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Construction Delay Analysis Using Daily Work Report Data for Short Construction Seasons

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Abstract: Some regions and states, such as Wyoming, have harsh weather conditions, forcing most transportation projects to be completed under tight schedules. However, construction projects are not only delayed by weather conditions, but also delayed by other factors such as contractor's competency, resource availability, coordination issues, and safety. Also, the construction method, geographical location of the projects, and inability to follow baseline schedules accurately due to the contractor's resource allocation are also reasons for the delay. This paper discusses the main reasons for the delay in the public transportation projects based on Daily Work Reports (DWRs) from five different transportation projects of the last three years in Wyoming. This paper focuses on the inconsistencies of the contractor's schedules to complete the project according to the baseline schedule. First, the authors collected DWRs and baseline schedules from the Wyoming Department of Transportation (WYDOT). Second, the DWR data are compared against the baseline schedules to determine the reasons for delaying their significance. Finally, the paper presents the recommendations to mitigate the effects of delays on public transportation projects as well as to improve the documentation process of DWR data.

Keywords: Transportation Project, COVID-19, Baseline Schedule, Daily Work Reports, Schedule Delay.

1. INTRODUCTION

Highway construction projects mainly consist of outdoor activities that are heavily affected by different operational and environmental conditions [1]. Most studies identify factors of uncertainty and parties responsible for the delay [2]. Delays in construction projects, cost overruns, and low quality have long been common problems in construction and engineering [3]. Many factors cause delays in construction projects, some falling within the owner's liability and some within the contractor's [4]. Delays also caused by the owner, such as delay in submitting drawings and specifications, frequent change orders, incorrect/insufficient site information, and communication gap between the main contractors and subcontractors [5]. Some of the factors affect the construction industry due to the complex relationship among employers, architects, engineers, and the contractors [4]. In contrast, others are local problems or problems out of human control, such as weather, floods, earthquakes, and Coronavirus (COVID-19) [4].

In the last three years, the most critical factors which was responsible for the construction delay was COVID-19. COVID- 19 has a significant impact on almost all areas of economic life in the world [6].The spread of this disease poses an unprecedented challenge with unpredictable economic consequences [7]. It is impacting the public construction industry by causing operational and financial issues [8]. Besides Covid-19, the weather is another important factor, especially in the short construction season.. And when it comes to weather-related delays, a time extension provision that does not include weather delays can be confusing and argumentative. [9]. Due to climate change influences, the construction industry's vulnerability to weather-related delays has become an essential topic within the last decade [10]. Consequences of adverse weather on construction projects include productivity problems, work stoppage, damaged materials, and thus schedule delays and cost overruns [9].

Many construction projects fail to meet their baseline schedules because of different factors. After identifying the most critical causes of delay, the parties to the projects shall then be able to reduce delays to the projects. Despite various attempts to find a generic solution to mitigate delays, the performance of projects continues to be poor, and delay in projects seems inevitable [11]. Well-organized recorded data of completed highway projects, where a project's progress is documented, can be an excellent source of information for developing reliable production rate estimates [1]. This study utilizes historical project records of the last three years such as DWRs, baseline schedules, and construction reports from the WYDOT regional offices to identify critical factors affecting the production rates of significant highway activities.

This paper aims to evaluate the baseline schedules submitted to WYDOT before the commencement of work in terms of activity sequencing, weather impacts, and scope gaps. Finally, the expected result of this study is to provide guidelines and recommendations for engineers at the WYDOT to help manage the root causes of short-term construction project delays.

2. LITERATURE REVIEW

Delay is defined as a time overrun beyond the project completion date agreed by the parties. Various approaches were used in the previous studies to determine the causes of delays in public transportation projects, and DWRs analysis was one of them.

Jeong et al. (2019) investigated a production rate-based method to evaluate contractors' performances. Based on each controlling activity's historical data, a three-tier categorization (i.e., high performance, medium performance, and low performance) was suggested for each activity. Monte Carlo simulation was used to establish distribution for each tier to make distinctions among the three tiers. For a specific project, contractors could be evaluated to categorize those activities relevant to the project [12].The study of Woldesenbet et al. (2012) showed that DWR-based production rates were significantly different from Oklahoma Department of Transportation (ODOT) production rate chart, experienced resident engineers' and contractors' estimates. It also indicated that conventional approaches in estimating production rates such as the rule of thumb, experts' opinion, and engineering judgment might be erroneous, leading to incorrect estimation of activity duration and project contract time [13]. Most of the researchers evaluated factors affecting construction delay from the historical data such as DWRs by using the Relative Importance Index (RII) method. Jarkas [11] applied the RII method to determine the ranking of the different delay factors.The primary outcome of the Jarkas [11] research was the errors and omissions in design drawings, then change orders during execution, and the third-ranked was a delay in responding to requests for information. In Turkey, "financial factors" were the first-ranked to be considered [14].

Table 1 depicts the overall ranking of the four major groups which are labor, technological, management, and exogenous (relating to or developing from external factors) in the extended construction seasons [15;16]. Jarkas (2012) and Jarkas (2015) have confirmed the prominent influence of the labor group factors on the productivity of construction operations in the extended construction seasons (Kuwait and Oman). The labor group factors ranked first with an average RII of 0.793. On the other hand, the technological groups, management groups, and exogenous group factors come in second, third, and fourth, with an average RII of 0.786, 0.725, and 0.693, respectively. Thus, this research will also use similar method to determine critical factors of delay.

Table 1. Group factors: average relative importance index and ranks achieved

Productivity group	Group factors average RII	Group rank
Labor	0.793	1
Technological	0.786	2
Management	0.725	3
Exogenous	0.693	4

3. RESEARCH METHODOLOGY

Figure 1 including phases I, II and III illustrate the research methodology used in this paper to identify causes of delay and recommendation for improvement. The study is conducted in in three main phases.

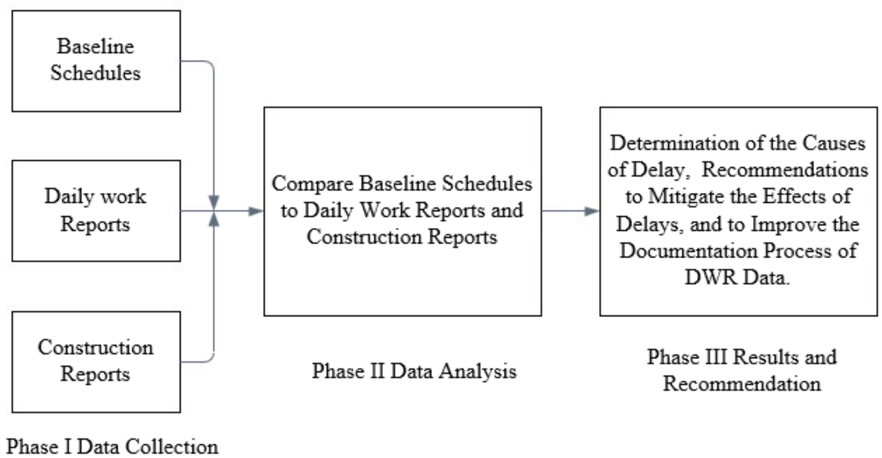

Figure 1. Research methodology and phases

In phase I, the research team collected data from the WYDOT regional offices. In phase II, the researchers compared the baseline schedules with DWRs and construction reports. Finally, the research team provided recommendations to mitigate the effects of delays and improve DWR data's documentation process.

3.1. Data Collection

The research team collected baseline schedules, DWRs, and construction reports data of the five different projects of the district-5 in Wyoming. 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 the complete reclamation. Contractors illustrated the projects' activities through Gantt charts which indicated the number of days required per activity. On the other hand, 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. The projects' scope of work ranged from new construction to maintenance and rehabilitation. These projects included various activities such as grading, placing crushed base, concrete slab replacement, concrete pavement, curb, and gutter, electrical, placing floors, chip seal, box removal, and sidewalk replacement.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.

3.2. Data Analysis

After collecting DWRs, the research team compared baseline schedules to DWRs and construction reports. Researchers analyzed DWRs to determine the actual activity duration, activity sequences, work stoppages, and the factors that affected public transportation project delays in short construction seasons. There were inconsistencies between the baseline schedules and DWRs. In the DWRs, The authors noticed 'unknown reason' for not working on specific day. For example, one of the projects, 'dirt and pipe' activity, required 18 days less time than the actual one, whereas 'hot plant mix activity' needed six more days than the baseline schedule. Researchers found twenty-three delay factors from the DWRs and construction reports (Table 2). The authors categorized all the delay factors into four groups: exogenous, management, technological, and labor. During the evaluation of the DWRs, researchers marked the most critical factors which were frequent and affected other factors, and less critical factors were less effective.

Based on the ranking of the causes, it was possible to evaluate the most important ones that influenced project time. The authors also used the RII method to determine the most critical factors responsible for the delay in the construction projects which were obtained from DWR. 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. Authors determined the scores for each factor and group of factors based on the frequency, number of delay days, and severity weight in the projects from the DWRs.The researchers used the following equation of the RII to evaluate the significant delays of the five different projects.

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

Where W, represents the rating given to each factor (ranging from 1 to 5) by the researchers, 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.

4. RESULTS AND DISCUSSION

According to the data analysis, 22 factors into four groups such as management, exogenous, technological, and labor are responsible for the delay in public transportation projects are presented in Table 2. In this study, the weather was the main factor that ranked 1, obtaining 0.88 RII, starting delay of the projects by the contractors ranked 2 (0.72 RII), and COVID-19 ranked 3 (0.67 RII). Although there was no specific delay data by the COVID-19 in the DWRs, it had significant impacts on other factors such as lack of skilled labor, equipment issue, shortage of materials, and communication gap. COVID-19 was vital in delaying construction projects. According to the construction reports from WYDOT, contractors arranged 14 days of self-quarantine and implemented it to practice social distancing in the workplace. When employees experienced symptoms, the contractor sent them home until they could provide a negative test for COVID-19. As a result, the operating speed of most of the projects was slow, and contractors faced a shortage of materials, lack of equipment availability, and labor. Before the COVID-19 pandemic, project superintendents were available all the time in person during the project. Because this was not possible during the pandemic, there was a communication gap between site management and labor force. Also, the mill had some issues, such as sinking through the asphalt base due to soft area and lack of fully operational capability. Projects were also affected by the calculation issue of the flare (safety devices) finishing time which required more than the estimated time.

Table 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. 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 the 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 that had ultimately led to the late start date on the project B of 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 pre-construction meeting to start the project prior to May 1st. Because of the abnormally cold and wet March and April, the project 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 effort to increase production 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+ days. The excavation and pipe crew on this project were scheduled to mobilize on August 12th, 2019. Due to the delay of the previous project, this crew was unable to mobilize until October 21st.

The contractor got another project ”Project C”, and the anticipated start date was July 15, 2019. This project sits at an elevation of 9400’. 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 the planned production to accelerate the project to make up for the lost time. With the increased person-hours and rent 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 was the change orders during execution. All the projects had change orders issued by the WYDOT, and the range was one to six. Frequent change orders led to project delays and affected the other projects. A total of $690000.00 additional costs were issued in change orders for the five projects.

Out of 22 factors, 22.72% (Weather, COVID-19, location of the projects, discover sinkhole, and erosion) were in the exogenous group, related to external factors. 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. Besides, this group also had a shortage of materials and equipments, damaged equipment and mailbox, clearing issue, and communication gap between site management and the labor force. Approximately 31.81% of factors (Change orders during the construction period, faulty materials, test issue, mill issue, 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.

Researchers also explained the overall ranking of the four major groups. According to Table 3, the 'exogenous' group factors, with an average RII 0.97, rank 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 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

5. CONCLUSIONS AND RECOMMENDATIONS

This research has determined 22 factors divided into four main groups that often lead to construction delays and cost overruns for the public transportation projects in Wyoming, USA. These groups are management, exogenous, technology, and labor groups. The main weaknesses were the failure to meet schedule requirements. Besides, COVID-19 played a critical role in delaying the public transportation projects for the past two years. Most contractors faced 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 the inferior construction methods, respectively.

According to the above discussion, the following recommendations are suggested. (i) Baseline schedules should be realistic durations and not just satisfy contract requirements. (ii) 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, labor workforce, more overtime, contractors could not make up for the lost work due to starting delay. (iii) Workforce resources should be improved through training before starting the project, especially health and safety-related training. We 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. (iv) 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. (v) Contractors should explain the 'unknown reasons' in the DWR to improve the documentation process of DWRs. (vi) Although contractors prioritized the labor group factors in the extended construction seasons, they should focus on exogenous and management groups of factors in the short construction seasons.

This study was limited to five projects of the district-5 in the Wyoming. Further Research should be undertaken in the long construction seasons to identify the details of the evaluation processes of the delay analysis system augmented with the simulation model.

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