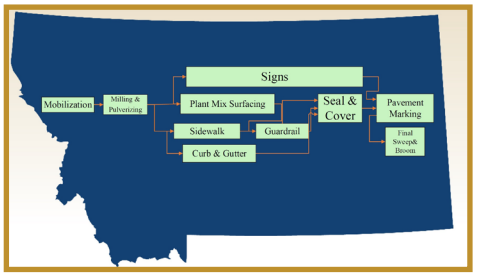
Montana Department of Transportation December 2020

RESEARCH PROGRAMS

# Project Summary Report: FHWA/MT-20-003/9344

**Authors:** H. David Jeong, Ph.D.
Hamed Alikhani
Chau Le

Texas A&M University, College Station, TX




# EFFECTIVE PRODUCTION RATE ESTIMATION AND ACTIVITY SEQUENCING LOGICS USING DAILY WORK REPORT DATA

https://www.mdt.mt.gov/research/projects/const/production_rates.shtml

## Introduction

Accurate and reliable project duration estimation 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 and it also provides a general guide on sequencing major work items of highway projects. However, the production rates calculated, based on previous experience and judgement of MDT engineers, have not been updated for more than a decade and the construction logic description in the manual is not specific enough to be useful for contract time developers.

Phase I of this project focused on modernizing the production rate estimation process of major controlling work items using the historical project performance data available in the MDT AASHTOWare SiteManager. An MS Excel-based Production Rate Estimation Tool (PRET) was developed as an implementation tool. 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, the first quartile, and the third quartile production rates based on the historical data.

Phase II of this project involved the analysis of SiteManager's historical project data to identify construction sequence patterns of major work activities and the development of construction activity sequence logic diagrams for different types of highway projects. Visualized critical path method-based logic diagrams for five major work types were developed.

The PRET and the construction logic diagrams developed in this project are powerful data driven tools which are expected to significantly enhance the current contract time determination process with higher confidence, and defensible and verifiable documentation. The tools may also allow less experienced personnel to gain confidence as they learn how to consistently estimate reasonable production rates and determine contract times.

## What We Did

To accomplish the goal of this research project, the research team first conducted a kick off meeting with the MDT technical panel members to make a clear mutual understanding of the project objectives, data requirements, and research methodologies.

In Phase 1, the research team obtained and analyzed the last 10 years of daily work reports (DWR) of MDT highway projects stored in SiteManager to estimate realistic production rates of major work items. Descriptive analysis, regression analysis,

and Monte Carlo simulation were used to offer insights into historical projects' characteristics and production rates of 31 major controlling activities. The results of the descriptive analysis were statistical measures (i.e., mean, first quartile, median, and third quartile) of controlling activities which provide more practical, detailed, and updated production rate estimates in comparison with the current published values. In addition, variations of production rates in terms of different seasons of work, districts, area types (urban/rural), and project estimate budget levels were evaluated. Regression equations were also developed to estimate production rates of each controlling activity. For each activity, factors that have a significant effect on production rate were included in the regression model as predictor variables. A production rate-based method was proposed to evaluate a contractor's performances and a Microsoft Excel based Production Rate Estimation Tool (PRET) was developed to assist MDT practitioners in estimating realistic production rates.

In Phase 2, the research team analyzed the SiteManager data to a) identify most common project types, b) identify common controlling activities and extend the current list of controlling activities, c) develop as-built schedules out of DWR data, and d) develop a construction activity sequence logic diagram for each project type that illustrates frequent controlling work items and their sequential relationship. In total, six major project types were identified from the DWR data analysis. The current list of controlling work items was determined to be incomplete with several missing items and insignificant items. Thus, the research team extended and enhanced the list based on the DWR data analysis results. A computer algorithm was developed and a Microsoft Excel tool was used to analyze the DWR data to develop an as-built bar-chart schedule for each project. A common sequence pattern of major work items for different types of projects was identified. The research team conducted a workshop style meeting with MDT's schedulers to obtain their practical knowledge on frequent controlling work items, the most common project types, and the dominant sequential pattern of work items for different work types. This meeting was helpful and successful to validate the DWR data analysis results and incorporate the schedulers' practical knowledge into finalizing the list of controlling work items and developing evidence-based construction work sequence logics for different project types.

The results of this research project are expected to help MDT quickly identify the most common controlling work items, estimate reasonable and reliable production rates of the controlling work items, and a proper construction sequence of them for common types of highway projects. The research findings are expected to significantly improve the accuracy and reliability of MDT's scheduling and contract time determination efforts. This project will allow MDT to be equipped with powerful visual scheduling resources to enhance the current contract time determination procedure.

## What We Found

### *Major Factors affecting Production Rates*

Based on the historical project performance data analysis, the following factors were determined to have significant impact on the production rates of controlling work items: a) quantity of work, b) season of work, c) area type (urban vs. rural), d) districts, and e) budget size. These factors were used to develop regression equations for estimating reasonable production rates. Also, MDT schedulers and contract time developers may need to pay attention to these factors in estimating production rates and finalizing project duration.

### *Production Rate Estimation Tool (PRET)*

PRET will allow MDT engineers to estimate production rates of controlling work activities more systematically and efficiently while considering the main factors that significantly affect production rates of each controlling activity. Since this tool is based on the statistical relationships found between the production rates and various factors, MDT personnel can obtain more accurate and realistic production rate estimates. The tool also provides common statistical measures such as the first quartile, mean, average, and the third quartile production rates based on the historical data for comparison and final production rate adjustment purpose. Figure 1 shows the initial input screen page of the tool.

### *Common project types*

The DWR data analysis results show that the most common highway project types in MDT include i) overlay (urban), ii) overlay (rural), iii) safety, iv) seal & cover, and v) bridge reconstruction and rehabilitation and account for 60%

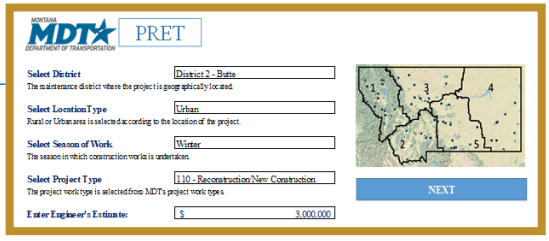



**Figure 1: Production Rate Estimation Tool (PRET) Initial Input Screen**

of the total 730 projects in the DWR database. Construction activity sequence logic diagrams were developed for these common types of projects.

### *Controlling work items*

Controlling work items are the work items that are likely to affect the duration of a project. The Phase 1 list of controlling work items includes 31 items. From a comprehensive DWR data analysis, review of controlling work items in other DOTs and discussions with MDT scheduling experts, the Phase 2 list has been expanded into 48 items. The expanded list now covers more than 90% of the activities in the DWR database.

### *Construction activity sequence logic diagrams*

As-built schedules of representative projects for each project type were integrated with MDT schedulers' knowledge and experience to develop a common sequence logic diagram for each project type. The diagram in Figure 2 below shows the sequence logic for common work items for overlay projects in urban areas.

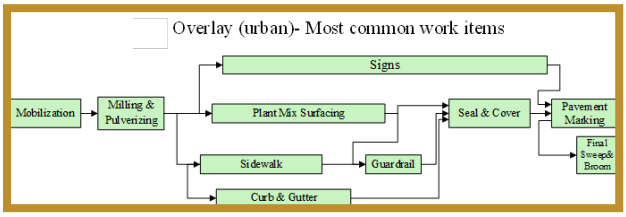



**Figure 2: Construction Activity Sequence Logic for Urban Overlay Projects**

## What the Researchers Recommend

There are eight recommendation ideas for immediate implementation.

### *Recommendation 1:*

This research project resulted in the development of an MS Excel-based Production Rate Estimation Tool (PRET) which is immediately available for use and implementation for production rate estimation of controlling work items as part of contract time determination. Once a user enters input parameters specific to a new project, production rates can be automatically estimated based on regression models embedded in the Excel tool. Statistical measures such as mean, median, first, and third quartile values are also available in the tool. It is recommended MDT use the PRET tool as part of their contract time determination process.

### *Recommendation 2:*

This research project identified statistically significant factors that may affect the production rates of work items and contract time of a project. The key factors include bid quantity, project type, project size, season of work, districts, and area type (urban/rural). It is recommended that MDT contract time developers carefully consider those factors as part of their contract time determination process.

### *Recommendation 3:*

The project team recommends the MDT contract time determination manual be updated by creating a new section that describes how to use the PRET and its value. The tool and the user manual may need to be added to the appendix section as formal documentation and easy reference for future users.

### *Recommendation 4:*

This research project resulted in the development of a three-tier system that can evaluate a contractor's performance in terms of its historical production rates of controlling work items. This system may have value as a new pre-qualification criterion of potential contractors for a time-sensitive project. Poor performance contractors can be pre-screened to reduce the possibility of schedule delay or MDT can give careful considerations before awarding those contractors a contract.

### *Recommendation 5:*

Controlling work items are those likely to affect the duration of a project. MDT is recommended to use the expanded list of controlling work items in developing the schedule and contract time of a new project. The current list of controlling work items includes 31 items. By analyzing as-built schedules, the research team identified that the current list doesn't effectively cover all controlling activities that may affect the total duration of a project. It was recognized that some controlling work items were missing, and some of the existing items in the current list could be aggregated together to one controlling item. The current list has been extended to a new list of 48 items, where each item may include multiple pay items.

### *Recommendation 6:*

This project resulted in the development of standard sequence logic diagrams of major controlling work items for five common highway project types. The research team recommends MDT schedulers use the diagrams as a supporting resource in estimating accurate, defensible contract times for future projects. The diagrams can also be used as training material for inexperienced schedulers.

### *Recommendation 7:*

The project team recommends that the new list of controlling items and the visual sequence logic diagrams should be included in MDT's contract time determination manual in the appendix as formal documentation and easy reference for future users.

### *Recommendation 8:*

The research team identified the dates that pay items are charged in the Daily Work Reports (AASHTOware SiteManager) may sometimes differ from actual construction dates of the pay items. Some of those dates may include actual payment dates to contractors on the items. This research project used daily work reports to develop as-built schedules which may include some of those errors. The project team recommends MDT ask contractors to submit an as-built schedule at the completion of a project using the MDT's list of controlling work items, not their own work breakdown structure used for the project. The accumulation of accurate as-built schedules will lead to more realistic scheduling and time estimation for future projects.

**For More Details . . .**

The research is documented in Report FHWA/MT-20-003/9344, https://www.mdt.mt.gov/research/projects/const/production_rates.shtml.

***MDT Project Manager:***
Susan Sillick, ssillick@mt.gov, 406.444.7693

***Researcher's Organization Project Manager:***
David Jeong, djeong@arch.tamu.edu, 979.458.9380

To obtain copies of this report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.

**MDT Implementation Status:** December 2020

An implementation meeting was held, during which the Researcher and the Technical Panel discussed each of the former's recommendations. The Technical Panel responded with what MDT can reasonably implement. This discussion was documented in the implementation report, which can be found at the above URL. In addition, a detailed implementation plan will be developed and monitored until implementation is complete.