MOUNTAIN-PLAINS CONSORTIUM

MPC 22-469 | A. Abdelaty and M.S. Jamal

GUIDELINES FOR DEVELOPING AND REVIEWING BASELINE SCHEDULES FOR WYOMING TRANSPORTATION PROJECTS

MOUNTAIN-PLAINS CONSORTIUM REGION 8

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16. Abstract

Due to the short construction season in Wyoming, contractors must complete many transportation projects on a tight schedule. Unfortunately, contractors often cannot create accurate schedules that consider logical work ordering, reasonable productivity, and weather events. Inaccurate baseline schedules can be problematic for progress monitoring and lead to costly schedule slippage. Therefore, this project reviews the current practices and standards used by several departments of transportation (DOTs) and the US Government Accountability Office (GAO) to improve baseline schedules. Afterward, the research team collected baseline schedules and daily work report (DWR) data to identify issues and causes of schedule delays in the State of Wyoming. The DWR data make up a rich dataset that includes the construction activity's actual start and end dates. Therefore, the researchers determine the existing workflow and causes of delay. Additionally, the research team created an as-built schedule based on the DWR data for one project to evaluate the accuracy of baseline schedules. Moreover, this project compares baseline schedules and the GAO best practices for project schedules. The research team also conducted a questionnaire survey targeting resident engineers in Wyoming to identify schedule delay causes. Finally, the research team developed recommendations to improve baseline schedules and the DWR's documentation process to ensure future realistic implementations.

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Guidelines for Developing and Reviewing Baseline Schedules for Wyoming Transportation Projects

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ABSTRACT

Due to the short construction season in Wyoming, contractors must complete many transportation projects on a tight schedule. Unfortunately, contractors often cannot create accurate schedules considering logical work ordering, reasonable productivity, and weather events. Inaccurate baseline schedules can be problematic for progress monitoring and lead to costly schedule slippage. Therefore, this project reviews the current practices and standards used by several departments of transportation (DOTs) and the US Government Accountability Office (GAO) to improve baseline schedules. Afterward, the research team collected baseline schedules and daily work report (DWR) data to identify issues and causes of schedule delays in the State of Wyoming. The DWR data make up a rich dataset that includes the construction activity's actual start and end dates. Therefore, the researchers determine the existing workflow and causes of delay.

Additionally, the research team created an as-built schedule based on the DWR data for one project to evaluate the accuracy of baseline schedules. Moreover, this project compares baseline schedules and the GAO best practices for project schedules. The research team also conducted a questionnaire survey targeting resident engineers in Wyoming to identify schedule delay causes. Finally, the research team developed recommendations to improve baseline schedules and the DWR's documentation process to ensure future realistic implementations.

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EXECUTIVE SUMMARY

This research investigated the current practices of the schedule standards used by other departments of transportation (DOTs) to improve baseline schedules and project control. The research team evaluated the accuracy of the selected baseline schedules provided by the Wyoming DOT against the daily work reports (DWRs), US Government Accountability Office (GAO) best practices for project schedules, and a questionnaire survey. Researchers determined several inconsistencies in this baseline schedule compared with the DWR data, such as unrealistic durations for activities, missing information, missing relationships between construction activities, and the unexplained durational gap between activities. The research team also found inaccuracies in the selected baseline schedules by comparing them with the GAO best practices for project schedules. None of the baseline schedules fully satisfied capturing all activities, sequencing, assigning resources, and establishing the duration of all activity requirements. The lack of float management, critical path management, and horizontal and vertical traceability verification in the baseline schedules are also found. The research team also conducted a questionnaire survey to collect responses from the residents and district construction engineers regarding the challenges, root causes of schedule delays, and the inaccuracy of the baseline schedules. Based on the responses collected, the research team found that 60% of the overall respondents indicated that the quality of the submitted baseline schedules was below average. In addition, the survey showed that 43% of respondents said the projects had been delayed beyond the original schedule because of contractors. Moreover, the research team also determined the significant delay factors affecting project schedule delays through the DWR analysis and the questionnaire survey. All the identified delay factors were ranked using the relative importance index (RII) method, in which the significance of each delay factor is based on a five-point Likert scale. Although severe weather was ranked first based on the DWR analysis, labor shortages in every scope of work ranked first in the survey results. For example, according to the DWR evaluation, the top three significant delay factors were weather, the contractors' starting delays, and COVID-19, respectively. On the other hand, based on the survey results, the top three delay factors were labor shortages in every scope of work, lack of required equipment or materials, and poor communication and coordination with contractors and other parties. The research team concluded that the main reason for these differences was the inaccurate and missing information in the DWRs. The main outcome of this research is a list of recommendations to improve the baseline schedules submitted by the contractors before starting the work. The findings created under this research can be used to develop accurate baseline schedules and the DWR documentation process to improve future projects.

1. INTRODUCTION

1.1 Introduction

Because of Wyoming’s short construction season, contractors should complete many transportation projects on time. Several factors influence the project schedule, such as the contractor’s capabilities and resource availability, weather conditions, and project delivery method. A contractor’s ability to generate an accurate project schedule with realistic productivity rates and logical work sequencing is referred to as the contractor’s capability. The construction production rate determines the contract completion time when preparing the final contract for bidding and contract management (Aoun 2013). Contractors frequently generate inaccurate schedules to reflect the execution plan, explain acceptable production, or fail to account for weather events. If an incorrect baseline schedule is accepted before the construction, it will be challenging to track and monitor the project’s progress. Unlike building construction, heavy civil construction projects are significantly impacted by weather events throughout the project schedule (Ibbs and Kang 2018; Ballestoros-Perez 2018). Therefore, DOTs should coordinate contractor’s project activities following relevant priorities, such as extreme weather conditions in Wyoming.

Due to Wyoming's short construction season, the stipulated completion time may be short, prompting the contractors to push or accelerate the construction schedule to meet the contract completion time, making the project schedule even more challenging. Also, the construction schedule may be influenced by the project delivery method. According to a survey, incentives or disincentives can favor construction schedules, whereas cost-plus-time contracts can force a project’s completion date to be delayed (Choi et al. 2012). Therefore, it is essential to design an accurate construction schedule for infrastructure projects during the short construction season when most tasks are critical. Developing construction efficiency through economy and timeliness will undoubtedly increase the return on investment regarding taxpayer money (Atego 2018). The American Association of State Highway and Transportation Officials (AASHTO) was surveyed to evaluate the problem’s scope and identify the causes contributing to the rise in construction costs (Damnjanovic et al. 2009). This survey helps to avoid transportation service disruptions and scheduling delays. The research team also conducted a questionnaire survey among WYDOT resident engineers and district construction engineers. The principal purpose of this survey is to determine the challenges and root causes of schedule delays for Wyoming transportation projects. According to the survey, around 60% of the submitted schedules were below average. This survey also identified the 10 most significant delay factors, and labor shortages in every scope of work was the most critical factor. After completing this survey, engineers from the Wyoming Department of Transportation (WYDOT) must also be able to analyze and detect inaccurate project plans or schedules before beginning construction. This allows WYDOT engineers to track the progress of construction projects and make recommendations for improvements as needed.

1.2 Research Objectives

The main objectives of this report are as follows:

- To evaluate the accuracy of baseline schedules submitted to WYDOT prior to commencement of work in terms of activity sequencing, weather impacts, and scope gaps
- To quantify the significance of factors affecting project schedule delay
- To develop recommendations and guidelines for developing and reviewing baseline schedules

1.3 Data Collection

The research team collected baseline schedules and DWRs for five different projects in Wyoming. Researchers also conducted a questionnaire survey that included 10 different categories of questions distributed to WYDOT resident engineers and district construction engineers of the five districts in Wyoming.

Figure 1.1 Data collection area

1.4 Work Plan

Figure 1.2 shows the research work plan. There are seven main tasks summarized in this plan. In the first task, "Literature Review," the research team will summarize the previous research findings relevant to the study objectives.

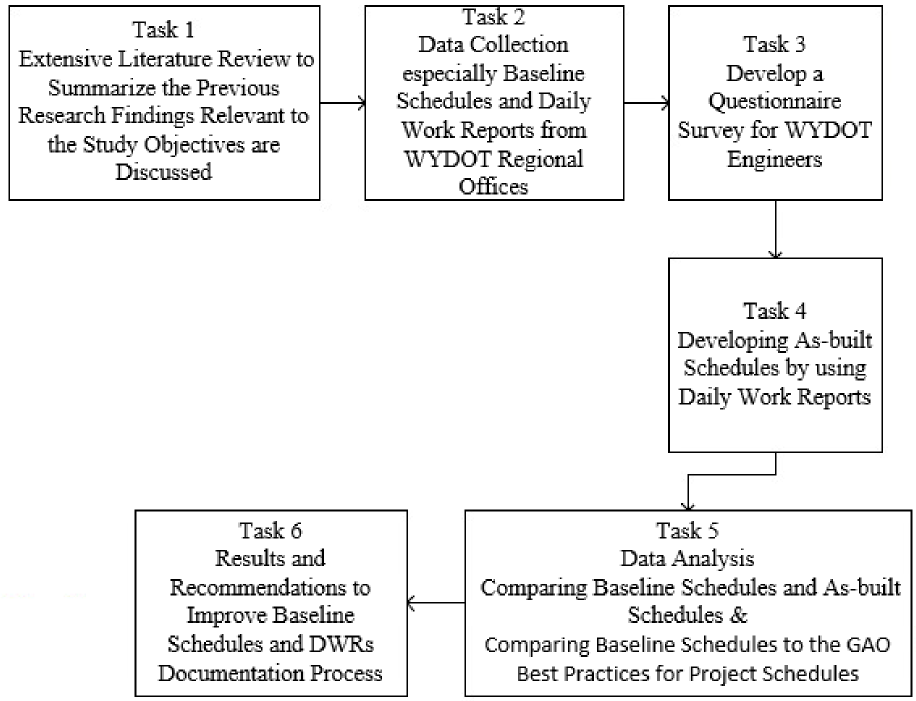


Figure 1.2 Work plan for this research

The second task, "Data collection," involves collecting baseline schedules and daily work report (DWR) data for multiple projects to represent all regions in Wyoming. In the third task, "Questionnaire survey," the project team will develop a survey and distribute it to Wyoming resident engineers and district construction engineers to identify project scheduling challenges and best practices. In the fourth task, "Developing as-built schedules," the project team will use DWR data to reconstruct as-built schedules for the selected set of projects. In the fifth task, the project team will compare baseline schedules to as-built schedules to identify progress deviation and root causes of schedule inaccuracies. The project team will also compare the selected baseline schedules against the seven best practices for project schedules identified by US Government Accountability Office (GAO). In this fifth task, the research team will determine the weak points and strong points of the selected baseline schedules, which are submitted by the contractors. Finally, the project team will develop a list of recommendations and guidelines for developing and reviewing baseline schedules and the DWR documentation process.

1.5 Expected Outcomes

The expected outcomes of this research are listed as follows:

- To create guidelines or recommendations for WYDOT engineers to review baseline schedules in terms of activity sequencing and historical weather impacts by region
- To figure out the delay factors and their magnitude on the selected projects
- To create as-built schedules for select projects based on DWR data

This report presents recommendations for WYDOT engineers to use when evaluating contractor baseline schedules before work commencement. WYDOT engineers will be able to identify inappropriate activity sequencing and failure to account for weather events. Additionally, WYDOT should be able to determine the significant delay factors and their magnitude on the selected projects, which will help them to evaluate accurate baseline schedules. The archiving of as-built schedules for select projects is the third outcome of this study. By looking at as-built schedules for previous projects, WYDOT engineers will be able to determine the sequencing of construction activities more effectively.

1.6 Report Organization

The entire report is organized through six chapters. A short summary of each chapter of the report is presented below.

- Chapter one presents the introduction, research objectives, data collection, work plan, expected outcomes, and organization of the study.
- Chapter two presents a literature review of existing DOT practices.
- Chapter three illustrates the research methodology and data collection.
- Chapter four covers a comparative analysis between DWRs and baseline schedules. It also includes the comparative analysis between baseline schedules and as-built schedules and the comparison between selected baseline schedules and the best practices of project schedules.
- Chapter five represents a summary of the questionnaire survey, which includes an introduction, description, result and analysis, and recommendations.
- Finally, chapter six presents the conclusions of the research study and a list of recommendations to improve the submitted baseline schedules and the DWR documentation process.

2. LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the analysis of related departments of transportation (DOTs) practices related to preconstruction conferences, weekly planning and reporting meetings, baseline schedules, and scheduling best practices. It also includes the progress schedule standards, critical path method (CPM) schedule, update schedule, and DWR standards. Strategies on construction contract time determination are also included in this chapter to develop recommendations and guidelines for developing and reviewing baseline schedules between WYDOT and other state DOTs.

2.2 Summary of Schedule Standards and Practices

The researchers' first step was to investigate how other state DOTs determined the schedule standards and practices for their highway construction projects. The researchers looked at computerized and manual systems in current use by other state DOTs to identify the general order of managing work items.

2.2.1 Preconstruction Conference

A preconstruction meeting is an opportunity to discuss the project's requirements and specifications with the contractor who will accomplish the project. Arizona Department of Transportation (ADOT) requires a preconstruction meeting for the public transportation projects. In this meeting, the contractor meets with the engineer and must provide a schedule outlining the order in which the contractor expects to complete the work. This meeting also includes the dates on which the contractor and its subcontractors may begin work on tasks, such as material procurement and equipment installation. The material procurement refers to the description of the purchasing process of the goods and services and the equipment installation means the actions which are required to attach the equipment. The procurement of one-of-a-kind items, the submission of drawings, plans, and other data required by the specifications for the engineer's review and approval, and the anticipated completion dates are also included. The schedule must follow the CPM. Similarly, the North Dakota DOT (NDDOT) also requires a preconstruction meeting led by an engineer who is familiar with the field or job site conditions. Before the meeting, the engineer creates a list of parties who will be invited to the meeting and send it to the contractor. Within 48 hours of the meeting's completion, contractors distribute the results. Before sharing the notes, the contractor allows the engineer to review and approve them. The notes include a discussion of issues that have arisen since the last meeting and agenda information that will be of interest to those who have been invited to the meeting. Then the contractor provides a written schedule for such work for the next week and a preliminary schedule for the following week (ADOT 2021; NDDOT 2020).

2.2.2 Weekly Planning and Reporting Meeting

As part of the project weekly planning, ADOT requires contractors to submit a workforce plan that shows sufficient labor and equipment to complete the project. The contractor interacts weekly with the engineer at a mutually convenient location and time to discuss construction activities; however, a meeting may be excused if mutually agreed upon due to weather situations, work progress, or other factors. During the meeting, the contractor provides the engineer with a detailed, documented schedule of construction activities and phases of work for the next two weeks, as well as the construction activities conducted the previous week. The anticipated start and completion dates of work activities are detailed in this documented schedule. Similarly, the Colorado Department of Transportation (CDOT) requires contractors to submit a weekly plan in writing, including the contractor's and all subcontractors' planned activities for the next two weeks after the submittal date, as well as actual days worked versus scheduled for the week prior to the submittal date. The description, duration, sequence of work operations, and planned lane closures are all included in this schedule for the next two weeks. A time-scaled logic diagram or the other standard format can be used for the weekly schedule plan. However, the contractor's schedule report submission deadlines do not apply to the weekly planning schedule. This weekly planning schedule includes schedule revision which is required in the event of any major change to the work. These changes include a change to the critical path, addition or deletion of activities, and phasing revisions. A description of the steps that must be taken for the task to be completed within the contract time is also included in this scheduled meeting. In this weekly meeting, contractors submit updated method statements and schedule revisions. In this situation, the contractor must explain why the projected completion date was missed in the job progress narrative report that comes with the schedule. The schedule revision becomes the project schedule once it has been accepted (ADOT 2021 and CDOT 2017).

2.2.3 Schedule Standards

According to ADOT and California Department of Transportation (Caltrans) schedule standards requirements, the schedule must demonstrate the interrelationships between the activities, as well as the project's regulating items of work. Contractors have to prosecute the work according to the schedule, and they must ensure that all subcontractors and suppliers at any tier also prosecute the work according to the schedule standards. The contractor has to provide the information needed to support activity time durations, such as estimated personnel, equipment, product quantities, and production rates. The schedule must show that the tasks will be done no later than the contract completion date. The contractor has to propose significant modifications in the progress schedule in a written communication with the engineer.

The main reason for the communication with the engineer is that significant modifications can change the critical path and controlling item of work. Similarly, CDOT stipulated that the contractor has no authority to sublet, sell, transfer, assign, or dispose of the contract without the engineer's written permission. Before the subcontractor can start working, the contractor must first obtain permission from the engineer by submitting a completed sublet permit application. On the other hand, the Texas Department of Transportation (TxDOT) requires several steps regarding schedule standards, such as determining the need for a schedule, identifying project rigor and project phase, creating an initial schedule per phase, and linking the schedule to each phase. It also includes requirements for creating a baseline schedule, assigning project baseline and tracker codes, updating the schedule at least monthly, progressing the baseline, and revising the schedule according to the necessity (ADOT 2021; CDOT 2019; Caltrans 2018; TxDOT 2018).

2.2.4 Progress or Updated Schedules

A progress schedule is a version of the work schedule issued by the contractor after the guaranteed project schedule, in accordance with the project updates time extensions, claims, payments, tardiness, and recovery (Hinze et al. 2004). The contractor uses activity descriptions to make the work easy to recognize. Based on CDOT requirements, CDOT will not accept the use of bar charts instead of a retained logic scheduling option in the project schedule if the contractors use Oracle Primavera. The contractor may submit a revised progress schedule for evaluation and approval if the engineer has extended the completion date or if the project overrun is expected to be greater than 5% (CDOT 2017).

According to NDDOT, if an error is identified by the contractor or engineer after the engineer has accepted a schedule, the contractor must remedy the issue in the next scheduled submission. If the contractor fails to prepare and submit an acceptable progress schedule to the engineer as required by the contract, progressive estimates will be withheld until the contractor submits an acceptable schedule. Although ADOT accepts a revised progress schedule every 30 days throughout the contract, CDOT accepts it within 15 calendar days. To ensure that the project is completed on time, the contractor should produce a monthly updated schedule detailing the status of work completed to date and also work that has yet to be completed as planned. Changes to revised schedules that do not modify a critical path or extend the anticipated completion date beyond the present schedule may be included by the contractor. Adding or removing activities, modifying activity limits, changing durations, and changing logic are examples of these changes (NDDOT 2020; CDOT 2017).

According to Caltrans, after one month of the acceptance of the baseline schedule, the contractor should meet with the engineer to discuss work progress on or before the 1st of each month. The updated schedule includes the revisions from acceptable revised schedules, as well as a data date of the 21st day of the month or another date determined by the engineer. Any changes to the scheduled work must be justified in writing by the contractor. If any suggested changes in planned work result in a critical path or near critical path being shifted or the schedule completion date being pushed back, the contractor must submit a revised schedule within 15 days of the proposed modification. Within 30 days of construction completion, the contractor must submit a final revised as-built schedule with real start and finish dates for the activities (Caltrans 2018).

Similarly, the New Hampshire Department of Transportation (NHDOT) requires contractors to update the schedule as needed to reflect real work revisions and progress, as well as to document all contract revisions that have been granted, including all time extensions. Contractors must include the start and end times of each activity, the percentage completed, and the remaining length of activities that have already begun and are still running. Within 72 hours after the job site meeting with engineers, contractors need to submit two copies of the schedule change to the engineer for evaluation (NHDOT 2016).

2.2.5 Critical Path Method Schedule

CPM is a method to determine the early and late time for all activities in the project and to help identify all critical activities (Hinze 2004). Caltrans has two different types of requirements based on the value of the project. If the total bid is less than \$1 million, the contractor has to submit a CPM baseline schedule, including the original time scale network diagram, contract number, CPM schedule number, and file name. However, if the contract has a total bid over \$5 million, the contractor must submit baseline, monthly updated, and final updated schedules, each consistent in all respects with the time and order of contract work requirements. Similarly, NDDOT requires the calculation and submission of a standard CPM schedule. To calculate the CPM schedule, the contractor must provide total float based on finish dates, schedule durations as contiguous, and start to start lags from early dates. However, the main part of the CPM schedule is a narrative report which includes an explanation of the overall plan to complete the project, number of crews, types of workers, types of equipment, and the working days per week. The early start, predecessor and successor, longest path, total float, and phase by early start are also available in a CPM schedule. The graphical description of a CPM schedule is in a bar chart view of all activities grouped by phase and stage and sorted by early start date (Caltrans 2018; NDDOT 2020).

2.2.6 Baseline Schedule

A baseline schedule is a project timeline that is fixed and cannot be changed. It is used to keep track of a project’s progress, including meeting contract milestones and staying under budget (Hinze 2004). The baseline schedule should include the entire scope of work and also how the contractor intends to finish all tasks. The actions that define the critical path must be shown on the baseline schedule. NDDOT requires a baseline schedule where contractors should submit the work to be done by the contractor, subcontractors, suppliers, departments, and third parties. The contractor should not use negative lag, start-to-finish relationships, open ends, limitations, and manually updated dates in an effective baseline schedule. In a baseline schedule, the project start date, scheduled completion dates, and other contract milestones, such as phase start or finish dates or site access or availability dates, are critical.

A variety of activities, such as submittal review and approval, fabrication, delivery, installation, testing, sampling and testing intervals, and settlement and cure periods, are also included in the baseline schedule. For each activity in the baseline schedule, the contractor should submit the following activities: a unique alphanumeric activity ID, activity description, codes for responsibility, and phasing or staging. Unless the contractor requests a longer term and the department permits it in writing, the duration must be expressed in workdays. However, in California, Caltrans requires a baseline schedule within 20 days of contract approval and 20 days for review of that submitted baseline. The number of critical and near-critical paths should be kept to a minimum. The baseline schedule must not extend beyond the number of original working days. Additionally, a data date of contract approval must be included in the baseline schedule. If the contractor begins work before the contract is approved, the baseline schedule must provide a data date of the contractor's first day on the job site. If a contractor submits an early completion baseline plan that shows work being completed in less than 85% of the original working days, the baseline schedule must be augmented with resource allocations for each task activity and time-scaled resource histograms.

For contractors and subcontractors, resource allocations must be provided to a level of detail that allows for report generation based on labor skills and equipment classes. Contractors should employ average composite teams to show the labor impact of job site construction activities. To ensure that resources are not duplicated in concurrent tasks, optimize and level labor resources to reflect a reasonable plan for completing the activity. The labor trades and equipment classes to be employed must be shown in the time-scaled resource histograms. (NDDOT 2020; Caltrans 2018).

2.2.7 Daily Work Report

One of the most important documents collected by contract administrators is the daily work report. It is a record of all phases of the project, including the contractor's operations and completed work, orders given or received, unexpected conditions, delays in operations, visitors, and discussions with the contractor. The significance of DWRs cannot be overstated, and contractors can be used as evidence in court cases and as a deciding factor in resolving claims. Except when work is interrupted, the DWRs must be prepared every day between the start and finish of the project. The contract administrator must sign the document because it is an official document. DWRs may be completed electronically, but contractors must print and make them available for review by specific DOT and FHWA personnel during site visits and reviews (NHDOT 2016).

According to NHDOT, the following are all included in the DWRs: weather, visitors on site, contractor and subcontractors present at the project (including type and quantity of human resources and equipment), and the progress of work (including day count or percent project complete with reference to the completion date or a number of allotted working days). It also includes nonworking days with an explanation for nonworking day status, extenuating circumstances that may have a bearing on working days or time extensions, items of work completed with an approximate quantity and locations given (typically referenced to centerline stations), and items of work completed with an approximate quantity and locations given (typically referenced to centerline stations). Discussions with the contractor about the work, public safety, or construction signing, including a record of any actions or decisions taken, are available in DWRs. The DWR data also contain a variety of activities and information, such as accident information, police or flaggers, utility coordination, and a copy of the daily worker sign-in sheet, which is required by state law. It includes notations of prospective modification orders or claims by the contractor and conversations with landowners and abutters, as well as notations of meetings, phone calls, and discussions with stakeholders, visitors, or suppliers. Any entries in the quantity book, record book, field book, lab book, or other files collected for the project must be noted in the DWRs (NHDOT 2016).

2.2.8 Use Computer Software to Prepare Each Schedule

Caltrans requires the approval of uses of the computer software to prepare each schedule. For approval, the contractor must give a description of its planned schedule software. The software must be compatible with the engineer's current version of the Microsoft Windows operating system. Primavera P6 for Windows, or an equivalent, must be included in the scheduling software. Any proposed schedule software that is compatible with Primavera P6 must be capable of developing files that can be imported into Primavera P6, as well as comparing two schedules and reporting on changes in activity ID, activity description, constraints, calendar assignments, durations, and logic ties. Data, network diagrams, and reports are all available. Contractors deliver a data-storage device that includes the schedule data, sets of originally plotted, time-scaled network diagrams, and copies of a narrative report for each schedule submittal. The narrative report must be prepared in the following order, with all relevant papers included: the transmittal letter, work done during the time, and identification of any unique labor, equipment, or material conditions. It also provides a description of the present critical path, as well as issue areas, critical path changes, and the scheduled completion date since the last scheduled submission. Current and projected delays, such as the cause of the delay, the impact of the delay, and the delay's corrective action, and the reasons for the early or late scheduled completion date are all key factors to consider while preparing each schedule. Based on CDOT requirements, the contractor must inform the engineer in writing, prior to or during the preconstruction conference, of the scheduling software they will use to manage the project. After the original schedule is submitted, the contractor's decision and use of scheduling software cannot be changed (Caltrans 2018; CDOT 2017).

2.3 Contract Time Determination

Determining the construction contract period is one of the most important and difficult tasks as it directly affects the project completion time and price, contractor bidding behavior, project quality, safety, and inconvenience to the public. Developing construction flow logic is one of the most difficult processes involved in determining the length of a construction contract. Previous studies have determined the criteria to sequence the project activities. According to a study by Jeong et al. (2020), an activity sequence logic data report with DWR provides standard construction sequence logic diagrams for the five most common project types, such as city, regional, seals and covers, safety, and bridge construction and rehabilitation. These visual, logical diagrams were created based on the DWR analysis and the experiences of the Montana Department of Transportation (MDT) controller. Visual, logical diagrams can be a powerful resource as they can provide planners with quick and reliable visual assistance in completing the duration of a project. Diagrams can also be used to train novice schedulers and give them confidence in estimating contract times. This study also focuses on the design logic diagrams, which can update and revise the current contract timing manual (Jeong et al. 2020).

Similarly, Indiana also uses an experienced project engineer to determine contract time. Their system is a similar hand-written procedure that uses a contract determination worksheet form to establish contract time for their highway construction projects. The project engineer develops the project activities, the project activity logic, the relationship between these activities, and which of these are the project duration controlling activities. The project duration or contract time is the result of this contract time determination procedure. Workdays are also converted into calendar days. The project engineer then adjusts for any other factor that merits consideration, such as holidays, permit restrictions, delivery time of materials, and any specific time that a ramp, bridge, or road needs to be put back in service (Bertram et al. 1997).

However, the TxDOT contract time determination system uses five sensitivity factors to adjust project duration resulting in the contract time. These sensitivity factors are location, traffic conditions, complexity, soil conditions, and quantity of work. The DOT allows the contractors to adjust for differing project characteristics. Controlling activity link logic is predetermined and programmed in their software system. The study says that only experienced users are allowed to modify the controlling activity relationship logic. From the engineer's estimate, the design quantities and units are input in the predetermined format. The controlling activities and their calculated durations are then transferred to the super project to generate a project bar chart schedule (Hancher et al. 1992).

On the other hand, the Kentucky State Government selects Microsoft as its exclusive office software provider for the project performance documentation. The Kentucky Contract Time Determination System (KY-CTDS) is the new method to be used for the determination of contracts for highway construction projects in the Commonwealth of Kentucky. It utilizes standard office software packages, MS Excel and MS Project 98, to add structure to the process, perform calculations, and produce tabular and graphical documentation for the planning process. The system is simple, robust, and user-friendly. Because using the project templates is easy and transparent for the user, it is a powerful working tool in the planning process (Werkmeister et al. 2000).

Similarly, in studies by Werkmeister et al. (2000), the activity names, the resultant activity durations, and the activity relationship logic of the MS Excel project worksheet were transferred via the clipboard to MS Project Template. The engineer inserts the clipboard contents into the MS Project template and yields the user a graphical presentation of the project and a calculation of the total working days of the project. The engineer saves the same unique file name used to associate it with the project in MS Excel, and it becomes part of the project's digital and manual copy documentation on how the contract time was calculated (Werkmeister et al. 2000).

3. RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the following three phases: data collection, data analysis and results, and recommendations (see Figure 3.1). In phase I, data were collected from the WYDOT regional offices. In phase II, the research team conducted a questionnaire survey targeting the resident and district construction engineers in Wyoming. The survey aimed to identify the main causes of schedule delay for transportation projects as well as recommendations to mitigate schedule delay. The researchers also merged and analyzed baseline schedules and DWRs to create as-built schedules. Then the research team compared baseline schedules to as-built schedules to evaluate the quality of baseline schedules as well as develop recommendations to improve baselines schedules. Additionally, researchers also compared the baseline schedules against the GAO best practices for project schedules. Finally, the research team developed recommendations to improve baseline schedules and the DWRs documentation process.

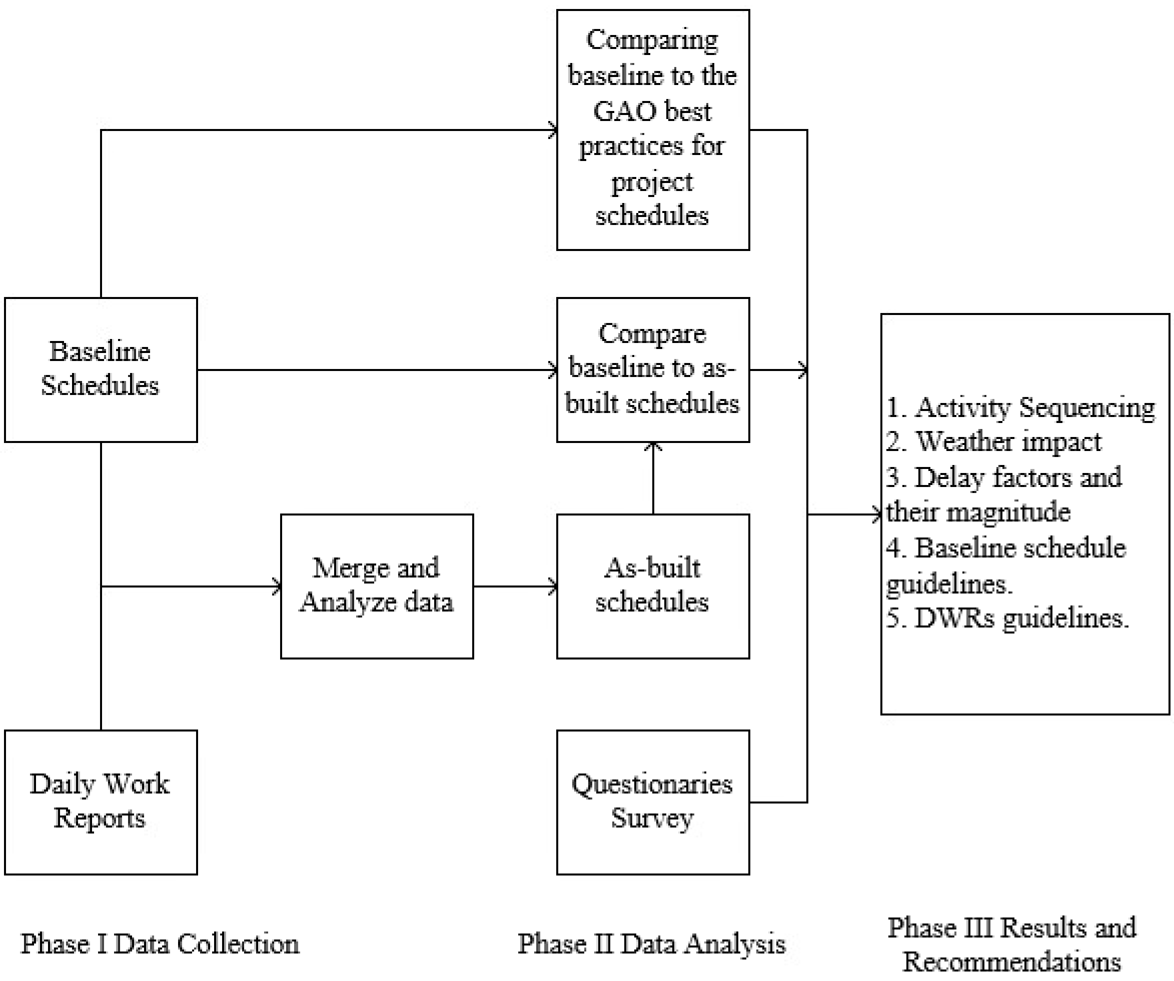


Figure 3.1 Research methodology and phases

3.2 Data Collection

The research team obtained DWRs and baseline schedules from the WYDOT regional offices for five different projects that represented new construction, maintenance, and rehabilitation. The projects typically consisted of the following activities: crushing and stockpiling crushed surfacing material, fencing, median cable barrier, draining, milling plant mix, lane rental, bent cap replacement, drilled shaft foundations, installing signs, rockfall mitigation, pavement markings, bituminous pavement surfacing, bridge rehabilitation, and miscellaneous works. The five projects were worth a total of $23.43 million.

3.3 Questionnaire Survey

The questionnaire was sent to 28 resident engineers and district construction engineers in Wyoming's five districts via email. There were both closed-ended and open-ended questions in the survey. There were 10 different types of questions in the survey. Finally, the research team obtained 14 resident engineers and four district construction engineers' complete responses. The details and results of the questionnaire survey are discussed in Chapter Five.

3.4 Data Analysis

The research team used the DWR data and baseline schedules to reconstruct as-built schedules. To create as-built schedules, researchers merged and analyzed baseline schedules and daily work reports. As-built schedules explain the actual activity duration, activity sequencing, and work stoppage. By comparing baseline schedules to as-built schedules, the research team evaluated previous project progress, improper activity sequencing, and weather influences using forensic schedule delay analysis. As part of their aim, researchers also identified the most significant delay factors from the DWR evaluation and a questionnaire survey. To achieve this aim, the research team used an appropriate analytical method, which is the relative importance index (RII) (Durdyev et al. 2017). The details of the calculation of this method are discussed in Chapter Four. The research team evaluated the baseline schedules of the selected projects by comparing the schedules against the GAO best practices for project schedules. The comparison against the GOA best practices for project schedules are made to formulate recommendations to improve the quality of future baseline schedules prepared by contractors.

4. COMPARE BASELINE TO AS-BUILT SCHEDULES

4.1 Introduction

This chapter provides an analysis of the DWRs, baseline schedules, and construction reports collected from the WYDOT regional offices. The research team created as-built schedules after the evaluation of the DWR data. The purpose of this chapter is to compare baseline to as-built schedules for Wyoming transportation projects. Based on the evaluation of the DWRs, baseline schedules, and construction reports, the research team explains the inconsistency between baseline schedules and DWRs, and significant factors that influence public transportation projects' completion in Wyoming. Additionally, the research team used the RII method to determine the most important factor responsible for schedule delay. Finally, a list of recommendations from the DWR data evaluation to mitigate schedule delay is discussed at the end of this chapter.

4.2 Data Description

The research team collected data for five different projects (Figure 4.1) located in District 5 in Wyoming. The projects' scope of work ranged from new construction to maintenance and rehabilitation. The total value of the five projects was approximately $23.43 million, and the total length was 20 miles. The range of the total amount of the five projects was $1.88 million to $14.63 million, and the total length was 1.3 miles to 7.0 miles, respectively.

The baseline schedules included a list of all construction activities, such as mobilization, installing temporary traffic control, stripping topsoil, unclassified excavation, installing guardrail, placing topsoil, installing delineators, and reclamation. Contractors illustrated the projects' activities through Gantt charts, which indicated the start date, finish date, and the number of days required per activity. Also, the DWR data provided a rich dataset recorded in the project location by the contractor. The DWRs included detailed activities during the construction periods and factors considered affecting the construction delays. Also, the construction reports contained the type of work, total value, full length, and location of the projects.

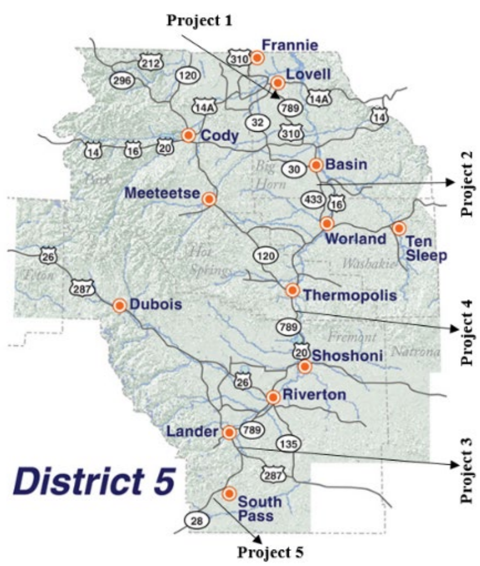


Figure 4.1 Location of the five projects

4.3 Data Analysis and Result

The data analysis and result part were conducted in three phases. In phase I, the research team compared the DWR data and baseline schedules obtained from the WYDOT regional offices. In phase II, the researchers created as-built schedules based on the DWRs to compare the as-built schedules against the baseline schedules. Finally, in phase III, the research team evaluated baseline schedules by comparing them against the GAO best practices for project schedules.

4.3.1 Comparative Analysis between DWRs and Baseline Schedules

After collecting DWRs, the research team compared baseline schedules to DWRs. The research team analyzed DWRs to determine the actual activity duration, activity sequencing, work stoppages, and the factors that affected public transportation project delays in short construction seasons. Researchers found 22 delay factors from the DWRs and construction reports. The research team categorized all the delay factors into four groups: exogenous, management, technological, and labor.
The most important factors that influenced the project schedule were evaluated based on the prioritization of the factors. The researchers used the RII approach to identify the most important factors causing delays in the construction projects collected from DWR. The data were analyzed using the Likert Scale, which uses a five-point scale with values ranging from 1 to 5, with 1, 2, 3, 4, and 5 representing a very low, low, moderate, high, and very high impact, respectively. During the evaluation of the DWRs, researchers marked the most critical factors, which were frequent and significant in the DWRs, whereas less critical factors were less frequent and significant. To evaluate the significance of delays in the five separate projects, the research team used the following RII equation:

$$RII = \frac{\mathbf{\Sigma W}}{AN} \quad \text{(i)}$$

Where W represents the rating given to each factor (ranging from 1 to 5) based on the factor frequency and significance in the DWRs, A is the highest weight (i.e., 5 in this research study), and N is the total number of projects. The higher the RII value, the more important it is. Below is the example of the RII calculation of the “weather” factor in the project according to equation (i).

$$RII = \frac{\mathbf{\Sigma W}}{AN} = \frac{\{(1*0)+(2*0)+(3*2)+(4*0)+(5*3)\}}{(5*5)} = \frac{\mathbf{21}}{25} = 0.84$$

Table 4.1 shows the overall RII calculation based on the DWR analysis. Researchers evaluated a total of five DWRs to get the significant delay factors. The research team identified all of the delay factors of a specific project. For example, researchers determined 10 different factors out of 22 factors of a DWR, and in that specific project, the research team put a very low rating on the rest of the 12 factors. In these 10 different factors, researchers ranked them according to their impacts on that project. During this time, researchers focused on the repetition and the delay causes to rate these factors. Researchers put the higher value when the factors were repetitive and had a great impact on the project for the schedule delay. On the other hand, researchers provided a lower value to those factors that were less frequent and had less impact on the projects for the schedule delay. For instance, if the value of W of a factor was five meant that the factor was the most frequent and highly impactful regarding schedule delay. On the contrary, if W was equal to 1 meant that the factor was less frequent or there was no significant delay in the projects. Again, repetition was not only the main criterion to get a higher rank. The research team identified the rank of the starting delay being due to the contractors and COVID-19 based on their impacts rather than repetition. The research team compared the DWR with the baseline schedule, and if there was any significant starting delay found, researchers put a high rating on the starting delay of that specific project. Similarly, researchers ranked COVID-19 not only for the repetition but also for the indirect impacts, such as labor shortages and equipment unavailability.

Table 4.1 The calculation of the rank of all the causes of project delays based on DWRs analysis

	Factors	RII	Very Low	Low	Moderate	High	Very High
1	Weather	0.84	0	0	2	0	3
2	Starting Delay of the projects by the Contractors	0.72	1	0	0	3	1
3	COVID-19	0.68	1	0	1	2	1
4	Equipment Issue	0.56	2	0	1	1	1
5	Traffic Control Issue	0.56	2	0	1	1	1
6	Accident Due to Poor Site Safety	0.52	1	1	2	1	0
7	Project Location	0.52	1	1	2	1	0
8	Change Order	0.48	1	2	1	1	0
9	Damaged Equipment	0.48	1	2	1	1	0
10	Damaged Mailbox	0.44	2	1	1	1	0
11	Inaccurate Model	0.36	2	2	1	0	0
12	Discovered Sinkhole	0.32	3	1	1	0	0
13	Communication Gap	0.32	3	1	1	0	0
14	Clearing Issue	0.32	3	1	1	0	0
15	Calculation Issue	0.32	3	1	1	0	0
16	Mill Issue	0.32	3	1	1	0	0
17	Lack of skilled labor	0.28	4	0	1	0	0
18	Test Issue	0.28	4	0	1	0	0
19	Soil Erosion Issue	0.28	4	0	1	0	0
20	Labor's Physical Fatigue	0.28	4	0	1	0	0
21	Shortage of Materials	0.28	4	0	1	0	0
22	Faulty Materials	0.24	4	1	0	0	0

According to the data analysis, 22 factors categorized into four groups as management, exogenous, technological, and labor are responsible for the delay in public transportation projects; these are presented in Table 4.2. The research team determined all the factors of delay after the evaluation of each and every DWR. In this study, weather was the main factor that ranked 1 (obtaining 0.84 RII), starting delay of the projects by the contractors ranked 2 (0.72 RII), and COVID-19 ranked 3 (0.68 RII). Although there was no specific delay data by COVID-19 in the DWRs, it had significant impacts on other factors such as lack of skilled labor, equipment issues, material shortages, and communication gaps. COVID-19 was a significant issue in delaying construction projects. According to the construction reports from WYDOT, contractors arranged for 14 days of self-quarantine and implemented a social distancing practice in the workplace. When employees experienced symptoms, the contractor sent them home until they could provide a negative COVID-19 test. As a result, the operating speed of most of the projects was slow, and contractors faced a shortage of materials, equipment, and labor. The research team determined from the DRWs there was "less work due to personnel shortage, material shortages, and the absence of project superintendents." Also, the mill had some issues, such as sinking through the asphalt base due to soft areas and a lack of fully operational capability. Projects were also affected by the calculation error during the construction period, which required more than the estimated time. The research team ranked some of the factors in spite of having a zero-day schedule delay for the following reasons. For example, researchers noticed there was slow progress of work due to workforce injuries, sudden material shortages, and faulty materials. The research team identified “contractor did not work after lunch due to the lack of materials” in the DWRs. Although there was no entire day delay, researchers ranked it according to the impact.

Table 4.2 The rank of all the causes of project delays

Rank	Factors	RII	Related Group	Number of Delay Days
1	Weather	0.88	Exogenous	22
2	Starting Delay of the projects by the Contractors	0.72	Management	10
3	COVID-19	0.68	Exogenous	N/A
4	Equipment Issue	0.56	Management	7
5	Traffic Control Issue	0.56	Management	18
6	Accident Due to Poor Site Safety	0.52	Management	5
7	Project Location	0.52	Exogenous	5
8	Change Order	0.48	Technological	5
9	Damaged Equipment	0.48	Management	5
10	Damaged Mailbox	0.44	Management	12
11	Inaccurate Model	0.36	Technological	2
12	Discovered Sinkhole	0.32	Exogenous	4
13	Communication Gap	0.32	Management	2
14	Clearing Issue	0.32	Management	2
15	Calculation Issue	0.32	Technological	1
16	Mill Issue	0.32	Technological	1
17	Lack of skilled labor	0.28	Labor	2
18	Test Issue	0.28	Technological	2
19	Soil Erosion Issue	0.28	Exogenous	1
20	Labor’s Physical Fatigue	0.28	Labor	0
21	Shortage of Materials	0.28	Management	0
22	Faulty Materials	0.24	Technological	0

Many projects faced weather-related problems due to not starting the projects according to the baseline schedule. Additionally, contractors did multiple projects in parallel and could not maintain project schedules for the different project locations. For instance, one of the contractors requested the resident engineer to extend project A’s completion date due to B and C projects’ late completion. The contractor explained that they experienced adverse weather on multiple projects in the 2019 construction season, which ultimately led to project B’s late start on August 12, 2019. Throughout the spring/summer, contractors worked vigorously to make up for the lost work time by working more overtime and weekends than previously planned. In addition, contractors had hired multiple leased trucks and subcontracted a portion of their work to compensate for the lost time. Even with the added effort, there was no feasible way to make up for the abnormally wet spring that delayed the start/completion of their early-season projects.

Due to the high elevation and the amount of work to complete, the contractor anticipated that project B would begin in the spring of 2019. The contractor held a preconstruction meeting to start the project prior to May 1. Because of the abnormally cold and wet weather in March and April, the ground was too wet to begin until the first week of June. To make up for the late start, the contractor worked six 10-12 hours days a week as weather allowed throughout the summer, although the project was only bid to work 45-50 hours per week. As part of the increased production effort to make up for the lost month, the contractor leased eight additional trucks to assist in hauling special borrow excavation and crushed base to complete the project. Even with the additional days worked and the hiring of leased trucks, the contractor could not make up for the lost 30-plus days. The excavation and pipe crew on this project were scheduled to mobilize on August 12, 2019. Due to the delay of the previous project, this crew was unable to mobilize until October 21.

The contractor received another project, project C, and the anticipated start date was July 15, 2019. This project sits at an elevation of 9,400'. Typically, the snow at this location is gone near the July 4, 2019, holiday weekend. With the heavy snowfall that spring, the snow on the slope above this side did not melt off until mid-August. Once the snow melted, the contractor mobilized to the project site without delay. Again, the contractor worked six days a week and leased an additional excavator and motor grader to increase planned production to accelerate the project to make up for the lost time. With the increased person-hours and rental equipment, the contractor was able to complete a large portion of the work in a shortened duration, allowing the crew to mobilize to the project around October 1, 2019. Although this was much later than the scheduled start time for the specific project, this crew was initially planned to be on-site in early September to install reinforced concrete pipe and complete the work. Another vital factor that affects construction project delays is the change orders during execution. All the projects had change orders issued by WYDOT, with the range being one to six. Frequent change orders led to project delays and affected the other projects. A total of $690,000 in additional costs were issued in change orders for the five projects.

Out of 22 factors, 22.72% (weather, COVID-19, location of the projects, discovery of sinkhole, and erosion) were in the exogenous group, related to external factors. According to the evaluation of the DWRs, 36.36% of factors were related to the management group. The management group included starting delays of the projects by the contractors, accidents due to poor site safety, and traffic control issues due to poor construction methods. In addition, this group also had a shortage of materials and equipment, damaged equipment and mailbox, a clearing issue, and a communication gap between site management and the labor force. Approximately 31.81% of factors (change orders during the construction period, faulty materials, test issues, mill issues, inaccurate model, and calculation error) were in the technological group. And around 8.7% of factors (lack of skilled labor and labor's physical fatigue) were related to the labor group.

The research team also ranked the four major groups using RII. According to Table 4.3, the exogenous group factors, with an average RII of 0.97, ranked first over the management, technological, and "labor" group factors, which come in second, third, and fourth, with an average RII of 0.90, 0.57, and 0.30, respectively. Because of the management issue (especially the project's starting delay by the contractors), contractors faced more exogenous factors during their construction periods.

Table 4.3 Average RII and ranks

Group Factors	RII	Rank
Exogenous	0.97	1
Management	0.90	2
Technology	0.57	3
Labor	0.30	4

4.3.2 Comparative Analysis between Baseline Schedules and As-Built Schedules

After collecting DWR from the WYDOT regional offices, the research team created an as-built schedule for one project. Researchers noted each and every activity during the construction of the DWRs. Afterward, the research team merged and analyzed baseline schedules and DWRs to create as-built schedules. Then, a comparison between baseline schedules to as-built schedules is made to determine baseline schedule inaccuracies. Figure 4.2 shows a baseline schedule collected from WYDOT. The research team determined several inconsistencies in this baseline schedule when compared with the DWR data. There was no link between one activity and another, and there was an unexplained gap between the two activities. For instance, there was no link between crushing, dirt and pipe (concrete), and hot plant mix activities in the baseline schedule. Additionally, there was an unexplained timing gap between hot plant mix approaches, chip seals, delineators, and reclamation activities. In the DWRs, the researchers noticed an “unknown reason” for not working on a specific day. After creating the as-built schedule, the researchers compared it with the baseline schedule. Although there were only nine different activities in the baseline schedule, there were 17 different types of activities in the as-built schedule of the same project. In the baseline schedule presented in Figure 4.2, the nine different types of activities were crusher mobilization, crushing, dirt and pipe, milling plant mix, hot plant mix, hot plant mix approaches, chip seal, delineators, and reclamation.

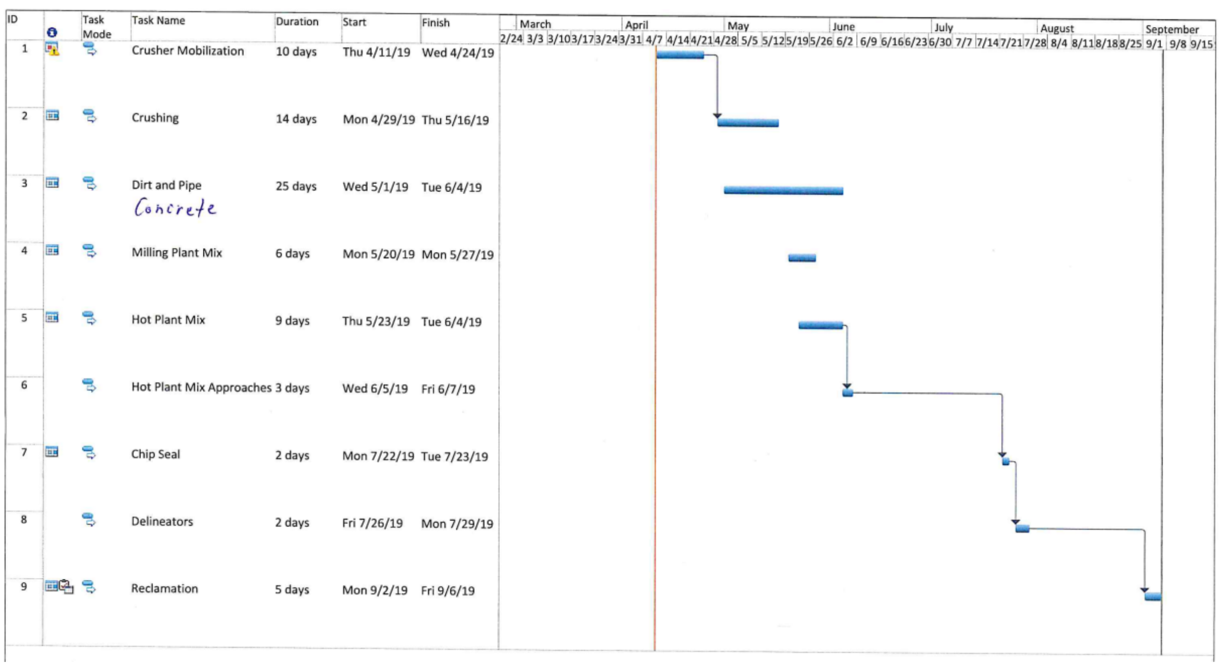
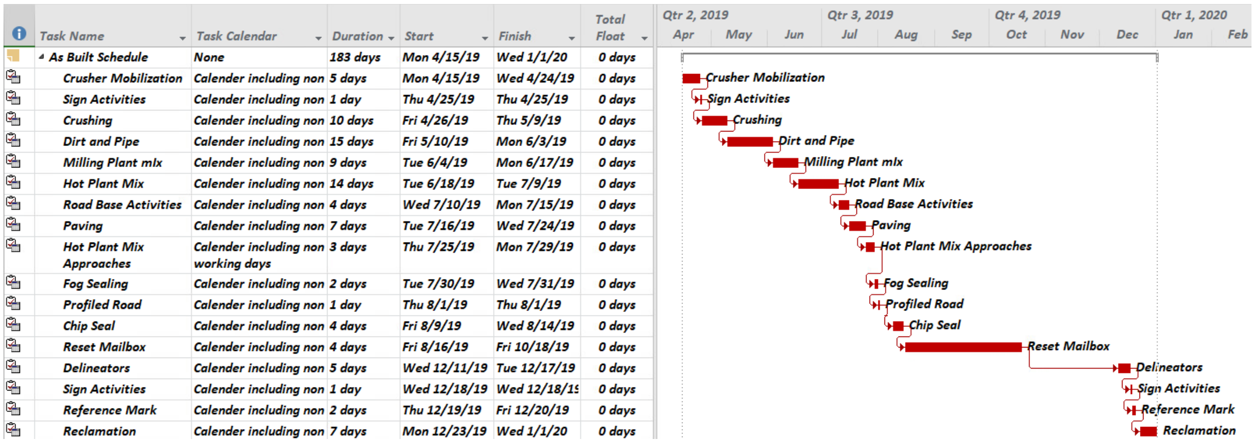


Figure 4.2 Baseline schedule

However, researchers noticed an additional eight different types of activities in the as-built schedule (Figure 4.3). These are sign activities, road base activities, paving, fog sealing, profiled road, reset mailbox, and reference mark. Contractors did not set up realistic durations for activities. For example, the “dirt and pipe” activity required 10 fewer days than the actual one, whereas the “hot plant mix activity” needed five more days than the baseline schedule. According to the baseline schedule and the as-built schedule, milling plant mix, hot plant mix, chip seal, delineators, and reclamation activities required more time than the baseline schedule. On the other hand, crusher mobilization, crushing, and dirt and pipe (concrete) activities required less time than the baseline schedule. The submitted baseline schedules typically have a start date and end date indicated; however, no early start or late finish is indicated. The research team obtained this information from the questionnaire survey respondents and the comparison between the selected baseline schedule and the survey results.



Task Name	Task Calendar	Duration	Start	Finish	Total Float
As Built Schedule	None	183 days	Mon 4/15/19	Wed 1/1/20	0 days
Crusher Mobilization	Calender including non	5 days	Mon 4/15/19	Wed 4/24/19	0 days
Sign Activities	Calender including non	1 day	Thu 4/25/19	Thu 4/25/19	0 days
Crushing	Calender including non	10 days	Fri 4/26/19	Thu 5/9/19	0 days
Dirt and Pipe	Calender including non	15 days	Fri 5/10/19	Mon 6/3/19	0 days
Milling Plant mix	Calender including non	9 days	Tue 6/4/19	Mon 6/17/19	0 days
Hot Plant Mix	Calender including non	14 days	Tue 6/18/19	Tue 7/9/19	0 days
Road Base Activities	Calender including non	4 days	Wed 7/10/19	Mon 7/15/19	0 days
Paving	Calender including non	7 days	Tue 7/16/19	Wed 7/24/19	0 days
Hot Plant Mix Approaches	Calender including non working days	3 days	Thu 7/25/19	Mon 7/29/19	0 days
Fog Sealing	Calender including non	2 days	Tue 7/30/19	Wed 7/31/19	0 days
Profiled Road	Calender including non	1 day	Thu 8/1/19	Thu 8/1/19	0 days
Chip Seal	Calender including non	4 days	Fri 8/9/19	Wed 8/14/19	0 days
Reset Mailbox	Calender including non	4 days	Fri 8/16/19	Fri 10/18/19	0 days
Delineators	Calender including non	5 days	Wed 12/11/19	Tue 12/17/19	0 days
Sign Activities	Calender including non	1 day	Wed 12/18/19	Wed 12/18/1§	0 days
Reference Mark	Calender including non	2 days	Thu 12/19/19	Fri 12/20/19	0 days
Reclamation	Calender including non	7 days	Mon 12/23/19	Wed 1/1/20	0 days

Figure 4.3 As-built schedule

4.3.3 GAO Scheduling Best Practices Benchmarking

The research team compared the selected baseline schedules against seven different best practices for project schedules defined by the GAO (Guide 2012; Han et al. 2017). A summary of the GAO recommended best practices is described as follows:

- Best Practice 1 (BP#1): The requirements for this best practice are capturing all activities, capturing all effort, work breakdown structure, activity names, and activity codes.
- Best Practice 2 (BP#2): The requirements for this best practice are sequencing all activities, predecessor and successor logic, incomplete and dangling logic, summary logic, data constraints, using lags and leads, and path convergence in the baseline schedules.
- Best Practice 3 (BP#3): Assigning resources to all activities, resource effort, and duration, loading activities with resources, and resource leveling are included in this practice.
- Best Practice 4 (BP#4): This practice includes establishing the duration of all activities, such as durations, estimating durations, and calendars.
- Best Practice 5 (BP#5): This best practice requires schedulers to create baseline schedules that can be traced horizontally and vertically.
- Best Practice 6 (BP#6): This best practice requires schedulers to confirm that the critical path is valid to manage the critical path effectively.
- Best Practice 7 (BP#7): This best practice requires schedulers to ensure that the total float is reasonable with regard to the total project duration. Float management is also included in this practice.

The research team compared five different projects in Wyoming against seven best practices for project schedules. According to Table 4.4, the baseline schedule of project #2 was better than any other project. During the evaluation of the baseline schedule of project #2, the research team noticed only the unavailability of proper assigning to all activities and float management. On the other hand, there was plenty of inconsistency in project #5's baseline schedule, and it did not satisfy any best practice requirements. The researchers did not find capturing and sequencing of all activities, proper assigning resources to all activities, establishing the duration, tracing horizontally and vertically, critical path, and float management requirements in the baseline schedule of project #5. The main weaknesses of these projects were to satisfy best practices three, six, and seven's checklists. However, around 80% of projects satisfy best practice four's requirements.

Table 4.4 Best practice (BP) for project schedule

Practice Name	Project #1	Project #2	Project #3	Project #4	Project #5
BP#1	×	✓	✓	×	×
BP#2	×	✓	✓	×	×
BP#3	×	×	×	×	×
BP#4	✓	✓	✓	✓	×
BP#5	×	✓	✓	×	×
BP#6	×	✓	×	×	×
BP#7	×	×	×	×	×

4.4 Conclusions

A daily work report is one of the most important documents to evaluate a project's activities. During the DWR evaluation to create the as-built schedules, the research team determined 22 factors divided into four main groups that often lead to construction delays and cost overruns of the projects. These groups are management, exogenous, technology, and labor groups. After evaluation of the DWRs, the research team determined the top five significant delay factors, which were weather, starting delay of the projects by the contractors, COVID-19, equipment issues, and traffic control issues, respectively. Besides, COVID-19 has played a critical role in delaying public transportation projects for the past two years. Most contractors faced a scarcity of materials, equipment, labor, and full-time personnel. Quarantines and vaccination rules created schedule delays, and it was common in all of the projects based on the DWRs.

Researchers also merged the baseline schedules and DWRs to create as-built schedules. During the development of the as-built schedules, researchers focused on each and every activity from the DWRs. The research team determined several inconsistencies in the baseline schedules and the DWRs. Researchers noticed unrealistic durations for activities and the unexplained durational gap in the baseline schedules. Also, the research team compared the baseline schedules with the seven best practices for project schedules. Unfortunately, all five projects were not able to satisfy the requirements of best practices three and seven. Assigning resources to all activities and float management were included in best practices three and seven, respectively. Project #5's baseline schedule was not accurate enough to fulfill any of the best practices. Comparatively, #2's baseline schedule is slightly better than the rest of the other projects because of satisfying five best practice requirements out of seven.

4.5 Recommendations

According to the above discussion, the following recommendations are suggested.

a) Contractors and public agencies must maintain an agreement before the project awarding date to start the project according to the baseline schedule. Despite additional equipment, workforce, and more overtime, contractors could not make up for the lost work due to starting delays.
b) Workforce resources should be improved through training before starting the project, especially health- and safety-related training. The research team noticed that accidents due to poor site safety were common in most of the projects, and it ranked 6 (RII of 0.52) out of 22 different types of factors.
c) Before starting the project, the highway agency must be careful about the objectives and the long-term plan. A realistic plan and goal will limit design changes. It will reduce the delay of the project and mitigate additional costs. Researchers noticed that change orders during the construction period were common in all of the projects, and these change orders affected completing the projects on time.

d) Contractors should explain the "unknown reasons" in the DWRs to improve the documentation process. The research team found several "No Work Today" notations in the DWRs, but there were no specific reasons behind them.
e) Baseline schedules should be realistic in representing durations and not just satisfying contract requirements. Researchers noticed that most of the baseline schedule was not accurate enough. Many activities required less time than the original one, whereas many of them required more time than baseline schedules. The research team determined the proper establishment of the duration of all activities from the selected baseline schedules.
f) All of the projects did not satisfy the best practice for schedule requirements. The research team determined that all baseline schedules did not capture all activities. Additionally, baseline schedules did not have a work breakdown structure, activity names, or codes.
g) The contractor should include proper sequencing of all activities in the baseline schedule. Researchers noticed from the selected baseline schedules that there was no proper sequencing of all activities, such as predecessor and successor logic, summary logic, using date constraints, lags, and leads.
h) The main weakness of these baseline schedules was the unavailability of the assigning resources to all activities. Contractors should focus on assigning resources and efforts in their project schedules.
i) Around 80% of the total projects had no critical path identified to manage the schedule or critical work. The contractor should identify and confirm the validity of the critical path before submitting the baseline schedules.
j) Finally, contractors have to ensure a reasonable total float in their baseline schedules. None of the submitted baseline schedules had float information presented to WYDOT.

5. QUESTIONNAIRE SURVEY

5.1 Introduction

This chapter presents a description and discussion of the questionnaire survey distributed to WYDOT resident engineers and district construction engineers. The principal purpose of this survey was to determine the challenges and root causes of schedule delays for Wyoming transportation projects. Based on the responses collected, the research team explained the significant factors that influence public transportation project completion in Wyoming. Additionally, the research team used the RII method to determine the most important factors responsible for schedule delay. Finally, a list of recommendations to mitigate schedule delay is discussed at the end of this chapter.

5.2 Description

The survey was distributed electronically to 28 resident engineers and district construction engineers of the five Wyoming districts. The survey consisted of closed-ended and open-ended questions.
The survey was divided into10 sections. First, respondents were asked to provide personal information for potential follow-up. Second, the research team asked questions regarding schedule delays in the past three years. Third, participants were asked for the overall rating of the schedules submitted by contractors prior to commencement of work in terms of accuracy, logic representation, tracking and controlling construction activities, and communication scope of work and timeline. Fourth, the questions were related to the significant factors of schedule delay. Fifth, respondents were asked to provide a rating of the frequency of the work types listed in the last three years. Sixth, project delivery methods have been dealt with in the state of Wyoming. Seventh, strategies have been utilized to encourage contractors to finish the project on time. Eighth, an open-ended question related to the strategies employed in the district to avoid/mitigate schedule delay was. Ninth, questions related to the challenges that COVID-19 brought to completing WYDOT projects within schedule were asked. Finally, the survey included an open-ended question so respondents could provide recommendations to improve the quality of schedules submitted by contractors (i.e., enforcing schedule standards and use of specific software).

5.3 Result and Analysis

The research team received complete responses from 14 resident engineers and four district construction engineers (64.23%). There were two incomplete responses. Among the 18 complete respondents, 72% agreed to a follow-up interview in the future. Figure 5.1 indicates the graphical representation of the location of the respondents. It shows that all survey participants represented five different districts of Wyoming.

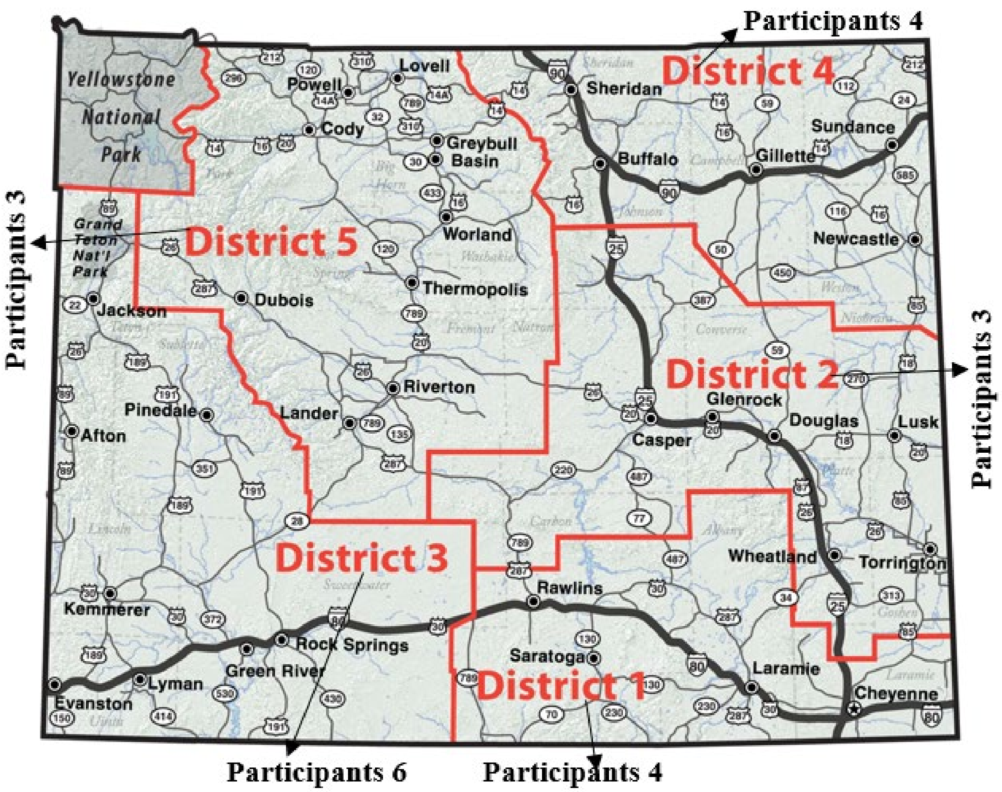


Figure 5.1 Location of the participants

According to Figure 5.2, although preventive maintenance projects were a little higher, all of the projects were almost equally distributed in the last three years. The preventive maintenance projects were around 38%, whereas 34% of projects were related to new construction and 28% were related to major rehabilitation types of projects.

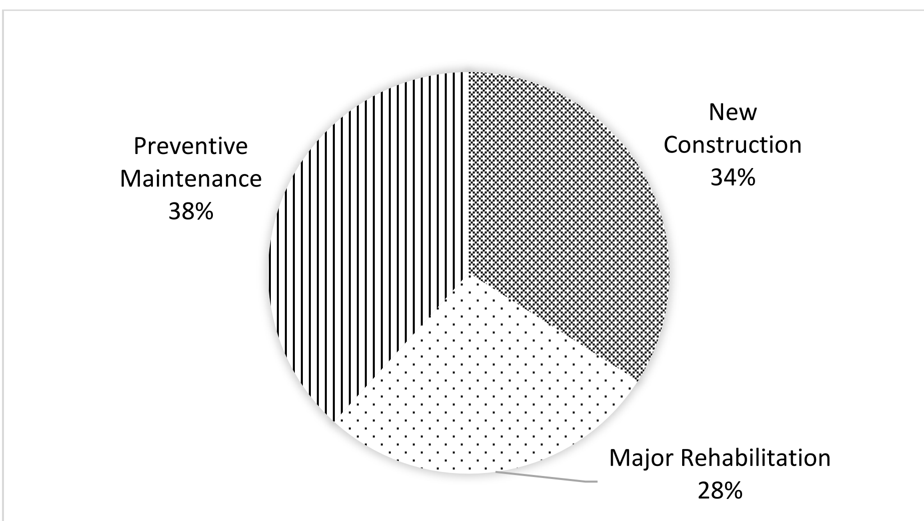


Figure 5.2 Frequency of the work types

According to the survey, most importantly, 88.89% of responders were using the traditional design/bid/build method (Figure 5.3) to deal with in the state of Wyoming, whereas 11.11% used the construction management general contracting method.

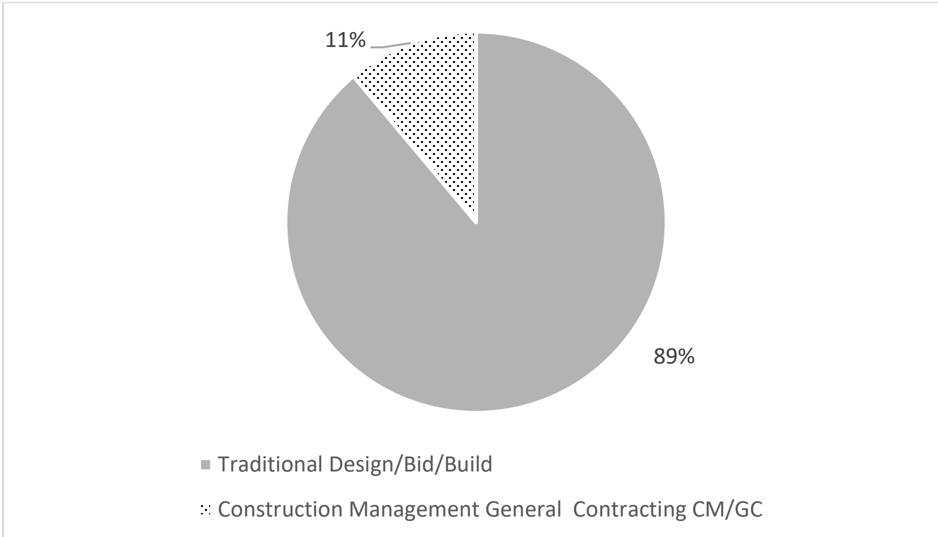


Figure 5.3 Project delivery method

Figure 5.4 shows that 43% of respondents said the projects had been delayed beyond the original schedule because of the contractors. On the other hand, 25% said the reason for the schedule delays were due to WYDOT, and 32% mentioned other reasons for schedule delays.

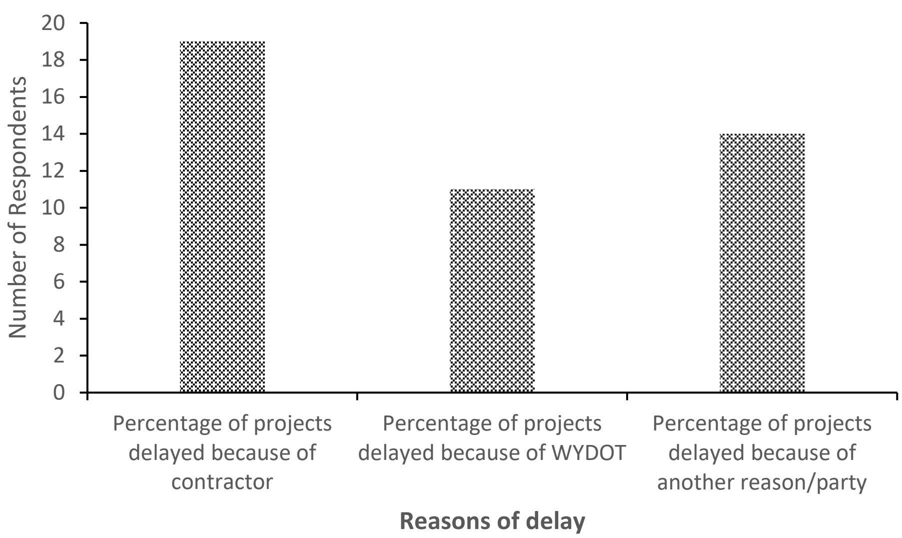


Figure 5.4 Projects delayed beyond the original schedule

The research team used a 5-point Likert scale so respondents could rate the quality of the schedule. Respondents were asked to rate the quality of the schedules submitted by contractors prior to commencement of work in terms of accuracy, logic representation, tracking and controlling activities, and communication scope of work and timeline. Unfortunately, 60% of respondents marked it as below the average rate, and only 5% said the overall schedule rate was good. According to Table 5.1, only 35% of respondents rated the overall rating schedules submitted by the contractors as average, and there were no "excellent" project schedule ratings.

Table 5.1 Overall rating schedules submitted by the contractors prior to commencement of work

Rating	Percentage of the respondents
Poor	5.00%
Fair	55.00%
Average	35.00%
Good	5.00%
Excellent	0.00%

The research team received responses of the 10 factors regarding schedule delay (Table 5.2). Researchers determined those factors while evaluating the DWR data from the last three years' projects among the five Wyoming districts. Based on the ranking of the causes, it is possible to evaluate the most important ones that influenced project time. The research team used the RII method to determine the most critical factors responsible for the delays in construction projects, which were obtained from the survey. Researchers analyzed the gathered information through the Likert scale based on a 5-point scale with values from 1 to 5, where 1, 2, 3, 4, and 5 represent a very low, low, moderate, high, and very high response, respectively. The research team chose the following equation of the RII to evaluate the significant delays.

$$RII = \frac{\Sigma \mathbf{W}}{AN} \text{..(i)}$$

Where W represents the rating given to each factor (ranging from 1 to 5) by the respondents, A is the highest weight (i.e., 5 in this research study), and N is the total number of respondents. The higher the RII value, the more important it is. The "labor shortage in every scope of work (skilled, semi-skilled, unskilled)" factor was the most significant; and "accident or poor site safety management" was the least significant. A shortage of required equipment and poor communication with contractors were the 2nd and 3rd most significant factors, respectively. The "Contractors not starting work as stipulated" factor was the 4th most significant, and rework during construction was 5th. According to the survey, COVID-19, weather, traffic control, and the geographic location of the project were the 6th, 7th, 8th, and 9th significant factors for the schedule delay.

Table 5.2 The rank of all the causes of project delays

SL	Factors	RII	Very Low	Low	Moderate	High	Very High
1	Labor shortage in every scope of work (skilled, semi- skilled, unskilled)	0.78	1	0	5	6	6
2	Shortage of required equipment or materials	0.71	0	3	5	7	3
3	Poor communication and coordination with Contractor and other parties	0.68	3	1	4	6	4
4	Contractor not starting work as stipulated	0.57	1	7	4	6	0
5	Rework due to errors (design/faulty materials/ taste issue) during construction	0.5	3	5	8	2	0
6	COVID-19	0.48	4	7	5	0	2
7	Severe weather condition at the job site	0.44	3	10	4	0	1
8	Traffic control issue	0.37	7	8	2	1	0
9	Geographic location of the project	0.34	8	7	3	0	0
10	Accident or poor safe management	0.28	12	5	1	0	0

The survey also contained an open-ended question regarding other factors that affected the project schedules. Most of the resident engineers supported a physical meeting of the contractor with RE at the project prior to bidding on the job to avoid unexpected project delays. One of the respondents suggested that making it mandatory to do a job showing with the RE on projects over $1 million would eliminate many problems that pop up either in claims or delays to the project. Escalating and fluctuating material costs and delivery schedules were also significant factors for most of the responders. Geological issues and the unknown factors that occur during construction were also significant factors for schedule delays.

The research team asked about the strategies employed by the district to avoid schedule delays, and participants provided detailed responses about those. Most of the responders said consistent and continual communication with the contractor was the main strategy to mitigate schedule delays. Many of them followed weekly progress meetings and schedule updates. Some of them said they were open to giving more time for extra work that was beyond the control of the contractor. However, some of the respondents said that liquidated damage strategies are effective, whereas some of the respondents were encouraged to follow incentive/disincentive strategies to avoid schedule delays in the projects.
Most of the responders (around 46%) used liquidated damage strategies (Figure 5.5) to deter contractors from finishing their projects on time. Around 27% of responders used the incentive/disincentive method, and 21% of responders used the cost-plus-time (A+B) strategy to complete the project in a timely manner.

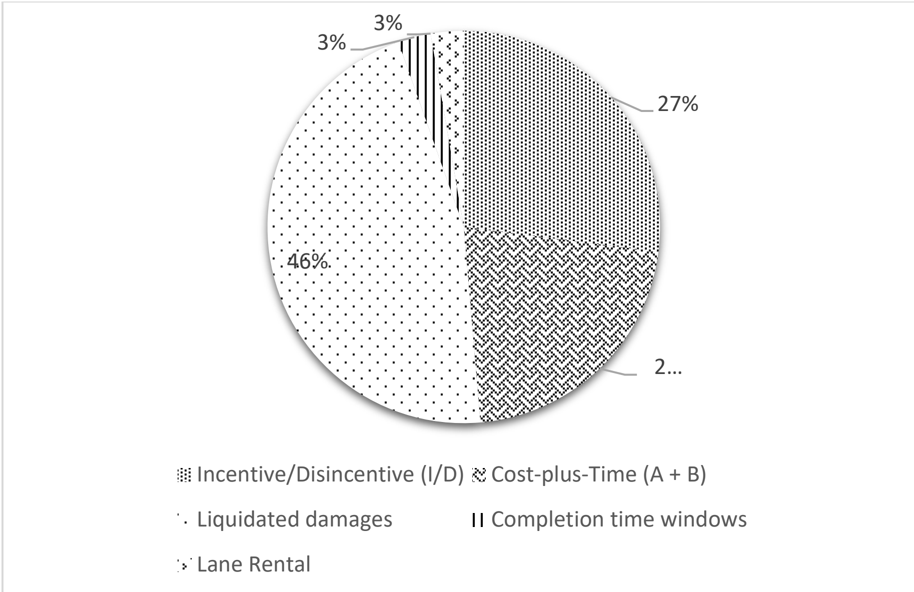


Figure 5.5 Strategies for completing projects on time

The significant challenges COVID-19 brought to completing WYDOT projects within schedule were personnel issues, labor and material shortages, and price increases. However, some of them mentioned that there were no challenges and even helped them to reduce traffic.

5.4 Recommendations

The main recommendations for improving the submitted schedule are as follows:

a) Based on the respondents' opinions, enforcing mandatory schedule submittals with consistency across a district and the state was the main criteria to improve schedule quality. The resident engineers and district construction engineers suggested having a pay item on most jobs associated with the schedule. Instead of holding an entire estimate, that item could include a set cost, which could be pulled from the contractor if a schedule was late or incomplete. And that money would not be returned later if the schedule eventually showed up. For example, it is a mandatory regulation for the schedule to be due on May 1; if it showed up on May 10, after the resident engineer asked for it, then the contractor would not receive that $1,000 for the May pay application, and it would follow the same approach in the next month.

b) Although schedule standards helped to improve the quality of schedules submitted by contractors, they still did not make them accurate. Some of the respondents mentioned that contractors who were poor at schedules tended to overlook 75% of the items needed and would just put one together because it was required. Contractors should intend to stick to it.

c) Many resident engineers recommended allowing other relationships other than finish to start in the submitted schedules. Although finish to start was the most commonly used relationship, allowing start to start or percent complete would allow for better modeling of some of the current situations resident engineers were facing. Some of the respondents said that start to start relationship might be better for material procurement. The submitted schedule typically had a start date and end date indicated; however, no early start or late finish is indicated, so any delay puts the contractors behind schedule. Typically, resident engineers received schedules that show rapid work and an early finish.

d) The contractor should submit accurate schedules that satisfy minimum requirements. One of the respondents shared experiences that about half of the contractors are meeting the bare minimum of the requirement and are not really tracking the progress of the project through the software. Again, about half are just linking what they see as the critical path and not connecting any other tasks. Then when the task is complete, they just put the start date and end date. They are not using percent complete when updating schedules. To do this effectively, the respondent recommended that most contractors would require someone full time just to manage the schedules.

e) Respondents also mentioned that submitting for a specific software did not help WYDOT as there was no one that could utilize the submitted schedule. Education on scheduling software for the contractors should be mandatory. Contractors could use some training on scheduling and on knowing when they have more than enough work and not overstretch themselves.

f) According to the opinions of the respondents, some sort of incentives for schedule accuracy and disincentives for inaccuracy is also important to improve schedule quality. Contractors should not overestimate productivity more than reality. Most of the contractors showed a high production value that they would either not attain or it did not account for anything like a breakdown. The contractor should set up realistic durations for work activities. Contractors typically overestimated their anticipated production rates without taking weather, labor and equipment shortages, etc. into consideration.

g) Contractors should focus on the anticipated weather delays and float management in their submitted schedules. Respondents rarely received the standard specifications list or anticipated the number of weather delays per month into the schedule. Besides, schedules rarely showed any float indicated on the schedule.

h) Finally, subcontractors should clearly define the schedules. According to the respondents, this problem seems to be all-encompassing. Some schedules list non-critical path items like fences or signs as a continuous activity from the beginning to the end of the project, which does not give an indication of when they anticipate completing the work or how long it will take. Others list narrow windows for these activities that show how long they anticipate them to take and when they might start; however, most of the time, they seem to have little bearing on when the subcontractor will actually be working on the item.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the summary of the findings, discussions, conclusions of the research, and a list of recommendations for future projects. The main objective of this chapter is to discuss the main conclusions and recommendations drawn from the different chapters presented in this report.

6.2 Summary of the Research Study

This research presents challenges of schedule delays for Wyoming transportation projects. The research team evaluated five different transportation projects' baseline schedules and DWRs.

The researchers' first step was to review other states' DOT schedule standards and practices for their highway construction projects. The researchers looked at computerized and manual systems in current use by other state DOTs. DOTs have developed various guidelines to identify the general order of managing work items. According to the previous studies, most DOTs require preconstruction conferences and weekly planning and reporting meetings to complete the projects on time. DOTs also require schedule standards that demonstrate the interrelationship between the activities and the project's regulating items of work. It was found that DOTs provided minimum schedule requirements of the progress schedule, CPM schedule, update schedule, baseline schedules, DWRs, and the application of the software to prepare each schedule. The review of the literature found that DOTs used visuals, logical diagrams, bar charts, CPM schedules, and personnel experiences to determine project duration.

The research team's second step was to analyze the collected data, such as DWRs and baseline schedules from the WYDOT regional offices. After collecting data, the research team compared DWRs to baseline schedules to determine the actual activity duration, activity sequencing, work stoppages, and the factors that affected public transportation projects. Researchers used the RII method to determine the significant factors of delay. During the DWR evaluation, researchers marked the most critical factors, which were frequent and significant in the DWRs, whereas less critical factors were less frequent and significant. This research has determined 22 factors divided into four main groups that often lead to construction delays and cost overruns for Wyoming public transportation projects. These groups are management, exogenous, technology, and labor groups. The main weakness was the failure to meet schedule requirements. COVID-19 has also played a critical role in delaying public transportation projects for the past two years. Most contractors faced a scarcity of materials, equipment, labor, and personnel. Among the 22 various factors, the overall top five causes of delay were weather, starting delay of the projects by the contractors, COVID-19, equipment issues, and traffic control issues due to inferior construction methods, respectively.

Researchers also merged and analyzed baseline schedules and DWRs to create one as-built schedule. The comparison between baselines to as-built schedules found several inconsistencies in the collected data. There was no link between one activity and another, and there was an unexplained gap between the two activities. In the DWRs, the researchers noticed an "unknown reason" for not working for several days. The research team also compared the five selected baseline schedules against seven different best practices for project schedules defined by the GAO. It was found that none of the five different projects satisfied the best practice for the project schedule's requirements. Selected baseline schedules had only the establishment of the duration of all activities. However, all of these projects lacked the assigning resources to all activities and float management. Among the five selected baseline schedules, only one project's baseline schedule was slightly better because of capturing all activities, sequencing all activities, establishing of the duration of all activities, horizontal and vertical traceability, and critical path management. On the other hand, the remaining projects' baseline schedules had missed all of these requirements except the establishment of the duration of all activities. The research team determined one of the project's baseline schedules was the most inaccurate, and it did not satisfy any of the best practice requirements.

The researchers' third and final step was to conduct a questionnaire survey distributed to WYDOT resident engineers and district construction engineers. The main purpose of this survey was to determine the challenges and schedule inaccuracies of public transportation projects in Wyoming. A list of recommendations for improving the submitted baseline schedules were also included in this survey. The research team received 64.23% of completed responses among the 28 participants. There were 10 different types of questions asked of the respondents. Based on the survey, researchers found an almost equal distribution of work types, such as preventive maintenance, new construction, and major rehabilitation type of activities. The traditional design/bid/build method was the most popular in Wyoming, and around 90% of the respondents supported it. The survey also showed that 43% of respondents said the projects had been delayed beyond the original schedule because of the contractors. On the other hand, 25% said the reason for the schedule delay was due to WYDOT, and 32% mentioned the other reasons for the schedule delay. In that survey, around 60% of the respondents marked the submitted schedule as below average, whereas 35% rated it as average. According to the questionnaire survey, around 46% of respondents suggested using liquidated damage strategies to mitigate this schedule delay. However, about 27% supported using the incentive/disincentive method, and 21% of respondents used the cost-plus-time (A+B) strategy to complete the project on time.

The research team also asked the respondents to rate the 10 different factors regarding schedule delays. Researchers found inconsistency between the survey results and DWR analysis regarding the factor of schedule delays. Although in the DWR analysis, researchers found the weather as the most significant factor, respondents ranked it as seventh out of 10. Among the 10 different factors, the overall top five significant delay factors were labor shortages in every scope of work, shortages of required materials, poor communication and coordination with the contractor, stipulated starting delays by the contractor, and rework due to errors during construction, respectively. The research team concluded that the main reasons for these differences was the inaccuracy of the DWRs.

6.3 Recommendations

Based on the questionnaire survey responses, literature review, and data analysis, the following recommendations are discussed as follows:

a) The contractor and engineers have to be in agreement when starting the project according to the baseline schedules in the preconstruction meeting. After evaluating the DWRs and baseline schedules, the research team found that most of the contractors were not able to complete the projects due to starting delays of their projects. Based on the survey result, it was the fourth ranked delay factor out of 10 different significant delay factors of the projects.
b) Contractors have to submit a realistic duration of activities in their baseline schedule. According to the questionnaire survey, most of the respondents suggested continuing a weekly planning and reporting meeting with the engineers. This weekly planning meeting includes schedule revisions, which are required in the event of any major change to the work. Through this meeting, the communication between engineers and contractors will be improved, and the contractor will have an opportunity to discuss the delay reasons behind any activity's completion date. The main reason for the communication with the engineer is that significant modifications can change the critical path and controlling item of work. Besides, the contractor should include the reasonable total float in their baseline schedules. The research team evaluated selected baseline schedules, and none of the submitted baseline schedules had float information presented to WYDOT.

c) Contractors should follow a schedule standards requirement. According to the literature review and the questionnaire survey, enforcing mandatory schedule submittals with consistency across a district and the state is the main criterion for improving schedule quality. The resident engineers and the district construction engineers already included a pay item on most jobs associated with the schedule standards. Respondents recommended that contractors take mandatory education on schedules, and contractors must take necessary training on schedules.
d) Baseline schedules should get approval after meeting the requirements of some or all GAO best practices for project schedules. The research team compared selected baseline schedules against GAO's seven different best practices for project schedules. Unfortunately, none of the selected projects submitted to WYDOT met the GAO best practice requirements. The contractor should focus on the availability of the capturing of all activities, sequencing all activities, assigning resources to all activities, establishing the duration of all activities, horizontal and vertical traceability, validation of the critical path, and float management in their baseline schedules.
e) Contractors should not only depend on the baseline schedule. Contractors have to submit a progress schedule in a timely manner and a monthly updated schedule to complete the project on time. During the evaluation of the baseline schedules, researchers found an unnecessary durational gap between activities, which led to the project delay.
f) DWR data are among the most important documents of a project, and they are a record of all phases of the project. Contractors should prepare an accurate DWR to complete the project on time. During the DWR evaluation of the selected projects, the research team found several inconsistencies. Researchers noticed an "unknown reason" for not working for several days. Similarly, the research team did not find accurate starting and ending dates for most of the baseline schedule's each and every activity in the DWRs. The research team found various significant delay factors from the DWR analysis and the questionnaire survey. For example, from the DWR analysis, researchers found weather as the most important delay factor, whereas a labor shortage in every scope of work factor was the most critical delay factor based on the questionnaire survey. The research team concluded that missing information and inaccurate information about the DWRs was the main reason for these different outcomes. The contractor should prepare an accurate DWR every day, and the contract administrator must approve or review this document.
g) Contractors must give a description of their planned schedule software to get the approval during the preconstruction meeting. The respondents noted that submitting for a specific software does not help WYDOT as there is no one that can utilize the submitted schedule. The software must be compatible with the engineer's current version of the operating system. For example, Primavera P6 for Windows or an equivalent must be included in the scheduling software.
h) Contractors have to improve the quality of the baseline schedules to complete the project on time. Most of the respondents found that the submitted schedule typically has a start date and end date indicated; however, no early start or late finish is indicated, and so any delay puts the contractors behind schedule. Typically, resident engineers get schedules that show rapid work and an early finish, and this sets them up to request either more money or more time.

6.4 Limitations

This study was limited to five projects located in Wyoming. Further research should be undertaken to support the recommendations and conclusions presented in this research.

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