Effective Production Rate Estimation and Activity Sequencing Logics Using Daily Work Report Data (Phase – II)

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TABLE OF CONTENTS

List of Tables ii
List of Figures iii
Problem Statement 1
Background Summary 2
Benefits and Business case 3
Objectives 4
Research Plan 5
MDT Involvement 8
Products 9
Implementation 10
Schedule 11
Budget 12
Staffing 14
Facilities 15
References 16

List of Tables

Table 1: Project Schedule 11
Table 2: Budget Broken Down by Federal and State Fiscal year.......... 12
Table 3: Proposed Budget Broken Down by Task 12
Table 4: Proposed Budget Broken Down by Products 12
Table 5: In-Country Travel Costs (Trip 1) 13
Table 6: In-Country Travel Costs (Trip 2) 13

List of Figures

Figure 1 Phase II Research Goal 4
Figure 2 Overall Research Plan 5
Figure 3 Bar Chart based Project Schedule 6
Figure 4 Activity Sequencing Logic Diagram 7

Problem Statement

Contract time for state highway projects is the maximum time allowed in the contract for completion of all work contained in the contract documents (FHWA 2002). An accurate forecast of contract time is crucial to contract administration as the predicted duration and associated cost form a basis for budgeting, planning, monitoring and even litigation purposes. Excessive contract time is costly because it extends the construction crew's exposure to traffic, prolongs the inconvenience to the public (unnecessary increase of road user costs), and subjects motorists to less than desirable safety conditions for longer periods of time. Insufficient contract time results in higher bids, overrun of contract time, increased claims, substandard performance, and safety issues. Due to significant importance of contract time determination, Title 23 Code of Federal regulations (CFR) Section 635.121 requires that States should have adequate written procedures for the determination of contract time, and most state DOTs including MDT have a written document describing their procedure to determine a project's contract time.

Accurate and reliable contract time determination is highly dependent upon two major issues; a) production rate estimation of major work items, and b) sequencing of those work items. The MDT manual on contract time determination provides the list of major work items and corresponding production rates (MDT 2008). The production rates were determined from various sources but were mainly based on previous experience and judgement of MDT engineers. The manual further recommends that the production rates must be revised every two years. However, the current production rates are at least ten years old. Additionally, the manual states that factors such as type of construction, bad weather delays, complexity, cost, traffic volumes, length, etc. can also affect production rates. However, the manual does not clearly provide a structured procedure on how to quantify the effects of those factors on production rates. Instead, it simply recommends the use of engineering judgement for production rate adjustment.

MDT currently uses the AASHTOWare – SiteManager that includes daily work reports for more than 700 completed projects. The daily work reports include various project characteristics information, daily quantity of work accomplished for each work item, start and end date of each work item, labor and equipment usage information, weather, etc. This rich data set can be used to estimate realistic production rates of major work items. Also, this digital data set can be used to identify the actual sequence of work items (activities). MDT is transitioning from SiteManager to a web based AASHTOWare Project Construction and Materials. The digital data required for production rate estimation in the new web-based system will still be accessible and available.

In Phase I, the AASHTOWare SiteManager's historical project data were obtained and analyzed to develop an MS Excel based production rate estimation tool (PRET). The PRET uses regression models to estimate production rates of up to 31 major work items and it also shows common statistical measures such as mean, average, 25% and 75% production rates based on the historical data. Phase II is needed to develop construction activity sequencing logics for different types of projects based on historical data, which can help MDT quickly identify the most common work sequence of the given project and determine the project schedule. These new tools are expected to significantly improve the accuracy and reliability of MDT's contract time determination. This project will not only allow MDT to be equipped with powerful data driven tools to enhance the current contract time determination procedure but also allow MDT to be one of the leading state DOTs to provide a benchmarking example that other DOTs can follow.

Background Summary

FHWA (2002) recommends that in estimating production rates of work items, an accurate database should be established by using normal historical rates of efficient contractors. It further states that the most accurate data can be obtained from site visits and/or review of project records (i.e., field diaries and other construction documents) where the contractor's progress is clearly documented based on work effort, including work crew makeup during a particular time frame. For most DOTs, data collection from site visits may not be a financially feasible solution because the data should be collected from a significant number of projects across the state and also, the data should be updated every two to three years to meet FHWA's recommendations. An excellent alternative approach is to use a well-organized dataset of completed highway projects, where a project's progress is clearly documented. Daily work reports which are part of AASHTOWare- SiteManager include a variety of project related data. Daily performance at the work item level is recorded by inspectors. The daily work reports contain information about project characteristics, the entire list of work items, daily quantity of work accomplished for each work item, start and end date of each work item, labor and equipment usage information, weather, significant communications with contractors, etc. This digital data set provides very rich and useful data appropriate for production rate estimation. Phase I used this historical dataset to successfully developed an MS Excel based Production Rate Estimation Tool (PRET). Also, this rich historical data set can be used to identify the actual sequence of major activities as it contains information about the start and end dates of each work item. The actual sequence of key work items for different types of projects will help MDT to more realistically determine contract time of highway projects.

Benefits and Business Case

This project is expected to significantly improve the MDT's current contract time determination practices and the progress monitoring of major construction activities during construction. The PRET which was already developed in Phase I and the activity sequencing logic diagrams that will be developed in Phase II will a) provide a basis for better planning of resources for highway projects, b) provide data driven and verifiable documentation for a stronger defense in contract time disputes, and c) allow less experienced personnel to gain confidence as they learn how to consistently estimate reasonable production rates and determine contract times. Successful implementation of the project outcomes will allow MDT to avoid unnecessarily lengthy duration of highway projects. So, it would minimize the construction crew's exposure to traffic and reduce the inconvenience to the public (unnecessary increase of road user costs). The research products will also allow MDT to avoid unreasonably short duration for highway projects which typically results in increased exposure of construction crews to safety hazards and substandard performance.

Objectives

The overall goal of the Phase II is to develop construction sequence logics for major types of MDT projects using historical data available in daily work reports in order to enhance the MDT's current contract time determination procedures (Figure 1).

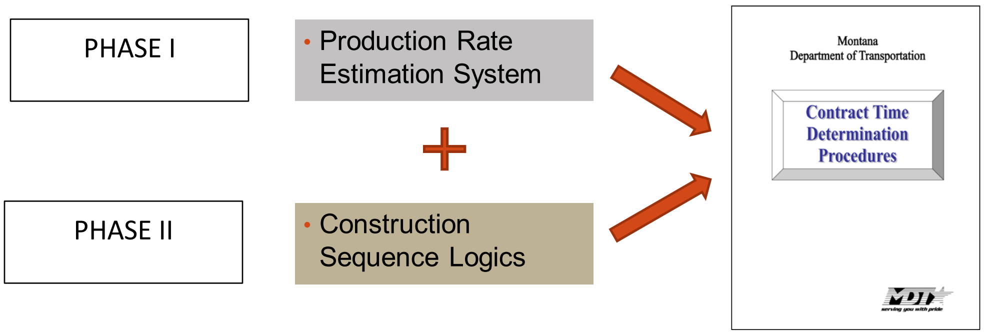


Figure 1. Phase II Research Goal

The specific objectives of Phase II are below.

- Obtain and analyze the MDT site manager's data to find activity sequence patterns for major types of projects
- Develop construction activity sequence logics for different types of highway projects

Research Plan

Figure 2 shows the overall research plan for Phase II and major deliverables.

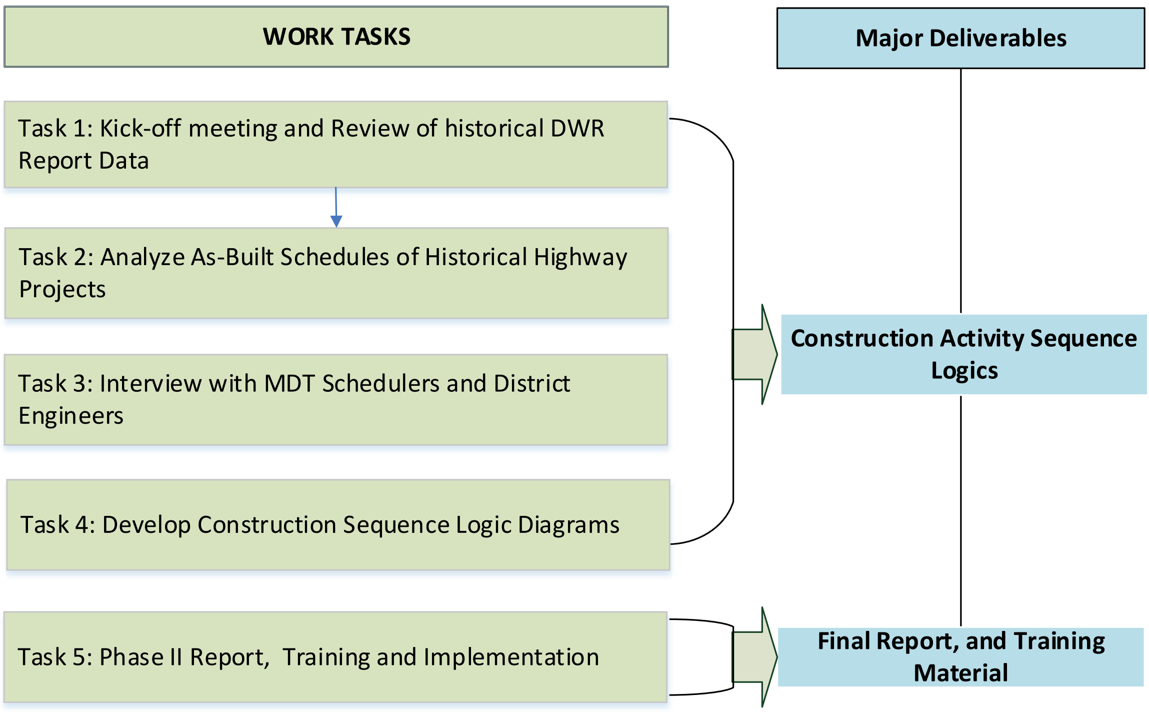


Figure 2. Overall Research Plan

Task 1: Kick-off Meeting and Review of historical daily work report data

The research will begin with a Phase II kick off meeting between the research team and the MDT technical panel members. This will give a clear understanding of expectations from the MDT as well as tasks to be completed by the research team. The research team will also review and effectively synthesize the existing literature on activity sequencing of highway projects and project schedule determination processes. The research team already has the last 10 years of daily work report data and the team will evaluate and reorganize the data to facilitate the analysis of as-built schedules of major project types.

Task 2: Analyze As-Built Schedules of historical highway projects

The research team will analyze the historical daily work report data to develop as-built schedules of major types of highway projects. The research team will develop a computer algorithm that will import the DWR data and automatically develop an as-built bar-chart schedule for a project under consideration. A common sequence pattern of major activities and variations will be identified in this task. Projects of the same work type have high similarities in terms of activity sequencing. For example, a pavement rehabilitation project begins with traffic control activities followed by demolition of existing pavement, and construction of new pavement. Activity start and finish data of previous projects are available in daily work reports. These data will be used to identify the pattern and sequence of controlling activities for each project type. The available data attributes from MDT's daily work report software include universal project number (UPN), project type, activity code, mile post and/or coordinates of the activities, the labor and equipment resources used, controlling activity indicator, and the amount of work done. The controlling activities and long duration activities will be the focus of the study while short and less important activities will be removed from the database to facilitate the analysis. The data will be analyzed and transformed programmatically to develop visual as-built schedules. A programming language will be used to automatically arrange the activity-date data for a particular project. This data will then be exported to a scheduling program such as MS Project to develop a visual as-built schedule representing the actual sequences of activities conducted (Figure 3).

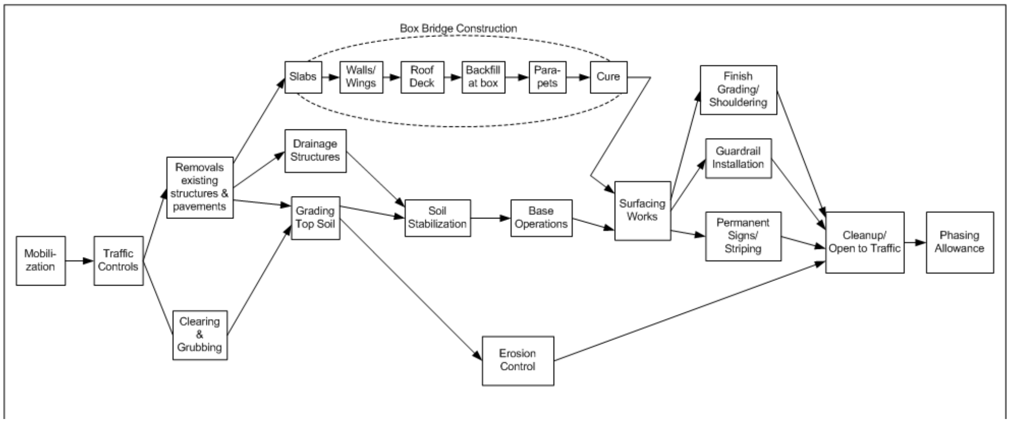
Figure 3. Bar Chart Based Project Schedule

Task 3: Interview with MDT Schedulers and District Engineers

The research team will have extensive workshop style meetings with MDT's schedulers and representative district engineers to obtain their knowledge on common sequence patterns of major work items for different types of highway projects. Any significant sequence variations and their causes will be documented to provide sufficient flexibility is adjusting work sequences of a project under different operating environment and conditions. The findings of Task 2 (common sequences and any major variations) will be fully discussed with the MDT schedulers and district engineers to facilitate the discussion processes and develop evidence-based work sequences.

Task 4: Develop Construction Activity Sequence Logic Diagrams

Using the findings from Tasks 2 and 3, the research team will develop common activity sequence logic diagrams for different types of highway projects as shown in Figure 4. Discussions and explanations for any variation needed will be explained for MDT schedulers to make appropriate adjustment in project scheduling and contract time determination. The results from this task will be used to generate a template-based scheduling system that will significantly help MDT to determine a more defensible contract duration with confidence.



Task 5: Training and Implementation

This is the final task of the study. In this task, a training session will be provided to the MDT personnel for rapid dissemination of the research findings. A step-by-step process will be described using visual examples to explain how activity sequencing logic diagram can be used in determining a project's schedule and ultimately contract time. A user's manual will be developed and used for training MDT staff. The final report that encompasses all task results, findings, and products will be prepared for the panel's review and approval.

MDT Involvement

The proposed study will require involvement of MDT personnel and resources. The research team will need assistance from MDT personnel who have knowledge in the current practices of contraction time determination. The research team may need to interview highly experienced MDT schedulers and district engineers who have years of field experience and understand the sequences of construction activities and various constraints that may change the common sequence of activities. In addition, the MDT personnel are expected to be available for meetings regarding research tasks and issues identified during the research. The MDT's historical daily work reports will be required for this study.

Products

Research products to be developed from Phase II include:

- Construction activity sequence logics for major project types
- Meeting notes
- Quarterly progress reports
- Task reports
- Final presentation
- Final report
- Final report cover image
- Project summary report
- Implementation meeting and report
- Onsite training for MDT staff involved with contract time determination

All products will be prepared using the latest MDT guidelines and requirements to meet MDT quality standards. Texas A&M University has a full-time technical writing and publications staff. All products will be reviewed and edited by the technical writer to ensure professional quality.

Implementation

The Construction administration services bureau will be responsible for implementation of the research results. The implementation plan for the project is as follows:

- On-site workshop style training for MDT staff in Task 5
- Train other potential users of the research products by the construction administration services bureau or by the research team – month 2
- Performance evaluation of the research products by the construction administration services bureau – month 5
- Update the products as required by the construction administration services bureau or by the research team– month 7
- Implement the products state-wide by the construction administration services bureau – Month 8

The implementation of the research products is expected to modernize the process of determining contract times of highway projects. A workshop style training will be provided in Task 5 as part of this project. Any additional training costs are not currently budgeted in this proposal.

Schedule

Phase II is expected to start on May 15,2019. Major milestones are included in the proposed schedule in Table 1.

Table 1: Project Schedule

		Task and Month ->	2019								2020
			May 15	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PHASE II	1	Kick-off meeting and Review of historical daily work report data									
	2	Analyze As-Built Schedules of historical highway projects									
	3	Interview with MDT Schedulers and District Engineers									
	4	Develop construction activity sequence logic Diagrams									
	5	Phase II Report, Training and Implementation							Panel Review		
Major Milestones											
Kick-off Meeting											
Construction Activity sequence logics											
Draft Final Report submission											
Workshop Style Training											

Budget

The total budget for Phase II is $45,000 and the itemized budgets are provided below.

Table 2: Budget Broken Down by Federal and State Fiscal Year

Item	Federal FY		State FY	
	2018-2019	2019-2020	2018-2019	2019-2020
Salary, Jeong	$6,266	$7,135	$1,446	$11,955
Salary, GRA	$3,724	$3,476	$621	$6,579
Total Benefits	$2,138	$2,270	$441	$3,967
Travel	$1,403	$1,403	$0	$2,805
Materials	$0	$0	$0	$0
Indirect Cost (48.5%)	$6,562	$6,928	$1,216	$12,274
Tuition	$1,912	$1,784	$319	$3,377
FY Total	$22,005	$22,995	$4,043	$40,957

Table 3: Proposed Budget Broken Down by Task

Task	Budget
1.Kick off Meeting/ Review of Historical DWR data	$4,043
2. Analyze As-Built Schedules of historical higway projects	$8,272
3. Interview with MDT Schedulers and District Engineers	$9,690
4.Develop Construction Activity seuence logic diagrams	$11,745
5.Phase II report, Training and Implementation	$11,251
Total	$45,000

Table 4: Proposed Budget Broken Down by Products

Product	Budget
Activity Sequencing logic diagrams	$33,749
Final report, final report cover image, and project summary	$5,626
Onsite training for MDT, implementation meeting, and report	$5,626
TOTAL	$45,000

Itemized In-country Travel Costs

Two trips are planned for this project. The estimated cost details of each trip are provided in the following Tables.

Table 5: In-Country Travel Costs (Trip 1)

Meeting with MDT Schedulers	Unit Cost	Quantity	Total Cost
Airfare (1 person)	$800	1	$800
Lodging (1 room/night)	$100	2	$200
Per Diem (3 days)/person	$40	3	$120
Retal Car/Day	$70	3	$210
Fuel	$30	1	$30
Parking in airport	$14	3	$42
Total			**$1,402**

Table 6: In-Country Travel Costs (Trip 2)

Training and Final Presentation	Unit Cost	Quantity	Total Cost
Airfare (1 person)	$801	1	$801
Lodging (1 room/night)	$100	2	$200
Per Diem (3 days)/person	$40	3	$120
Retal Car/Day	$70	3	$210
Fuel	$30	1	$30
Parking in airport	$14	3	$42
Total			**$1,403**

Staffing

A highly qualified research team has been assembled for this research project. The PI has sufficient experience and knowledge in project scheduling, cost estimating, risk management, project delivery process and project management which are a required set of expertise for successful completion of the proposed project.

Dr. Jeong has conducted several research projects on the active use of construction data to support data-driven decisions. Most of his previous and current research projects are highly related to project scheduling, production rate estimation, project estimating, cost engineering, highway project management, infrastructure asset management and data analytics for project management. He has published more than 50 technical journal and conference papers in this area for the past 10 years. He also has 6 years of industry experience in bridge construction projects as project engineer and cost engineer. He has won the 2015 Construction Industry Institute (CII) distinguished professor of the year award, 2010 CII outstanding researcher of the year award. He is the recipient of the 2008 Institute of Industrial Engineers (IIE) Transactions Award for Best application paper in Operations Engineering. Several of Dr. Jeong's past funded research projects that are directly related to this work are listed below:

- Principal Investigator, "Systematic Approach for Determining Construction Contract Time – A guidebook" National Cooperative Highway Research Program 08-114, National Academies of Science, 2018-2020,
- Co-Principal Investigator, "Preconstruction Services Estimating Guidebook," 2013-2015, NCHRP Project 15-51,
- Principal Investigator, "Data and Information Integration Framework for Highway Project Decision Makings", Oklahoma Transportation Center, 2012-2013
- Principal Investigator, "Procedures and Models for Estimating Preconstruction Engineering Costs of Highway Projects", Oklahoma Transportation Center, 2010-2012
- Principal Investigator, "Development of Improved System for Contract Time Determination (Phase I, II, and III), Oklahoma Department of Transportation and Oklahoma Transportation Center, 2006, 2007, 2008-2010.

A PhD level graduate student will get involved in this project. The student is currently involved in the NCHRP 08-114 and thus, a synergistic benefit is expected for the Phase II project. Table 7 provides the detailed breakdown of staff hours allocated for each work task for both options.

Table 7: Project Staffing

Name of Principal, Professional, Employee, or Support	Role in Study	Tasks						Percent of Time vs. Total Project Hours	Percent of Time - Annual Basis (total
		1	2	3	4	5	Total		
Dr. Jeong	PI	15	20	30	40	34	139	29%	7%
Grad Student	Data nalysis, and evaluation	30	100	50	100	68	348	71%	17%
TOTAL		**45**	**120**	**80**	**140**	**102**	**487**	**N/A**	**N/A**

Facilities

The scope of work outlined in the Research Plan has very little equipment or facility needs associated with any of the tasks. For this research, the level of support services within the institution will be more important than physical equipment and facilities, although Texas A&M University has exceptional facilities for high quality research.

References

Federal Highway Administration (FHWA) (2002) FHWA Guide for Construction Contract Time Determination procedures, http://www.fhwa.dot.gov/legsregs/directives/techadvs/t508015.htm

Montana Department of Transportation (MDT) (2008), Contract Time Determination Procedures, Montana Department of Transportation, Helena, MT.