project, to permit monitoring and evaluation of progress, and to do an analysis of time impacts" (Caltrans, 2011) (Caltrans b, 2011) (Caltrans.D, 2011) (Caltrans, 2010).

6.9.4 Schedule Specifications Survey

2 questions were included in the survey addressing maximum number of activities in a project schedule. The first question asked the respondents to select a range of the maximum number of activities that should be allowed in a project schedule (Table 6.9.1). Approximately 50% of the respondents suggested that there should be no restrictions on the number of activities used in a project schedule.

	Question: Some public agencies restrict the number of activities in a project schedule (e.g. 300 activities per schedule). In your opinion, the maximum number of activities in a schedule should be in the range:	Percentage
1	Between 50-100 activities	11.82%
2	Between 100-150 activities	5.45%
3	Between 150-200 activities	5.45%
4	Between 200-250 activities	3.64%
5	Between 250-300 activities	8.18%
6	Between 300-350 activities	2.73%
7	No restrictions	48.18%
8	Other:	14.55%

Table 6.9.1: Survey Result: Maximum Number of Activities

The second question addressed the correlation between the maximum number of activities and project size, duration, type, and sophistication (Table 6.9.2). The respondents were asked to answer each part of the question on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Generally, most respondents agreed that the maximum number of activities should rely on the factors listed above.

	The maximum number of activities used in a construction schedule should correlate with:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Project Size	3.64%	8.18%	7.27%	35.45%	45.45%
2	Project Duration	3.64%	15.45%	19.09%	40.00%	21.82%
3	Project Type	2.73%	5.45%	22.73%	43.64%	25.45%
4	Project sophistication (e.g. highway in an urban area compared to a highway in a rural area)	1.82%	7.27%	5.45%	38.18%	47.27%

Table 6.9.2: Survey Results: Maximum Number of Activities and Project Complexity

6.9.5 Summary and Recommendations

"The activity is a discrete element (or block) of work that is a tangible element of the project scope" (PMI, 2007) therefore a project schedule should have enough activities to identify all elements of the project regardless of size, duration, type, sophistication etc. Therefore, restricting the number of activities in a project schedule leads to consolidating project activities resulting in unquantifiable, unmanageable schedule activities.

6.10 Non-Construction Activities

6.10.1 Common Practices

Non-construction activities can be defined as any activity that is not direct construction or production but still required for the proper completion of the project on time. The UFGS categorizes non-construction activities into procurement activities, government activities, quality management, and turnover and closeout activities (UFGS, 2008).

- Procurement activities include but not limited to "submittal preparation, submittal and approval of material/equipment; material/equipment fabrication and delivery, and material/equipment on-site." (UFGS, 2008). According to the UFGS, the sequence of procurement activities is typically: submit, approve, procure, fabricate, and deliver.

- Governmental activities; governmental activities include submittal reviews, inspections/tests, and environmental permit approvals (UFGS, 2008).

- Turnover and Closeout Activities: "As a minimum, this will include all testing, specialized inspection activities, Pre-Final inspection, Punch List Completion, Final Inspection and Acceptance" (UFGS, 2008).

6.10.2 State Standard Specifications

The non-construction activities mentioned in the Standard Specifications and Construction Manuals are highlighted in Table 6.10.1. The main non-construction activities are procurement, mobilization, fabrication, review periods, submittals, and permitting. The state of Idaho specifies that "Activities shall include, but are not limited to engineering, surveying, permitting, submittals, approvals, procurement, fabrication and construction" (ITD 2004). Similarly, the state of New Jersey specifies the following: "Ensure that the schedule includes ROW availability dates, permits, submittals, working drawings, procurement, fabrication, delivery of materials, construction, and other activities necessary to complete the Work" (NJDOT 2007). The state of Nevada Standard Specifications is the most detailed of all states, requiring the addition of 5 non-construction activities: procurement activities, mobilization, submittals, review periods/ acceptance, fabrication, and permit restrictions.

State	Procurement activities	Mobilization	Submittals	Review periods/ acceptance	Fabrication	Permit Restrictions
Alaska	X	X	X		X	
Arizona	X					
California	X				X	
Colorado	X		X	X		
Delaware	X		X		X	X
Florida	X		X	X	X	

Hawaii	X	X	X		X	
Idaho	X		X	X	X	X
Iowa					X	
Kansas			X		X	
Kentucky				X	X	
Maryland	X		X		X	
Missouri		X				
Montana			X		X	X
Nevada	X	X	X	X	X	
New Hampshire	X		X	X		X
New Jersey	X		X		X	X
New York	X	X				
North Dakota			X	X	X	
Ohio	X		X	X	X	
Oklahoma	X		X	X	X	
Oregon	X		X		X	
Pennsylvania	X				X	X
Rhode Island	X		X			
Tennessee					X	
Texas	X				X	
Utah					X	
Washington					X	
West Virginia	X		X	X	X	
Wisconsin	X		X		X	
Wyoming	X		X		X	
Count	22	5	20	10	25	6

Table 6.10.1: DOT Standard Specification: Non-Construction Activities

6.10.3 State Special Provisions

Several state DOT projects require non construction activities to be represented in the project schedule. Table 6.10.2 summarizes these activities.

State	Provision / Project	Price	Procurement activities	Mobilization	Submittals	Review periods/ acceptance	Fabrication	Permit Restrictions
California	Contract No. 07-138204	$160,000,000.00	X		X	X		X
California	Contract No. 03-3797U4	$130,000,000.00	X		X	X		X
California	Contract No. 12-0G3304	$56,000,000.00	X		X	X		X
California	Contract No. 07-241304	$1,560,000.00						
California	Contract No. 05-0T3604	$1,120,000.00	X		X	X		X
Florida	Contract T2376	$19,453,029.69	X		X	X	X	
Florida	Contract T1322	$14,667,050.00	X		X	X	X	
Florida	Contract T2366	$1,912,362.28						
Florida	Contract T4299	$1,597,956.96	X		X	X	X	
Indiana	Contract # 33045-A	$141,778,367.70	X		X	X	X	
Indiana	Contract # 33049	$69,344,417.82	X		X	X	X	
Indiana	Contract # IR-30850-A	$26,200,000.00						
Indiana	Contract # 32756	$8,700,000.00						
Indiana	Contract # IR-31879-A	$2,960,000.00						
Kentucky	Contract ID - 111307	$53,549,206.66	X		X	X	X	
Kentucky	Contract ID - 111023	$17,223,036.46						
Kentucky	Contract ID - 111012	$8,510,265.82						
Kentucky	Contract ID - 111308	$2,911,145.71						
Ohio	Project Number: 110255	$54,923,975.95	X		X	X	X	
Ohio	Project Number: 113003	$12,224,208.50	X		X	X	X	
Ohio	Project Number: 110386	$7,171,036.00						
Ohio	Project Number: 110321	$3,658,484.63						
Oregon	SPS09350	Over $50 million	X		X	X	X	X
Oregon	SPS10694	Over $50 million						
Oregon	SPS 12076	Over $50 million	X		X	X	X	X
Oregon	SPS 14032	Over $50 million						
Oregon	SPS14197	Over $50 million						
Oregon	SPS14949	Under $50 million						
Oregon	SPS06025	Under $50 million						
Oregon	SPS12874	Under $50 million						
South Carolina	Project Number: BR26(012)	$75,748,835.57		X				X
South Carolina	Project Number: BR88(066)	$17,346,264		X				X
South Carolina	Project Number: MR11(071)	$6,673,974.58		X				X
South Carolina	Project Number: RS10(087)	$3,440,083.5		X				X
Washington	CONTRACT NO :007936	$53,398,008.88	X		X	X	X	X
Washington	CONTRACT NO : 006933	34,000,000.00	X		X	X		X

Washington	CONTRACT NO :007417	$14,689,000.00						
Washington	CONTRACT NO : 007685	$9,790,516.54						
Washington	CONTRACT NO :007686	$7,264,345.36						
Washington	CONTRACT NO :007669	$6,595,797.58						
Washington	CONTRACT NO :008086	$3,569,039.50						
Washington	CONTRACT NO :007645	$2,574,636.90						
Washington	CONTRACT NO :007897	$2,425,312.86						
Washington	CONTRACT NO :007660	$2,286,623.00						
Washington	CONTRACT NO : 007276	$421,974.00						

Table 6.10.2: DOT Project Special Provisions: Non-Construction Activities

6.10.4 Schedule Specifications Survey

Survey respondents were asked to select the non-construction activities to be included in the submitted construction schedule; the results are summarized in Table 6.10.3. Over 70% of the respondents believe that including procurement, submittals, submittal review times and fabrication activities is beneficial in a project schedule. Over 50% of the respondents recommended adding mobilization and permitting activities.

	Please select from the following list the non-construction activities that are essential and need to be included in construction schedules:	Percentage
1	Mobilization	55.45%
2	Procurement activities (particularly long lead items)	78.18%
3	Submittals	70.00%
4	Submittal review period and approval activities	78.18%
5	Permitting activities	53.64%
6	Fabrication	78.18%

Table 6.10.3: Survey Results: Non-Construction Activities

6.10.5 Summary and Recommendations

Approximately 50% of states Standard Specifications include at least one non-construction activity provision, as shown in Table 6.10.1, which is also supported by the survey results in which over 70% recommended including these activities. Non-construction activities can directly impact the critical path; therefore including such activities is essential for creating a realistic, factual project schedule. Including non-construction activities can also help represent the logistical and managerial aspects of a construction project.

7 SCHEDULE MANAGEMENT

7.1 Resource and Cost Loading

7.1.1 Common Practices

Schedule cost loading is the addition of cost estimates to schedule activities. Cost estimates can include various cost components such as labor cost, equipment cost, and material cost (PMI, 2007). The UFGS requires that all activities, procurement activities (material and equipment) and construction activities should be cost loaded. The UFGS also requires that "each cost loaded activity shall have a quantity breakdown and unit of measure" (UFGS, 2008). The main purpose of cost loading the activities is to determine the earnings (payments) during each update period and "The aggregate value of all activities coded to a contract schedule shall equal the value of the contract." (UFGS, 2008).

Resource loading is simply adding the resources needed to perform a certain task to schedule activities. Resources can be divided into three categories: workforce, equipment, and materials. These resources can be integrated into the scheduling software (recommended by NASA), or on a separate spreadsheet. Prior to assigning resources to activities, it is recommended to build a resource pool that includes all the potential resources to be used in the project. There are also specific data elements that must be associated with each resource that are critical to accomplishing effective resource loading. These resource data elements include, but are not limited to, the following: (NASA, 2010)

1- Resource name (employee names are not recommended due to dynamic work assignment changes, add new resource names as-needed)

2- Resource description (e.g., organization name, support contractor company name)

   - Resource Types (e.g., workforce, material, or consumables)

3- Element of cost:

   - Travel

- Personnel
- Other Direct Cost
- Support Contractor
- Equipment
- Contracts
- Material
- Overhead and G&A

4- Center identifier (use official Center acronym)

5- Maximum number of units available Standard Unit Rate (project to determine)

6- Overtime Rate (project to determine)

7- Cost per Use (project to determine)

8- Accrual method (start, prorated, end)

9- Resource Calendar (reflects active periods of resource availability - project to determine)

The PMI warns that "if overall resources and their availability are not considered, the critical path method calculation can sometimes produce unachievable schedules." To prevent this, resources should be added and assigned so that resource leveling techniques can be employed (PMI, 2007).

7.1.2 State Standard Specifications

The Standard Specifications of all states fail to mention any cost loading requirements, except for New Mexico and West Virginia Standard Specification. New Mexico requires that the submitted baseline bar graph schedule show each activity's estimated cost and percent of total bid amount (NMDOT, 2007). Virginia DOT requires the contractor to add dollar values to the schedule activities (WVDOT, 2010). The Florida Construction Project Administration Manual (CPAM) mentions that if any activity is cost loaded, the cost should conform to the bid amount for the same type of work (FDOT, 2009).

5 States mention resource loading in their Standard Specifications or Construction Manuals. Maryland requires all construction activities to be resource loaded with manpower, equipment, and

materials (MarylandDOT, 2008), whereas New Jersey prohibits any resource loading (NJDOT, 2007). The state of Utah restricts the use of resource loading "if resource limitations can affect the prosecution of the work" (UDOT, 2008). Rhode Island and Arizona require the contractor to resource load the schedule when the project is significantly behind schedule (RIDOT, 2004) (ADOT, 2000). "TxDOT does not need to have resource loading to the level of detail where we know each hammer, nail and piece of form plywood that may be needed" (TXDOT, 2003).

7.1.3 State Special Provisions

The Special Provision of SR 8 (I-10) Improvements Project in Florida requires that each schedule activity shall be cost loaded. Activity cost loading shall be consistent with the bid breakdown. The sum total of the activity cost loading shall be equal to the current contract value (FDOT, 2010) (FDOT.c, 2010). Project SR161 SR18 Interchange Improvements 7936, a $50 million plus project in Washington, also require cost loading the project schedule and that the contractor shall "allocate a value for each bid item listed in the summary of quantities to each relevant activity in the schedule" (WSDOT, 2010). The US-17 Bypass & SC 707 Interchange project in South Carolina, on the other hand, specifically requested the cost loading of all activities using the functionality of Primavera software (SCDOT.a, 2011).

Few states mention resource loading in their Special and Supplemental provisions. Florida prohibits the use of resource leveling but requires resource loading in the detailed schedule diagrams. West Virginia does not specifically mention the term "resource load," but requires the following from contractors (WVDOT, 2010):

- Number of shifts per work day, hours per shift for activity
- Number of work days per week for activity
- Major equipment and corresponding hours for activity
- Manpower by Trade or entity and corresponding hours for activity

- Activity usage profile cost of contractor's Income

Texas Special Provisions included the following: "Plan and incorporate major resources, such as crews and heavy equipment, into the schedule. Accurately represent the planned labor and equipment to achieve the estimated productivity rates. Associate planned resources with individual schedule activities" (TXDOT, 2004).

7.1.4 Schedule Specifications Survey

Since the majority of the Standard Specifications and the Special Provisions do not include any cost loading provisions, the survey included multiple questions to capture the reason behind the omission of this provision. The questions were formulated in a matrix form as shown in Table 7.1.2 and Table 7.1.2 :

	Question: The reasons that a public agency might request a resource-loaded or cost-loaded schedule include:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	Justifying additional costs when changes occurs	0.91%	9.09%	19.09 %	56.36 %	14.55 %
2	Ensuring work is adequately staffed to meet the schedule demand	0%	8.18%	20.91 %	57.27 %	13.64 %
3	Conveying to the contractor the importance of the project timelines	0%	12.73 %	39.09 %	39.09 %	9.09%
4	Tracking the use of all resources	1.82%	11.82 %	40.91 %	37.27 %	8.18%
5	Tracking the use of "critical" resources	0%	8.18%	29.09 %	44.55 %	18.18 %
6	Public agency fear of project not finishing on time	0.91%	20.91 %	33.64 %	36.36 %	8.18%
7	Public agency fear of cost overruns	0.91%	18.18 %	36.36 %	37.27 %	7.27%
8	No specific reason	16.36%	11.82 %	66.36 %	3.64%	1.82%

Table 7.1.1: Survey Results: Advantages of Cost/ Resource Loaded Schedules

	Question: I would not generally encourage resource-loaded or cost loaded schedules because:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	It takes time for public agency personnel to manage them	10.91%	18.18%	30.00%	37.27%	3.64%
2	Their development costs the project more money	9.09%	19.09%	32.73%	33.64%	5.45%
3	They delay the contractor's schedule submittal	8.18%	25.45%	40.91%	22.73%	2.73%
4	Not all construction schedule activities matches the contract bid items	7.27%	16.36%	30.00%	39.09%	7.27%
5	Contractor may not be good at handling/managing them	9.09%	17.27%	23.64%	40.91%	9.09%
6	Contractor refuses to make proprietary information public and/or accessible to their competitors	7.27%	14.55%	40.00%	32.73%	5.45%

Table 7.1.2 Survey Results: Disadvantages of Cost/ Resource Loaded Schedules

The respondents were asked to answer each part of the question on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree). The standard deviation was approximately 1 for all questions. From the responses of the first survey question, it can be concluded that the majority of the respondents agree that resource and cost loading is a good project control tool. The responses to the second question lament the complexity of developing resource and cost loaded schedules. It reveals the lack of skilled and sophisticated schedulers on the contractor and the DOT side. It also highlights the high costs of developing such schedules.

7.1.5 Summary and Recommendations

The importance of resource loading is interconnected with the importance of a well-defined critical path. The critical path is controlled by the relationships that define the sequencing of work and by the duration of each activity. The duration of each activity is a function of the resources that are involved in achieving it; therefore, the resources control the critical path. Unfortunately, many contractors refuse to resource load their schedules for fear that they might reveal their secrets to the competition. Added to this, without resource loading the contractor assumes that he has unlimited resources when developing the schedule.

Cost loading was rarely mentioned in the Standard Specifications and the Special Provisions. Only two states, Florida and New Mexico, include very simple stipulations for cost loading in their Standard Specifications. The Special Provisions of only 4 projects in Washington, Florida, and South Carolina include detailed cost loading provisions as shown in Table 7.1.3.

	Project Name	State	Cost
1	SR 8 (I-10) Improvements Contract T2366	Florida	$1,912,362.28
2	SR 786 Improvements Contract T4299	Florida	$1,597,956.96
3	US-17 Bypass & SC 707 Interchange Project Number: BR26(012)	South Carolina	$75,748,835.57
4	SC-5 Lancaster Bridge Replacement	South Carolina	$17,346,264.00
5	S-13 & SC 19 Roadway Improvements	South Carolina	$6,673,974.58
6	SC 39 Roadway Improvements	South Carolina	$3,440,083.50
7	I-5 Interchange Improvements Contract No :007936	Washington	$53,398,008.88

Table 7.1.3: DOT Project Special Provisions: Cost Loading Provisions

Cost loading has many advantages. It can help the owner keep the contractor from front loading the project for payment purposes, and helps expose unbalanced bids. "Therefore, cost-loading of the project is generally a good idea but it can backfire and lead to problems. Owners need to be careful when specifying that the activity updating is tied directly to the processing and approval the contractor's monthly pay estimate" (Martin J. Bradley, 2005).The contractor can also benefit from the ability analyze the project financially using earned value analysis.

Developing cost loaded schedules takes time, effort, and specialized skilled professionals, which essentially means additional cost to the project.

7.2 Schedule Risk Analysis

7.2.1 Common Practices

A requirement for schedule risk analysis is a far more technical requirement than a CPM schedule; it requires showing how the project milestones and completion times will be affected under risks and uncertainties. The PMI suggests that: "Schedule risk analysis should be used for projects where the standard CPM durations and critical paths are viewed as risky by stakeholders. Furthermore, the schedule risk analysis should, at minimum, address the risk event(s) identified as having a high probability and impact" (PMI, 2007). According to the PMI, the most commonly used method is the Program Evaluation and Review Technique (PERT). PERT utilizes 3 points in estimating activity duration: an optimistic value, a most likely value, and a pessimistic value - then calculates the activity duration using ((OV+4MLV+PV)÷6). If significant historical data is available for activity duration, this data can be represented through a function and simulation tools can be employed (e.g. Mote Carlo simulation) (PMI, 2007).

The following are optional schedule components as defined by the PMI (PMI, 2007):

- Activity Cumulative Probability Risk Distribution: "A table of dates and their associated cumulative probabilities of occurrence for schedule activity completion. Dates are derived using analytical techniques such as Monte Carlo calculations. When applied to the project end date, the value is equivalent to the Project Cumulative Probability Risk Distribution" (PMI, 2007). As a good practice, the PMI suggests that the risk analysis process should be used when the project schedule can impact the project objectives.
- Activity Most Likely Duration: "The total number of work periods in calendar units assigned to perform the schedule activity, considering all of the variables that could affect performance, and is determined to be the most probable activity duration" (PMI, 2007).

- Activity Optimistic Duration: ”The total number of work periods in calendar units assigned to perform the schedule activity, considering all of the variables that could affect performance, and is determined to be the shortest possible activity duration” (PMI, 2007).
- Activity Pessimistic Duration: “The total number of work periods in calendar units assigned to perform the schedule activity, considering all of the variables that could affect performance, and is determined to be the longest possible activity duration” (PMI, 2007).
- Activity Risk Criticality Index:” The probability that the schedule activity will be on a critical path” (PMI, 2007).

Similarly, NASA recommends including three values for activity durations: most likely duration, optimistic duration and pessimistic duration (NASA, 2010). NASA defined the optimistic value as “the least amount of time required to complete the task should identified risks not materialize and/or identified opportunities are realized, or the minimum duration the owner of the task will permit” (NASA, 2010) and the pessimistic value as “the greatest amount of time required to complete the task should identified risks materialize and identified opportunities are not realized, or the maximum duration the owner of the task will permit” (NASA, 2010). NASA suggests, as a best practice, that these values be based on duration uncertainty and the probability of associated risks. NASA also recommends the use of expected activity duration-which is the average of the most likely, pessimistic, and optimistic values- in project schedules (NASA, 2010).

As a risk mitigation method, NASA recommends including a schedule margin (contingency) in the schedule. This can be achieved by adding a schedule margin activity, use of milestones, constraint dates, and relationship lag values (NASA, 2010).

The schedule margin should be determined based on several factors as follows:

- Expert judgment
- Rules of thumb
- % of overall project (or activity) duration
- Calculated by expected value of risk impacts
- Through insight gained from a probabilistic schedule risk assessment

7.2.2 State Standard Specifications

The states of Hawaii, New Jersey, Washington, and Wyoming require PERT. New Jersey DOT Standard Specifications give the resident engineer the right to require a PERT chart as follows: "The RE may require 3 color paper copies of…….a network diagram (PERT) printed on 36 x 22-inch plans detailing the activity relationships" (NJDOT, 2007). Similarly, Wyoming DOT required the contractor to submit a "logic diagram in color, depicting no more than 50 activities on each 11 in × 17 in [280 mm × 430 mm] sheet and with each sheet including title, match data for diagram correlation, and a key. In the diagram (which may be a time-scaled, Program Evaluation and Review Technique (PERT) chart)" (WYDOT, 2010).

Hawaii DOT Standard Specifications require 2 submissions of PERT charts as follows (HDOT, 2005):

- Initial schedule: Two sets of color time-scaled project evaluation and review technique charts ("PERT") using the activity box template of Logic – Early Start or such other template designated by the Engineer
- Bi-weekly: After the acceptance of the initial TSLD and when construction starts, the Contractor shall submit four plotted progress schedules, two PERT charts, and reports on all construction activities every two weeks (bi-weekly)

7.2.3 State Special Provisions

Two New Jersey projects included provisions regarding PERT as follows: "The RE may require 3 color paper copies of the preliminary schedule, Gantt Chart, as specified in 153.03.02.2.e, and a network diagram (PERT) printed on 36 × 22-inch plans detailing the activity relationships." (NJDOT.c, 2007) (NJDOT.e, 2007). This was identical to their Standard Specifications.

Two projects in Ohio (USR 50 Improvements Project Number: 110255 and USR 20 Resurfacing Project Number: 113003) included PERT requirements as follows: "Submit a diagram in PERT chart format showing the logic of the baseline schedule" (Ohio DOT, 2011) (Ohio DOT.b, 2011).

7.2.4 Summary and Recommendations

CPM scheduling method assumes there is only one outcome for each of the modeled activities. In reality, in the construction industry there are multiple outcomes for each activity, these outcomes can be identified and managed through a schedule risk analysis model (Christian, 1999). Only 4 State DOTs require PERT (or any risk technique) in their Schedule Specifications, and only 4 of the studied projects required PERT. Given the critical nature of DOT projects, the lack of risk management tools can be costly - especially with complex projects. But the main question is: should this be a requirement for a minimally acceptable schedule? This research recommends that these risk analysis is included on a project basis, therefore, should not be a Standard Specification Provision.

7.3 Preliminary / Initial Schedules

7.3.1 Common Practices

Preliminary schedules (sometimes referred to as initial or interim schedules) are summarized schedules that cover a period of time ranging from 30-120 days and are submitted prior to the submission of the baseline progress schedule. These schedules are generally required after signing the contracts in order to ascertain how the contractor will proceed during the first one or two months of the project. The UFGS requires the submission of a preliminary schedule covering the initial 90 days of work. The schedule is to be submitted in no longer than 15 calendar days from the acknowledgment of the notice to proceed. According to the UFGS, the preliminary schedule shall follow certain requirements as follows (UFGS, 2008) :

- Cost Loading.
- Early start and late finish constrained.
- Include plan and program preparations.
- Include submission, design permitting and approval activities (e.g. quality control plan, safety plan, and environmental protection plan).

7.3.2 State Standard Specifications

Thirteen states require the preparation of preliminary schedules in their Standard Specifications. The differences between the preliminary schedules specifications between these states can be broken down into three categories: submittal date and review time, coverage period, and the level of detail.

7.3.2.1 Submittal Date and Review Time

Colorado's Standard Specifications require that the initial schedule be submitted "10 working days prior to the start of work" (CDOT 2011). Other states, such as New Hampshire, require the preliminary schedule to be submitted "at least 10 calendar days before the preconstruction meeting" (NHDOT, 2010). Nevada's Standard Specifications include a more detailed provision that requires the submission "within 14 days of the Notice of Award, and no later than 7 days before the Preconstruction Conference" (NDOT 2010). Once the schedule is submitted, the engineer is allowed some review time. The engineer will review the initial schedule at the preconstruction meeting (NDOT 2010). Wyoming Standard Specifications allow 5 days of review time after the submission date (WYDOT 2010), whereas New Jersey allows 14 days of review time (NJDOT 2007). Table 7.3.1 summarizes the submittal dates and the allowable review times of the thirteen states that adopted preliminary schedules.

	State	Submittal Date	Review time	Coverage
1	Alaska	Before proceeding with any work on site	N/A	60 days
2	Colorado	10 working days prior to the start of the work	N/A	90 days
3	District of Columbia	N/A	N/A	1 month
4	Montana	N/A	N/A	60 days
5	Nevada	Within 14 days of the "Notice of Award," and no later than 7 days before the Preconstruction Conference	10 days	30 days
6	New Hampshire	At least 10 calendar days before the preconstruction meeting	5 days	60 days
7	New Jersey	15 days after the execution of the contract	14 days	*90/120 days
8	North Dakota	Within 45 calendar days after the Contract execution or prior to the start of work (whichever comes first),	N/A	90 days
9	Oregon	10 Calendar Days prior to the preconstruction conference,	7 days	60 days
10	Rhode Island	21 calendar days from the receipt of the Apparent Low Bidder Letter	10 days	90 days
11	Washington	No more than five calendar days after the date the contract is executed	N/A	60 days
12	West Virginia	30 calendar days of contract award	N/A	60 days
13	Wyoming	At the preconstruction meeting	5 days	60 days

Table 7.3.1: DOT Standard Specifications: Preliminary Schedule Submittal Date, Review Time, and Coverage Period

7.3.2.2 Coverage Period

In general, the preliminary schedules' are intended to cover relatively short periods of time. Preliminary schedule coverage time required by the 13 states ranges between 28-120 days. Most the states specify these coverage periods regardless of the project complexity, size, or price. New Jersey's Standard Specifications are one exception, "For contracts with a Total Contract Value of less than $40 million, provide the schedule for at least the first 90 days of the Project. For contracts with a Total Contract Value of more than $40 million provide the schedule for at least the first 120 days of the Project" (NJDOT, 2007). Washington and Oregon have a similar approach for the addition of such provisions; both states divide the scheduling specification into three types of schedules (Type A, B and C) according to project complexity (duration, cost, and nature). As a result, the requirement for the preliminary schedules change based on the type of schedule required (see Table 7.3.2).

Schedule type	Submittal Date	Coverage Time	Review Period
Washington			
Type A	N/A	N/A	N/A
Type B	Five calendar days after the date the Contract is executed	60 days	N/A
Type C	No later than the first working day	60 days	N/A
Oregon			
Type A	N/A	N/A	N/A
Type B	10 Calendar Days prior to the preconstruction conference	60 days	7 days
Type C	10 Calendar Days prior to the preconstruction conference	60 days	7 days

Table 7.3.2: Preliminary Schedules as Required in Washington and Oregon Project Special Provisions

The coverage times for other states are summarized in Table 7.3.1.

7.3.2.3 Level of Detail

Preliminary schedules' level of detail required by the state DOTs can range from a simple bar chart to a more detailed CPM schedule, and in some instances both. The District of Columbia limits its preliminary schedule provisions to "Schedule showing sequence and timing of first month's operations" (DDOT, 2009). Alaska provides more details including mobilization, submittals, procurement, and construction (AKDOT, 2004). Colorado Standard Specifications require the inclusion of procurement, construction, and submittal activities (CDOT, 2011). In addition, the specifications require the addition of very basic groups of activities that describe the time period after the coverage period (90 days). The specifications also require the submission of a time scaled logic diagram (CDOT, 2011). The states of New Hampshire and Wyoming require a very detailed preliminary schedule as follows (WYDOT, 2010) (NHDOT, 2010):

1- The activities needed to perform and complete the work, activities that might delay contract completion, and critical activities.

2- The planned start and completion dates for each activity, the duration of each activity (stated in working days, and with activities of more than 15 working days in duration broken into two or more activities distinguished by location or some other feature), and the sequencing of all activities.

3- The quantity and the estimated daily production rate for critical activities.

4- An indication of how the schedule accommodates adverse weather days for each month.

5- Dates related to the procurement of materials, equipment, articles of special manufacture, etc.

6- Dates related to the submission of working drawings, plans, and other data specified for review or approval by the department.

7- Dates related to required inspections of structural steel fabrication, etc.

8- Dates related to specified activities by the department and third parties.

7.3.3 State Special Provisions

State of Oregon projects SPS09350 MLK/Grand O-Xing and SPS 12076, I-5: Victory Blvd. to Lombard St. includes initial schedule provisions. The two projects require the submission of an initial schedule ten days prior to the preconstruction conference covering the work intended for the first 60 days (Oregon DOT, 2006) (Oregon DOT, 2008). 9 projects in 4 different states include preliminary schedule provisions; Table 7.3.3 summarizes the submittal dates, the allowable review times, and coverage periods of the 9 projects.

State	Project	Cost	Submittal Date	Review time	Coverage
Iowa	Contract ID 97-0296-175	$4.3M	At the preconstruction conference	N/A	N/A
Iowa	Contract ID 78-0801-330-A	$11M	At the preconstruction conference	N/A	N/A
Iowa	Contract ID 56-0611-117-M	$25M	At the preconstruction conference	N/A	N/A
Iowa	Contract ID 65-5341-068	$ 61M	At the preconstruction conference	N/A	N/A
Kentucky	109-PIKE, CONTRACT ID - 111307	$54M	At the Preconstruction Conference	N/A	28 days
Ohio	Project Number: 110255	$55M	At the preconstruction conference	N/A	90 days
Ohio	Project Number: 113003	$12M	At the Preconstruction Conference	N/A	90 Days
Oregon	SPS09350	>$50 M	Ten workdays prior to the preconstruction conference	N/A	60 Days
Oregon	SPS 12076	>$50 M	Ten workdays prior to the preconstruction conference	N/A	60 Days

Table 7.3.3: DOT Project Special Provisions: Preliminary Schedule Submittal Date, Review Time, and Coverage Period

7.3.4 Schedule Specifications Survey

The survey included two questions regarding the preliminary schedule coverage period and schedule review time. The survey results are presented in Table 7.3.4 and Table 7.3.5.

	If used, preliminary schedules should cover an initial period of:	Frequency	Percentage
1	0 days (no need for preliminary schedules)	25	22.73%
2	30 days	18	16.36%
3	60 days	22	20.00%
4	90 days	14	12.73%
5	120 days	3	2.73%
6	A number of days around 5% of project duration	8	7.27%

7	A number of days around 10% of project duration	8	7.27%
8	Other:	12	10.91%

Table 7.3.4: Survey Results: Preliminary Schedules Coverage Period

Approximately 23% of the survey respondents suggested that preliminary schedules are not needed; however, 49% of the respondents recommended a coverage period between 30-90 days.

	I would encourage the review time for preliminary or baseline schedules to be:	Frequency	Percentage
1	Between 5-10 days	49	44.55%
2	Between 10-15 days	41	37.27%
3	Between 15-20 days	10	9.09%
4	Between 20-25 days	2	1.82%
5	More than 25 days	0	0.00%
6	Other:	8	7.27%

Table 7.3.5: Survey Results: Preliminary Schedules Review Time

Almost 45% of the survey respondents recommend a review period between 5-10 days and 37% recommend a period of 10-15 days. This means that a high percentage, around 81%, of the respondents recommended a review period that is 15 days or less.

7.3.5 Summary and Recommendations

It is advantageous to submit a full baseline schedule at the beginning of the project covering the entire period of the project. However in some occasions contractors might not have sufficient time to develop such a schedule. Consequently, in order to accelerate the process, a preliminary schedule with a limited coverage period can be submitted, buying the contractor some time to develop a fully detailed schedule. For example, a project can span for multiple years including hundreds of activities; therefore, developing a detailed baseline schedule can be lengthy and the period between the contract award and the notice to proceed is not reasonable.

The notice to proceed and the preconstruction conference should be used as reference points for preliminary schedule submittal. It is recommended that the preliminary schedule is submitted 15 calendar days after the notice to proceed and 10 days before the construction schedule preconstruction conference. The DOT engineer should review the preliminary schedule and return it to the contractor within 10 days which aligns with the survey results in which approximately 82% of respondent recommended a review time between 5 -15 days.

Requiring a specific coverage period in the Standard Specifications is not recommended because this coverage period can exceed the project duration. 13 states require the submission of preliminary schedules in their Standard Specifications. Only 3 states out the 13 require these schedules based on project complexity, as explained above. The inconclusive survey result shown in Table 7.3.4 supports the argument that requiring a specific coverage period without regard to the project duration, cost, and complexity is not recommended.

7.4 Baseline Schedule

7.4.1 Common Practices

"The first version of the schedule that is developmentally complete to be approved for capture or copied for future reference is called the project baseline schedule" (PMI, 2007). NASA defines the baseline schedule as "the original approved plan plus or minus approved scope changes" (NASA, 2010).

Baseline schedules are used to facilitate comparison of progress against the original plan. The baseline becomes the benchmark to measure the progress and performance of the project. According to the PMI, "every project should have a baseline schedule in place before the execution of the project work commences" (PMI, 2007). The baseline schedule is the benchmark used to monitor the progress of the project; baseline schedules are unchanged throughout the project duration, but sometimes major changes happen to the project that makes tracing the baseline schedule meaningless. In this case, the schedule can be re-baselined to capture the major changes (NASA, 2010).

The UFGS requires that the Contracting Officer and Contractor participate in a preliminary meeting to discuss the schedule requirements prior to the Contractor preparing the Project Baseline Schedule (UFGS, 2008). Within 42 calendar days after the notice to proceed (NTP), the Contractor shall submit an initial schedule that demonstrates a reasonable and realistic sequence of activities representing all work activities that are necessary to complete the project (UFGS, 2008).

7.4.2 State Standard Specifications

The Florida Construction Project Administration Manual (CPAM) defines the baseline schedule as: "The required schedule of work activities that is initiated by the Contractor. This schedule defines the Contractor's plan to complete the construction project within the allotted time consistent with the contract documents "(FDOT 2009). Baseline schedules can be used to coordinate activities on the project (e.g. subcontractors, suppliers, utilities, and submittals) (UDOT 2008). Baseline schedule can also provide the basis to monitor the progress and performance of the project (NDOT 2009) (NMDOT 2007). The focus of this section will be on the submittal and review procedures of baseline schedules adopted by state DOTs.

7.4.2.1 Submittals period

Most of the states specify a specific period to submit a baseline schedule; Arkansas Standard Specifications require the baseline schedule to be submitted "a minimum of ten (10) days prior to the scheduled Pre-Construction" (ASHTD 2003). California Standard Specifications requires the schedule to be submitted "within 20 working days of approval of the contract" (Caltrans 2006). Most of the states differ in the period of time given for the development of the schedule and the reference point that presents the deadline of submission. States require different reference points for schedule submittal: preconstruction meeting, the notice to proceed, contract execution, or the commencement of work. New Jersey Standard Specifications does not provide one submission date, but rather related the submission periods to the project cost (see Table 7.4.1). The state of Washington also relates the submission times to the complexity of the project. Table 7.4.2 summarizes the submission periods and the adopted reference points in the 50 states. Table 7.4.2 shows that 19 states adopt the preconstruction meeting as a reference point for the submission of the schedule, whereas 8 states do not mention any submission time requirement.

Project Construction Cost (PCC) ($ million)	Days to Submit Baseline Schedule After Approval of Preliminary Schedule
PCC < 5	14
5 ≤ PCC < 15	21
15 ≤ PCC < 40	28
PCC ≥ 40	35

Table 7.4.1: New Jersey Baseline Submittal Time

7.4.2.2 DOT Review Time

After the submission of the baseline schedule, the engineer is given a short period of time to review the schedule Table 7.4.2 identifies the 14 states that have included schedule review time provisions in their specifications. Florida has specified a period of 15 days for the engineer to review the schedule from the day of receipt (FDOT, 2010). Other states, like Wisconsin, specify a review period of 5 days after the preconstruction meeting, but since the baseline schedule has to be submitted at least 14 days before the preconstruction meeting the total review time comes to at least 20 days (WIDOT, 2011). Other review times are shown in Table 7.4.2.

State	Submittal Period	Review Time
Alabama	Prior to the Preconstruction Conference	N/A
Alaska	At least five working days before the preconstruction	N/A
Arizona	At the preconstruction conference	N/A
Arkansas	A minimum of ten (10) days prior to the scheduled Pre-Construction	N/A
California	Within 20 working days of approval of the contract	N/A

State	Submittal Period	Review Time
Colorado	Within 45 calendar days after the Engineer's acceptance of the Initial Schedule	7 days
Connecticut	N/A	N/A
Delaware	Schedule must be submitted to the District Engineer before the preconstruction meeting	N/A
District of Columbia	Prior to commencing any work	N/A
Florida	Within 21 calendar days after Contract award or at the preconstruction conference, whichever is earlier	15 days
Georgia	immediately following the receipt of the Notice to Proceed	N/A
Hawaii	Within 15 days from the date of notice of intent to enter the contract.	N/A
Idaho	At or before the preconstruction conference.	10 days
Illinois	After the award of the contract and prior to starting work	N/A
Indiana	The schedule shall be submitted at the pre-construction conference	N/A
Iowa	N/A	10 days
Kansas	Preconstruction conference	N/A
Kentucky	30 days when requested	N/A
Louisiana	Prior to or at the preconstruction conference and before beginning work on the project	N/A
Maine	Within 21 Days of Contract Execution and before beginning any on-site activities	20 days
Maryland	Within 30 days after Notice to Proceed	N/A
Massachusetts	Within 30 days after Notice to Proceed	N/A
Michigan	Within 15 calendar days of contract	N/A
Minnesota	At least 5 days prior to the Contract starting date	N/A
Mississippi	N/A	N/A
Missouri	Prior to or at the preconstruction conference.	N/A
Montana	N/A	N/A
Nebraska	The schedule shall be presented and briefed to the Engineer at the Preconstruction Conference	N/A
Nevada	Within 15 days after acceptance of the preliminary progress schedule	15 days
New Hampshire	Within 30 calendar days after providing the initial bar chart	N/A
New Jersey	Table 7.4.1: New Jersey Baseline Submittal Time	14 days
New Mexico	The Baseline Schedule shall be submitted in its entirety at or before the preconstruction conference	10 days
New York	Within five days after date of commencement of work	N/A
North Carolina	No later than 7 days prior to the preconstruction conference	N/A
North Dakota	Within 45 calendar days after the Contract execution or prior to the start of work (whichever comes first)	N/A
Ohio	At or before the preconstruction conference	14 days

State	Submittal Period	Review Time
Oklahoma	Within 30 days after the preconstruction meeting	N/A
Oregon	Within 30 Calendar Days after First Notification	N/A
Pennsylvania	N/A	N/A
Rhode Island	Within 30 days after the Preconstruction Conference	10 days
South Carolina	N/A	N/A
South Dakota	N/A	N/A
Tennessee	N/A	N/A
Texas	Before starting work on a construction	N/A
Utah	Within 14 calendar days of the Notice of Award	7 days
Vermont	Within 10 calendar days after the award of the Contract	N/A
Virginia	At least 7 calendar days prior to beginning work	N/A
Washington	Type "A" no later than 10-days after the date the contract is executed/type; "B" and "C" no later than 30 calendar days after the date the Contract is executed	15 days
West Virginia	Within 60 calendar days of the contract award date	N/A
Wisconsin	At least 14 calendar days before the preconstruction meeting	5 days
Wyoming	10 calendar days before the preconstruction conference,	5 days

Table 7.4.2: DOT Standard Specification: Baseline Schedule Submittal Period and Review Time

7.4.3 State Special Provisions

Most of the states have not amended or added any provisions for baseline schedule submission. Some minor changes are adopted, but nothing significant. The states of Iowa and South Carolina do not include baseline schedule submission provisions in their Standard Specification, but when looking at the Special Provisions of projects in both states a considerable improvement is made; the state of Iowa Special Provisions require the submission of a progress schedule "at least five calendar days prior to starting work" (IowaDOT, 2009). On the other hand, South Carolina requires the submission of a baseline schedule "15 days prior to the preconstruction conference" and also gave the engineer a period of 10 days to either approve or reject the schedule (SCDOT, 2007). In both states, the addition of baseline submission provisions is found in all reviewed projects (4 projects in each state ranging from $3-$75 million).

Table 7.4.3 summarizes the submittal dates and review periods amended and/or added in the Special Provisions of 20 projects in 7 different states.

State	Project #	Cost	Submittal Period	Review Time
California	Contract No. 07-138204	$160M	Within 20 days of contract approval	20 days
California	Contract No. 03-3797U4	$130M	Within 20 days of contract approval	20 days
California	Contract No. 12-0G3304	$56M	Within 20 days of contract approval	20 days
California	Contract No. 07-241304	$1.56M	Within 20 days of contract approval	21 days
California	Contract No. 05-0T3604	$1.12M	Within 20 days of contract approval	22 days
Florida	Contract T2376	$19.5M	Within 30 calendar days after execution of the Contract or preconstruction conference whichever is earlier	30 days
Florida	Contract T1322	$14.5M	Within 30 calendar days after execution of the Contract or preconstruction conference whichever is earlier	30 days
Florida	Contract T2366	$2M	N/A	N/A
Florida	Contract T4299	$1.6M	Within 30 calendar days after execution of the Contract or preconstruction conference whichever is earlier	30 days
Indiana	Contract # 33045-A	$142M	No later than the date of the preconstruction conference	N/A
Indiana	Contract # 33049	$69M	No later than the date of the preconstruction conference	N/A
Indiana	Contract # IR-30850-A	$26.2M	N/A	N/A
Indiana	Contract # 32756	$8.7M	N/A	N/A
Indiana	Contract # IR-31879-A	$3M	N/A	N/A
Kentucky	109-PIKE, CONTRACT ID - 111307	$53.5M	Within 14 days of the Notice to Begin Work	10 days
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$17M	N/A	N/A
Kentucky	104 various, CONTRACT ID - 111012	$8.5M	N/A	N/A
Kentucky	35-PERRY, CONTRACT ID - 111308	$2.9M	N/A	N/A
Ohio	Project Number: 110255	$ 55M	The Contractor shall submit a baseline schedule within 60 days of the execution of the Contract	21 days
Ohio	Project Number: 113003	$12.2M	The Contractor shall submit a baseline schedule within 60 days of the execution of the Contract	22 days

Ohio	Project Number: 110386	$7M	N/A	N/A
Ohio	Project Number: 110321	$3.6M	N/A	N/A
South Carolina	Project Number: BR26(012), 08 February	$75.7M	Within 30 calendar days after award of the Contract or 15 days prior to the preconstruction conference, whichever is earlier	10 days
South Carolina	Project Number: BR88(066), 09 November	$17.3M	Within 30 calendar days after award of the Contract or 15 days prior to the preconstruction conference, whichever is earlier	11 days
South Carolina	Project Number: MR11(071),14 December	$6.7M	Within 30 calendar days after award of the Contract or 15 days prior to the preconstruction conference, whichever is earlier	12 days
South Carolina	Project Number: RS10(087), 08 march	$3.4M	Within 30 calendar days after award of the Contract or 15 days prior to the preconstruction conference, whichever is earlier	13 days

Table 7.4.3: DOT Project Special Provisions: Baseline Schedule Submittal Period and Review Time

7.4.4 Schedule Specifications Survey

The survey included a question addressing the adequate review time for a baseline schedule.

Table 7.4.4 presents the results of the survey. 81.82% of the DOT personnel surveyed suggest that a period between 5-15 days is a sufficient period of time to review the baseline schedule. Only one respondent selected a period of more than 25 days.

	I would encourage the review time for preliminary or baseline schedules to be:	Percentage
1	Between 5-10 days	44.55%
2	Between 10-15 days	37.27%
3	Between 15-20 days	9.09%
4	Between 20-25 days	1.82%
5	More than 25 days	0.00%
6	Other:	7.27%

Table 7.4.4: Survey Results: Baseline Schedule Review Time

Two of the respondents suggested that a baseline schedule review should be a continuous task. One respondent commented as follows: “Depends on the complexity of the schedule. A day is sufficient for simple schedules, but several or more days may be needed for complex schedules". Another respondent said: "Sadly, depends on staffing, but should not delay work".

7.4.5 Summary and Recommendations

Baseline schedules serve as a reference point for any future schedule updates, and are essential in case of any time delay claims or disputes. A Baseline schedule is the first version of the schedule that is developmentally complete. "The Baseline Schedule should be the contractor's reasonable, feasible, contemporaneous vision on "day-one" of how he anticipates all elements (activities) of the project will be performed in individual duration and in correlated sequence(s)" (Martin J. Bradley, 2005).

A total of 42 state DOTs required the submittal of a baseline schedule prior to the project start and gave the engineer a period between 5 and 20 days to review the schedule, but most DOTs did not specify a specific period (so the survey asked the question) and, surprisingly, most respondents selected a period between 5 and 15 days.

This research recommends that he review time should not be limited to any period; it should be determined by many factors such as project duration, size, and complexity. Due to the importance of the baseline schedule, many reviews should occur in order to develop a factual project schedule that is developmentally complete and meets the specifications.

7.5 Look-Ahead Schedules

7.5.1 Common Practices

Look-Ahead schedules are detailed schedules extracted from the construction schedule, usually covering a period of 3-weeks (UFGS, 2008).The information included in the look-ahead schedules is generally more detailed in order to provide better control on project activities. According to the UFGS, these short term schedules should be updated weekly, therefore covering the week it is updated and two weeks ahead (UFGS, 2008).The look-ahead schedule should be in a bar chart form that includes (UFGS, 2008):

- Upcoming outages, closures, preparatory meetings, and initial meetings.
- Identification of critical path activities.

7.5.2 State Standard Specifications

Look-ahead schedules "will greatly increase the planning of the work and the efficiency of implementation. It will be to the benefit of all parties, not least the Contractor" (DDOT, 2009). 11 states mention look-ahead schedules in their Standard Specifications or Construction Manuals. The coverage period of these schedules ranged from one to three weeks. Alaska Standards Specifications require the contractor to submit a look-ahead schedule every two weeks during construction. The look-ahead schedule should detail the proposed operations for the forthcoming two weeks (AKDOT, 2004).

The Washington state Construction Manual and Standard Provisions provide a more detailed approach to look-ahead schedules. WSDOT requires the submittal of a weekly look-ahead schedule that includes sufficient detail as follows (WSDOT, 2010):

- Contractor and all subcontractor activities for the next two weeks
- Description of the work
- Duration of the work.
- Sequence of the work.
- Planned hours of work: necessary to evaluate the results of unsuitable weather on the critical path and to assess working days charges correctly.

Table 7.5.1 shows the coverage and submittal periods of look-ahead schedules in various states.

State	Submittal	Look-ahead coverage
Alaska	Every two weeks	2 weeks
Arizona	Weekly	2 weeks
Delaware	Every two weeks	2 weeks
District of	N/A	2 weeks

Columbia		
Florida	N/A	2 weeks
Hawaii	Weekly	3 weeks
Montana	N/A	60 days
New Hampshire	N/A	60 days
Washington	Weekly	1 week
Wisconsin	N/A	60 days
Wyoming	N/A	60 days

Table 7.5.1: DOT Standard Specifications: Look-Ahead Schedules Submittal and Coverage

7.5.3 State Special Provisions

Six states includelook-ahead schedule provisions in their projects' Special Provisions. Table 7.5.2 summarizes the look-ahead provisions in a number of projects. The table shows the submittal frequency and the look-ahead schedule coverage period. Most of the projects require a weekly submission; State of Ohio projects 110255 and 113003 require a monthly look-ahead schedule covering the following 6 weeks of work as follows: "Submit the following information….A Six Week Look Ahead Schedule in bar chart format. This schedule will have all the requirements of the baseline schedule in bar chart format except that it shall be limited to those activities that have an early start or early finish within a six week period of the data date." (Ohio DOT, 2011) (Ohio DOT.b, 2011).

The coverage period for look-ahead schedule ranged from 1 to 6 weeks. Indiana projects 33045 and 33049 included the following provisions: "Contractor shall provide a 3-week look-ahead schedule, including the number of work crews, work hours and the specific portions of the work to be performed during the 3 week period" (Indiana DOT, 2011) (Indiana DOT, 2010).

State	Provision / Project	Price	Submittal	Coverage
Florida	Contract T2376	$19,453,029.69	Weekly	2 weeks
Florida	Contract T1322	$14,667,050.00	Weekly	2 weeks
Florida	Contract T2366	$1,912,362.28		
Florida	Contract T4299	$1,597,956.96	Weekly	2 weeks
Indiana	Contract # 33045-A	$141,778,367.70	Weekly	3 weeks
Indiana	Contract # 33049	$69,344,417.82	Weekly	3 weeks

Indiana	Contract # IR-30850-A	$26,200,000.00		
Indiana	Contract # 32756	$8,700,000.00		
Indiana	Contract # IR-31879-A	$2,960,000.00		
Missouri	Project Number:J6U1086	$21,826,136.89	Weekly	2 weeks
Missouri	Project Number: J4I2023B	$4,944,372.11		
Missouri	Project Number:J5P0738	$9,793,257.30		
Missouri	Project Number:J0I2176	$15,741,185.35		
Ohio	Project Number: 110255	$54,923,975.95	Monthly	6 weeks
Ohio	Project Number: 113003	$12,224,208.50	Monthly	6 weeks
Ohio	Project Number: 110386	$7,171,036.00		
Ohio	Project Number: 110321	$3,658,484.63		
Oregon	SPS09350	Over $50 million		
Oregon	SPS10694	Over $50 million		
Oregon	SPS 12076	Over $50 million		
Oregon	SPS 14032	Over $50 million	Weekly	3 weeks
Oregon	SPS14197	Over $50 million		
Oregon	SPS14949	Under $50 million	Weekly	3 weeks
Oregon	SPS06025	Under $50 million		
Oregon	SPS12874	Under $50 million		
Washington	CONTRACT NO :007936	$53,398,008.88	Weekly	1 week
Washington	CONTRACT NO : 006933	34,000,000.00	Weekly	1 week
Washington	CONTRACT NO :007417	$14,689,000.00	Weekly	2 weeks
Washington	CONTRACT NO : 007685	$9,790,516.54		
Washington	CONTRACT NO :007686	$7,264,345.36		
Washington	CONTRACT NO :007669	$6,595,797.58		
Washington	CONTRACT NO :008086	$3,569,039.50		
Washington	CONTRACT NO :007645	$2,574,636.90		
Washington	CONTRACT NO :007897	$2,425,312.86		
Washington	CONTRACT NO :007660	$2,286,623.00		
Washington	CONTRACT NO : 007276	$421,974.00	Weekly	2 weeks

Table 7.5.2: DOT Project Special Provisions: Look-Ahead Schedules Submittal and Coverage

7.5.4 Schedule Specifications Survey

The survey respondents were asked about the look-ahead schedules coverage period. 81.65% of respondents recommend the use of look ahead-schedule. 55.96% of the respondents suggest a coverage period of 2 weeks is adequate. One of the respondents recommended that the look-ahead schedule should cover one week back and two weeks forward. Table 7.5.3 summarizes the results.

	If required, look-ahead schedules should cover a period of:	Percentage
1	0 weeks (no need for Look ahead schedules)	11.01%
2	1 week	3.67%

3	2 weeks	55.96%
4	3 weeks	13.76%
5	More than 3weeks	8.26%
6	Other:	7.34%

Table 7.5.3: Survey Results: Look-Ahead Coverage Period

7.5.5 Summary and Recommendations

Look-ahead schedules are snapshot schedules generated from master project schedules covering a short period of time. Look-ahead schedules help focus the planning effort on present and near future project activities rather than looking at the schedule as a whole (which can be cumbersome, since some projects have hundreds of activities spanning long durations).

Look-ahead schedules can also help coordinate subcontractor work during coordination meetings, especially when dealing with unsophisticated subcontractors. Look-ahead schedules provide an efficient, easy to use, tool to report activity progress.

Based on the survey results, 81.65% of the survey respondents agree that look-ahead schedules are beneficial regardless of the coverage period. This result conflicts with state DOT Standard Specifications, since only 10 states require look-ahead schedules (20%).

Several state projects were analyzed to test the effect of project cost on look-ahead schedules. By examining Table 7.5.2, it can be found that cost was irrelevant when requiring look-ahead schedules. Based on the information presented above, it is recommended that the look-ahead schedule to be submitted weekly covering 3 weeks ahead.

7.6 Schedule Updates

7.6.1 Common Practices

The UFGS requires that the contractor submit schedule updates on a monthly basis, but the contracting officer can request the issuance of an update at any point depending on the progress of work (discussed in detail in section 7.7 Schedule Review / Revisions). Before the submission of a schedule update, the contractor and contracting officer discuss the progress in a periodic schedule update meeting. Based on the meeting, the contractor issues the updated schedule. The AACEI recommends that the schedule update should reflect the whole project's status on a certain date. The AACEI also recommends that schedule updates should occur on a specific date, preferably coinciding with progress payments (AACEI, 2008).

Schedule update submittals can include various reports, graphics, tables, and narratives. It also can either be digital (soft copy) or physical (hard copy). The AACEI recommends that, at a minimum, the schedule update submittal shall consist of a schedule narrative and a soft copy of the schedule in the native format. The AACEI chose these two specific submittals for the following reasons (AACEI, 2008):

- The schedule narrative is a very important tool to communicate the status of the project especially for a non-technical owner.
- The soft copy of the schedule can be utilized to generate various reports, graphics, and table sorts as needed by the schedule reviewer.
- Minimize Cost: reducing unnecessary submittals reduces cost
- Minimize Liability: the owner (in this case DOT) assumes more liability with all the additional submittals.

The AACEI discusses the advantages and disadvantages of hard copy vs. soft copy submittals of schedule updates. The main advantage of having a soft copy of the schedule is that the reviewer can print reports, sort activities, trace logic, and generate graphics in a way that optimizes the schedule review process. The main disadvantage of soft copies is that they can be inadvertently corrupted or misused, especially when handled by an inexperienced scheduler. On the other hand, the main advantages of hard copies are obvious: hard copies won't change over time and are hard to manipulate (AACEI, 2008).

The UFGS required the following to be submitted with every Preliminary, Initial and updated schedule (UFGS, 2008):

1- Data CDs: 2 CDs labeled with the project information containing the current schedule and all previous schedules.

2- Narrative report: A report that includes:

    - a description of the activities on the 2 most critical paths with a total float less than 20 days

    - a description of all problem areas/delays and how to resolve them

3- Approved changes verification: All previously approved schedule changes

4- Schedule reports: report should contain Activity Numbers, Activity Description, Original Duration, Remaining Duration, Early Start Date, Early Finish Date, Late Start Date, Late Finish Date, Total Float, Actual Start Date, Actual Finish Date, and Percent Complete.

5- Activity reports: a list of all activities sorted by activity ID

6- Logic reports: A list of all predecessors and successors for every activity

7- Total float reports: a list containing all the activities showing the total float sorted in ascending order

8- Earning report

9- Network Diagram: showing the interdependence between all activities, showing the following:

- Continuous flow: flow from left to right showing activity number, description, duration and estimated earned value diagram
- Project milestone dates
- Critical path: show the critical path
- S-curves

7.6.2 State Standard Specifications

Schedule updates are important tools to control the project performance (time and money) and are usually the basis for payment; therefore, it comes as no surprise that 30 states adopted schedule update provisions. The differences in these provisions are mainly the frequency of updates and the characteristics of the updated schedule (e.g. what to include in the schedule update). Different states require different updating cycles, ranging from 1 week to 90 days. Update frequency is discussed in depth in section 5.23 Update Cycle.

Schedule updates include information that can facilitate the work of the engineer: actual completion dates and percentage completion (CDOT, 2011) (ITD, 2004), approved time extensions, supplemental agreements, activity description, anticipated durations, anticipated float, and the anticipated work schedule for the next month (FDOT, 2009). Alongside the schedule, 16 states require the submittal of a written narrative (See Table 7.6.1). Wyoming Standard Specifications require the submittal of a narrative summary of progress during the month that describes the following (WYDOT, 2010):

1- Shifts in the critical activities from the previous update

2- Sources of delay

3- Potential problems

4- Work planned for the next 30 calendar days

5- Revisions to the CPM schedule, including but not limited to additions, deletions, or revisions to activities, revisions to activity durations, or revisions to the planned sequence of work or the method and manner of its performance.

Similarly Utah Standard Specifications include the following detail schedule narrative requirement (UDOT, 2008):

1. The construction philosophy supporting the approach to the work outlined in the baseline schedule. Address the reasons for the sequencing of work and describe any limited resources, potential conflicts, and other salient items that may affect the schedule and how they may be resolved.
2. The justification for activities with durations exceeding 15 working days.
3. The justification for constraints used.
4. The justification for unusual calendars used.
5. The approach used to apply relationships between activities for example, all ties are based on physical relationships between work activities - rebar must be placed before concrete is placed or relationships are used to show limited resources - bridge two follows bridge one because the Contractor only has one bridge crew etc.
6. The project critical path and challenges that may arise associated with the critical path.
7. How the coordination with other entities will be handled.

Schedule updates can be submitted as hard copies and/or soft copies (native format, P6, MS project etc...). For example New Hampshire Standard Specifications include the following specification:

"Provide the following items with each schedule submission. Submit 1 paper copy and 1 electronic file of the schedule to the Engineer. The Contractor shall include the following in the paper submission: A logic diagram in color, depicting no more than 50 activities on each 11 by 17 in. [280 by 430 mm] sheet, and with each sheet including title, match data for diagram correlation, and a key" (NHDOT, 2010).

Table 7.6.1 summarizes the schedule update submittal requirement in each state.

State	Soft Copies	Hard Copies	Schedule narrative
Alabama		x	
Alaska	x	x	
California		x	
Colorado	x	x	x
District of Columbia		x	
Hawaii	x	x	x
Idaho	x	x	x
Iowa		x	
Kentucky			x
Maryland	x		x
Missouri	x		x
Montana	x	x	x
Nebraska		x	
Nevada	x	x	
New Hampshire	x	x	x
New Jersey	x	x	
New Mexico	x	x	x
North Dakota	x	x	x
Oklahoma		x	
Oregon	x	x	x
Rhode Island	x	x	x
Utah	x	x	x
Washington		x	
West Virginia		x	x
Wisconsin	x	x	x
Wyoming	x	x	x
Total	16	23	16

Table 7.6.1: DOT Standard Specifications: Schedule Submittal Requirements

After the submission of the schedule, the engineer reviews the progress updates. Based on the engineer's review, the schedule can be accepted or rejected. Florida Construction Manual describes an in-depth procedure to review the schedule and stresses upon certain key points as follows (FDOT, 2009):

1- Check to make sure that the actual dates (for activities either in-progress or completed) and the percent complete/days remaining are historically accurate.

2- Run the scheduling calculation in "view" mode and Primavera will itemize the "open ends". With SureTrak, display the predecessors and successors as columns on the left side of the bar chart. Check to make sure that all "open ends" are closed, so that all calculated float values are accurate and not inflated. All activities except the first one should have predecessors, and all activities except the last one should have successors.

3- Similarly, run the scheduling calculation in "view" mode and Primavera will itemize the "out-of-sequence progress". Remedy the out-of-sequence progress by making logic changes that are agreed to between the engineer and the contractor.

4- Ensure on a continuous basis that the Contractor is pursuing the critical path work activities. The "two-week look ahead schedules" and "controlling items of work" that the Contractor submits should indicate that he is primarily working on the critical or near critical activities at a minimum.

5- Run a comparison using "Claim Digger" between the current monthly update, the previous update, and the baseline to see if the Contractor made any unauthorized changes to either the original durations or logic or, if he added any unauthorized constraints. If he did, bring it to his attention and resolve it with the contractor.

6- In addition, the "Claim Digger" comparison will itemize the "activities that should have started this update, but did not" and the "activities that should have finished this update, but did not." Bring these to the contractor's attention, particularly the critical or near critical activities, in order to help get him back on track.

7- Lastly, check to make sure that all holidays and weather days granted through the update are put into the schedule's calendar as "non-work" days, so that they are considered when the schedule is calculated.

7.6.3 State Special Provisions

The state of Ohio also requested documents that should be submitted alongside the updated schedule as follows (Ohio DOT, 2010):

1- Six Week Look Ahead CPM Schedule in Bar Chart Format

2- Logic Diagram (If requested by the Engineer)

3- Activity ID Sort (If requested by the Engineer)

4- Total Float Sort (If requested by the Engineer)

5- Detailed Predecessor/Successor Sort (If requested by the Engineer)

6- Schedule Statistics Report

7- Electronic files

24 of the reviewed projects include schedule narrative requirement in their Standard Specifications, Table 7.6.2 lists all these projects. Indiana project 33045 and 33049 include a very detailed Specification for schedule narrative/report:

For each monthly update CPM schedule submittal, the narrative report shall include the following (Indiana DOT, 2011) (Indiana DOT, 2010):

1. A statement comparing the scheduled completion date to the contract completion date and any change in the scheduled completion date from the previous accepted submittal.
2. An explanation if the scheduled completion date is projected to occur after the contract completion date.
3. A statement comparing the scheduled completion of work associated with each intermediate completion date, I/D date, or closure period in the contract as well as any changes in these scheduled dates or closure periods from the previous accepted submittal.
4. An explanation if work associated with any contract milestone date or closure period is projected to occur after the dates or projected to require a longer duration than set out in the contract.
5. A list of activities that have been added or deleted from the schedule since the last accepted submittal and an explanation for the addition or deletion.
6. A list of all changes in activity relationships, predecessors, or successors since the last accepted submittal and an explanation for each change.

7. A list of activities with original durations that have been changed since the last accepted submittal along with an explanation regarding how the change is planned to be accomplished.

8. A description of the work performed since the last accepted submittal.

9. A description of and explanation for any changes between the work performed since the last accepted submittal and the work planned at the time that submittal was made.

10. A detailed description of any unresolved problems that are anticipated or that have been encountered. If a contractual notice of a changed condition or a claim in accordance with 105.16 has been submitted and the Department response is pending, the description shall indicate the date of the notice or claim submittal.

11. A statement that identifies any unresolved actual and anticipated delays. The statement should include identification of the delayed activity, the party apparently responsible for the delay, the type of delay, the cause of the delay, the effect of the delay on other activities and project milestones and identification of actions required to mitigate the delay.

12. A detailed description of the critical path.

13. A list of activities which have become critical since the last accepted submittal.

The schedule submittal method adopted by the state projects is listed in Table 7.6.2. Twenty six projects require soft copies, twenty one require hard copies, and 21 require both. The state of Indiana projects 33045 and 33049 provide a detailed submittal method provision for schedule updates as follows:

Each CPM schedule submittal shall include the following (Indiana DOT, 2011) (Indiana DOT, 2010):

1. A letter of transmittal identifying the schedule submittal and contents.
2. A narrative report …….. No narrative report is required for the final CPM schedule.
3. An electronic file of the schedule in Primavera .XER format that is completely compatible with and may be directly imported into Primavera Contractor 5.0 without any loss or modification of data o need for any conversion or other software. Any electronic schedule file submitted by the Contractor that is not completely compatible with the Department's Primavera Contractor 5.0 software will be rejected.
4. A copy of the critical path gantt chart, including lines representing relationships between activities, measuring 11" x 17" or larger. This item is not required for a final CPM schedule.

State	**Provision / Project**	**Price**	**Soft Copies**	**Hard copies**	**Schedule Narrative**
California	Contract No. 07-138204	$160M	x	x	x
California	Contract No. 03-3797U4	$130M	x	x	x
California	Contract No. 12-0G3304	$56M	x	x	x
California	Contract No. 07-241304	$1.56M	x	x	x
California	Contract No. 05-0T3604	$1.12M			
Florida	Contract T2376	$19.5M	x	x	x
Florida	Contract T1322	$14.5M	x	x	x
Florida	Contract T2366	$2M			
Florida	Contract T4299	$1.6M	x	x	x
Indiana	Contract # 33045-A	$142M	x	x	x
Indiana	Contract # 33049	$69M	x	x	x

Indiana	Contract # IR-30850-A	$26.2M			
Indiana	Contract # 32756	$8.7M			
Indiana	Contract # IR-31879-A	$3M			
Kentucky	109-PIKE, CONTRACT ID - 111307	$53.5M	x	x	x
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$17M			x
Kentucky	104 various, CONTRACT ID - 111012	$8.5M			x
Kentucky	35-PERRY, CONTRACT ID - 111308	$2.9M			x
Ohio	Project Number: 110255	$55M	x	x	x
Ohio	Project Number: 113003	$12.2M	x	x	x
Ohio	Project Number: 110386	$7M			
Ohio	Project Number: 110321	$3.6M			
Oregon	SPS09350	>$50M	x	x	x
Oregon	SPS10694	>$50M			
Oregon	SPS 12076	>$50M	x	x	x
Oregon	SPS 14032	>$50M			
Oregon	SPS14197	>$50M			
Oregon	SPS14949	<$50M			
Oregon	SPS06025	<$50M			
Oregon	SPS12874	<$50M			
South Carolina	Project Number: BR26(012), 08 February	$75.7M	x	x	x
South Carolina	Project Number: BR88(066), 09 November	$17.3M	x	x	x
South Carolina	Project Number: MR11(071),14 December	$6.7M	x	x	x
South Carolina	Project Number: RS10(087), 08 march	$3.4M	x	x	x
Washington	CONTRACT NO :007936 (Type C)	$53.4M	x	x	x
Washington	CONTRACT NO : 006933	$34M			
Washington	CONTRACT NO :007417 (Type A or B)	$14.7M		x	x
Washington	CONTRACT NO : 007685 (Type A)	$9.8M		x	
Washington	CONTRACT NO :007686 (Type A)	$7.3M		x	
Washington	CONTRACT NO :007669 (Type A)	$6.6M			
Washington	CONTRACT NO :008086	$3.6M			

Washington	CONTRACT NO :007645 (Type A)	$2.6M		x	
Washington	CONTRACT NO :007897	$2.4M			
Washington	CONTRACT NO :007660 (Type A or B)	$2.3M		x	
Washington	CONTRACT NO : 007276	$0.4M	x	x	x
West Virginia	PROJECT NUMBER X347-H-74.85 00 ACAP-0484(246)	$82.5M	x	x	
West Virginia	PROJECT NUMBER X312-H-81.35 03 ACAP-0484(299)	$25M			
West Virginia	PROJECT NUMBER S318-33-0.01 00	$6.4M			
West Virginia	PROJECT NUMBER S399-STR/IP-11 03 IM-2011(026)D	$2.8M			
Total			21	26	24

Table 7.6.2: DOT Project Special Provisions: Schedule Update Submittal Requirements

7.6.4 Schedule Specifications Survey

The survey included one question addressing the update cycle duration (shown in Table 7.6.3), asking the respondents to select the most suitable update period. 45% of respondents selected a 1 month update cycle, 13% selected biweekly update cycles and only 6% selected one week. 19% of respondents believed that the update period should depend on the project type. 10% did not find any benefit in periodic schedule updates and left the decision to the engineer to request schedule updates. One respondent suggested that schedule update cycles should be "monthly on large projects, as requested by engineer on smaller projects" and another respondent suggested that contractor should update the schedule weekly but schedule should be submitted bi-weekly to monthly.

	The frequency of schedule updates: In your opinion the most efficient updating cycle should be:	Percentage
1	1 week	6.36%
2	2 weeks	13.64%
3	3 weeks	0.00%
4	1 month	45.45%

5	2 months	0.91%
6	3 months	0.00%
7	Only when requested by the engineer	10.00%
8	It varies as it depends on the project type	19.09%
9	Other:	4.55%

Table 7.6.3: Survey Results: Schedule Update Cycle

The survey included a question regarding soft copy submittals of project schedules, the results were previously discussed in section 6.1 Scheduling Software. Table 6.1.3: Survey Results: Scheduling Software and Project Complexity show that the majority of survey respondents believe that soft copies of the schedule should be required when the project is complex. But respondents were neutral when asked if soft copies should be submitted regardless of project complexity.

7.6.5 Summary and Recommendations

Updating the schedule is an essential task for both time and cost management. Having a project baseline schedule is only the first step towards good scheduling practices; the baseline schedule is a static tool that only represents a snap shot of the project's initial plan. Frequent cyclical schedule updates are essential to transform a static baseline schedule into a dynamic schedule that reflects the actual status of the project plan at a given point; in other words adding a 3rd dimension: time.

The frequency at which the schedule should be updated can vary depending on project type, project complexity, and associated risk. The PMI suggests, that the frequency of schedule updates needs to be "long enough for the information from the last update to have been issued to the project team and for the team to have had a chance to act on the new information prior to the next status" (PMI, 2007). Translating this to DOT projects and construction in general, a monthly update seems to be a reasonable frequency or cycle for the following reasons:

- The percent completion reported in the schedule updates can be used in the pay applications.

- In general, one month is enough time to capture considerable project progress easily comparable to previous schedule updates.

Approximately 50% of the survey participants suggested that 1-month schedule updates are the most efficient. Similarly, approximately 50% of the states' Standard Specifications require a 1-month update cycle.

As discussed in Section 7.6.1, the AACEI suggests that, as a minimum, a schedule update submittal should include a schedule soft copy and a schedule narrative (AACEI, 2008). The UFGS also required both soft copies and schedule narratives. Contrary to industry recommended standard, upon review of state Standard Specifications, only 16 states require soft copies and 16 require schedule written narratives (which is line with the survey results were respondents encourage the use of schedules on complex projects only).

This research recommends that, at a minimum, the schedule submittal should include a narrative report and a soft copy of the schedule.

7.7 Schedule Review / Revisions

7.7.1 Common Practices

The AACEI recommends that the schedule revision, at a minimum, should include a schedule narrative and a copy of the schedules native format (AACEI, 2010a). It can also include the following (AACEI, 2010a):

- Printed reports, as required by scheduling specifications
- Graphics, as required by scheduling specification.

The schedule narrative is an important tool to identify issues, explain the plan, and establish deliverables (AACEI, 2010a). The schedule narrative for recovery schedules is similar to the schedule update narrative discussed in section 7.6 Schedule Updates. "Because a narrative supports and adds to the understanding of the submitted recovery schedule, review and use of an incomplete recovery schedule submittal is inefficient and possibly misleading" (AACEI, 2010a).

NASA defines schedule revisions as "Schedule maintenance". According to NASA, schedule maintenance is an on-going process that happens parallel to schedule updates. Before any schedule maintenance activity occurs, it is highly recommended to store an electronic copy of the original schedule network for record, along with the reason for the change and the person authorizing the change (NASA, 2010). The schedule maintenance consists of different tasks that fall into three categories: existing task/ milestone revisions, adding new tasks, and logic modification (NASA, 2010):

1- Three types of existing task/ milestone revisions can be made: data revisions, informational changes, or task/milestone deletion. Data revisions normally include changes in task/ milestone dates, duration, resource allocation, or location within the data structure (i.e., WBS), whereas informational changes are revisions to task/milestone notes, descriptions, or coding data (NASA, 2010).
2- New Tasks are usually added to better define the scope or to add new work scope. Both scenarios require special attention to the structure, coding, network logic, duration, resource allocation, and risk data. Adding new tasks/milestones can result in a longer duration for the project (NASA, 2010).
3- Logic modifications "are necessary on occasion to maintain an accurate reflection of the work being performed" (NASA, 2010). Logic modifications can affect different variables in the project schedule, such as task duration and overall project time (NASA, 2010).

The UFGS left the decision of initiating a schedule review to the Contracting Officer. If at any point the contracting officer believes that the contractor is falling behind the approved schedule, the Contracting Officer can request an increase in the number of shifts, days of work, and overtime shifts; after that contractor is requested to submit a reviewed schedule for approval (UFGS, 2008).

7.7.2 State Standard Specifications

Twenty eight states include schedule revision provisions in their Standard Specifications. Schedule revisions can be triggered by many factors - different states requested revisions for different reasons. Some states are very general, requesting revisions upon substantial changes to the schedule (MNDOT, 2005) (AKDOT, 2004) (ADOT, 2000) (ODOT, 2008) (RIDOT, 2004) (TXDOT, 2004). Other states listed the events that trigger a schedule review. For example: delays in the schedule, change in logic, time extensions, change in resources, addition/modification/ deletion of activities, and changes to the critical path. Table 7.7.1 summarizes the events that trigger schedule revisions in state Standard specifications.

	State	General	Delays in schedule	Changes in Logic	Time extensions	Changes in resources	Scope changes	Changes in critical path
1	Alabama	x			x			
2	Colorado		x	x		x	x	
3	District of Columbia	x						
4	Idaho	x						
5	Iowa	x	x					
6	Kentucky	x						
7	Maine	x						
8	Maryland		x	x	x	x	x	x
9	Michigan		x		x		x	
10	Minnesota	x						

11	Missouri	x	x					
12	Nebraska	x						
13	Nevada	x	x	x				x
14	New Hampshire		x				x	
15	New Mexico	x						
16	North Carolina	x						
17	North Dakota		x				x	x
18	Ohio	x	x					
19	Oklahoma		x	x			x	x
20	Oregon	x						
21	Pennsylvania	x	x					
22	Rhode Island	x	x					
23	Tennessee	x						
24	Texas	x						
25	Virginia	x						
26	Washington	x	x		x		x	x
27	Wisconsin	x	x				x	
28	Wyoming	x	x					
	Frequency	22	15	4	4	2	8	5
	Percentage	44.0%	30.0%	8.0%	8.0%	4.0%	16.0%	10.0%

Table 7.7.1: DOT Standard Specifications: Events Causing Schedule Revisions

7.7.2.1 Delays in the Schedule:

Any delay in the schedule will result in schedule review to spot the reasons behind the delay and find ways to mitigate the delay. The amount of delay that is considered significant varies from state to state. Iowa standard specifications require schedule revisions if the schedule falls 10 working days behind (IowaDOT, 2009).while District of Columbia specifies a schedule revision if schedule falls behind more than 5 percent or 4 weeks, whichever is longer (DDOT, 2009). Table 7.7.2 summarizes the maximum delay in schedule that can trigger a schedule review. Other states do not mention any specific delay, but rather leave the decision of initiating a schedule review to the judgment of the engineer (WSDOT, 2010) (MDOT, 2011) (MarylandDOT, 2008) (KDOT, 2007).

State	Percentage	Duration
Iowa	N/A	10 days
District of Columbia	5%	4 weeks
Kansas	N/A	14 calendar days

Nevada	5%	20 days
New Mexico	N/A	7 days
Tennessee	15%	N/A
Ohio	N/A	14 days
Washington	10%	10 Days
Wisconsin	N/A	14 calendar days
Wyoming	N/A	14 calendar days

Table 7.7.2: DOT Standard Specifications: Schedule Delays Triggering Schedule Reviews

7.7.2.2 Change in the logic of the schedule

Any change in the logic and sequence of the operations that impacts the approved progress schedule calls for a schedule revision and a submittal of a new reviewed schedule. (FDOT, 2010) (MarylandDOT, 2008) (MDOT, 2003) (NDOT, 2010) (NHDOT, 2010) (WSDOT, 2010).

7.7.2.3 Time extensions

When a time extension is granted, the contractor shall review the schedule and submit a reviewed schedule. (ALDOT, 2008) (WSDOT, 2010)

7.7.2.4 Changes in resources

Any increase or decrease in the major equipment, material, labor, or any extra work is basis for schedule revision which results in a submittal of a new revised schedule (KDOT, 2007) (MarylandDOT, 2008) (MDOT, 2003) (NDOT, 2010).

7.7.2.5 Addition, modification, and deletion of activities

Any addition, deletion, or modification of activities requested by engineer or required by contract that impact the progress of work calls for a revision of the schedule and a submittal of a revised schedule (CDOT, 2011) (MarylandDOT, 2008) (WIDOT, 2011)

7.7.2.6 Changes to the critical path

Any changes that affect the critical path of the project schedule call for a revision of the schedule and a submittal of a revised schedule. (WSDOT, 2010) (NMDOT, 2007)

7.7.2.7 Other changes

- A change in the calendars or to the calendar to which an activity is assigned. (MarylandDOT, 2008)
- A change to, addition of, or deletion of a date or time constraint. (MarylandDOT, 2008)
- A change to, addition of, or deletion of an activity code. (MarylandDOT, 2008)
- A change to an activity description. (MarylandDOT, 2008)
- Any change other than updating an activity (MarylandDOT, 2008)
- The reasons for the overlap of controlling operations change. (MDOT, 2003)

The result of the schedule revision is usually a submittal of a new revised schedule unless the engineer agrees to include the changes in the next update (MarylandDOT, 2008). Rhode Island interestingly requires the contractor to resource load the revised schedule (RIDOT, 2004).

7.7.3 State Special Provisions

The Special Provisions of 10 projects include schedule revision clauses. Four California projects allowed adding/deleting activities, changing constraints, changing durations, and changing logic if these changes do not alter the critical path or delay the schedule completion. If the critical path is impacted or the schedule is delayed, contractor should: "submit a revised schedule within 15 days of the proposed change" (Caltrans, 2010) (Caltrans, 2011) (Caltrans b, 2011) (Caltrans.C, 2011). Table 7.7.3 summarizes the events triggering schedule revisions.

Kentucky's Pike project and Ohio projects 110255 and 113003 shared the same special provision for schedule revisions as follows: "The Work may require and/or the Contractor may make revisions to the CPM schedule. Addition of new activities (fragnets required) or new calendars or changes to existing activities, calendars or logic constitute a revision. All revisions must be reported in a Logic Modification Report. The Logic Modification Report is a separate CPM update which includes all the changes recommended by the contractor within the current Biweekly update schedule. It shall include a Narrative explanation of the necessary changes accompanying the Biweekly update schedule. Any revision which modifies the critical path or impacts an interim date or project completion date is considered a Logic Modification. A fragnet is defined as the sequence of new activities that are proposed to be added to the existing schedule. The fragnet shall identify the predecessors to the new activities and demonstrate the impacts to successor activities. If submitted as a fragnet, the Contractor shall compute two Finish Dates. The first Finish Date shall be computed without consideration of any impact by the fragnet. The second Finish Date shall be computed with consideration of any impact by the fragnet. The Contractor shall also submit a written narrative stating the reason for the proposed revisions. The Engineer shall "accept" or "reject" proposed revisions within ten days of receipt of appropriate schedules and narrative. All approved revisions will be incorporated into the Biweekly Update Schedule which will become the Revised Biweekly Update Schedule" (Kentucky DOT, 2011) (Ohio DOT, 2011) (Ohio DOT.b, 2011).

State	Provision / Project	Price	General	Add / Delete	Delays in schedule	Changes in Logic	Time extensions	Changes in	Scope changes	Changes in critical
Alaska	Project No. STP-0002(128)/61179	>$5M			x					x
Alaska	Project No. 62056	>$1M								
Alaska	Project No. MGE-EBL MGS-0002(166)162219	>$2.5M								
Alaska	Project No. 69588	>$0.5M								
California	Contract No. 07-138204	$160M			x					x
California	Contract No. 03-3797U4	$130M			x					x

California	Contract No. 12-0G3304	$ 56M			x					x
California	Contract No. 07-241304	$1.56M								
California	Contract No. 05-0T3604	$1.12M			x					x
Kentucky	109-PIKE, CONTRACT ID - 111307	$53.5M		x	x	x				x
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$17M								
Kentucky	104 various, CONTRACT ID - 111012	$8.5M								
Kentucky	35-PERRY, CONTRACT ID - 111308	$2.9M								
Ohio	Project Number: 110255	$55M		x	x	x				x
Ohio	Project Number: 113003	$12.2M		x	x	x				x
Ohio	Project Number: 110386	$7M								
Ohio	Project Number: 110321	$3.6M								
Oregon	SPS09350	>$50M	x							
Oregon	SPS10694	>$50M								
Oregon	SPS 12076	>$50M	x							
Oregon	SPS 14032	>$50M								
Oregon	SPS14197	>$50M								
Oregon	SPS14949	<$50M								
Oregon	SPS06025	<$50M								
Oregon	SPS12874	<$50M								
Total			2	3	8	3				7

Table 7.7.3: DOT Project Special Provisions: Events Causing Schedule Revisions

7.7.4 Schedule Specifications Survey

The survey respondents were asked to select the events that should trigger a schedule revision.

Approximately 93% of the survey respondents believed that any significant delays in the schedule should result in a schedule revision. More than 75% of the respondents suggest that any significant change in logic, time extension request, addition/deletion of any activity, or any change in the critical path should trigger a schedule revision. Approximately 60% of respondents did not believe that a change in calendars or changes in resources should trigger any revisions. Table 7.7.4 summarizes the results of the survey.

	Along with the periodical updates, schedule revision would be requested under certain events. In your opinion the events that should trigger a schedule "revisions" would include:	Percentage

1	Significant delays in the Schedule	92.72%
2	Significant change in the logic of the schedule	77.27%
3	Substantial when a time extensions is requested	82.73%
4	Changes in resources	33.64%
5	Addition, Modification, and Deletion of activities	77.27%
6	Changes to the critical path	84.55%
7	A change in the calendars or to the calendar to which an activity is assigned.	40.00%
8	A change to, addition of, or deletion of a date or time constraint	61.82%

Table 7.7.4: Survey Results: Events Triggering Schedule Revisions

7.7.5 Summary and Recommendations

Schedule revisions and schedule updates are very similar, the difference between both procedures is that schedule updates follow a certain frequency (monthly, bi-weekly, or weekly), schedule revisions, on the other hand are triggered by an event such as a change in the scope of work, major unforeseen condition, or major problems in the schedule and usually are requested by the engineer.

In a survey conducted by Patricia D. Galloway, the results showed that "nearly all respondents indicated that schedule updates were required and over 84% required schedule revisions. However, only 68% indicated that they distinguished between an update and a revision" (Galloway, 2006). Only 56% of the state DOT standard specification include schedule revision provisions compared to 92% of the DOT survey respondents and 84% according to Galloways survey (Galloway, 2006). The Special Provisions of the studied projects do not contribute significantly to boost the 56% result.

The Galloway survey also found that the main triggers for schedule revisions are as follows: project behind schedule (72%), change orders (72%), and critical path changes (56%). Other reasons include: "resource changes for either manpower or equipment, logic changes/duration changes/or contractor sequence changes, when requested by the owner; and when time extensions are approved" (Galloway, 2006).The events triggering schedule revision can be summarized into the following:

1- Significant delays in the Schedule
2- Significant change in the logic of the schedule
3- Time extensions is requested
4- Changes in resources
5- Addition, Modification, and Deletion of activities
6- Changes to the critical path
7- A change in the calendars or to the calendar to which an activity is assigned.
8- A change to, addition of, or deletion of a date or time constraint

With the exception of resource and calendar changes, more than 60% of the DOT survey respondents believed that all the events listed above should result in a schedule revision. This result stands at odds with DOT Standard Specifications where less than 16% of the Specification mentioned at least one of these events (see Table 7.7.1).

Evidently, most DOT standard specifications fail to address a critical aspect of project scheduling which is scheduling maintenance. Without periodic schedule updates and schedule reviews, the project schedule loses its value as a monitoring tool by becoming a static document, rather than a dynamic one. It is recommended that DOTs adopt a more closed approach regarding schedule revision provisions by adopting schedule revision clauses listing all the triggering events (listed above) in their Standard Specifications.

8 THE CONFORMANCE INDEX

The schedule Conformance Index, as defined by the PMI, is the degree to which the project schedule conforms to the best practices set by the PMI (PMI, 2007). As previously discussed, the PMI developed a list of required and optional schedule components (see Appendix D). In this section, the current research investigates the conformity of the State Standard Specification and Project Special Provisions to the PMI conformity matrix. The first condition for calculating the schedule Conformance Index is that the schedule should meet the required components listed in Table 3.4.1. If it the schedule fails to meet this requirement, it will be assessed as "does not meet minimum conformance standards" (PMI, 2007), and no further analysis is needed.

The State's Standard Specifications are first analyzed for conformance. Appendix F lists all PMIs' required scheduling components and the specifications are analyzed against it. It was found that all State Standard Specifications ***do not meet minimum conformance standards.*** Maryland, Oregon, Rhode Island, and Washington are the closest to conformity, scoring 22 of a possible 24 points, followed by Hawaii and Idaho at 21 and 20 points respectively. 17 states fail to score any points. The state standard specification scores are listed in Appendix F.

In a similar fashion, 53 state projects in 19 different states are analyzed[3] as shown in Appendix G. Again, it was found that all studied state projects ***do not meet minimum conformance standards***. South Carolina projects scored the highest at 22 out of 24, followed by California projects at 21 and Ohio at 20. Project scores are listed in Appendix G

Since the Project Special provisions supplement the Standard Specifications, the State Standard Specifications were overlaid against the Special Provisions. The same results are achieved; none of the studied projects met the minimum conformance standards.

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[3] State projects that did not include any scheduling specifications are not shown in table 1.3.1

9 CONCLUSION

At the beginning of this research effort a number of questions were asked: Are the Standard Scheduling Specifications in the 50 states DOTs sufficient? How do these specifications compare to industry best practices? What are the recommended state DOT standard scheduling specifications? The content review of state standard scheduling specifications, the subsequent comparative analysis with industry best practices (PMI, AACEI, UFGS, NASA), and the survey results indicate that the state DOT standard scheduling specifications are not sufficient and do not meet industry best practices. Section 8 studied the conformance index (as defined by the PMI), based on this indicator it was found that all state DOT standard scheduling specifications do not meet minimum conformance standards.

The content analysis, the comparative analysis, and the survey questionnaire for each of the identified scheduling elements (e.g. maximum activity durations, the use of activity constraints, schedule update procedure, etc...) are used to develop a recommended standard specification targeted towards meeting the scheduling needs of the state DOTs. Since the questionnaire did not include any scheduling professionals from the contractors' side, the following recommended specification may not meet the contractor's expectations. These scheduling specifications can be used by all states to develop a minimally acceptable schedule regardless of project complexity.

9.1 Recommended DOT Standard Scheduling Specifications

1. General

1.1. Scheduling Responsibility

The specifications should clearly identify the party responsible (typically the General Contractor) for creating, updating, and reviewing the project schedule. The Contractor should also identify a qualified scheduler.

1.2. Training Requirement for Contractor, Subcontractor, Owner

The specifications should include a provision requiring the contractor to provide a certain amount of training to DOT scheduling staff if requested.

1.3. Construction Schedule Preconstruction meeting

The meeting should occur prior to the commencement of work. All project parties (DOT, Contractor, Subcontractors) should be involved in this meeting. The meeting shall discuss the initial/preliminary schedule, schedule deliverables, schedule submittal procedures, and identify responsible schedulers.

2. Schedule Development

2.1. Scheduling Software

The DOT encourages the contractor to use Primavera P6 or MS project to develop the schedule. If the contractor chooses to utilize different software, contractor shall provide sufficient software training to DOT scheduling engineer prior to the commencement of work.

2.2. Scheduling Method

Contractor is required to use the critical path method (CPM) to develop the schedule regardless of project size, cost, or complexity.

2.3. Work Breakdown Structure (WBS)

The upper levels of the WBS shall be developed using the UNIFORMAT 11 division system. WBS codes shall be integrated with activity codes pursuant to section 2.7.1

2.4. Non-Construction Activities

In addition to construction activities, the project schedule shall include the following activities:

- Mobilization
- Procurement activities (particularly long lead items)
- Submittals
- Submittal review period and approval activities
- Permitting activities
- Fabrication

2.5. Project Milestones

At a minimum the schedule shall have a "Start Project" milestone, and a "Finish Project" milestone. No activity shall precede the Start Project milestone, and no activity shall succeed the Finish Project milestone. Other milestones can be used to highlight major project events such the start of a phase or the end of a phase.

2.6. Schedule Components

2.6.1. Project Name

The project schedule shall clearly show the project name.

2.6.2. Project Schedule ID

The project schedule shall have a unique identification number. At a minimum the ID shall include the DOT contract number and the data date.

2.6.3. Maximum Number of Activities

There are no restrictions on the number of activities in the project schedule. The schedule shall include a sufficient amount of activities assuring better planning, monitoring, and execution of the project.

2.7. Activity Components

2.7.1. Activity Coding System

As a minimum schedule activities shall be coded with the following:

- Phase: Most civil projects are built in phases or stages. A 2-digit code is suggested.
- Area: Used if the project has distinct subprojects, e.g. a highway subproject and a bridge subproject. Also, to be used if the contractor has multiple separate contracts for the same project, e.g. highway contract, bridge contract. A 2-digit code is suggested. Example: 00 if only one contract for the project.
- Work Items/Systems: Preferably UNIFORMAT or a modified version to include civil works. A 5-digit code for the Uniformat is suggested.
- Work Type/Masterformat: Two levels of the CSI Masterformat divisions, e.g. 03 concrete, 0322 concrete forming. A 4-digit code is suggested.
- Responsibility: A 6 digit alphanumerical code is suggested. This allows the development of different codes to different subcontractors of the same trade, e.g. MECH01, MECH02.

2.7.2. Activity ID

Activities shall be coded with a unique alphanumerical identifier; it is recommended that the activity ID correlates with activity codes.

2.7.3. Activity Description

Activity Descriptions shall be clear and concise; it is suggested to use a verb and noun to describe the activity (example: install scaffold)

2.7.4. Activity Duration

Construction activities shall have a duration not exceeding 20 working days and shall not be less than 1 day. Non-construction activities could have longer durations (example: delivery of a long lead item). The project schedule shall clearly show Activity Original Durations.

2.7.5. Activity Actual Duration

The updated project schedule shall clearly show the Activity Actual Duration

2.7.6. Remaining Activity Duration

The project schedule shall show the remaining activity duration for each active activity. Remaining Activity Durations shall be used to update the schedule.

2.7.7. Activity Early Start/ Finish and Late Start/ Finish

The project schedule shall clearly show the early start/finish dates and late start/finish dates.

2.7.8. Actual Start and Finish Dates

The project schedule shall clearly show the actual start/finish dates.

2.7.9. Lead/Lag

The project schedule shall clearly show the lead and lag times for each activity. It is recommended that lead/lag times are replaced with activities when possible.

2.7.10. Float

The project schedule shall clearly show the free and total float for each activity. Negative float is not allowed in the baseline schedule. It is acceptable for schedule updates to have negative float. If used, negative float shall be documented in the schedule narrative.

Float shall be considered as a shared commodity between the Owner and Contractor.

2.7.11. Critical Path

The project schedule shall clearly identify critical activities and the critical path. The critical path shall be calculated using the longest path. Multiple critical paths are allowed and shall be documented in the schedule narrative.

2.7.12. Percent Complete

The project schedule shall clearly show the percent complete for each activity. Activity percent completion shall reflect the physical percent completion not the duration percent completion.

2.7.13. Activity Calendars

Calendars shall be assigned to each activity. All calendars shall account for holidays, weather, and state specific shutdowns. As a minimum, the contractor shall utilize the following calendars:

- 5-day week calendar including holidays
- 6-day week calendar including holidays
- 7-day week calendar including holidays
- 7-days week calendar without holidays (used for activities such as concrete cure)

2.8. Relationships

The project scheduler shall utilize finish to start (FS) relationships as much as possible. finish to finish (FF) and start to start (SS) relationships are allowed with lags no greater than the predecessor/successor duration, but is not recommended. The use of start to finish relationships (SF) is prohibited. No open ends are allowed in the project schedule; all activities and milestones shall have a predecessor and a successor with the exception of the “Start project” and “Project Finish” milestones.

2.9. Logic Constraints

The use of logic constraints are allowed in the project schedule. The constraints shall not alter the critical path of a project in a way that would be considered detrimental or harmful to the owner [e.g. highway agency, DOT, County, City], or in a way that might lead to time and cost impacts to the owner”.

2.10. Out of Sequence Activities

Retained logic shall be the method utilized to progress out-of-sequence activities. Progress override is not allowed.

2.11.Resource and Cost Loading

The project schedule shall be resource and cost loaded. The aggregate cost shall match the project bid.

3. Schedule Submittals

3.1. Schedule Narrative

Along with every schedule submittal, contractor shall submit a schedule narrative. The schedule narrative shall include the following:

- A brief description of the contractor’s proposed construction sequencing, the main challenges, and major resources (only required for the baseline schedule submittal)

- A general statement of the project status compared to the baseline schedule.
- Major milestones completed and upcoming major activities.
- Identify upcoming challenges/Risk.
- Identify critical path and near critical activities.
- Identify all added/deleted activities and logic.
- Identify all the changes made to activity durations.
- Identify all constraints used.
- Identify all calendars used.
- The status of all long lead items, equipment, and labor availability.
- Recovery plans if applicable.

3.2. Preliminary Schedule Submission Deadline and Review Period

The preliminary schedule shall be submitted 15 calendar days after the notice to proceed and 15 days prior to the construction schedule pre-construction conference. The preliminary schedule coverage period is to be determined by the DOT scheduling engineer in the projects special provision. The DOT engineer shall review and return the schedule within 10 days.

3.3. Baseline Schedule Submission Deadline and Review Period

The baseline schedule shall be submitted within 21 days after the approval of the preliminary schedule. The DOT engineer shall review and return the baseline schedule within 10 days. The data date in the baseline schedule shall be the notice to proceed date. The baseline schedule shall not have any actual start or finish dates.

3.4. Schedule Update

Contractor shall submit a schedule update monthly on a specific date approved by the engineer. The DOT engineer shall review and return the baseline schedule within 10 days. The updated schedule shall also follow the requirements delineated in this specification.

3.5. Look-Ahead Schedules

Contractor shall submit a 3-week look-ahead schedule every week. The look-ahead schedule shall be submitted in bar chart format clearly highlighting the critical and near-critical activities. The look-ahead schedule shall also follow the requirements delineated in this specification.

3.6. Schedule Revision

At any point during the project, the DOT engineer can request a schedule revision. Contractor shall submit a schedule revision within 5 days of the request. The events triggering the schedule revision can be summarized to the following:

1- Significant delays in the Schedule.

2- Significant change in the logic of the schedule.

3- Time extensions is requested.

4- Changes in resources.

5- Addition, Modification, and Deletion of activities.

6- Changes to the critical path.

7- A change in the calendars or to the calendar to which an activity is assigned.

8- A change to, addition of, or deletion of a date or time constraint.

3.7. Submittal Method

All schedules shall be submitted in a soft copy format compatible with the software agreed upon by the project team. Contractor shall provide hard copies of the schedule if requested.

10 Future Research

This research excluded project complexity and simply focused on standard scheduling specifications. The next step would be looking at how project complexity (cost, duration, number of sub-contractors etc.) impacts the level of scheduling specification detail. Also, expanding this research to include the contractor's point of view would be beneficial in order to develop a complete specification that satisfies all parties.

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Appendix A: Reviewed Standard Specifications and Other Related State DOT Publications

State	Agency	Abbreviation	Publication	Edition
Alabama	Alabama Department of Transportation	ALDOT	Standard Specification for Highway Construction	2012
Alabama	Alabama Department of Transportation	ALDOT	Construction Manual	8/15/2000
Alabama	Alabama Department of Transportation	ALDOT	Approved General Application Special Provisions for The 2008 ALDOT Standard Specifications For Highway Construction	5/23/2011
Alaska	Alaska Department of Transportation and Public Facilities	Alaska DOT&PF	Standard Specification for Highway Construction	2004
Alaska	Alaska Department of Transportation and Public Facilities	Alaska DOT&PF	Construction Manual	4/15/2010
Alaska	Alaska Department of Transportation and Public Facilities	Alaska DOT&PF	Approved Modifications for the Standard Specification for Highway Construction	5/3/2010
Arizona	Arizona Department of Transportation	ADOT	Standard Specification for Road and Bridge Construction	2008
Arizona	Arizona Department of Transportation	ADOT	Construction Manual	8/1/2009
Arkansas	Arkansas State Highway and Transportation Department		Standard Specification for Highway Construction	2003
Arkansas	Arkansas State Highway and Transportation Department		Resident Engineer's Manual	2004
California	California Department of Transportation	Caltrans	Standard specifications	5/1/2006
California	California Department of Transportation	Caltrans	Construction Manual	7/1/2005
California	California Department of Transportation	Caltrans	Standard Special Provisions 08-012	1/14/2011

State	Agency	Abbreviation	Publication	Edition
Colorado	Colorado Department of Transportation	CDOT	Standard Specifications for Road And Bridge Construction	6/1/2005
Colorado	Colorado Department of Transportation	CDOT	CDOT Construction Manual	8/1/2004
Colorado	Colorado Department of Transportation	CDOT	Standard Special Provisions - Revision of Section 108 - Critical Path Method	8/19/2011
Connecticut	Connecticut Department of Transportation	CTDOT	Standard Specifications for Roads, Bridges and Incidental Construction	1/1/2002
Connecticut	Connecticut Department of Transportation	CTDOT	Construction Manual	1/1/2011
Connecticut	Connecticut Department of Transportation	CTDOT	Supplemental Specification Section 1.08 Prosecution and Progress	1/1/2002
Delaware	The Delaware Department of Transportation	DelDOT	Standard Specifications for Road and Bridge Construction	8/1/2001
Delaware	The Delaware Department of Transportation	DelDOT	DelDOT Construction Manual	1/1/2001
District of Columbia	District of Columbia Department of Transportation	DDOT	Standard Specifications for Highway and Structures	2009
District of Columbia	District of Columbia Department of Transportation	DDOT	Construction Management Manual	5/1/2010
Florida	Florida Department of Transportation	FDOT	Standard Specifications for Road and Bridge Construction	2010
Florida	Florida Department of Transportation	FDOT	Construction Project Administration Manual (CPAM)	5/11/2009
Florida	Florida Department of Transportation	FDOT	Project Manual Handbook	2/29/2008
Florida	Florida Department of Transportation	FDOT	Special Provisions SP0080302A	2010
Georgia	Georgia Department of Transportation	GDOT	Standard Specifications Construction of Transportation Systems	6/21/2001
Georgia	Georgia Department of Transportation	GDOT	Supplemental Specifications for Construction of Roads and Bridges	3/1/2008
Hawaii	Hawaii Department of Transportation	HDOT	Standard Specifications for Road and Bridge Construction	2005
Hawaii	Hawaii Department of Transportation	HDOT	Construction Best Management Practices Field Manual	1/1/2008

State	Agency	Abbreviation	Publication	Edition
Hawaii	Hawaii Department of Transportation	HDOT	DOT / FEDERAL PROJECTS Special Provisions for 2005 Standard Specifications	2/6/2006
Idaho	Idaho Transportation Department	ITD	Standard Specification for Highway Construction	2004
Illinois	Illinois Department of Transportation	IDOT	Standard Specifications For Road and Bridge Construction	1/1/2007
Indiana	Indiana Department of Transportation	INDOT	Standard Specification	2010
Indiana	Indiana Department of Transportation	INDOT	Recurring Special Provisions 108-C-215 Critical Path Method Schedule	4/1/2010
Iowa	Iowa Department of Transportation	Iowa DOT	Standard Specification for Highway and Bridge Construction	2009
Iowa	Iowa Department of Transportation	Iowa DOT	Developmental Specifications for Construction Project Schedules	10/20/2009
Kansas	Kansas Department of Transportation	KSDOT	Standard Specifications for State Road and Bridge Construction	2007
Kansas	Kansas Department of Transportation	KSDOT	Construction Manual	4/1/2004
Kentucky	Kentucky Transportation Cabinet	KYTC	Standard Specifications For Road and Bridge Construction	12/14/2007
Kentucky	Kentucky Transportation Cabinet	KYTC	Construction Guidance Manual	5/1/2009
Kentucky	Kentucky Transportation Cabinet	KYTC	Supplemental Specifications to The Standard Specifications for Road and Bridge Construction, 2008 Edition	7/5/2011
Louisiana	Louisiana Department of Transportation and Development	DOTD	Standard Specifications for Roads and Bridges	2006
Louisiana	Louisiana Department of Transportation and Development	DOTD	Construction Contract Administration	8/1/2005
Maine	Maine Department of Transportation	MaineDOT	Standard Specifications for Highways and Bridges	2002
Maryland	Maryland Department of Transportation	MDOT	Standard Specifications for Construction and Materials	7/1/2008

State	Agency	Abbreviation	Publication	Edition
Maryland	Maryland State Highway Administration	MDOT	Construction Manual	6/7/2004
Massachusetts	Massachusetts Department of Transportation	massDOT	Standard Specifications for Highways and Bridges (Supplemental)	5/25/2010
Michigan	Michigan Department of Transportation	MDOT	Standard Specifications for Construction	2003
Michigan	Michigan Department of Transportation	MDOT	Special Provision for Critical Path Method Network Schedule 12SP102(B)	7/24/2002
Minnesota	Minnesota Department of Transportation	MnDOT	Standard Specifications for Construction	2005
Minnesota	Minnesota Department of Transportation	MnDOT	Contract Administration Manual	4/15/2005
Mississippi	Mississippi Department of Transportation	MDOT	Standard Specifications for Road and Bridge Construction	2004
Mississippi	Mississippi Department of Transportation	MDOT	Construction Manual	4/14/2010
Missouri	Missouri Department of Transportation	MoDOT	Standard Specifications for Highway Construction	2/1/2011
Montana	Montana Department of Transportation	MDT	Standard Specifications for Road and Bridge Construction	2006
Montana	Montana Department of Transportation	MDT	Supplemental Specification for Montana Standard Specifications for Road and Bridge Construction 2006 Edition	5/12/2011
Nebraska	Nebraska Department of Roads	NDOR	Standard Specifications for Highway Construction	2007
Nebraska	Nebraska Department of Roads	NDOR	Contract Administration and Inspection Procedures	2002
Nevada	Nevada Department of Transportation	NDOT	Standard Specifications for Road and Bridge Construction	2001
Nevada	Nevada Department of Transportation	NDOT	Construction Manual	1/1/2009
New Hampshire	New Hampshire Department of Transportation	NHDOT	Standard Specifications for Road and Bridge Construction	8/1/2010
New Jersey	New Jersey Department of Transportation	NJDOT	Standard Specifications for Road and Bridge Construction	2007
New Jersey	New Jersey Department of Transportation	NJDOT	Construction Scheduling Standard Coding and Procedures For Designers and Contractors Manual	2001

State	Agency	Abbreviation	Publication	Edition
New Mexico	New Mexico Department of Transportation	NMDOT	Standard Specifications for Highway and Bridge Construction	2007
New York	New York Department of Transportation	NYSDOT	Standard Specifications	5/1/2008
North Carolina	North Carolina Department of Transportation	NCDOT	Standard Specifications for Roads & Structures	2006
North Dakota	North Dakota Department of Transportation	NDDOT	Standard Specifications for Road and Bridge Construction	2008
North Dakota	North Dakota Department of Transportation	NDDOT	North Dakota DOT Supplemental Specifications	10/21/2011
Ohio	Ohio Department of Transportation	ODOT	Construction and Material Specifications	2010
Ohio	Ohio Department of Transportation	ODOT	Manual of Procedures	2009
Ohio	Ohio Department of Transportation	ODOT	PN 105 – Critical Path Method Progress Schedule For Short Duration Projects	7/16/2010
Ohio	Ohio Department of Transportation	ODOT	PN 107 - Critical Path Method Progress Schedule	7/16/2010
Oklahoma	Oklahoma Department of Transportation	ODOT	Standard Specifications for Road and Bridge Construction	2008
Oklahoma	Oklahoma Department of Transportation	ODOT	Oklahoma DOT Special Provisions Contractor's Critical Path Method Schedule Requirements	1/4/2010
Oregon	Oregon Department of Transportation	ODOT	Standard Specification for Construction	2008
Oregon	Oregon Department of Transportation	ODOT	Construction Manual	2010
Oregon	Oregon Department of Transportation	ODOT	Supplemental Oregon Standard Specifications for Construction	1/1/2006
Oregon	Oregon Department of Transportation	ODOT	Standard special provisions for the 2008 standard Specifications	8/18/2011
Pennsylvania	Pennsylvania Department of Transportation	PennDOT	Construction Specifications	2011
Rhode Island	Rhode Island Department of Transportation	RIDOT	Standard Specifications for Road And Bridge Construction	2004
South Carolina	South Carolina Department of Transportation	SCDOT	Standard Specifications for Highway Construction	2007

State	Agency	Abbreviation	Publication	Edition
South Carolina	South Carolina Department of Transportation	SCDOT	Construction Manual	2004
South Carolina	South Carolina Department of Transportation	SCDOT	Critical Path Method Project Schedules (Project values ≥ $5 Million)	11/30/2004
South Dakota	South Dakota Department of Transportation	SDDOT	Standard Specifications for Roads and Bridges	2004
Tennessee	Tennessee Department of Transportation	TNDOT	Standard Specification for Road and Bridge Construction	2006
Tennessee	Tennessee Department of Transportation	TNDOT	Supplemental specifications for the 2006 standard specifications	3/1/2006
Texas	Texas Department of Transportation	TXDOT	Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges	2004
Texas	Texas Department of Transportation	TXDOT	Construction Contract Administration Manual	2007
Texas	Texas Department of Transportation	TXDOT	Standard Special Provisions SP008-049	2004
Texas	Texas Department of Transportation	TXDOT	Standard Special Provisions SP008-050	2004
Texas	Texas Department of Transportation	TXDOT	Standard Special Provisions SP008-086	2004
Utah	Utah Department of Transportation	UDOT	Standard Specifications for Road And Bridge Construction	2008
Vermont	Vermont Department of Transportation	VTRANS	Standard Specification for Construction	2006
Vermont	Vermont Department of Transportation	VTRANS	Construction Manual	2009
Virginia	Virginia Department of Transportation	VDOT	Road and Bridge Specifications	2007
Virginia	Virginia Department of Transportation	VDOT	S108C00 - CPM PROGRESS FOR SCHEDULE CATEGORY III PROJECTS	3/1/2011
Virginia	Virginia Department of Transportation	VDOT	S108D00 - CPM PROGRESS FOR SCHEDULE FOR CATEGORY IV PROJECTS	3/1/2011
Washington	Washington State Department of Transportation	WSDOT	Standard Specifications for Road, Bridge, and Municipal Construction	2010
Washington	Washington State Department of Transportation	WSDOT	Construction Manual	2010

State	Agency	Abbreviation	Publication	Edition
West Virginia	West Virginia Division of Highways	WVDOH	Standard Specifications for Roads and Bridges	2010
West Virginia	West Virginia Division of Highways	WVDOH	Construction Manual	2002
West Virginia	West Virginia Division of Highways	WVDOH	Supplemental specifications for the 2010 standard specifications	1/1/2011
Wisconsin	Wisconsin Department of Transportation	WIDOT	Standard Specifications for Highway and Structures	2011
Wyoming	Wyoming Department of Transportation	WYDOT	Standard Specifications for Road And Bridge Construction	2010

Appendix B: List of Reviewed Project Special Provisions

State	Project Name	Year	Project code	Cost	Description
Alaska	Emmonak Landfill Road	2011	Project No. STP-0002(128)/61179	Greater than $5,000,000	Construct a new gravel road to the proposed landfill site. The project includes embankment construction, culvert installation, signing, and application of dust palliatives.
Alaska	Van Horn Road West	2011	Project No. 62056	Between $1,000,000 and $2,500,000	This project consists of grading, widening, rehabilitation, resurfacing, and drainage improvements along Van Horn Road West.
Alaska	Marshall Airport Access Road Bridge Replacement,	2011	Project No. MGE-EBL MGS-0002(166)162219	Between $2,500,000 and $5,000,000	Replace the existing drainage structure on the Marshall Airport Road with a bridge at Wilson Creek. Reconstruct approximately 1,900' of the road in the vicinity of the Wilson Creek crossing.
Alaska	Port alexander inner harbor improvements	2011	Project No. 69588	Between $500,000 and $1,000,000	Reconstruction of inner float, removal of existing timber float system and placement of new timber
California	Route 80/84 to Watt Ave Overcrossing Highway Construction	2011	Contract No. 03-3797U4	$130,000,000.00	FOR CONSTRUCTION ON STATE HIGHWAY IN YOLO AND SACRAMENTO COUNTIES IN AND NEAR WEST SACRAMENTO AND SACRAMENTO FROM ROUTE 80/84 SEPARATION TO WATT AVENUE OVERCROSSING
California	Route 47 Junction Highway construction	2010	Contract No. 07-138204	$160,000,000.00	FOR CONSTRUCTION ON STATE HIGHWAY IN LOS ANGELES COUNTY IN LONG BEACH AND LOS ANGELES ON ROUTE 47 FROM OCEAN BOULEVARD TO ROUTE 103 JUNCTION AND ON ROUTE 103 FROM ROUTE 47 JUNCTION TO ANAHEIM STREET OVERHEAD

State	Project Name	Year	Project code	Cost	Description
California	Route 55/91to Route 91/241 Highway Construction	2011	Contract No. 12-0G3304	$56,000,000.00	FOR CONSTRUCTION ON STATE HIGHWAY IN ORANGE COUNTY IN ANAHEIM AND YORBA LINDA FROM ROUTE 55/91 SEPARATION TO ROUTE 91/241 SEPARATION
California	Willow Creek Bridge - North of San Benito River Bridge Highway Construction	2011	Contract No. 05-0T3604	$1,120,000.00	FOR CONSTRUCTION ON STATE HIGHWAY IN SAN BENITO COUNTY ABOUT 20 MILES SOUTH OF HOLLISTER FROM WILLOW CREEK BRIDGE TO 2.0 MILES NORTH OF SAN BENITO RIVER BRIDGE
California	North of LA Tijera Blvrd Overcrossing - Route 90/405 Highway Construction	2011	Contract No. 07-241304	$1,560,000.00	FOR CONSTRUCTION ON STATE HIGHWAY IN LOS ANGELES COUNTY IN LOS ANGELES AND CULVER CITY FROM 0.8 KM NORTH OF LA TIJERA BOULEVARD OVERCROSSING TO 0.4 KM SOUTH OF ROUTE 90/405 SEPARATION
Florida	SR 9 (I-95) Improvements	2010	Contract T2376	$19,453,029.69	The Improvements under this Contract consist of Milling & Resurfacing, Curb & Gutter, Lighting, Concrete Pavement Slab Replacement, Bridge Approach Expansion Joint Rehabilitation, Highway Signing, Guardrail, Sidewalk and other incidental construction on SR 9 (I-95) in Duval County from approximately 900 feet south of the Greenland Road Underpass to approximately one-half mile south of the J.T. Butler Boulevard overpass (approximately six miles).

State	Project Name	Year	Project code	Cost	Description
Florida	SR 683 (US 301) Highway Improvements	2009	Contract T1322	$14,667,050.00	The Improvements under this Contract consist of adding lanes, reconstruction, milling & resurfacing, widening, drainage improvements, lighting, signalization and signing & pavement marking on State Road 683 (US 301) from Wood Street northerly 2.604 miles, to Myrtle Street in the City of Sarasota, Sarasota County.
Florida	SR 8 (I-10) Improvements	2010	Contract T2366	$1,912,362.28	The Improvements under this Contract consist of Base Work, Shoulder Treatment, Guardrail and other incidental construction on SR 8 (I-10) at SR 55 & SR 14 in Madison County.
Florida	SR 786 Improvements	2010	Contract T4299	$1,597,956.96	The Improvements under this Contract consist of 3R upgrades along SR 786 / PGA Blvd from West of Florida's Turnpike to East of Military Trail (Palm Beach County). Specific improvements include milling and resurfacing the existing pavement, sidewalk/ADA ramp construction, signing & pavement marking improvements, signalization modifications, landscape and irrigation improvements.

State	Project Name	Year	Project code	Cost	Description
Illinois	I-57 Bridge Construction	2010	Contract No. 60J27-325	$29,105,000.88	The work under this contract includes, but is not limited to: Installation of embankment, pavement widening and resurfacing, shoulders, barrier wall, temporary pavement and associated items along northbound and southbound I-57 and C/D Road A as shown on the plans; the removal and reinstallation of I-57 bridge over I-294; the construction of C/D Road A bridge over I-294; the construction of I-57 and C/D Road A bridge over Ramp B; and the removal and replacement of the inside and outside shoulder and associated safety items along I-294 at the locations of proposed bridge piers.
Illinois	U.S. Route 30 Improvements	2011	Contract No. 62479-136	$42,262,986.89	The work to be performed under this contract consists of the reconstruction of U.S. Route 30 and reconstruction of the intersections intersecting U.S. 30. The improvement includes the construction of retaining walls, noise walls, box culverts, storm sewer, traffic signals, pavement marking, and all incidental and collateral work necessary to complete the project as shown on the plans and as described herein.

State	Project Name	Year	Project code	Cost	Description
Illinois	Route 22 Imrpovements	2010	Contract No. 60860-071	$11,989,460.90	The project is located on Illinois Route 22 (Half Day Road) just East of I-94 in the Village of Bannockburn and extends in an easterly direction where it ends just West of US Route 41 (Skokie Highway) in the Village of Highland Park in Lake County. The length of the improvement is 12,932.03 feet (2.449 miles).This project consists of roadway widening, reconstruction, resurfacing and traffic signal modernization. Also included in the scope of work is installation of curb and gutter, barrier median, sidewalk, storm sewers, drainage structures, pavement markings and signing, erosion control, landscaping and all incidental and collateral work necessary to complete the project as shown on the Plans and as described herein.
Illinois	FAU Route 2652 Improvements	2010	Contract No. 63379	$4,234,991.28	The project begins at a point on te centerline of FAU Route 2652(S Villa Avenue), beginning at Madison Street and extending notherly for a distance of 5352 feet to St. Charles Road. The scope of work consists of reconstrcution, refsurfacing, curb and gutter, sidewalks, pavement marking, lighting, signing, storm sewers, warter main, sanitary sewers, streescape.
Indiana	PR 69 From White River New Bridge Construction	2011	Contract # 33045-A	$141,778,367.70	New road and bridge construction
Indiana	PR 69 From North Fork Prairie Creek Roadway Construction	2010	Contract # 33049	$69,344,417.82	New road construction
Indiana	SR 25 Bridge Construction	2011	Contract # IR-30850-A	$26,200,000.00	New road and bridge construction

State	Project Name	Year	Project code	Cost	Description
Indiana	Various Roads Throughout Madison County Roadway Construction	2010	Contract # 32756	$8,700,000.00	Road constrcution
Indiana	Kenil Worth Road Over US 31 New Road Construction	2009	Contract # IR-31879-A	$2,960,000.00	New road construction
Iowa	I-29 Over singing Hills Blvrd Bridge Replacement	2011	Contract ID 97-0296-175	$4,305,957.84	BRIDGE REPLACEMENT - PPCB
Iowa	I-80 Over West Nishnabotna River Bridge Replacement	2010	Contract ID 78-0801-330-A	$10,922,813.56	RECONSTRUCTION - BRIDGE DECK REPLACEMENT
Iowa	U.S. 61 Fort Madisoin Bypass	2010	Contract ID 56-0611-117-M	$24,879,964.82	PCC PAVEMENT - NEW
Iowa	IOWA 534 Over Missouri River Bridge Construction	2010	Contract ID 65-5341-068	$ 61,346,140.60	BRIDGE NEW
Kansas	I-70 lanes Improvements	2010	Project No. 70-27 KA 0729-01	$14,000,000	milling and concrete inlay of I-70 lanes and milling and HMA overlay of the ramps beginning at 8.3 miles East of Russell/Ellsworth County Line East to 0.7 mile West of East Junction of K-14 in Ellsworth County.
Kansas	Bridges No. 670-105-1.28(244) and 670-105-1.29(243) Expansion Joint Replacement	2011	Project No. 670-105 KA 1294-01	$3,000,000	The replacement of expansion joints to Bridges No. 670-105-1.28(244) and 670-105-1.29(243) on I-670 in the Wyandotte County.
Kansas	Bridge No. 92-52-18.48 (026) Repairs	2011	Project No. 92-52 KA 1507-01	$3,000,000	The pier repairs, strip seal assemblies, concrete surface repairs and replacement of the rocker bearings for the Bridge No. 92-52-18.48 (026) on K-92 in the City of Leavenworth in Leavenworth County.

State	Project Name	Year	Project code	Cost	Description
Kansas	I-70 Highway Reconstruction	2011	Project No. 70-91 KA 0718-01	$43,000,000	the reconstruction of I-70 from Colorado state line east to Caruso interchange in Sherman County.
Kentucky	Pike-Virginia State Line Road(US 460) Grade and Drain	2011	109-PIKE, CONTRACT ID - 111307	$53,549,206.66	PIKEVILLE-VIRGINIA STATE LINE ROAD (US 460) US 460-KY80 FROM BEAVER CREEK STATION TO THE VIRGINIA STATE LINE (SECTION 8B), A DISTANCE OF 1.84 MILES. GRADE & DRAIN. SYP NO. 12-00263.82.
Kentucky	Hendersen Pavement with Grade and Drain	2011	104-HENDERSON, CONTRACT ID - 111023	$17,223,036.46	AUDUBON PARKWAY (PW 9005) JPC OVERLAY ON AUDUBON PARKWAY FROM MP 8.525 TO THE GREEN RIVER BRIDGE AND BRIDGE DECK OVERLAY ON THE KY 416 BRIDGE. JPC PAVEMENT WITH GRADE & DRAIN. SYP NO. 02-02040.00.
Kentucky	William H. Natcher Pkwy Pavement	2011	104 various, CONTRACT ID - 111012	$8,510,265.82	WILLIAM H. NATCHER PARKWAY (PW 9007) SURFACING FOR THE EXTENSION OF WILLIAM H. NATCHER PARKWAY TO US 231 AT DYE FORD ROAD AND SIGNING ON PARKWAY. PAVEMENT (WITH ALTERNATIVES). SYP NO. 03-00053.10.
Kentucky	Jeff-Cornettsville Rd grade and drain with asphalt surface.	2011	35-PERRY, CONTRACT ID - 111308	$2,911,145.71	JEFF-CORNETTSVILLE ROAD (KY 7) CORRECT ROCKFALL HAZARD FROM MP 8.3 TO MP 8.5, A DISTANCE OF 0.34 MILES. GRADE & DRAIN WITH ASPHALT SURFACE. SYP NO. 10-05005.00.
Missouri	Broadway Blvrd bridge replacement	2011	Project Number: J4I2023B - ROUTE I-670 - JACKSON COUNTY, 110422-411	$4,944,372.11	Replace Broadway Blvd. Bridge over Rte. I-670
Missouri	I-70 to the Mississippi River Br Interchange	2011	Project Number:J6U1086 - ROUTE I-70 - ST LOUIS CITY, 110422-601	$21,826,136.89	New interchange to connect I-70 to the Mississippi River Br.

State	Project Name	Year	Project code	Cost	Description
Missouri	Route 63 - Boone County Brigde Rehabilitation	2011	Project Number:J5P0738 - ROUTE 63 - BOONE COUNTY, 110527-503	$9,793,257.30	Rehabilitation of Bridge Decks
Missouri	Route I-55 Resurface	2011	Project Number:J0I2176 - ROUTE I-55 - VARIOUS COUNTIES, 110527-x10	$15,741,185.35	Resurface w/ Superpave, alt. underseal (poly., hot asphalt)
Nebraska	I-80 - Salt Creek Interchange	2010	CONTRACT ID: 1477, CALL ORDER: 100	$37,347,409.36	I-80, SALT CREEK BR,WB WAVERLY INTERCHANGE BR, STREAM BR W OF WAVERLY, STREAM BR W OF 98TH ST.,56TH ST. WAVERLY INTERCHANGE
Nebraska	US-75/US-34, Platteview Intersection	2010	CONTRACT ID: 2176A, CALL ORDER: 200	$19,060,644.85	US-75/US-34, PLATTEVIEW INTERSECTION
Nebraska	Kearney East Bypass Interchange	2011	CONTRACT ID: 4103A, CALL ORDER: 420	$13,509,472.41	KEARNEY EAST BYPASS INTERCHANGE
Nebraska	US-183/Sargent North	2011	CONTRACT ID: 6232, CALL ORDER: 605	$4,779,840.64	US-183, SARGENT NORTH
New Jersey	Route 168 Benigno Blvrd	2007	ROUTE 168 BENIGNO BOULEVARD CONTRACT NO. 006048005	$3,103,000.00	ROUTE 168 BENIGNO BOULEVARD
New Jersey	Route 440 Ramp over State St	2007	ROUTE 440 RAMP V OVER STATE STREET AND CONRAIL DECK REPLACEMENT CONTRACT NO. 004096470, FEDERAL PROJECT NO. BR-7811(117)	$7,505,600.00	ROUTE 440 RAMP V OVER STATE STREET AND CONRAIL DECK REPLACEMENT , CITY OF PERTH AMBOY COUNTY OF MIDDLESEX

State	Project Name	Year	Project code	Cost	Description
New Jersey	Route 183 Bridge over New Jersey transit	2007	RECONSTRUCTION OF ROUTE 183 BRIDGE CONTRACT NO. 000950476, FEDERAL PROJECT NO. NHS-0035(180)	$12,913,266.42	RECONSTRUCTION OF ROUTE 183 BRIDGE OVER NEW JERSEY TRANSIT AND NETCONG CIRCLE (ROUTE US 46) ROUTE 183(from South of Helen Way to Maple Avenue ROUTE US 46) (from East of Main Street to West of Helen Way.) GRADING, PAVING, DRAINAGE AND STRUCTURES
New Jersey	Route 7, Hackensack River	2007	Route 7, Hackensack River (Wittpenn) Bridge Contract No. 000068087	$64,444,447.00	Route 7, Hackensack River (Wittpenn) Bridge, Contract 1,
New Mexico	Lobato Trestle Crossing Over Wolf Creek	2011	Contract/ Project No. : G3a52/AC-GRIP-054-2(6)163	$19,240,623.75	Bridge Replacement, replace existing railroad bridge. Earthwork, erosion control.
New Mexico	I-40 Roadway reconstruction	2008	Contract/ Project No. : G1143/AC-GRIP-BR-EB-NH-040-3(155)161	$41,831,520.90	Roadway Reconstruction, pavement sections, ramp rehabilitation, cold milling, concrete and metal barrier installations, structure, miscellaneous construction
New Mexico	US 67/87 Roadway new construction	2009	Contract/ Project No. : 3435/BR-0104(16)52	$2,396,767.00	Roadway New Construction, pavement sections,accelaration deccelaration lanes, rest areas, parking lots, earthwork, metal barrier installation,major structures, new bridge construction , continious concrete slab.
New Mexico	I-10 Las Cruces to Texas state line roadway reconstruction	2009	Contract/ Project No. : ESG18A2R/AC-GRIP-(IM-NH)-010-2(111)143	$36,204,549.75	Roadway Reconstruction, pavement sections, metal barrier installations, earthwork,traffic control.
North Carolina	I-295 Payetteville outer loop	2011	Contract ID: C202684	$55,258,773.41	Grading, Drainage, Paving, Signing, Walls and Structures
North Carolina	US 401 Rolesville bypass project	2011	Contract ID: C202538	$24,956,387.67	Grading, Drainage, Paving, C&G, Signals, and Culverts

State	Project Name	Year	Project code	Cost	Description
North Carolina	US 52 from Greyhound to Akron Dr	2011	Contract ID: C202598	$13,121,586.40	Grading, Drainage, Paving, Signing, Signals, and Retain walls
North Carolina	US 321 resurfacing	2011	Contract ID: C202690	$5,113,273.80	Resurfacing and shoulder reconstruction
North Carolina	US 220A	2010	Contract ID: C202671	$3,137,734.53	Milling, resurfacing and shoulder reconstruction
Ohio	USR 50 Improvements	2011	Project Number: 110255	$54,923,975.95	PART 1 FOR IMPROVING SECTION HAM-50-18.79, PART 1, U.S. ROUTE 50 IN THE CITY OF CINCINNATI, HAMILTON COUNTY, OHIO,IN ACCORDANCE WITH PLANS AND SPECIFICATIONS BY GRADING, DRAING, PAVING WITH CONCRETE BASE, CONSTRUCTING MSE WALLS AND REHABILITATING EXISTING STRUCTURES. PART 2 FOR IMPROVING SECTION HAM-50-19.03, PART 2, U.S. ROUTE 50 IN THE CITY OF CINCINNATI, HAMILTON COUNTY, OHIO, IN ACCORDANCE WITH PLANS AND SPECIFICATIONS BY GRADING, DRAINING, RESURFACING WITH ASPHALT CONCRETE AND REHABILITATING EXISTING STRUCTURES
Ohio	USR 20 Resurfacing	2011	Project Number: 113003	$12,224,208.50	FOR IMPROVING SECTION SAN-20-3.77, U.S. ROUTE 20, SANDUSKY COUNTY, OHIO, IN ACCORDANCE WITH PLANS AND SPECIFICATIONS BY PLANING AND RESURFACING, UPGRADING GUARDRAIL AND RELATED WORK.

State	Project Name	Year	Project code	Cost	Description
Ohio	I-70 Improvements	2011	Project Number: 110386	$7,171,036.00	FOR IMPROVING SECTIONS FAI-70-0.00 (LIC), INTERSTATE ROUTE 70 IN THE CITIES OF COLUMBUS AND PICKERINGTON; VILLAGE OF KIRKERSVILLE; VIOLET, ETNA AND HARRISON TOWNSHIPS, FAIRFIELD AND LICKING COUNTIES, OHIO, IN ACCORDANCE WITH PLANS AND SPECIFICATIONS BY PAVEMENT REPAIR, PAVEMENT PLANING, ASPHALT PAVING, PAVEMENT MARKINGS, AND RELATED WORK.
Ohio	USR-60 Resurfacing	2011	Project Number: 110321	$3,658,484.63	FOR IMPROVING SECTION MUS-60-8.86, STATE ROUTE 60 IN THE CITY OF ZANESVILLE, WAYNE TOWNSHIP, MUSKINGUM COUNTY, OHIO, IN ACCORDANCE WITH PLANS AND SPECIFICATIONS BY RESURFACING WITH ASPHALT CONCRETE, INSTALLING GUARDRAIL, CURB RAMPS, DETECTOR LOOPS AND PAVEMENT MARKINGS.
Oregon	OR99E MLK/Grand Construction	2006	SPS09350, (MLK/Grand O-Xing UPRR 02115 & 08905 Viaducts Section, Final, August 15, 2006	Over $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING, ILLUMINATION & ROADSIDE DEVELOPMENT OR99E: MLK/GRAND O-XING UPRR 02115 & 08905 VIADUCTS SECTION PACIFIC HIGHWAY EAST MULTNOMAH COUNTY
Oregon	US26 John Day Construction	2004	SPS10694_US26_John_Day_-_Prairie_City_Section_RV_03-03-04	Over $50 million	Paving, Guardrail, and Signing US26: John Day - Prairie City Section John Day Highway Grant County

State	Project Name	Year	Project code	Cost	Description
Oregon	I-5 Victory Blvrd Construction	2008	SPS 12076, I-5: Victory Blvd. to Lombard St. Section, Final, 02-01-08	Over $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING, ILLUMINATION, SIGNALS & ROADSIDE DEVELOPMENT I-5: VICTORY BLVD. TO LOMBARD ST. SECTION PACIFIC HIGHWAY MULTNOMAH COUNTY
Oregon	I-84 Sandy River/Jordan River	2010	SPS 14032 I-84: Sandy River – Jordan Rd	Over $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING, ILLUMINATION & ROADSIDE DEVELOPMENT I-84: SANDY RIVER – JORDAN RD - BUNDLE 210 COLUMBIA RIVER HIGHWAY MULTNOMAH COUNTY
Oregon	I-5 Beltline Interchange	2006	SPS14197 I-5: Beltline Interchange (Eugene/Springfield) Section Final w/addenda 2-17-06	Over $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING, ILLUMINATION, SIGNAL, & ROADSIDE DEVELOPMENT I-5: BELTLINE INTERCHANGE (EUGENE-SPRINGFIELD) SECTION PACIFIC HIGHWAY LANE COUNTY
Oregon	I-5 Iowa Street Viaduct	2010	SPS14949, I-5: SW Iowa Street Viaduct Br #08197, Contract, 4/29/2010	Under $50 million	Grading, Drainage, Structures, Paving, Signing & Automatic Traffic Recorder I-5: SW Iowa Street Viaduct Br #08197 Section Pacific Highway Multnomah County
Oregon	OR217 Sunset Highway	2007	SPS06025, OR217: Sunset Hwy - Tualatin Valley Hwy Section, Final, 8/18/08	Under $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING, ILLUMINATION, SIGNALS & ROADSIDE DEVELOPMENT OR217: SUNSET HWY - TUALATIN VALLEY HWY SECTION BEAVERTON-TIGARD HIGHWAY WASHINGTON COUNTY

State	Project Name	Year	Project code	Cost	Description
Oregon	I-205 Willamette River Bridge	2006	SPS12874, I-205: Willamette River Bridge - Pacific Highway (Unit 3) Section, Final with Addenda, 4-27-06	Under $50 million	GRADING, DRAINAGE, STRUCTURES, PAVING, SIGNING AND ILLUMINATION I-205: WILLAMETTE RIVER BRIDGE - PACIFIC HIGHWAY (UNIT 3) SECTION EAST PORTLAND FREEWAY CLACKAMAS AND WASHINGTON COUNTIES
South Carolina	US-17 Bypass & SC 707 Interchange	2011	Project Number: BR26(012), 08 february	$75,748,835.57	BRIDGE, HOT MIX ASPHALT, EXCAVATION, UTILITIY RELOCATIONS, LANDSCAPING, TRAFFIC SIGNALS, SMOOTH WALL PIPE, GROUND MODIFICATION, & PAVEMENT MARKINGS
South Carolina	SC-5 Lancaster Bridge Replacement	2011	Project Number: BR88(066), 09 november	$17,346,264.00	Type: BRIDGES, HOT MIX ASPHALT, EXCAVATION, DRAINAGE, GUARDRAIL, UTILTIY RELOCATION, & PAVEMENT MARKINGS
South Carolina	S-13 & SC 19 Roadway Improvements	2010	Project Number: MR11(071),14 december	$6,673,974.58	Resurfacing
South Carolina	SC 39 Roadway Improvements	2011	Project Number: RS10(087), 08 march	$3,440,083.50	RESURFACING
Tennessee	I-40 Resurfacing	2010	Contract No. CNJ389	$9,847,821.45	The resurfacing on I-40 beginning at S.R. 48 (L.M. 0.40) and extending to the Williamson County line (L.M. 17.86). Project Length - 17.460 miles IME-40-3(151), 41001-8150-44 The resurfacing on I 40 beginning at L.M. 8.98 in Hi
Tennessee	SR-36 Improvements	2011	Contract No. CNK030	$43,976,311.77	The grading, drainage, construction of four (4) concrete box bridges and seven (7) retaining walls, and paving on S.R. 36 beginning at S.R. 354 (Boone Avenue) (L.M. 2.90) and extending to S.R. 75 (L.M. 7.00).

State	Project Name	Year	Project code	Cost	Description
Tennessee	I-81 Resurfacing	2011	Contract No. CNK911	$4,850,150.16	The resurfacing on I-81 beginning at the Washington County line (L.M. 0.00) and extending to 1.0 mile north of I-26 (L.M. 4.31), including bridge deck repair.
Tennessee	US 412 Bridge Construction	2011	Contract No. CNK916	$16,771,748.78	The grading, drainage, construction of four (4) bridges, and paving on U.S. 412 (S.R. 99) beginning 0.38 mile west of the Natchez Trace Parkway and extending to 0.27 mile west of Big Swan Creek Road.
Washington	I-5 Interchange Improvements	2010	CONTRACT NO :007936	$53,398,008.88	I-5 SR 161/SR 18 INTERCHANGE IMPROVEMENTS
Washington	SR-24/ I-82 Improvements	2005	CONTRACT NO : 006933	$34,000,000.00	SR 24 I-82 TO KEYS ROAD
Washington	I-405 Bridge Construction	2007	CONTRACT NO :007417	$14,689,000.00	I-405 NE 10TH ST - BRIDGE CROSSING
Washington	I-90 Improvements	2009	CONTRACT NO : 007685	$9,790,516.54	I-90 SPOKANE AREA RUT REPAIR AND RAMP PAVING
Washington	SR-542 Roadway widening	2009	CONTRACT NO :007686	$7,264,345.36	SR 240 BELOIT RD. TO KINGSGATE WAY - WIDEN ROADWAY
Washington	I-5 Paving	2009	CONTRACT NO :007669	$6,595,797.58	I-5 52ND AVE W TO SR 526 NB PAVING
Washington	SR 542 Intersection Improvement	2011	CONTRACT NO :008086	$3,569,039.50	SR 542 EVERSON GOSHEN RD VIC TO SR 9 VIC INTERSECTION IMPROVEMENTS
Washington	SR-28 Quincy Area Paving	2009	CONTRACT NO :007645	$2,574,636.90	SR 28 QUINCY AREA PAVING 09B009
Washington	US-195 Paving	2010	CONTRACT NO :007897	$2,425,312.86	US 195 IDAHO STATE LINE TO COLTON - PAVING
Washington	I-5s Ramp paving	2009	CONTRACT NO :007660	$2,286,623.00	I-5 S 272ND ST TO SOUTHCENTER PARKWAY RAMP PAVING
Washington	Grass Creek Bridge Special Repair	2007	CONTRACT NO : 007276	$421,974.00	GRASS CREEK BRIDGE - SPECIAL REPAIR

State	Project Name	Year	Project code	Cost	Description
West Virginia	Davis - Bismark Secs 06, 07, and 08	2010	PROJECT NUMBER X347-H-74.85 00 ACAP-0484(246)	$82,486,513.79	CONST NEW/RELOC 4 LANE ROAD W/BRIDGE(S) CORR. H: DAVIS - BISMARK SECTION 6, 7 & 8 6.2 MI W WV 42 - WV 93 CONN
West Virginia	Bismark EWV 42/93	2011	PROJECT NUMBER X312-H-81.35 03 ACAP-0484(299)	$24,985,760.15	CONSTRUCT MAINLINE PAVEMENT BISMARK E WV42/93 I/S - E CO3 FORE KNOBS 0.4 MI E WV93 / WV42 I/S - 0.68 MI N E FORE KNOBS
West Virginia	William S Ritchie Jr Bridge	2011	PROJECT NUMBER S318-33-0.01 00	$6,418,830.00	CLEAN AND PAINT STRUCTURE C & P WILLIAM S RITCHIE JR BRIDGE (2972) 0.43 MILE WEST OF WV 68
West Virginia	Statewide Interstate Stripping	2011	PROJECT NUMBER S399-STR/IP-11 03 IM-2011(026)D	$2,769,430.00	PAVEMENT MARKINGS INTERSTATE STRIPING STATEWIDE

Appendix C: Survey Questionnaire

Statistics for Construction Scheduling Specifications

Total submissions: 110

** Calculated using numeric values*

Long response
Question

Public agency Name (e.g. Arizona DOT, City of Redmond, etc)?

Total responses (N): 110 Did not respond: 0

Statistics are not calculated for this question type.

Long response
Question

Name (optional):

Total responses (N): 66 Did not respond: 44

Statistics are not calculated for this question type.

Long response
Question

Title (optional):

Total responses (N): 71 Did not respond: 39

Statistics are not calculated for this question type.

Long response
Question

Email (optional):

Total responses (N): 54 Did not respond: 56

Statistics are not calculated for this question type.

Matrix - one answer per row (button)
Question

Some managers consider construction schedules as valuable management tools. Your perception about construction schedules could be explained as follows, they ...

Row 1

Help establish deliverable goals (milestones)

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	1	0.91%
3	Neutral	4	3.64%
4	Agree	54	49.09%
5	Strongly agree	50	45.45%

Row 2

Help monitor and measure progress

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	0	0.00%
3	Neutral	5	4.55%
4	Agree	52	47.27%
5	Strongly agree	52	47.27%

*Response statistics**

Row1	
Mean	4.37
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	0.69
Row2	
Mean	4.40
Median	4.00
Mode	4, 5
Min/Max	1/5
Standard deviation	0.67
Row3	
Mean	3.97
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	0.90
Row4	
Mean	3.46
Median	4.00
Mode	4
Min/Max	1/5
Standard	

Standard deviation	0.99

Row5

Mean	1.84
Median	2.00
Mode	2
Min/Max	1/5
Standard deviation	0.88

Row6

Mean	1.79
Median	2.00
Mode	2
Min/Max	1/5
Standard deviation	0.78

Row7

Mean	1.86
Median	2.00
Mode	2
Min/Max	1/5
Standard deviation	0.85

Row 3

Help manage change conditions

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	9	8.18%
3	Neutral	13	11.82%
4	Agree	56	50.91%
5	Strongly agree	31	28.18%

Row 4

Help pressure the contractor to finish on time and under budget

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	3	2.73%
2	Disagree	15	13.64%
3	Neutral	36	32.73%
4	Agree	40	36.36%
5	Strongly agree	16	14.55%

Row 5

Are not needed; a project can be managed without them

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	43	39.09%
2	Disagree	50	45.45%
3	Neutral	11	10.00%
4	Agree	4	3.64%
5	Strongly agree	2	1.82%

Row 6

Are not needed because construction sequence changes frequently

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	42	38.18%
2	Disagree	53	48.18%
3	Neutral	12	10.91%
4	Agree	2	1.82%
5	Strongly agree	1	0.91%

Row 7

Are not needed; stakeholders' timeline questions can be answered in a different way

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	40	36.36%
2	Disagree	52	47.27%
3	Neutral	12	10.91%
4	Agree	5	4.55%
5	Strongly agree	1	0.91%

Matrix - one answer per row (button)

Response

Question

The list of shortcomings that I usually encounter in the contractor's construction schedules include:

Row 1

Illegible printed copies of the schedule submittals.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	16	14.55%
2	Disagree	55	50.00%
3	Neutral	27	24.55%
4	Agree	10	9.09%
5	Strongly agree	2	1.82%

Row 2

Inadequate activity detail (e.g "footing" instead of "footing formwork")

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	2	1.82%
2	Disagree	20	18.18%
3	Neutral	27	24.55%
4	Agree	53	48.18%
5	Strongly agree	8	7.27%

Row 3

Inadequate grouping of activities (e.g into phases, WBS, etc..)

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	2	1.82%
2	Disagree	18	16.36%
3	Neutral	29	26.36%
4	Agree	56	50.91%
5	Strongly agree	5	4.55%

Row 4

Inadequate formatting of the bar colors and the font and size of the activity information.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	6	5.45%
2	Disagree	29	26.36%
3	Neutral	48	43.64%
4	Agree	26	23.64%
5	Strongly agree	1	0.91%

Row 5

Missing activities required by the contract (e.g. procurement, submittals, etc..)

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	3	2.73%
2	Disagree	12	10.91%
3	Neutral	15	13.64%
4	Agree	65	59.09%
5	Strongly agree	15	13.64%

*statistics**

	Mean	Median	Mode	Min/Max	Standard deviation
Row1	2.34	2.00	2	1/5	0.90
Row2	3.41	4.00	4	1/5	0.93
Row3	3.40	4.00	4	1/5	0.88
Row4	2.88	3.00	3	1/5	0.86
Row5	3.70	4.00	4	1/5	0.93
Row6	3.46	4.00	4	1/5	1.00
Row7	3.09	3.00	3	1/5	0.80
Row8	3.40	3.00	3	1/5	0.91
Row9	3.30	3.00	4	1/5	

Standard deviation	0.99

Row10

Mean	3.13
Median	3.00
Mode	3, 4
Min/Max	1/5
Standard deviation	0.88

Row11

Mean	3.61
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	0.92

Row12

Mean	3.12
Median	3.00
Mode	3
Min/Max	1/5
Standard deviation	0.85

Row 6

Missing critical activities or critical path.

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	2	1.82%
2	Disagree	22	20.00%
3	Neutral	22	20.00%
4	Agree	51	46.36%
5	Strongly agree	13	11.82%

Row 7

Inadequate sorting based on early start.

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	2	1.82%
2	Disagree	20	18.18%
3	Neutral	58	52.73%
4	Agree	26	23.64%
5	Strongly agree	4	3.64%

Row 8

Incomplete network logic (e.g open ends, no successors, etc.)

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	17	15.45%
3	Neutral	41	37.27%
4	Agree	39	35.45%
5	Strongly agree	12	10.91%

Row 9

Not accouting for contract restrictions (e.g holidays, traffic control restrictions, etc)

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	28	25.45%
3	Neutral	29	26.36%
4	Agree	41	37.27%
5	Strongly agree	11	10.00%

Row 10

Wrong construction sequencing for the construction tasks.

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	2	1.82%
2	Disagree	27	24.55%
3	Neutral	39	35.45%
4	Agree	39	35.45%
5	Strongly agree	3	2.73%

Row 11

Unreasonable activity duration.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	1	0.91%
2	Disagree	14	12.73%
3	Neutral	28	25.45%
4	Agree	51	46.36%
5	Strongly agree	16	14.55%

Row 12

Unreasonable number of activities.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	1	0.91%
2	Disagree	26	23.64%
3	Neutral	47	42.73%
4	Agree	31	28.18%
5	Strongly agree	5	4.55%

Multiple choice - one answer (button)
Question

From your experience, the maximum duration assigned to construction activities (excluding procurement activities, submittals, etc..) should be in the range of :

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Less than 5 days	3	2.73%
2	Between 5-10 days	17	15.45%
3	Between 10-15 days	17	15.45%
4	Between 15-20 days	21	19.09%
5	Between 20-25 days	6	5.45%
6	Between 25-30 days	5	4.55%
7	No restrictions	30	27.27%
8	Other:	11	10.00%

	*Response statistics**
Mean	4.82
Median	4.00
Mode	7
Min/Max	1/8
Standard deviation	2.16

Long response
Question

The reasons for choosing the above duration range include:

Total responses (N): 110 Did not respond: 0

Statistics are not calculated for this question type.

Multiple choice - multiple answers (check)
Question

Some scheduling best practices and state construction scheduling specifications require the inclusion of non-construction activities. Please select from the following list the non-construction activities that are essential and need to be included in construction schedules:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Mobilization	61	55.45%
2	Procurement activities (particulary long lead items)	86	78.18%
3	Submittals	77	70.00%
4	Submittal review	86	78.18%

	*Response statistics**
Mean	4.11
Median	4.00
Mode	2, 4, 6
Min/Max	1/8
Standard deviation	2.01

	period and approval activities		
5	Permitting activities	59	53.64%
6	Fabrication	86	78.18%
7	Milestones	77	70.00%
8	Other:	8	7.27%

Multiple choice - multiple answers (check)
Question

The PMI defines activity codes as "one or more numerical or text values that identify characteristics of the work". I would prefer to have the construction schedule activities coded by:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Project phase/stage	67	60.91%
2	Project work breakdown structure (WBS)	49	44.55%
3	Construction division (concrete, earthwork, etc)	38	34.55%
4	Responsibility (e.g. general contractor, subs, etc)	25	22.73%
5	Other:	7	6.36%

Response statistics*	
Mean	2.23
Median	2.00
Mode	1
Min/Max	1/5
Standard deviation	1.18

Multiple choice - one answer (button)
Question

Some public agencies restrict the number of activities in a project schedule (e.g. 300 activities per schedule). In your opinion, the maximum number of activities in a schedule should be in the range:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Between 50-100 activities	13	11.82%
2	Between 100-150 activities	6	5.45%
3	Between 150-200 activities	6	5.45%
4	Between 200-250 activities	4	3.64%
5	Between 250-300 activities	9	8.18%
6	Between 300-350 activities	3	2.73%
7	No restrictions	53	48.18%
8	Other:	16	14.55%

Response statistics*	
Mean	5.65
Median	7.00
Mode	7
Min/Max	1/8
Standard deviation	2.35

Matrix - one answer per row (button)
Question

The maximum number of activities used in a construction schedule should correlate with:

Row 1

Project size

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage

Response statistics*	
Row1	
Mean	4.11
Median	4.00
Mode	5
Min/Max	1/5
Standard deviation	1.09
Row2	

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	4	3.64%
2	Disagree	9	8.18%
3	Neutral	8	7.27%
4	Agree	39	35.45%
5	Strongly agree	50	45.45%

	Mean	3.61
	Median	4.00
	Mode	4
	Min/Max	1/5
	Standard deviation	1.10
Row3		
	Mean	3.84
	Median	4.00
	Mode	4
	Min/Max	1/5
	Standard deviation	0.96
Row4		
	Mean	4.22
	Median	4.00
	Mode	5
	Min/Max	1/5
	Standard deviation	0.97

Row 2

Project duration

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	4	3.64%
2	Disagree	17	15.45%
3	Neutral	21	19.09%
4	Agree	44	40.00%
5	Strongly agree	24	21.82%

Row 3

Project type (Highway, bridge etc..)

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	3	2.73%
2	Disagree	6	5.45%
3	Neutral	25	22.73%
4	Agree	48	43.64%
5	Strongly agree	28	25.45%

Row 4

Project sophistication (e.g. highway in an urban area compared to a highway in a rural area)

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	2	1.82%
2	Disagree	8	7.27%
3	Neutral	6	5.45%
4	Agree	42	38.18%
5	Strongly agree	52	47.27%

Matrix - one answer per row (button)
Question

The reasons that a public agency might request a resource-loaded or cost-loaded schedule include:

	*Response statistics**	
Row1		
	Mean	3.75
	Median	4.00
	Mode	4
	Min/Max	1/5
	Standard deviation	0.85
Row2		
	Mean	3.76
	Median	4.00
	Mode	4
	Min/Max	2/5
	Standard deviation	0.79
Row3		
	Mean	3.45
	Median	3.00
	Mode	3, 4

Row 1

Justifying additional costs when changes occurs

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Strongly disagree	1	0.91%
2	Disagree	10	9.09%
3	Neutral	21	19.09%
4	Agree	62	56.36%
5	Strongly agree	16	14.55%

Row 2

Ensuring work is adequately staffed to meet the schedule demand

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	0	0.00%
2	Disagree	9	8.18%
3	Neutral	23	20.91%
4	Agree	63	57.27%
5	Strongly agree	15	13.64%

Row 3

Conveying to the contractor the importance of the project timelines

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	0	0.00%
2	Disagree	14	12.73%
3	Neutral	43	39.09%
4	Agree	43	39.09%
5	Strongly agree	10	9.09%

Row 4

Tracking the use of all resources

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	2	1.82%
2	Disagree	13	11.82%
3	Neutral	45	40.91%
4	Agree	41	37.27%
5	Strongly agree	9	8.18%

Row 5

Tracking the use of "critical" resources

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	0	0.00%
2	Disagree	9	8.18%
3	Neutral	32	29.09%
4	Agree	49	44.55%
5	Strongly agree	20	18.18%

Row 6

Public agency fear of project not finishing on time

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	1	0.91%
2	Disagree	23	20.91%
3	Neutral	37	33.64%
4	Agree	40	36.36%
5	Strongly agree	9	8.18%

Row 7

Public agency fear of cost overruns

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	1	0.91%
2		20	18.18%

Min/Max	2/5
Standard deviation	0.83

Row4

Mean	3.38
Median	3.00
Mode	3
Min/Max	1/5
Standard deviation	0.87

Row5

Mean	3.73
Median	4.00
Mode	4
Min/Max	2/5
Standard deviation	0.86

Row6

Mean	3.30
Median	3.00
Mode	4
Min/Max	1/5
Standard deviation	0.92

Row7

Mean	3.32
Median	3.00
Mode	4
Min/Max	1/5
Standard deviation	0.89

Row8

Mean	2.63
Median	3.00
Mode	3
Min/Max	1/5
Standard deviation	0.87

Numeric value	Answer	Frequency	Percentage
	Disagree		
3	Neutral	40	36.36%
4	Agree	41	37.27%
5	Strongly agree	8	7.27%

Row 8

No specific reason

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	18	16.36%
2	Disagree	13	11.82%
3	Neutral	73	66.36%
4	Agree	4	3.64%
5	Strongly agree	2	1.82%

Matrix - one answer per row (button)
Question

I would not generally encourage resource-loaded or cost loaded schedules because:

Row 1

It takes time for public agency personnel to manage them

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	12	10.91%
2	Disagree	20	18.18%
3	Neutral	33	30.00%
4	Agree	41	37.27%
5	Strongly agree	4	3.64%

Row 2

Their development costs the project more money

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	10	9.09%
2	Disagree	21	19.09%
3	Neutral	36	32.73%
4	Agree	37	33.64%
5	Strongly agree	6	5.45%

Row 3

They delay the contractor's schedule submittal

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	9	8.18%
2	Disagree	28	25.45%
3	Neutral	45	40.91%
4	Agree	25	22.73%
5	Strongly agree	3	2.73%

Row 4

Not all construction schedule activities matches the contract bid items

Total responses (N): 110 Did not respond: 0

Numeric

*Response statistics**

	Mean	Median	Mode	Min/Max	Standard deviation
Row1	3.05	3.00	4	1/5	1.07
Row2	3.07	3.00	4	1/5	1.06
Row3	2.86	3.00	3	1/5	0.95
Row4	3.23	3.00	4	1/5	1.05
Row5	3.24	3.50	4	1/5	1.12
Row6	3.15	3.00	3	1/5	0.98

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	8	7.27%
2	Disagree	18	16.36%
3	Neutral	33	30.00%
4	Agree	43	39.09%
5	Strongly agree	8	7.27%

Row 5

Contractor may not be good at handling/managing them

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	10	9.09%
2	Disagree	19	17.27%
3	Neutral	26	23.64%
4	Agree	45	40.91%
5	Strongly agree	10	9.09%

Row 6

Contractor refuses to make proprietary information public and/or accessible to their competitors

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	8	7.27%
2	Disagree	16	14.55%
3	Neutral	44	40.00%
4	Agree	36	32.73%
5	Strongly agree	6	5.45%

Multiple choice - multiple answers (check)
Question

For schedule submission, i would encourage following activity information to be available:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Activity number	63	57.27%
2	Activity id	69	62.73%
3	Activity description	109	99.09%
4	Activity duration	106	96.36%
5	Early start	93	84.55%
6	Early finish	89	80.91%
7	Late start	79	71.82%
8	Late finish	83	75.45%
9	Remaining activity duration	62	56.36%
10	Percent completion (by quantity or cost)	79	71.82%
11	Total float	86	78.18%
12	Free float	60	54.55%
13	Other:	13	11.82%

	*Response statistics**
Mean	6.41
Median	4.00
Mode	3
Min/Max	1/13
Standard deviation	3.36

Matrix - one answer per row (button)
Question

Some public agencies restrict the use of any scheduling technique that might affect the schedule logic or the critical activities/path. From your experience, what would be the best policy for the contractor's use of the following scheduling techniques?

	*Response statistics**
Row1	
Mean	1.44
Median	1.00
Mode	1
Min/Max	1/3

Row 1

The use of Start-to-Start (SS) and Finish-to-Finish (FF) relationships

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Contractor should be allowed to use them	65	59.09%
2	Contractor should avoid them but inform the engineer if used	42	38.18%
3	Contractor should be prohibited from using them	3	2.73%

Row 2

The use of lead/lag times between activities

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Contractor should be allowed to use them	73	66.36%
2	Contractor should avoid them but inform the engineer if used	32	29.09%
3	Contractor should be prohibited from using them	5	4.55%

Row 3

The use of constraint dates (e.g. start no earlier than, No later than, etc)

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Contractor should be allowed to use them	68	61.82%
2	Contractor should avoid them but inform the engineer if used	34	30.91%
3	Contractor should be prohibited from using them	8	7.27%

Row 4

Construction schedules thave have multiple critical paths

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Contractor should be allowed to use them	33	30.00%
2	Contractor should avoid them but inform the engineer if used	36	32.73%
3	Contractor should be prohibited from using them	41	37.27%

Standard deviation	0.55
Row2	
Mean	1.38
Median	1.00
Mode	1
Min/Max	1/3
Standard deviation	0.57
Row3	
Mean	1.45
Median	1.00
Mode	1
Min/Max	1/3
Standard deviation	0.63
Row4	
Mean	2.07
Median	2.00
Mode	3
Min/Max	1/3
Standard deviation	0.82

Multiple choice - one answer (button)
Question

For simple and short-duration projects, construction schedules could be devloped based on a bar chart created by a spread sheet such as Excel. For complex (as well as simple projects) the schedules could be devlelped based on

*Response statistics**	
Mean	1.76
Median	2.00
Mode	2
Min/Max	1/3

the Critical Path Method (CPM). From your experience, CPM should be used:

Standard deviation	0.49

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	All the time regardless of project complexity.	29	26.36%
2	On complex projects; simple bar charts should be sufficient for smaller, less complex projects.	78	70.91%
3	Other:	3	2.73%

Multiple choice - one answer (button)
Question

If used, preliminary schedules should cover an initial period of:

	*Response statistics**
Mean	3.62
Median	3.00
Mode	1
Min/Max	1/8
Standard deviation	2.35

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	0 days (no need for preliminary schedules)	25	22.73%
2	30 days	18	16.36%
3	60 days	22	20.00%
4	90 days	14	12.73%
5	120 days	3	2.73%
6	A number of days around 5% of project duration	8	7.27%
7	A number of days around 10% of project duration	8	7.27%
8	Other:	12	10.91%

Multiple choice - one answer (button)
Question

If required, look-ahead schedules should cover a period of:

	*Response statistics**
Mean	3.27
Median	3.00
Mode	3
Min/Max	1/6
Standard deviation	1.24

Total responses (N): 109 Did not respond: 1

Numeric value	*Answer*	*Frequency*	*Percentage*
1	0 weeks (no need for Look ahead schedules)	12	11.01%
2	1 week	4	3.67%
3	2 weeks	61	55.96%
4	3 weeks	15	13.76%
5	More than 3 weeks	9	8.26%
6	Other:	8	7.34%

Multiple choice - one answer (button)
Question

The frequency of schedule updates: In your opinion the most efficient updating cycle should be:

	*Response statistics**
Mean	4.84
Median	4.00
Mode	4
Min/Max	1/9
Standard deviation	2.36

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	1 week	7	6.36%
2	2 weeks	15	13.64%
3	3 weeks	0	0.00%
4	1 month	50	45.45%

Numeric value	Answer	Frequency	Percentage
5	2 months	1	0.91%
6	3 months	0	0.00%
7	Only when requested by the engineer	11	10.00%
8	It varies as it depends on the project type (e.g. dam with few bid items v.s. bridge with several bid items)	21	19.09%
9	Other:	5	4.55%

Multiple choice - one answer (button)
Question

I would encourage the review time for preliminary or baseline schedules to be:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Between 5-10 days	49	44.55%
2	Betweem 10-15 days	41	37.27%
3	Between 15-20 days	10	9.09%
4	Between 20-25 days	2	1.82%
5	More than 25 days	0	0.00%
6	Other:	8	7.27%

Response statistics*	
Mean	1.97
Median	2.00
Mode	1
Min/Max	1/6
Standard deviation	1.34

Matrix - one answer per row (button)
Question

I would encourage soft copies (e.g. Primavera project file) of the schedule to be requested by the agency if:

Row 1

Total project cost exceeds a particular threshold.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	5	4.55%
2	Disagree	16	14.55%
3	Neutral	29	26.36%
4	Agree	40	36.36%
5	Strongly Agree	20	18.18%

Row 2

The project is complex.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	3	2.73%
2	Disagree	6	5.45%
3	Neutral	14	12.73%
4	Agree	51	46.36%
5	Strongly Agree	36	32.73%

Row 3

The project duration exceeds a particular threshold.

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	5	4.55%
2	Disagree	15	13.64%
3	Neutral	28	25.45%

Response statistics*	
Row1	
Mean	3.49
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	1.09
Row2	
Mean	4.01
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	0.96
Row3	
Mean	3.52
Median	4.00
Mode	4
Min/Max	1/5
Standard deviation	1.08
Row4	
Mean	3.33
Median	3.00
Mode	3
Min/Max	1/5
Standard deviation	1.13

Numeric value	Answer	Frequency	Percentage
4	Agree	42	38.18%
5	Strongly Agree	20	18.18%

Row 4

Regardless of the reason (e.g. cost, complexity, or duration)

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Strongly disagree	5	4.55%
2	Disagree	20	18.18%
3	Neutral	41	37.27%
4	Agree	22	20.00%
5	Strongly Agree	22	20.00%

Multiple choice - multiple answers (check)
Question

Along with the periodical updates, schedule revision would be requested under certain events. In your opinion the events that should trigger a schedule "revisions" would include:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Significant delays in the Schedule	102	92.73%
2	Significant change in the logic of the schedule	85	77.27%
3	Substantial when a time extensions is requested	91	82.73%
4	Changes in resources	37	33.64%
5	Addition, Modification, and Deletion of activities	85	77.27%
6	Changes to the critical path	93	84.55%
7	A change in the calendars or to the calendar to which an activity is assigned.	44	40.00%
8	A change to, addition of, or deletion of a date or time constraint	68	61.82%
9	Other:	1	0.91%

	*Response statistics**
Mean	4.19
Median	4.00
Mode	1
Min/Max	1/9
Standard deviation	2.33

Multiple choice - one answer (button)
Question

Failure of the contractor to submit the required preliminary and/or baseline schedules on time should carry the following consequences:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	No consequence, just request more meetings to discuss the situation	5	4.55%
2	Warn the contractor of enforcing a breach of contract (default clause)	36	32.73%

	*Response statistics**
Mean	3.24
Median	3.00
Mode	2
Min/Max	1/5
Standard deviation	1.24

3	Enforce liquidated damages (or performance penalties)	20	18.18%
4	Hold more retention money from the contractor	26	23.64%
5	Other:	23	20.91%

Multiple choice - one answer (button)
Question

The most frequently mentioned scheduling software in the standard specifications and construction manuals are Primavera (P3 and P6), Ms Project, and SureTrak respectively. I would encourage the use of the following scheduling software for transportation projects:

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Primavera P3 or any newer version	69	62.73%
2	MS project	11	10.00%
3	Primevera SureTrak	11	10.00%
4	Other:	19	17.27%

	*Response statistics**
Mean	1.82
Median	1.00
Mode	1
Min/Max	1/4
Standard deviation	1.18

Multiple choice - one answer (button)
Question

Compatibility can be an issue when using scheduling software. My position on the issue is:

Total responses (N): 110 Did not respond: 0

Numeric value	*Answer*	*Frequency*	*Percentage*
1	Contractor should use the same scheduling software used by the DOT in order to avoid compatibility issues.	47	42.73%
2	Contractor should be given the freedom to choose any scheduling software capable of producing compatible file formats used by the DOT.	40	36.36%
3	Contractor should be given the freedom to choose any scheduling software under the conditions that contractor provide to DOT copies of the software and proper training.	12	10.91%
4	Contractor should be given the freedom to choose any scheduling software. Compatibility issues can be solved later on in the project as a joint effort between the two parties.	8	7.27%
5	Other:	3	2.73%

	*Response statistics**
Mean	1.91
Median	2.00
Mode	1
Min/Max	1/5
Standard deviation	1.04

Multiple choice - multiple answers (check)
Question

*Response statistics**

Construction schedules bid item: I would prefer that:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	A bid item is used for the baseline construction schedule	38	34.55%
2	A bid item is used for the updated schedules	21	19.09%
3	I have no preference for using a construction schedule bid item	51	46.36%
4	Other:	21	19.09%

Mean	2.42
Median	3.00
Mode	3
Min/Max	1/4
Standard deviation	1.07

Multiple choice - one answer (button)
Question

From my projects experience, on average, the lump sum cost listed by contractors for project schedules were:

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	Overpriced; e.g. the quality of the schedules were not matched by the price of the submitted schedules	23	20.91%
2	Adequate	31	28.18%
3	Underestimated; e.g. low priced for the high quality schedules submitted for the projects	12	10.91%
4	Other:	44	40.00%

	Response statistics*
Mean	2.70
Median	3.00
Mode	4
Min/Max	1/4
Standard deviation	1.20

Multiple choice - multiple answers (check)
Question

Some states require a lump sum cost, say $50,000, to be the minimum value for a schedule bid item. If such minimum lump sum value is used, from your experience, this lump sum cost should reflect (choose all that apply):

Total responses (N): 110 Did not respond: 0

Numeric value	Answer	Frequency	Percentage
1	The price of keeping a full time scheduler for the project.	18	16.36%
2	No minimum. Should be left to the contractor to decide.	40	36.36%
3	An expectation of the level of detail required in the project schedule.	50	45.45%
4	A message to the contractor that project timelines are important.	21	19.09%
5	Other:	18	16.36%

	Response statistics*
Mean	2.87
Median	3.00
Mode	3
Min/Max	1/5
Standard deviation	1.18

Long response
Question

Statistics are not calculated for this question type.

Thank you for your participation in the research. Please use the space below to add comments (e.g. on schedule shortcomings, resource/cost loaded schedules, pricing, etc), ideas, or references that would further help us in this research effort. Thank you Research Team

Total responses (N): 24 Did not respond: 86

Appendix D: PMI List of Required and Optional Schedule Components

Component	Sub-elements	Use
Pre-development		O
WBS ID		
Activity ID		R
Project Name		R
Project Schedule ID		R
Project Version		R
Calendar		
	Activity Calendar	O
	Project Calendar	R
	Resource Calendar	O
Data Date		R
Milestones		R
Development	Activity Original Duration	O
Project Start Constraint		
Activity Label		R
Unit of Measure		R
Duration		
		R
	Activity Remaining Duration	R
	Activity Actual Duration	R
	Activity Total Duration	O
	Activity Baseline Original Duration	R
	Activity Target Duration	O
	Project Original Duration	R
	Project Remaining Duration	R
	Project Actual Duration	R
	Project Total Duration	O
	Project Baseline Duration	R
	Project Target Duration	O
	Imposed Project Duration	O
Relationships		
	Finish to Start	R
	Start to Start	O
	Finish to Finish	O
	Start to Finish	O
Start Date		
	Activity Early Start Date	R
	Activity Late Start Date	R
	Activity Baseline Start Date	R
	Activity Target Start Date	O
	Activity Actual Start Date	R
	Activity Resource Leveled Start Date	O
	Project Early Start Date	R
	Project Late Start Date	R
	Project Baseline Start Date	R

Component	Sub-elements	Use
	Project Target Start Date	O
	Project Actual Start Date	R
	Project Resource Leveled Start Date	O
Finish Date		
	Activity Early Finish Date	R
	Activity Late Finish Date	R
	Activity Baseline Finish Date	R
	Activity Target Finish Date	O
	Activity Actual Finish Date	R
	Activity Resource Leveled Finish Date	O
	Project Early Finish Date	R
	Project Late Finish Date	R
	Project Baseline Finish Date	R
	Project Target Finish Date	O
	Project Actual Finish Date	R
	Project Resource Leveled Finish Date	O
Float		
	Total Float	R
	Free Float	R
Critical Path		R
Baseline Data Date		R
Maintenance and Status Reporting Percent Complete	Activity Physical Percent Complete	R
	Activity Duration Percent Complete	O
	Project Physical Percent Complete	R
	Project Duration Percent Complete	O
Update Cycle		R
Activity Code		O
Activity Cost Component		O
Activity Cost Estimate		O
Activity Effort		O
Activity Scope Definition		O
Assigned Quantity		O
Constraints		
	Finish Not Earlier Than	O
	Finish Not Later Than	O
	Finish On	O
	Mandatory Finish Date	O
	Mandatory Start Date	O
	Start Not Later Than	O
	Start Not Earlier Than	O
	Start On	O
	Expected Finish	O
	Project Finish Constraint	O

Component	Sub-elements	Use
Custom Field		O
Earned Value		O
Estimate at Completion (EAC)		O
Estimate to Complete (ETC)		O
Lag		O
Lead		O
Level		O
Presentation		O
Project Control Account		O
Project Cost Components		O
Project Cost Estimate		O
Project Description		
Project Manager		O
Resources		
	Resource Assignment	O
	Resource Availability	O
	Resource Description	O
	Driving Resources	O
	Resource ID	O
	Resource Lag	O
	Resource Leveling	O
	Resource Library/Dictionary	O
	Resource Rates/Prices	O
	Resource Type	O
Schedule Risk		
	Activity Risk Criticality Index	O
	Activity Most Likely Duration	O
	Activity Optimistic Duration	O
	Activity Pessimistic Duration	O
	Activity Cumulative Probability	
	Risk Distribution	O
Summary Activity		O
Update Cycle		O
Variance		
	Duration Variance	O
	Date Variance	O

Appendix E: UFGS Scheduling Specification Sections

3.1 GENERAL REQUIREMENTS
3.1.1 Approved Project Schedule
3.1.2 Schedule Status Reports
3.1.3 Default Terms
3.2 BASIS FOR PAYMENT AND COST LOADING
3.3 PROJECT SCHEDULE DETAILED REQUIREMENTS
3.3.1 Critical Path Method
3.3.2 Level of Detail Required
3.3.2.1 Activity Durations
3.3.2.2 Design and Permit Activities
3.3.2.3 Procurement Activities
3.3.2.4 Mandatory Tasks
3.3.2.5 Government Activities
3.3.2.6 Activity Responsibility Coding (RESP)
3.3.2.7 Activity Work Area Coding
3.3.2.8 Contract Changes/Requests for Equitable Adjustment (REA) Coding (MODF)
3.3.2.9 Contract Line Item (CLIN) Coding (BIDI)
3.3.2.10 Phase of Work Coding (PHAS)
3.3.2.11 Category of Work Coding (CATW)
3.3.2.12 Definable Features of Work Coding (FOW1, FOW2, FOW3)
3.3.3 Scheduled Project Completion and Activity Calendars
3.3.3.1 Project Start Date
3.3.3.2 Schedule Constraints and Open Ended Logic
3.3.3.3 Early Project Completion
3.3.4 Interim Completion Dates
3.3.4.1 Start Phase
3.3.4.2 End Phase
3.3.4.3 Phase "X" Hammock
3.3.5 Default Progress Data Disallowed
3.3.6 Out-of-Sequence Progress
3.3.7 Negative Lags and Start to Finish Relationships
3.3.8 Calculation Mode
3.3.9 Milestones
3.4 PROJECT SCHEDULE SUBMISSIONS
3.4.1 Preliminary Project Schedule Submission
3.4.2 Initial Project Schedule Submission
3.4.3 Design Package Schedule Submission
3.4.4 Periodic Schedule Updates
3.4.5 Standard Activity Coding Dictionary
3.5 SUBMISSION REQUIREMENTS
3.5.1 Data CD's
3.5.2 Narrative Report
3.5.3 Approved Changes Verification
3.5.4 Schedule Reports
3.5.4.1 Activity Report
3.5.4.2 Logic Report
3.5.4.3 Total Float Report
3.5.4.4 Earnings Report by CLIN
3.5.5 Network Diagram
3.5.5.1 Continuous Flow
3.5.5.2 Project Milestone Dates

Appendix F: DOT Standard Specifications Basic Schedule Components Matrix

State	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical	Baseline Start Date*	Baseline Finish Date*	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Show Critical Path	Update Cycle	Total (out of 24)
Alaska								x	x	x			x		x			x						1 W	7
Arizona													x										x	2 M	2
California							x											x		x				1 M	4
Colorado	x	x	x	x			x	x	x	x			x		x			x	x	x	x			1 M	15
Delaware	x				x	x		x	x			x	x	x	x	x	x	x	x		x			2 W	15
District of Columbia							x	x					x					x	x		x		x	2 W	8
Florida					x		x	x	x	x		x	x	x	x	x	x			x				1 M	13
Hawaii	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	2 W	21
Idaho	x				x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	1 M	20
Indiana																								1 M	1

State	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical	Baseline Start Date*	Baseline Finish Date*	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Show Critical Path	Update Cycle	Total (out of 24)
Iowa	x				x			x	x	x			x					x	x		x		x	2 W	11
Kansas								x	x				x					x	x					1 M	6
Kentucky					x	x	x	x	x			x	x	x	x	x	x	x	x			x	x	1 M	16
Maine							x		x											x					3
Maryland	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	1 M	22
Minnesota																		x					x		2
Missouri		x	x	x			x						x							x					6
Montana	x	x	x	x	x			x	x	x		x	x	x	x	x	x	x	x	x	x			1 M	19
Nebraska							x	x												x			x	1 M	5
Nevada	x				x		x	x	x	x			x		x			x	x	x	x		x	1 M	14
New Hampshire		x	x	x			x	x	x	x			x	x	x			x					x	1 M	13
New Jersey	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x				x	1 M	19
New Mexico					x		x	x	x				x					x	x	x	x	x	x	1 M	12
New York	x				x		x	x																1 M	5
North Dakota	x							x	x	x		x	x		x	x	x	x	x	x	x		x		14

State	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration*	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date*	Baseline Finish Date*	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Show Critical Path	Update Cycle	Total (out of 24)
Ohio		x	x				x	x	x									x		x			x		8
Oklahoma	x	x	x	x	x			x	x												x		x	1 M	10
Oregon	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	1 M	22
Pennsylvania								x					x												2
Rhode Island	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	2 W	22
Tennessee																								3 M	1
Utah	x				x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	1 M	19
Washington	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	1 M	22
West Virginia	x						x	x	x	x		x	x	x	x	x	x	x	x		x	x	x	1 M	17
Wisconsin	x				x		x	x					x	x	x			x		x	x			1 M	11
Wyoming		x				x	x	x	x	x			x	x	x			x	x		x		x	1 M	14
Total: 36	18	13	12	9	18	9	24	29	25	18	2	14	27	15	20	14	14	26	20	19	19	5	22	30	

Appendix G: DOT Project Special Provisions Basic Schedule Components Matrix

State	Provision / Project	Price	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date	Baseline Finish Date	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Negative Float	Show Critical Path	Update Cycle	Total
Alaska	Project No. STP-0002(128)/61179	> $5M								x	x	x			x		x									x		6
Alaska	Project No. MGE-EBL MGS-0002(166)162219	$2.5M - $5M																										0
Alaska	Project No. 62056	$1M - $2.5M																										0
Alaska	Project No. 69588	$0.5M - $1M																										0
California	Contract No. 07-138204	$ 160M	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x		x	x		No	x	1M	21
California	Contract No. 03-3797U4	$ 130M	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x		x	x		No	x	1M	21
California	Contract No. 12-0G3304	$ 56M	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x		x	x		No	x	1M	21
California	Contract No. 07-241304	$ 1.56M	x				x	x	x	x	x		x		x	x	x			x		x	x			x	1M	15
California	Contract No. 05-0T3604	$ 1.12M	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x		x	x		No	x	1M	21
Florida	Contract T2376	$ 19.5M	x				x		x	x	x	x			x					x	x	x	x	x	*	x	1M	15
Florida	Contract T1322	$ 14.5M	x				x		x	x	x	x			x					x	x	x	x	x	*	x	1M	15
Florida	Contract T2366	$ 2M																										0

State	Provision / Project	Price	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date	Baseline Finish Date	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Negative Float	Show Critical Path	Update Cycle	Total
Florida	Contract T4299	$ 1.6M	x				x		x	x	x	x			x					x	x	x	x	x	*	x	1M	15
Indiana	Contract # 33045-A	$ 142M	x				x	x	x	x	x				x	x	x						x		*	x	1M	13
Indiana	Contract # 33049	$ 69M	x				x	x	x	x	x				x	x	x						x		*	x	1M	13
Indiana	Contract # IR-30850-A	$ 26.2M																										0
Indiana	Contract # 32756	$ 8.7M																										0
Indiana	Contract # IR-31879-A	$ 3M																										0
Kentucky	109-PIKE, CONTRACT ID - 111307	$ 53.5M	x	x	x		x	x	x	x	x	x		x	x			x	x	x		x	x		* No	x	2W	19
Kentucky	104-HENDERSON, CONTRACT ID - 111023	$ 17M																										0
Kentucky	104 various, CONTRACT ID - 111012	$ 8.5M																										0
Kentucky	35-PERRY, CONTRACT ID - 111308	$ 2.9M																										0
Ohio	Project Number: 110255	$ 55M	x	x	x		x	x	x	x	x	x			x	x	x	x	x	x		x	x		*	x	1M	20
Ohio	Project Number: 113003	$ 12.2M	x	x	x		x	x	x	x	x	x			x	x	x	x	x	x		x	x		*	x	1M	20

State	Provision / Project	Price	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date	Baseline Finish Date	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Negative Float	Show Critical Path	Update Cycle	Total
Ohio	Project Number: 110386	$ 7M																										0
Ohio	Project Number: 110321	$ 3.6M																										0
Oregon	SPS09350	>$50M	x	x	x	x	x	x		x	x	x			x	x	x			x	x	x	x			x	1M	18
Oregon	SPS10694	>$50M																										0
Oregon	SPS 12076	>$50M	x	x	x	x	x	x		x	x	x			x	x	x			x	x	x	x			x	1M	18
Oregon	SPS 14032	>$50M																										0
Oregon	SPS14197	>$50M																										0
Oregon	SPS14949	<$50M																										0
Oregon	SPS06025	<$50M																										0
Oregon	SPS12874	<$50M																										0
South Carolina	Project Number: BR26(012), 08 February	$ 75.7M	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x		NO	x	1M	22
South Carolina	Project Number: BR88(066), 09 November	$ 17.3M	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x		NO	x	1M	22
South Carolina	Project Number: MR11(071),14 December	$ 6.7M	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x		NO	x	1M	22
South Carolina	Project Number: RS10(087), 08 march	$ 3.4M	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x		NO	x	1M	22
Washingt	CONTRACT NO	$	x	x	x	x	x	x	x			x	x		x		x					x					1W	1

State	Provision / Project	Price	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date	Baseline Finish Date	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Negative Float	Show Critical Path	Update Cycle	Total
on	:007936 (Type C)	53.4M																										3
Washington	CONTRACT NO : 006933	$ 34M							x		x				x					x	x		x					6
Washington	CONTRACT NO :007417 (Type A or B)	$ 14.7M		x	x			x	x	x	x		x		x		x			x	x	x	x	x		x	2W	16
Washington	CONTRACT NO : 007685 (Type A)	$ 9.8M																										0
Washington	CONTRACT NO :007686 (Type A)	$ 7.3M																										0
Washington	CONTRACT NO :007669 (Type A)	$ 6.6M																										0
Washington	CONTRACT NO :008086	$ 3.6M																										0
Washington	CONTRACT NO :007645 (Type A)	$ 2.6M																										0
Washington	CONTRACT NO :007897	$ 2.4M																										0
Washington	CONTRACT NO :007660 (Type A or B)	$ 2.3M		x	x			x	x	x	x		x		x		x			x	x	x	x	x		x	2W	16
Washington	CONTRACT NO : 007276	$ 0.4M		x	x			x	x	x	x		x		x		x			x	x	x	x	x		x	2W	16
West Virginia	PROJECT NUMBER X347-H-74.85 00 ACAP-0484(246)	$ 82.5M	x				x			x	x	x				x	x			x	x		x	x		x		12
West	PROJECT	$																										0

State	Provision / Project	Price	Activity Id	Project Name	Project Schedule ID	Project Version	Project Calendar	Data Date	Milestone	Activity Description	Activity Original Duration	Remaining activity Duration	Activity Actual Duration	Activity Baseline Original Duration	Relationships (Finish to Start)	Actual Start date	Actual Finish Date (Physical Completion)	Baseline Start Date	Baseline Finish Date	Early start / finish	Late start / finish	Percent Completion	Total Float	Free Float	Negative Float	Show Critical Path	Update Cycle	Total
Virginia	NUMBER X312-H-81.35 03 ACAP-0484(299)	25M																										
West Virginia	PROJECT NUMBER S318-33-0.01 00	$ 6.4M																										0
West Virginia	PROJECT NUMBER S399-STR/IP-11 03 IM-2011(026)D	$ 2.8M																										0
Total			21	17	17	11	21	20	22	24	25	15	9	5	21	16	21	11	11	22	14	21	24	7	16	24	23	

*Negative float will not be a basis for requesting time extensions