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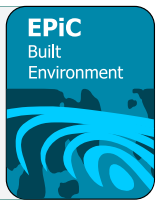

Approaches to Improving Production Rate Information for Highway Projects

Janghwan Suk[1], H. David Jeong[1], and Charles Gurganus[1]
[1]Texas A&M university

Many Departments of Transportation (DOTs) utilize production rate tables as a tool to provide production rate information for construction activities that DOT estimators should consider when developing a project schedule and contract time. This spreadsheet-based tool offers the advantage of accessibility without requiring prior knowledge, as a quick reference table. However, many DOTs do not update their tables with actual data (e.g., historical bid data), which limits the practical utility of the tables. It is necessary to assess whether these tables provide sufficient and reliable production rate information for DOT estimators to perform project scheduling. This study focused on the Texas Department of Transportation (TxDOT) construction production rate table and analyzed the production rate table in two phases: Phase 1: Identification of additional major work item candidates; Phase 2: Review and compare the production rate ranges with actual production rates. The findings from this study can be utilized not only to update the TxDOT construction production rate table but also to demonstrate the need of using actual data-driven production rate information.

Keywords: Production rate estimation, production rate table, major work item, highway project

Introduction

Understanding and estimating realistic production rates of construction activities that have the potential to be on the critical path are key processes for calculating the duration of a project, determining a reasonable contract time, and monitoring the progress of the project during construction (Woldesenbet, Jeong, & Oberlender, 2012). In many Departments of Transportation (DOTs), state-specific production rate information is available in the form of a table to ensure that DOT estimators use realistic production rates for these activities. Compared to nationwide production rates, statewide production rates are more reliable because they take factors influencing production rates into consideration in detail. Federal Highway Administration (2002) recommends managing production rates at the state level.

Many DOTs use production rate tables to provide state-specific production rates to DOT estimators. DOT production rate tables provide a range, typically consisting of low, high, and average (or median) values, or baseline production rate rather than a deterministic value. The production rate range or baseline production rate provides estimators with the flexibility to consider factors that affect the production rate. The guidance for selecting an appropriate production rate, which is included in the table or provided separately, may help estimate the reliable production rate for each activity.

Most of these DOT production rate tables include only the list of construction activities useful for its state. The construction activities critical for project scheduling vary by DOT, depending on the types of highway projects carried out within their states.

However, many DOTs do not update state-specific production rate information (Taylor, Sturgill, & Li, 2017). Notably, fewer DOTs update production rate information with objective data. For example, the Texas Department of Transportation (TxDOT) updates the production rate information in the TxDOT table based on subjective opinions from experts instead of utilizing actual data, such as daily work reports (DWRs) or historical bid data (Texas Department of Transportation [TxDOT], 2024). Regular and frequent updates based on objective data are necessary to reflect production rate changes over time due to technological improvements such as stringless paving and other advanced construction technologies. A table lacking actual data updates not only provides inaccurate production rates but also fails to provide a comprehensive list of major work items that are likely to stay on the critical path of a project.

This study focused on the TxDOT construction production rate table, a spreadsheet-based tool, to assess whether the information it provides for estimating production rates is practical. This research consisted of two phases: Phase 1: Identification of additional major work item candidates; Phase 2: Review and compare the production rate ranges with actual production rates. The findings from this study can be utilized to update the TxDOT construction production rate table and highlight the importance of data-driven production rate estimation and updates to DOT production rate tables.

Literature Review

The production rate information of major work items is essential for establishing a reasonable contract time, which is required to achieve the DOTs' ultimate goal of completing the project on time. Various project conditions (e.g., location, weather, or project type) significantly affect production rates, thus, using a single universal value is impractical and inaccurate. Many DOTs use production rate tables for providing production rates as ranges (typically three values; minimum, average, and maximum) or baseline production rates that allow for variability. This spreadsheet-based tool, offering intuitive understanding and easy access for users, enables convenient reference to the production rates of all activities in the tool with ease. The information provided by DOTs' production rate tables includes production rate values (e.g., production rate ranges or baseline production rates), a list of construction activities, units of measure, factors, and guidance.

Not all construction activities in a highway project are necessary for project scheduling; only specific activities, called controlling activities, are required (Jeong, Atreya, Oberlender, & Chung, 2009). Thus, a production rate table is expected to include all controlling activities, referred to as major work items in this study. The list of major work items varies by state. DOTs categorize major work items in more detail, tailoring them to their specific needs for project scheduling, rather than simply dividing them by specification or pay-item levels. For example, the Virginia Department of Transportation (VDOT) classifies excavation into small or irregular area projects and large quantity projects, providing production rates for each category. On the other hand, the TxDOT construction production rate table calculated production rates of excavation based on two soil types, earth and rock.

DOTs should establish criteria for calculating reliable production rates and provide appropriate information to ensure production rate tables are practical for their use. For example, the Wisconsin Department of Transportation (WisDOT) excluded the top and bottom quartiles of collected production rates as unreliable data to present reliable information in the table (WisDOT, 2022). TxDOT calculates

the production rates of major work items, using expert opinion-based surveys as a valuable source of information.

Prior research has focused on the production rate information provided in tables, such as the production rate range, unit of measure, and influencing factors. Studies have used unit of measures that incorporate crew size to provide more accurate production rates (O'Connor, Chong, Huh, & Kuo, 2004) or have utilized confidence intervals to address the limitations of deterministic values of production rates (Jiang & Wu, 2004). Additionally, studies on influential factors affecting production rates have analyzed the relationship between production rates and these factors using statistical approaches such as Analysis of variance (ANOVA) tests or t-tests (O'Connor & Huh, 2006; Woldesenbet, Jeong, & Oberlender, 2012). Factors that generally influence production rates include location, weather, soil type, traffic congestion, hauling distance, project size and type, and specific operations (Jeong, Le, & Devaguptapu, 2019).

Prior studies have not only contributed to the estimation of reliable production rates but have also implied key considerations for the practical use of DOT production rate tables. The production rates provided by DOT and the actual production rates calculated based on historical data can differ significantly depending on the major work items (Woldesenbet, Jeong, & Oberlender, 2012). Updating the table using those actual production rates can significantly minimize this discrepancy, and help estimators in determining a more reliable duration of a project. However, several DOTs either do not update their production rate tables using actual data or update them only at long intervals. For instance, the Arizona Department of Transportation (ADOT) has not updated its table since October 2018; it is crucial to review and analyze production rate tables using historical data.

Research Objectives

The main objective of this study is to assess the practicality of the TxDOT construction production rate table for providing estimators with sufficient and reliable production rate-related information. The study analyzed a) “whether the list of major work items is adequate for project scheduling,” and b) “whether the TxDOT table's production rate range provides an appropriate and reliable representation of the actual production rates.”

Research Methodology

The process of reviewing the current TxDOT construction production rate table consisted of two phases: Phase 1. Identification of additional major work item candidates; Phase 2. Review and compare the production rate ranges with actual production rates (Figure 1).

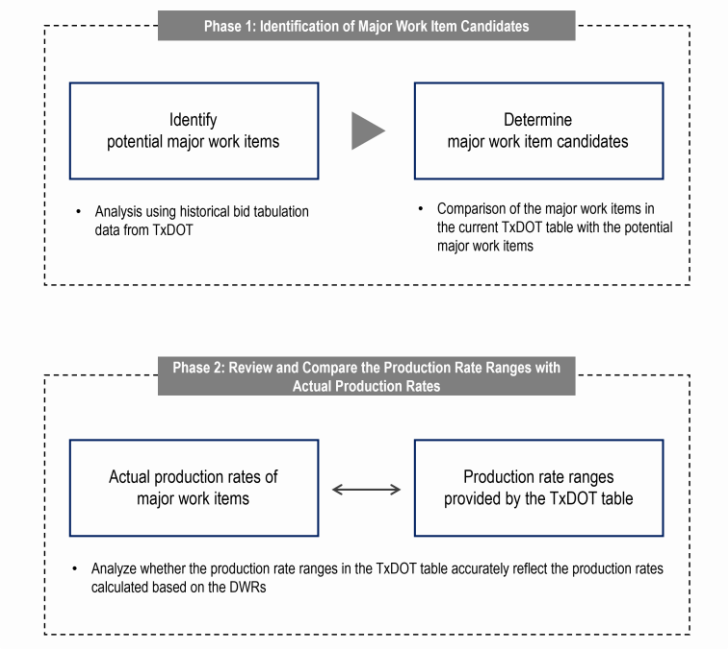

Figure 1. Research process of reviewing and analyzing the current TxDOT construction production rates table

Phase 1: Identification of Major Work Item Candidates

TxDOT defines a major work item as a work item included in the contract that has a total cost equal to or greater than 5% of the original contract or $100,000, whichever is less (TxDOT, 2024). The last two years (from May 2022 to April 2024) of bid tabulation data for more than two thousand highway projects, provided by TxDOT, were analyzed to identify work items frequently utilized as major work items in recent projects. The frequency of occurrence of each work item used as a major work item in the historical highway projects was measured to filter out work items that are less likely to become critical work items that may directly affect a project's schedule. In this study, the top 10% of the most frequent work items as major work items in the TxDOT highway projects were identified as potential major work items to be included in the production rates table.

Next, the list of major work items provided by the TxDOT table was reviewed for gaps with potential major work items. Major work item candidates were determined from potential major work items not included in the current TxDOT table. Considering that the TxDOT table does not provide maintenance work-related items with specification work item codes above 700, this study excluded all maintenance-related work in the process of determining major work item candidates. For example, guard fence repair with a specification work item code of 770 would be excluded from the major work item candidates in this study, even if it were to meet the conditions for being a potential major work item (i.e., not included in the TxDOT table).

Phase 2: Review and Compare the Production Rate Ranges with Actual Production Rates

The production rate ranges in the current TxDOT production rates table were evaluated with the production rate ranges calculated from DWRs provided by TxDOT. DWRs from 5,938 TxDOT highway projects over the past 10 years (from January 2014 to December 2023) were utilized to calculate the actual production rates, as leveraging production rate patterns over an extended temporal range enhances the reliability of the evaluation. The statistical distribution patterns of DWR-based actual production rates were compared with the production rate ranges provided in the TxDOT table. In this study, the deviation ratio has been developed to assess the reasonableness of the TxDOT table's production rate ranges. The definition of the deviation ratio is as follows:

$$Deviation\ ratio = \frac{Actual\ IQR\ not\ covered\ by\ TxDOT\ range}{TxDOT\ production\ rate\ range\ (High - Low)}$$

$IQR = Interquartile\ Range$

This ratio quantifies the extent to which the actual production rate falls outside the TxDOT table's range. In this study, it was established that when the deviation ratio exceeds 50%, the production rate range provided by the TxDOT table is inadequate to accurately represent actual production rates for practical use. This study focused on 12 major work items that have enough production rate data to perform statistical analysis and calculate the deviation ratio.

Results

Fourteen major work item candidates that are not covered in the current TxDOT table were identified through Phase 1 (Table 1). These work items are recommended for inclusion in the TxDOT production rate table. The major work item candidates identified through Update 1 include items that are already prioritized by other DOTs but overlooked by TxDOT, as well as those that should be critically considered for project scheduling in Texas. For example, a comparison with WisDOT and ADOT production rate tables reveals that riprap is included in other DOT tables but is absent from the current TxDOT production rate table. In contrast, conduit in Table 1 may require particular consideration as a major work item in Texas if conduit-related work items are not included in most DOTs' production rate tables.

Table 1. Major work item candidates

Specification code	Major work item candidates
134	Backfilling Pavement Edges
168	Vegetative Watering
351	Flexible Pavement Structure Repair
400	Excavation and Backfill for Structures
432	Riprap
438	Cleaning and Sealing Joints
467	Safety End Treatment
540	Metal Beam Guard Fence
544	Guardrail End treatments

545	Crash Cushion Attenuators
610	Roadway Illumination Assemblies
618	Conduit
644	Small Roadside Sign Assemblies
677	Eliminating Existing Pavement Markings and Markers

In Phase 2, major work items currently listed in the TxDOT table that do not adequately explain actual production rates were identified Figure 2). The major work items in Figure 2 include a) flexible base, b) removing treated and untreated base asphalt pavement, c) planing and texturing pavement, d) temporary special shoring/cofferdams, e) removing concrete pavement, and f) junction box. These major work items, unlike those shown in Figure 3, have deviation ratios exceeding 50%, indicating that the TxDOT table may not accurately reflect the actual production rates for these items (Table 2). For example, the deviation ratio for temporary special shoring/cofferdams is 245.7%. While the TxDOT production rate range of this work item does not exceed 1,000 SF/day, the actual production rate range is significantly higher, even including values around 2,800 SF/day.

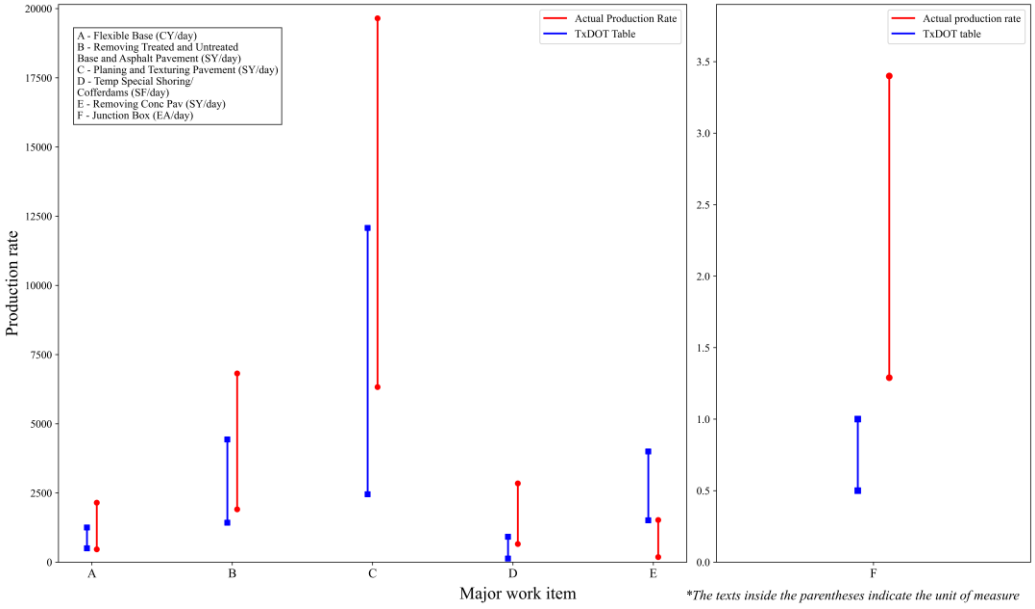

Figure 2. Major work items with significant differences between the TxDOT table and actual production rates

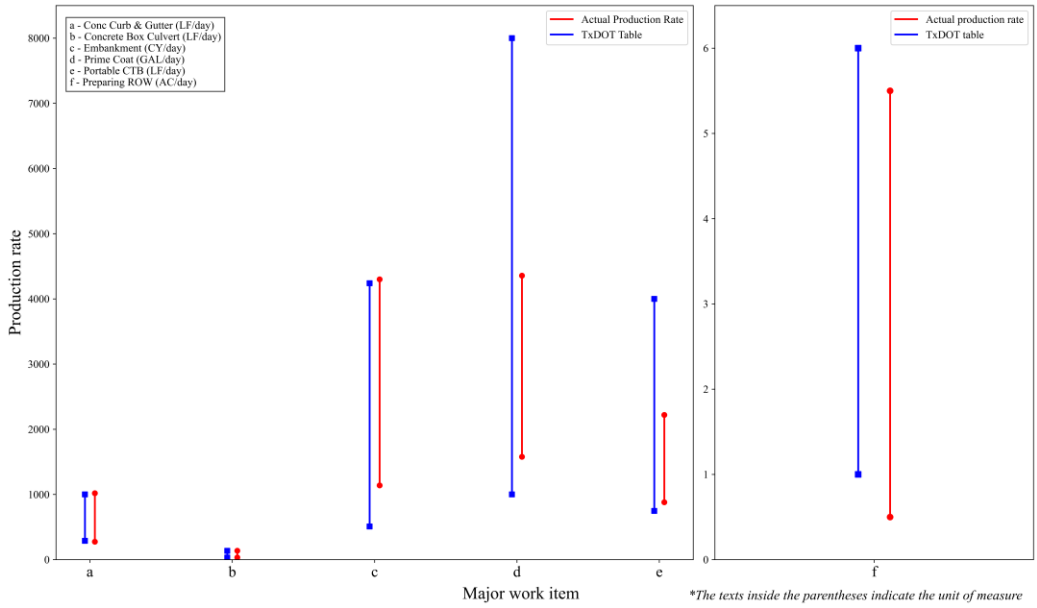

Figure 3. Major work items with similar production rates between the TxDOT table and actual production rates

Furthermore, the major work items in Figure 1 were analyzed by comparing the deviation ratios across subcategories of location to review whether geographical differences significantly impact the actual production rates, making the production rate ranges in the current TxDOT table impractical (Table 3). For example, the deviation ratio for planing and texturing pavement was less than 50% in metropolitan districts, whereas it exceeded 50% in rural and urban districts. The major work items where location was identified as the influential factor causing significant differences between the production rates in the TxDOT table and the actual production rates are: 1) planning and texturing pavement and 2) removing treated and untreated base and asphalt pavement.

Table 2. Deviation ratios for major work items

Symbol	Major work items	Deviation ratio (%)
A	Flexible Base	124.7
B	Removing Treated and Untreated Base and Asphalt Pavement	79.4
C	Planing and Texturing Pavement	78.7
D	Temp Special Shoring / Cofferdams	245.7
E	Removing Concrete Pavement	53.3
F	Junction Box	422
a	Conc Curb & Gutter	4.3
b	Concrete Box Culvert	0.9
c	Embankment	1.6
d	Prime Coat	0
e	Portable CTB	0
f	Preparing ROW	10

Table 3. Deviation ratio of major work items by subcategory of location

Major work item	Location			Influential factor
	Rural	Urban	Metropolitan	
Flexible Base	192 (>50%)	153 (>50%)	70 (>50%)	-
Removing Treated and Untreated Base and Asphalt Pavement	101 (>50%)	121 (>50%)	25.3 (<50%)	Location
Planing and Texturing Pavement	178 (>50%)	96.6 (>50%)	27.4 (<50%)	Location
Temp Special Shoring / Cofferdams	199.8 (>50%)	173 (>50%)	291 (>50%)	-
Removing Concrete Pavement	50.7 (>50%)	36.3 (<50%)	51.1 (>50%)	-
Junction Box	N/A	286 (>50%)	412 (>50%)	-

Conclusion and Discussion

Several DOTs, including the TxDOT, do not update production rate information with actual data, such as historical bid data and DWRs. This study focused on the TxDOT table to analyze whether the information in the current table is practical for DOT estimators, using a two-phase review and analysis process. In Phase 1, the study identified major work items that should be included in the TxDOT table but have not yet been incorporated. The fourteen major work item candidates were identified through an analysis based on historical bid data and practical review. This phase demonstrated how to identify work items that are already prioritized by other DOTs but overlooked in a specific state, and how to recognize state-specific major work items that may not be significant for other DOTs but are critical for project scheduling within the state, using WisDOT and MDOT production rate tables. A table that includes these work items can help provide TxDOT estimators with sufficient production rate information needed for reliable project scheduling. In Phase 2, the results showed that the production rate information for certain major work items in the current TxDOT table does not adequately represent actual production rates. Additionally, the study demonstrated how to identify factors that negatively impact the practical utility of the TxDOT production rate range, with a focus on the location factor. The deviation ratios were compared across the subcategories of location to assess whether geographical differences have influenced the discrepancy between the production rate ranges in the TxDOT table and the actual production rates. A production rate table updated with actual data that provides more detailed production rates for subcategories of factors, particularly for the major work items of 1) planning and texturing pavement and 2) removing treated and untreated base and asphalt pavement, delivers more practical information to TxDOT estimators.

The findings from this study highlight the necessity of continuous improvement and frequent updates using actual data to the DOTs' production rate table to ensure its effectiveness in assisting DOT estimators in project scheduling. Including an analysis of historical data (e.g., historical bid data and DWRs) in the update system enhances the DOT's table as a practical tool.

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