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**Development and Application of a Production Rate Resource
for Contract Time Determination**

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**Development and Application of a Production Rate Resource
for Contract Time Determination**

by

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Dedication

Al país que dejé atrás.

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Abstract

Development and Application of a Production Rate Resource for Contract Time Determination

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Production rates are significantly important for contract time determination procedures as these are essential for estimating the duration of every activity needed to complete a highway construction project. For this reason, many estimation systems, including Texas Department of Transportation's Contract Time Determination System (TXCTDS), explicitly depict production rate data of work items considered important in highway construction projects. Though many systems and databases available in the public domain provide an abundance of production rate data, they provide different rates for comparable work items. This research focusses on the development of the *Production Rate Resource*, a single, easy to use reference of production rate data gathered from publicly available sources intended to be used by TXDOT contract time estimators.

The resource was developed by gathering production rate information through conducting a literature review and organizing the found data into a well assembled Excel workbook. This arrangement contains Excel sheet tabs depicting the resource's introduction, details of the included production rate sources, a summary of the included

work items and their respective production rate data, and item worksheet tabs portraying the gathered production rate data for each work item. These item worksheets also contain production rate averages, graphs that allow comparison and analysis of the data through visual aid, and specific scope information provided by the original sources. A recommended process based on the critical path method (CPM) was also developed for conducting a contract time determination using the *Production Rate Resource*.

The gathered production rate data was then tested by conducting two contract time estimations of actual TXDOT highway construction projects using the recommended process. The results were compared with TXDOT's contract estimations for an in-depth analysis, and the findings led to significant improvements to the resource.

The final assembly of the *Production Rate Resource* provides production rate data for 59 highway construction work items provided by six publicly available sources.

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Chapter 1: Introduction

Contract Time Determination is needed to establish the duration of highway construction projects, and is a requirement for contract preparations. It is conducted by analyzing project activities through scheduling procedures in order to estimate the appropriate time frame within which the construction of a project can be executed, while preventing a long-extended delivery. The determination of appropriate production rates for the project's activities is essential for conducting an adequate estimation.

In 1992, a research study conducted at Texas A&M University and sponsored by the Texas Department of Transportation (TXDOT) was published in a report entitled *Construction Contract Time Determination*. The research's objective was to establish a rational contract duration estimation procedure of TXDOT's highway construction projects. The result was the development of a Contract Time Determination System for TXDOT (TXCTDS). The system provided production rates for a list of major highway construction activities in order to analyze the adequate production rates and factor modifiers as part of a process to determine a project's contract duration. To gather such production rate data, a number of survey requests were sent to other Departments of Transportation, TXDOT district engineers, and Texas highway constructors. The surveys resulted in a production rate baseline that identified three production rates (low, average, and high daily rates) for 46 work items.

In January 2016, the University of Texas at Austin's Construction Engineering and Project Management program (CEPM), in association with the Center for Transportation Research and TXDOT's Dallas District, initiated a comparative analysis of the aforementioned baseline production rates with comparable activities recorded in similar systems and knowledge bases in the public domain. The result of this effort is called the

Production Rate Resource. This research has gathered production rate information of highway construction work items from six sources: TXCTDS, the *Highway Production Rates Information System* (HYPRIS), the *Oklahoma Contract Time Determination System* (OKCTDS), the *Kentucky Contract Time Determination System* (KYCTDS), Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration* (FLDOT), and the *RSMeans Heavy Construction Cost Guide 2016*.

The *Production Rate Resource* juxtaposes the production rates of 59 major construction work items, comparing them on three levels - High, Mean, and Low - consistent with the determinations and specifications of each source. New production rates were determined based on the average production rates per activity of each level. Production rate levels are related to particular activity and project drivers and barriers, such as crews, equipment, weather, location, etc., which help to determine if a low, average, or high production rate is appropriate for the adequate interpretation of project specifications. The result is a single, easy to use database of major highway construction activity production rates gathered from the six aforementioned public sources.

This thesis report details the development of the *Production Rate Resource*. It documents the literature review of publicly available production rates sources, the methodology implemented for developing the resource, the case study procedures in which the resource was tested and their results, and a review of the resource's content and structure.

1.1 OBJECTIVES

The main objective of this research is to develop a resource that provides production rate data from multiple systems and knowledge bases in the public domain in one single database, intended to be used as a production rate reference for TXDOT contract time

determination procedures. The following specific objectives will help reach this main objective:

- Conduct a literature review to find the appropriate publicly available sources of production rate information for highway construction activities that are comparable to TXCTDS's production rate baseline.
- Identify activities contemplated in these sources that are missing in TXCTDS's baseline that are important for contract time determination purposes and could serve as supplemental production rate information.
- Develop a resource that organizes and juxtaposes the gathered data in an amenable format that would allow a contract time estimator the comparison and appropriate selection of production rates.
- Establish a recommended process for conducting a contract time determination using the developed resource while contemplating information and systems limitations.
- Test the information gathered by conducting case studies with the objective of estimating the contract duration of actual highway construction projects using the established contract time determination process.
- Improve the resource with the findings concluded in the conducted case studies.

1.2 SCOPE LIMITATIONS

The *Production Rate Resource* is limited to the information provided in the following six sources: the *Texas Contract Time Determination System* (TXCTDS), the *Highway Production Rates Information System* (HYPRIS), the *Oklahoma Contract Time Determination System* (OKCTDS), the *Kentucky Contract Time Determination System* (KYCTDS), Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration* (FLDOT), and the *RSMeans Heavy Construction Cost*

Guide 2016. The production rates extracted from these public sources are explicitly expressed as such.

Initially, only TXCTDS work items are to constitute the *Production Rate Resource* base. This limitation can only be surpassed if case study findings reflect the importance of additional work items, and production rate data for these is provided in at least two of the other public sources included in the resource.

Work item scope information from each source is exclusively extracted from definitions and descriptions within each source and its corresponding State's Department of Transportation specifications book.

All particular modifiers, such as sensitivity and adjustment factors, suggested in some of the original sources are excluded from this research, providing only the information contained within their base production rates. Furthermore, data exclusively available in software systems specified in each source's publications are excluded from this research as these were not accessible.

The case studies are limited to two TXDOT highway construction projects and the documentation provided for this task. More specific scope information regarding the case studies are documented in Section 5.2 of this report.

1.3 STRUCTURE OF THE REPORT

The structure of this report consists of six chapters. Chapter 1 serves as the introduction of the report, containing background information, objectives, and scope limitations. Chapter 2 contains the literature review depicting the information available in several publicly available production rate sources. Chapter 3 explains the methodology used for conducting the development of the *Production Rate Resource*, including a

flowchart of the steps followed. Chapter 4 encompasses the content and structure of the *Production Rate Resource*.

Chapter 5 explains the two case studies conducted in detail. Its first three sections specify the task's objectives, particular task limitations, and the estimation methodology used. The following two sections document each case study, containing analysis and calculation processes, the comparison of results with TXDOT estimations, and specific case study conclusions and recommendations. The chapter concludes with the improvements implemented to the *Production Rate Resource* based on the case study findings.

Finally, Chapter 6 comprises conclusions and recommendations.

Chapter 2: Literature Review

A literature review was conducted for the purpose of gathering information on production rate data used for contract time determination. Several publicly available systems and databases were reviewed and thoroughly analyzed to find the appropriate sources of information that would provide the resource's production rate content.

2.1 IMPORTANCE OF PRODUCTION RATE DATA IN CONTRACT TIME DETERMINATION

Production rates are significantly important for contract time determination as these are essential for estimating the duration of every activity needed to complete a highway construction project. Studies conducted by the Transportation Research Board to explore and develop systems for estimating contract durations of highway construction projects concluded that “realistic production rates are the key in determining reasonable contract times” (Herbsman et al. 1995). This fact is evidenced by the vital use of production rates in various contract time determination techniques, and the inclusion of production rate baselines in multiple Department of Transportation (DOT) contract time determination systems.

The FHWA Guide for Construction Contract Time Determination Procedures (2002) dictates that establishing production rates for each controlling item and adopting production rates to a particular project are some of the essential elements in determining contract time for most projects. The FHWA also dictates three contract time determination techniques: A) Bar charts, B) the Estimated Cost Method, and C) the Critical Path Method (CPM). Out of these three techniques, Bar charts and CPM count on the use of production rates to determine activity durations as part of their respective processes. Moreover, the guide states that “production rates may vary considerably depending on project size, geographic location, and rural or urban setting, even for the same item of work”; and that

“production rate ranges should be established in the State's written procedures based on project type (grading, structures, etc.), size, and location for controlling items of work.”

Hancher et al. (1992), as part of their research for developing the Texas Department of Transportation Contract Time Determination System, surveyed construction engineers from all State DOT's to gather information regarding the systems and production rate data used to establish contract time durations. The researchers received 38 responses from other DOT's, of which 22 percent used production rates from historical data, 30 percent used standard production rates established by the DOT, and 44 percent relied on personal experience.

2.2 SOURCES AND SYSTEMS THAT PROVIDE PRODUCTION RATE DATA

It is consistently common to find established production rate databases within State DOT contract time determination systems and procedures. State DOTs such as Texas, Oklahoma, Kentucky, and Florida contain documented contract time determination procedures that includes production rate baselines. These baselines typically come with production rate ranges, specifying low or minimum, average or mean, and high or maximum rates. Furthermore, other publicly available sources, such as the Highway Production Rates Information System (HYPRIS) and the RSMeans Cost Guides, provide production rate data useful in contract time determination procedures.

2.2.1 TXDOT CTDS

In 1992, Hancher et al. conducted a research study on contract time determination sponsored by the Texas Department of Transportation (TXDOT) at Texas A&M University. The research was published in a report titled *Construction Contract Time Determination*, and its main objective was to establish a rational procedure to determine the contract duration of TXDOT's highway construction projects. This procedure was

meant to be easy to use and manageable in order to resemble the various types of projects and work conditions throughout the state of Texas while accommodating to common production rates and quantities reflected in TXDOT projects.

The research resulted in the development of the Contract Time Determination System for TXDOT (TXCTDS). The system provided both a manual procedure and a computerized procedure to allow users to predict the duration of highway projects. The bar chart scheduling system allows the user to simply supply the work item quantities of the project and establish its duration by applying production rates. The system also covered a list of major highway construction activities in order to analyze the adequate production rates and factor modifiers for calculating the duration of these activities, with the flexibility to add unlisted major activities if required.

Although the system establishes that users can introduce their own production rates, it provides a production rate baseline of the considered major activities. To conclude these production rates, the researchers sent out surveys to other Departments of transportation, TXDOT district engineers, and Texas highway constructors. This baseline is composed of 46 major work activities specifying low, medium, and high production rates for each.

Furthermore, the system was intended to serve as a database of updated production rates by allowing the collection and analysis of future projects.

The TXCTDS baseline can be perceived in Table 3.3 (pages 21 and 22) of the *Construction Contract Time Determination* report, and Section 3.4 of the same report gives the description of the work included in the considered major work items.

Table 1: TXCTDS Daily Production Rates for Standard Work Items (Extracted from Hancher et al. 1992)

<u>MAJOR WORK ITEMS</u>	<u>UNIT</u>	<u>DAILY PRODUCTION RATE</u>		
		<u>LOW</u>	<u>AVERAGE</u>	<u>HIGH</u>
ROW Preparations				
- Clear and grub	Acres	1.0	3.0	6.0
- Remove old pavement	S.Y.	1,000	2,000	3,000
- Remove old curb & gutter	L.F.	600	1,200	2,000
- Remove old sidewalks	S.Y.	350	700	1,100
- Remove old drainage/utility str.	L.F.	100	300	500
Earth excavation	C.Y.	1,200	3,400	7,000
Rock excavation	C.Y.	500	1,100	1,500
Embankment	C.Y.	1,200	3,500	7,000
Drainage Structures/Storm Sewers				
- Pipe	L.F.	100	200	300
- Box culverts	C.Y.	10	15	25
- Inlets & manholes	Each	1	2	3
Bridge Structure				
- Cofferdams	S.Y.	100	200	300
- Piling	L.F.	200	300	400
- Footings	C.Y.	10	15	20
- Columns, Caps & Bents	C.Y.	4	7	10
- Wingwalls	S.F.	100	150	200
- Beams (erection only)	L.F.	150	200	250
- Bridge deck (total depth)	C.Y.	6	10	14
- Bridge curbs/walks	L.F.	50	80	120
- Bridge handrails	L.F.	150	200	300
Retaining walls	S.F.	100	150	200
Base Preparations				
- Lime stabilization	S.Y.	2,000	4,000	6,000
- Flexible base material	S.Y.	1,500	3,000	4,500
- Cement treated base material	S.Y.	1,500	3,000	4,500

Table 2: TXCTDS Daily Production Rates for Standard Work Items (cont.) (Extracted from Hancher et al. 1992)

		<u>DAILY PRODUCTION RATE</u>		
<u>MAJOR WORK ITEMS</u>	<u>UNIT</u>	<u>LOW</u>	<u>AVERAGE</u>	<u>HIGH</u>
New curb and gutter	L.F.	300	500	1,000
Asphalt pavement repair	S.Y.	100	200	300
Concrete pavement repair	S.Y.	50	100	200
Milling/planing	S.Y.	5,000	10,000	14,000
Hot mix asphalt base	Ton	500	1,200	2,000
Hot mix asphalt surface	Ton	500	1,200	2,000
Asphalt surface treatment (1 course)	S.Y.	30,000	50,000	70,000
Concrete paving (rebar + curing)	S.Y.	1,000	3,000	5,000
Precast traffic barriers	L.F.	500	1,000	1,500
Permanent Signing and Traffic Signals				
- Small signs	Each	10	20	30
- Overhead signs	Each	1.0	1.5	3.0
- Major traffic signals	Each	0.2	0.3	0.7
Pavement markings	L.F.	5,000	10,000	20,000
Seeding and landscape	S.Y.	2,000	4,000	7,000
Final clean-up	Sta.	10	30	50
		<u>DURATION IN WORKDAYS</u>		
<u>MAJOR WORK ITEMS</u>	<u>UNIT</u>	<u>LOW</u>	<u>AVERAGE</u>	<u>HIGH</u>
Initial traffic control	L.Sum	1	2	4
Detour	L.Sum	3	6	12
Major structure demolition	L.Sum	5	10	20
Remove old structures (small)	L.Sum	1	3	5
Bridge demolition	L.Sum	5	15	30
Erect temporary bridge	L.Sum	10	15	25
Remove temporary bridges	L.Sum	5	10	15

2.2.2 HYPRIS

Out of concern regarding the accuracy of TXCTDS's production rates, TXDOT, through the University of Texas's Center for Transportation Research, embarked a new study to pursue quality improvements of TXCTDS's production rate baseline. The research

was conducted by O'Connor et al. between 2002 and 2004 and was published in a report titled *Development of Improved Information for Estimating Construction Time*.

Research procedures initiated with conducting surveys on the use of TXCTDS within TXDOT's districts. Conclusions of these surveys were that contract time determinations were based on estimator's experiences and "best guesses", and that TXDOT needed an alternative reference that would provide more accurate production rates. Moreover, the consideration of factors that affected production rates, such as site conditions, weather, and type of the project, were deemed important drivers to the resulting duration of activities.

In order to establish a new database of accurate production rates, the researchers were sent out to record actual production rates for particular activities from ongoing projects throughout Texas. These observations took place in 63 projects from nine TXDOT districts, including Dallas, Houston, San Antonio, and Lubbock. The information gathered was refined by eliminating extremes and outliers, and went through regression analysis models for accuracy improvements.

The resulting efforts concluded minimum, mean, and maximum production rates for 26 highway construction work items, which can be viewed in Table 3.9 (page 42) of the *Development of Improved Information for Estimating Construction Time* report. As for the scope of work for each activity, tables 3.4, 3.5, 3.6, and 3.7 (pages 37 – 40) of the same report describe the scope differences between their research and TXCTDS, while its Appendix F includes work item sheets depicting scope inclusions and exclusions of 20 of the 26 considered highway construction work items.

The researchers also developed a user friendly information system for amenable access to these production rates. The system is called Highway Production Rates Information System (HYPRIS). The system is composed of an organized layout depicting

the observed production rates for each activity in work item sheets. These also include variations of these production rates when particular activity drivers were present (i.e. work zone area size and weather conditions). Additionally, they incorporate observation percentile tables, graphs, and box plot charts to allow user visualization and analysis of data points.

2.2.3 OKCTDS

According to the *Code of Federal Regulations* Title 23 Section 635.121, all States must have a properly established procedure for contract time determination, and The Federal Highway Administration (FHWA) must have these written procedures approved. However, by 2008, the Oklahoma Department of Transportation (ODOT) did not have written or approved procedures for contract time determination purposes. Acknowledging this fact led Jeong et al. to conduct research on developing a structured system for contract time determination of highway construction projects by analyzing critical construction activities and their respective production rates. Their research was documented in a report titled *Development of an Improved System for Contract Time Determination*.

In order to obtain and record a production rate chart of controlling activities, the researchers analyzed each considered activity and their production rates executed in recently completed projects. Furthermore, they consulted with projects engineers and schedulers to help determine the average production rates and upper and lower range limitations.

The resulting data is recorded in Table 5.5 (page 62) of their specified report. It is composed of 58 controlling activities and expresses minimum, average, and maximum production rate values. Controlling activity descriptions were not found in the report. Nonetheless, ODOT maintains activity definitions in the *2009 Standard Specifications*

Book, where they establish the minimum acceptable standards for all highway construction activities.

2.2.4 KYCTDS

Dr. Donn E. Hancher, lead researcher for TXDOT's CTDS, was also involved in the development of another Contract Time Determination System. This time, it was with the Kentucky Transportation Center at the University of Kentucky. The report of this research was titled *Kentucky Contract Time Determination System* and was published in 2000.

The main objective of this research was to update the contract time determination tool used by the Kentucky Transportation Cabinet (KyTC). This effort was aimed for KyTC to comply with FHWA's request that all States have an established and documented procedure for determining contract time.

The researchers set out to, among other tasks, review contract time determination systems from other DOTs, define the appropriate major activities driving contract time for every highway construction project classification carried out by KyTC, and develop the KY-CTDS: Kentucky Contract Time Determination System for KyTC with a corresponding user manual.

To determine the production rate baseline for the KY-CTDS, researchers relied on historical data and project engineers' experience. The system had the flexibility for the user to select a production rate within the established range due to the topography variance of the Commonwealth of Kentucky. This baseline was tested on recently completed and at the time active projects, and were considered verified after being found "challenging to the contractor but still reasonable". Researchers then established reasonable production rate

ranges considering project size and location, topography and site conditions, and job flexibility.

The baseline, composed of 38 controlling activities with their respective production rate ranges (lower limit, average value, and upper limit), can be perceived in Table 4 (page 13) of the *Kentucky Contract Time Determination System* report. Description of each work item is found in Appendix B of the report.

2.2.5 FLDOT

Florida Department of Transportation (FLDOT) has a documented *Guideline for Establishing Construction Contract Duration* dated on July 2010. It establishes that the whole documentation was derived from *Federal Highway Administration's Guide for Construction Contract Time Determination Procedures* (TA 5080.15 dated 10/15/2002). The document's purpose is to provide guidelines for construction contract time determination of FLDOT's highway projects.

Regarding the establishment of production rates, the 13 page report dictates that production rate ranges should consider project type, size, and location of considered controlling activities. It also dictates the establishment of a database "by using normal historical rates of efficient contractors". A historical data file of three to five years should be maintained and updated regularly for accuracy.

The production rate baseline is documented in a Microsoft Excel spreadsheet composed of low, mean and high production rates for 345 controlling activities, excluding procurement work items. As for scope of work definition, the guide considers only 38 activities.

2.2.6 RSMeans

The RSMeans Cost Guides, published by The Gordian Group, are well known cost estimation resources for construction jobs. Their guides cover most, if not all, construction work activities and delivers costs (bare costs and including overhead and profit) per unit of measurement for each. Particularly, the *RSMeans Heavy Construction Cost Guide 2016*, the 30th edition of this publication, is composed of a great quantity of work items related to big projects, such as highways and airports.

The mentioned guide includes brief descriptions for every item considered with multiple sub items that further specify a particular job. These sub item specifications include different equipment used, diverse site conditions, and particular work conditions, among others. Additionally, in order to calculate the bare and total costs, the guide includes columns reflecting the unit of measurement, crew specifications, the daily output per unit, and the labor-hours required to perform one unit. The guide defines the daily output as “the amount of work that the crew can do in a normal 8-hour workday, including mobilization, layout, movement of materials, and cleanup.”

2.2.7 Other Sources that Provide Production Rate Data

As demanded by the FHWA, most, if not all, DOTs contain documented contract time determination procedures that include production rate data. Some of these examples include the States of Idaho, Indiana, Wisconsin, Illinois, and Iowa, which include data in either production rate averages or ranges.

The Idaho Transportation Department’s *Contract Time Determination in Project Development* (2011) contains a section depicting the average productivity rates for 99 work activities. Iowa Department of Transportation’s *Letting Guidelines* (2016) includes tables specifying suggested daily construction rates in both English and metric units for 84 bid items. However, these sources do not provide production rate ranges.

Illinois DOT's *Bureau of Design and Environment Manual, Chapter Sixty-six Contract Processing* (2010) provides a table of production rates for major work items with low values for small projects and high values for larger projects.

Wisconsin DOT's *Facilities Development Manual* (2015) establishes production rate ranges for 31 work items without specifying averages.

Indiana DOT research (Jiang, 2009) concluded mean daily production rate tables for a great quantity of construction activities, further detailing variations when construction is conducted in rural or urban locations.

2.3 FINDINGS

The conducted literature review shows that there is a significant number of well-documented systems and methodologies for determining contract time that include production rate baselines with low/minimum, average/mean, and high/maximum production rates, similar to TXCTDS's baseline. While interpretations and uses within each system vary, these production rates are comparable when work item scope definitions are relatively similar.

To find the comparable work items within each source, a table was prepared juxtaposing the work items of the reviewed sources that provide low/minimum, average/mean, and high/maximum production rate data. Since the initial purpose of the research that led to this effort was to analyze the comparability of the TXCTDS baseline, its activities are listed in the first column. Each of the following columns represents each supplemental production rate source. The cells intercepting each work item are filled with a checkmark if it is included in the corresponding source, and remain empty when the source does not include the activity. Table 3 shows the described comparison.

Table 3: TXCTDS work items included in other public production rate sources

TXCTDS Work Items	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Clear and Grub		✓	✓	✓	✓
Remove old pavement		✓		✓	✓
Remove old curb & gutter					✓
Remove old sidewalks				✓	✓
Remove old drainage/utility str.					✓
Earth excavation	✓	✓	✓	✓	✓
Rock excavation					✓
Embankment	✓		✓		✓
Pipe	✓	✓	✓	✓	✓
Box culverts	✓	✓	✓	✓	✓
Inlets & manholes	✓	✓		✓	✓
Cofferdams		✓	✓	✓	✓
Piling	✓	✓	✓	✓	✓
Footings	✓			✓	✓
Columns, Caps & Bents	✓	✓		✓	✓
Wing walls	✓	✓		✓	✓
Beam Erection	✓	✓	✓	✓	✓
Bridge deck	✓	✓		✓	✓
Bridge curbs/walks					
Bridge handrails				✓	
Retaining walls	✓		✓	✓	✓
Lime stabilization	✓	✓			✓
Flexible base material	✓	✓	✓		✓
Cement treated base material	✓				✓
New curb and gutter	✓	✓	✓	✓	✓
Asphalt pavement repair			✓		
Concrete pavement repair			✓		
Milling/planing				✓	✓
Hot mix asphalt base		✓	✓		✓
Hot mixed asphalt surface	✓	✓	✓		✓
Asphalt surface treatment (1 course)				✓	
Concrete paving	✓	✓	✓	✓	✓
Precast traffic barriers	✓		✓	✓	✓
Small signs			✓	✓	
Overhead signs			✓	✓	
Major traffic signals			✓		
Pavement markings		✓	✓	✓	✓
Seeding and landscape		✓	✓	✓	✓
Final clean-up		✓	✓	✓	
Initial traffic control			✓		
Detour			✓		
Major Structure demolition					
Remove old structures			✓		
Bridge demolition					
Erect temporary bridge			✓		
Remove temporary bridge			✓		

Table 3 shows that HYPRIS includes 19 of the 46 TXCDTS work items, OKCTDS covers 21, KYCTDS coincides with 28, FLDOT contains 26, and RSMeans comprises 30. Moreover, 43 TXCTDS work items are included in at least one other source. More specifically, 7 TXCTDS work items are included in all of the other five sources, 12 are included in only four of the sources, 6 are included in three of the sources, 5 are included in two of the sources, 13 are included in just one other source, and 3 are not considered in any of the aforementioned sources.

After additional analysis, the supplementary sources include activities of importance for contract time determination that are not covered or further specified in TXCTDS. Some of these important activities are:

- Riprap: Included in OKCTDS, FLDOT, and RSMeans.
- Drilled shaft foundations: Included in HYPRIS, OKCTDS, FLDOT, and RSMeans.
- Concrete abutments: Included in HYPRIS, OKCTDS, and RSMeans.
- Mechanically Stabilized Earth (MSE) walls: Included in HYPRIS, and FLDOT.
- Guardrails: Included in OKCTDS, KYCTDS, and FLDOT.
- Precast concrete box culverts: Included in HYPRIS, FLDOT, and RSMeans.
- Approach slabs: Included in OKCTDS and FLDOT.
- Lighting: Included in OKCTDS, KYCTDS, FLDOT, and RSMeans
- Phasing allowance: Included in OKCTDS and KYCTDS.

Chapter 3: Research Methodology

The methodology process followed in the development of this research starts with conducting a literature review for selecting the publicly available sources that contain comparable production rate information with the TXCTDS baseline. The appropriate work items are then selected to create the Item Worksheets that reflect each work item's production rate information along with production rate averages. The new information is then tested in contract time estimations of TXDOT highway projects. Once the information is corroborated, the *Production Rate Resource* is assembled and the research concludes with a documented report. This section illustrates this procedure in the flowchart shown in Figure 1 and describes each step of the process.

3.1 ESTABLISH RESEARCH OBJECTIVES AND SCOPE LIMITATIONS

Clear objectives will guide the researcher into accurately conducting all activities and steps of the process. Scope limitations must be clear and well documented, recognizing the available resources for the task at hand, such as publicly accessible sources, computer software, Contract Time Determination systems, project documentation, and possible barriers.

3.2 CONDUCT A LITERATURE REVIEW ON PRODUCTION RATES IN CONTRACT TIME DETERMINATION SYSTEMS

A literature review must be conducted to understand the commonly used contract time determination processes and their use of production rates. Furthermore, this task will allow for the search and identification of production rate baselines and databases that are comparable with the TXCTDS production rates.

Figure 1: Research methodology flowchart

3.3 SELECT THE APPROPRIATE SOURCES FOR PRODUCTION RATE DATABASE

Once the literature review is concluded, the appropriate sources are selected for the *Production Rate Resource*'s constitution. These sources must provide production rates for activities similar to TXCTDS's baseline and must offer low, mean, and high production rates (or similar range information). If these are not provided, the low, mean, and high production rates must be clearly calculable. The sources must also be published after the *Construction Contract Time Determination* report (1992).

3.4 SELECT APPROPRIATE WORK ITEMS FOR PRODUCTION RATE RESOURCE

In order for a work item to be included in the resource, it must be included in the TXCTDS or in at least 2 of the other selected sources, and must provide work item information considered important for contract time determination. Scope information must also be available, whether it is an activity description or specific inclusions and exclusions.

3.5 DESIGN PROTOTYPE OF ITEM WORKSHEETS

Creating a Microsoft Excel template that is equipped with functions that link production rate table cells to average calculations and comparison charts, an Item Worksheet prototype is created to facilitate Item Worksheet creation repetitions. Ideally, plugging in the production rates into production rate cells automatically yield low, mean, and high averages and reflect information in visual charts.

3.6 CREATE ITEM WORKSHEETS

Using a copy of the designed prototype, the Item worksheets for each work item are created by introducing the production rates from each source and the scope information, and adjusting the automatic calculations when needed.

- Record production rates: All production rates from the selected sources are to be recorded in the production rate table, consistent with the low, mean, and high production rate denominations. If the production rates are in different units and a conversion is clearly calculable, the production rates are to be converted to the consistent units and the conversion process should be documented. If the units are different and a conversion is not clearly calculable, the production rates are to be recorded in the same fashion and the sources' units must be highlighted to identify the difference.

- Record scope definitions, inclusions and exclusions: scope information is then recorded into a scope table. If the source considers inclusions and exclusions, this information is copied to the corresponding inclusions and exclusions cells as is specified in the source. If the source only specifies a definition of the work item, this definition is copied to the corresponding inclusions cell. If an exclusion is implied by the documentation yet not specified in the text, these exclusions are added to the corresponding exclusions cell. If the text is too long for the assigned cell, the text may be paraphrased or summarized to make the text fit, without eliminating important work related wording.
- Adjust production rate averages and charts: When production rates with inconsistent units are introduced into an Item Worksheet, the average calculation cells and the graph charts must be adjusted in order to exclude these production rates. These adjustments allow for average calculations and comparison charts to show the provided information in consistent units while still showing the highlighted inconsistent unit production rates in the production rate table.

3.7 FILTER WORK ITEMS

Throughout the work item selection and Item Worksheet creation processes, production rate information additional to the provided in the TXCTDS may be discarded from inclusion in the *Production Rate Resource*. Complete work items may be discarded due to little importance for contract time determination purposes, and if scope of work is included as part of another work item. Furthermore, production rates from a specific source may be discarded if the scope information proves to be inconsistent with the relevant work item, and if the production rates can't be clearly identified as Low, Mean, or High.

3.8 CONDUCT CONTRACT TIME ESTIMATION FOR HIGHWAY PROJECTS

At this stage of the process, the information gathered is used to estimate contract durations on real TXDOT highway projects. The production rate averages calculated for the *Production Rate Resource* are primarily used, and are supported with production rates from the other selected sources when critical path work items are not included in the resource.

3.9 INCLUDE ADDITIONAL WORK ITEMS AND PRODUCTION RATE DATA INTO PRODUCTION RATE RESOURCE

The contract time estimation findings and experiences from the previous step may allow for considering the inclusion of more production rate sources and work items.

When adding another production rate source, the methodology returns to the work item selection step, adding more work items if considered, and then proceeding to adapting the Item Worksheets prototype to incorporate the new source. Since the new prototype would be different from all previously created Item Worksheets, new Item Worksheets are to be created for all work items using the new prototype by copying and pasting the information from the old Item Worksheets and including the production rates from the new source.

When including another work item, the latest designed prototype is used to create a new Item Worksheet.

3.10 DEVELOP THE PRODUCTION RATE RESOURCE

At this stage of the methodology, the *Production Rate Resource* is produced by creating the introductory and sources tabs and the summary sheet while organizing the Item Worksheets.

- Assemble Item Worksheets: Each Item Worksheet is revised to insure that the production rate data, the scope information, and the possible conversions are

accurate and well documented. Furthermore, each work item's identification number is consistent with the respective TXDOT identification number, and are arranged in order of this given number for reference.

- Create the Summary Sheet: The summary sheet is an Excel tab that expresses all the work items included in the *Production Rate Resource*, arranged in order of TXDOT specification number, and should show all the recorded production rates from all the included sources in one table. It should also show the calculated production rate averages.
- Create the Introductory Sheets: The resource is to have two introductory sheets:
 - An Introduction sheet, briefly describing the resource's purpose and content.
 - A Sources sheet, identifying the publications and systems used as production rate references and the criteria for extracting production rates and scope information from each source.

3.11 DEVELOP RESEARCH REPORT

The final step of the methodology is to document all activities involving the development of the *Production Rate Resource* in a report, explaining research objectives, scope limitations, the used methodology, the TXDOT project contract time estimations, the final version of the resource, and conclusions and recommendations.

Chapter 4: Production Rate Resource

The *Production Rate Resource* is the product of this research. It encompasses the production rate data of 59 highway construction work items extracted from six publicly available sources, calculating production rate averages and depicting the data in tables and graphics for visual analysis and comparison. The resource is proposed as a simple reference of production rate data for TXDOT contract time estimators.

This chapter describes the content of the *Production Rate Resource*. Its first section goes over the sources that provided production rate information for the resource followed by an explanation of its structure. The following sections depict the resource's components and their intended use, providing figures that exemplify these components.

A printout of the *Production Rate Resource* Excel workbook can be found in Appendix A of this report.

4.1 PRODUCTION RATE SOURCES

Six publicly available sources were selected to constitute the *Production Rate Resource* and provide production rate data for its included work items. The following is a list of these sources, specifying the publications from which the information was extracted, their authors, the total number of work items contained in their databases, and the number of work items included in the *Production Rate Resource* from each database.

Texas Department of Transportation Contract Time Determination System (TXCTDS):

- Publication: *Construction Contract Time Determination* (1992).
- Authors: Donn E. Hancher, William F. McFarland, Rifat T. Alabay.
- Work items contained in database: 46.
- Work items included in the resource: 46.

Highway Production Rate Information System (HYPRIS):

- Publication: *Development of Improved Information for Estimating Construction Time* (2004).
- Authors: James T. O'Connor, Wai Kiong Chong, Youngki Huh, Yao-chen Kuo.
- Work items contained in database: 26.
- Work items included in the resource: 24.

Oklahoma Contract Time Determination System (OKCTDS):

- Publication: *Development of an Improved System for Contract Time Determination* (2008).
- Authors: Hyung Seok Jeong, Garold D. Oberlender, Siddharth Atreya, Venkatesh Akella.
- Work items contained in database: 58.
- Work items included in the resource: 30.

Kentucky Contract Time Determination System (KYCTDS):

- Publication: *Kentucky Contract Time Determination System* (2000).
- Authors: Donn E. Hancher, Raymond F. Werkmeister.
- Work items contained in database: 38.
- Work items included in the resource: 31.

Florida Department of Transportation's Guideline for Establishing Construction Contract Duration (FLDOT):

- Publication: *Guideline for Establishing Construction Contract Duration* (2010).
- Authors: Florida Department of Transportation.
- Work items contained in database: 345.
- Work items included in the resource: 38.

RSMeans Heavy Construction Cost Data 2016 (RSMeans):

- Publication: *RSMeans Heavy Construction Cost Data 2016* (2015).
- Authors: Derrick Hale, The Gordian Group.
- Work items contained in database: over 15,500.
- Work items included in the resource: 38.

4.2 STRUCTURE

The structure of the *Production Rate Resource* is a simple arrangement of sequential Microsoft Excel tabs. The arrangement starts with an introduction tab, followed by the sources tab and the summary tab. After the summary tab, all item worksheets are displayed in ascending order of TXDOT specifications numbers. Figure 2 illustrates the described structure.

Figure 2: Production Rate Resource Structure

4.3 INTRODUCTION TAB

The introduction tab is included to briefly welcome the user to the *Production Rate Resource*. It is a text-only Excel sheet that begins with the description of the resource's purpose and identifying the public domain sources from which the production rate information was extracted. The next paragraph explains the production rate information found in each of the item worksheets and a short description of how the user can use or select the appropriate production rates. Finally, the introduction tab concludes with a summary of the resource's content, identifying the resource's tabs and their content in a bullet point scheme. Appendix A-1 contains the introduction tab's content.

4.4 SOURCES TAB

The purpose of the sources tab is to identify the publications and contract time determination systems from which the production rates were extracted for developing the *Production Rate Resource*. It also includes specifically what part of each publication and/or system details the production rates (e.g. a table number identified in the original publication) and how they were interpreted to be introduced in the item worksheets. Furthermore, this tab includes the sources of the scope table information, specifying sections from the original publications that provide definitions, inclusions, and/or exclusions for each work item. Appendix A-2 shows the sources tab's content.

4.5 SUMMARY TAB

The summary tab is composed by a table that encompasses all the work items included in the resource and the respective production rates from each of the original sources. Its intended use is to list the included work items as well as to pinpoint the most important production rate information of the resource, giving the user the option to avoid searching for the desired data in the more detailed item worksheets.

The first column of the table identifies the TXDOT specifications work item number for the corresponding work item; the second column gives the description of each work item; and the third column specifies the units for each work item. These are followed by six sets of three columns showing the Low, Mean, and High production rates from each of the six original sources. The table ends with a final set of three columns displaying the average Low, average Mean, and average High production rates. If an original source does not include a work item in their production rate database, the corresponding cell is filled with a dash (“-“) representing the lack of information. If an original source includes a particular work item yet the production rates are specified in different, hard to convert

units, the corresponding Low, Mean and High cells of the work item in that source are merged into one cell displaying the text “Inconsistent units”.

Appendix A-3 shows the content of the described summary table as it appears in the *Production Rate Resource*.

4.6 ITEM WORKSHEET TABS

The item worksheets are the main content of the *Production Rate Resource*. Each worksheet is a tab that includes all the production rate information recollected for each work item. Appendix A-4 contains the resource’s 59 item worksheets.

Each item worksheet includes a header, a rate table, a production rate comparison chart, a production rate range chart, and a scope table.

4.6.1 Header

The header of the item worksheet identifies, in order from left to right, the TXDOT specifications work item number, the work item name or description, and the unit of measurement. The units of measurement identified in the header is the unit used for all average calculations and graphics in the item worksheet. Figure 3 is an example of an item worksheet header.

Work Item #	Work Item	Unit of measurement
110	Excavation	CY/Day

Figure 3: Example of Item Worksheet Header

4.6.2 Rate Table

The rate table is where all the production rates are displayed. Each column represents each of the original sources, presenting the units in the first row, the Low production rates in the second row, the Mean production rates in the third row, and the

High production rates in the fourth row. The final column of the table expresses the average values of the Low, Mean, and High production rates. Figure 4 illustrates an example of the rate table, showing only three sources to facilitate visualization and printing.

Rate Table	TXCTDS	HYPRIIS	OKCTDS	Average
Units	CY/Day	CY/Day	CY/Day	CY/Day
Low	1,200	199	1,800	861
Mean	3,400	1,163	2,825	3,013
High	7,000	3,558	7,000	8,310

Figure 4: Example of an item worksheet's rate table

If a source does not include production rate information for the respective work item, the units, Low, Mean, and High cells of the corresponding source are merged into one cell and filled with the text: "No production rate information from source".

If a source includes production rate information for the respective work item in different units and these units were not converted, the production rates are given in the original units, highlighting the unit and production rate cells in yellow to pinpoint this event. Furthermore, the average calculations exclude the data from this source in the existence of this event.

Figure 5 illustrates an example of a rate table showing the occurrence of these two particularities in one item worksheet.

Rate Table	TXCTDS	OKCTDS	KYCTDS	Average
Units	SY/Day	No production rate information from source	TONS/Day	SY/Day
Low	100		20	100
Mean	200		50	200
High	300		80	300

Figure 5: Example of a rate table with two sources that do not provide production rate information and one source that provides production rate data in different unit

4.6.3 Production Rate Comparison Chart

The production rate comparison chart is a column chart that juxtaposes the Low, Mean, and High production rate values from each source and the respective calculated averages. This chart is displayed as a visual aid that allows the user to compare the variance of production rate values between the different sources. Figure 6 shows an example of a production rate comparison chart.

Figure 6: Production rate comparison chart example

In the event that a source does not include production rate information for a particular work item, or that a source includes production rate information in different units

that were not converted, the production rate comparison chart would exclude these sources showing only the sources with production rate data consistent with the unit of measurement identified in the header. Figure 7 illustrates an example of this event.

Figure 7: Production rate comparison chart example excluding sources that do not provide production rate data or provide production rate data in inconsistent units

4.6.4 Production Rate Range Chart

The production rate range chart helps the user visualize the ranges for which the different sources consider production rates to be Low, Mean, or High. The chart contains three box and whiskers plots representing the Low, Mean, and High production rate ranges.

Each plot's whisker extremes will illustrate the lowest and highest production rate values within the sources. The plot's box represents the interquartile range, limited at the bottom end by the first quartile and at the top end by the third quartile. Furthermore, a center line indicates the median data point and an "x" indicates the average. If production rate values exceed a difference of one and a half times the interquartile range lower than

the first quartile or higher than the third quartile, these values are considered outliers, represented as a dot over or under the respective box and whiskers plot.

In the event that a source does not include production rate information for a particular work item, or that a source includes production rate information in different units that were not converted, the production rate range chart would exclude these sources from its box and whiskers plots.

Figure 8 shows an example of a production rate range chart.

Figure 8: Production rate range chart example

4.6.5 Scope Table

The scope table contains the scope limitation descriptions provided by the original sources and the original units used with the corresponding conversions when needed.

The first and second rows are composed by the inclusions and exclusions from each source pertaining to the respective work item. The corresponding cell is filled with a text extract from the original source. Both the inclusion and exclusion cells are filled when a source explicitly contains scope inclusion and exclusion information. In the event that a

source provides only a definition or description of the work item, this text is introduced in the inclusions cell while filling the exclusions cell with the text: “No specific exclusions identified in source”. The exclusions cell can alternatively be filled with information implied as not included in the definitions or descriptions provided. If a source does not provide production rate data, the corresponding inclusions and exclusions cells are both filled with the text: “No production rate information from source”.

The third row shows the units used by the original sources to reflect the production rate data. If the data was converted to be consistent with the units of measurement described in the item worksheet header, conversion criteria information is provided in the fourth row. If a source provides data in consistent units with the header, the respective conversions cell is filled with the text: “Not needed”. If a source provides data in inconsistent, unconvertable units with the header, the respective conversions cell is filled with the text: “Not convertible”. Cells in these two rows are filled with the text “N/A” (not applicable) when the original source does not provide production rate information. Figure 9 shows an example of the scope table, showing only four sources to facilitate visualization and printing.

Scope Table	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	All activities required to construct cofferdams on a project	The installation, dewatering and minor excavation associated with building a cofferdam system for a bridge construction site	Cofferdams, including mobilization and temporary sheeting; Soldier beams and lagging H piles; No Hydrostatic head; Lagging only; Open sheeting no bracing
Exclusions	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	Tie-back method Trench box
Original units	N/A	Days	SY/Day	SF/Day
Conversions	N/A	Not convertible	Not needed	1 SF = 0.11111 SY

Figure 9: Scope table example

4.7 RECOMMENDED CONTRACT TIME DETERMINATION PROCESS

This section dictates the recommended procedure for conducting a contract time determination using the *Production Rate Resource*. This procedure includes gathering all available information on the desired project and scrutinizing this material to identify major project activities, and conducting the adequate calculations in order to obtain a contract duration in working days. The flowchart in Figure 10 illustrates this process. It covers 17 detailed steps categorized in four process sections: pre-contract time determination preparation, contract time determination calculation, establish and document assumptions, and analysis of results.

4.7.1 Pre-Contract Time Determination Preparation

The pre-contract time determination section allows for the proper preparation and information gathering in order to obtain the most accurate estimation. The section contains six steps described in the following list.

- 1. Establish and understand task objectives and scope limitations:** precise and identifiable objectives allow for an accurate assessment of the activities and steps to be conducted. Scope limitations need to be clear and well documented, recognizing available project documentation, accessible and appropriate tools, and analysis of barriers.
- 2. Gather information and documentation on the highway project:** For contract time determination, the more information gathered on the project, the more precise the calculations will be. These should include plans, major controlling activity specifications and work quantities, a general construction sequence, the Traffic Control Plan (TCP), and a Work Breakdown Structure determined by designers if available.

Figure 10: Contract time determination process flowchart

- Study plans, major work items, and estimated quantities:** A critical portion of the contract time estimation is to find out how many working days it takes to execute each activity at a particular point in a project, as these may be part of the project's critical

path. Analyzing plans and major work items helps to understand the physical location of activities, identify potential critical paths, and separate activity quantities into project phases.

- 4. Understand the construction sequence and Traffic Control Plan (TCP):** This step will allow for the general understanding of the project execution dictating that certain phases of the project are to be conducted in a particular sequence, most of the time due to the necessity of controlling ongoing traffic in certain physical areas. Although the construction sequence and TCP dictated may not seem the correct order of activities during the process, these are to be respected and considered a mandatory sequence.
- 5. Develop a Work Breakdown Structure (WBS) (if not provided):** Having an organized and detailed WBS reflecting the project's potential critical path activities while arranging these by construction sequence phases is necessary in order to determine the point in time of each activity's initiation. If not provided by the design team in the project documentation, the estimator should develop and assume a WBS for the contract time estimation.
- 6. Allocate activity quantities by construction sequence and TCP phases (if necessary):** If activity quantities are not divided by the project's phases, it cannot be assumed that the contract duration calculation would be the same as if they were contained within one work item. This analysis is subject to conditional factors (such as activity initiation and equipment demobilization) that are considered when determining production rate levels (following steps). These levels may vary in different phases of a project due to particular phase characteristics and physical location factors. If this division is not given in project specifications, separating activity quantities by project phases is of crucial importance.

4.7.2 Contract Time Determination Calculation

With a developed WBS with properly allocated activity quantities, the information is ready for the contract time calculation process. This section contains eight steps described as follows.

- 7. Identify production rate sources for each activity:** The next thing needed is an adequate production rate for each activity in each phase of the project. In order to do so, the recommended source for production rates is the *Production Rate Resource*. If a particular activity is not included within the aforementioned resource, it is recommended to use the sources contained within the *Production Rate Resource* as production rate references prior to consulting other databases.
- 8. Analyze activity production rate drivers:** The analysis of important drivers that affect the execution of each activity will help us determine the appropriate level of production rate. Some drivers to be considered are: work zone size, relative quantities of the activity, number and size of crews, and the equipment used for each activity.
- 9. Select a production rate level – low, mean, or high – for each activity and record production rate:** Taking into consideration the interpretation of plans and specifications for every particular activity in a correspondent project phase and the drivers analyzed in the previous step, the estimator is to assign a production rate level of Low (L), Mean (M), or High (H) for each activity. These are to be consistent with the Low/Minimum, Mean/Average, and High/Maximum categories in the sources selected in step 7. If there is insufficient information on activity drivers to determine a production rate level based on the information given, a Mean (M) level should be assumed.
- 10. Calculate number of working days for each activity given such production rates:**
A simple division calculation is required. Take the quantity of an activity divided by

its daily production rate to retrieve the duration of an activity in working days. This number is to be rounded up to a complete number of working days. If it is determined that an activity starts at a completion percentage of its preceding activity, the preceding activity's duration in working days should be multiplied by such percentage factor and rounded up to a complete number of working days. Furthermore, if it is assumed that there is more than one crew assigned to a particular activity, the production rate of the activity is multiplied times the number of crews assigned, hence yielding a higher production rate. This calculation is executed for every activity in the WBS.

- 11. Create a precedence network:** Reflecting the contract duration in a precedence network should help for understanding and analyzing the construction sequence, allowing for the verification of the WBS and the duration of each activity, each phase, and the project as a whole.
- 12. Reflect results in a Gantt chart or Linear Sequence Model (LSM):** For ease of visualization, it is necessary to reflect the precedence network on a Gantt chart or Linear Sequence Model. Doing so will allow to pinpoint logic ties (preceding and succeeding activities), activities executed in parallel, and the critical path.
- 13. Identify the critical path:** Identifying the longest path will show the sequence of activities that determine the contract duration. In this step, the path is reanalyzed to assure the appropriate sequence was established by depicting parallel paths and confirming the proper assignment of predecessor and successor activities.
- 14. Establish the contract duration of the project:** The estimator extracts the critical path activities and develops a table showing only these activities with their corresponding predecessor and their completion percentage. The sum of the critical path activity durations, considering completion percentage of predecessors, yields the project contract duration.

4.7.3 Establish and Document Assumptions

Establishing and documenting assumptions constitutes a section of its own since it is implemented in parallel throughout the process. While analyzing project documents and production rate sources, assumptions must be recorded as these may result in conditions and limitations. These are to be consistent with all contract duration calculations and should be documented for exceptions, considerations, and further analysis.

4.7.4 Analysis of Results

The final section of the process constitutes analyzing the results and preparing a final report. These two steps are described below.

15. Analyze resulting contract duration and compare with project designer's

estimation: The resulting contract duration is to be depicted for particularities in analysis criteria, project interpretation, critical path activities, quantity allocations within project phases, and production rates used. If the project designer's estimation and/or other third party analysis are available, the comparison of the resulting contract duration with this information is recommended, scrutinizing differences in the aforementioned matters. This step allows to identify errors and misinterpretations that can be corrected to reflect more accurate results.

16. Prepare task report: The final step is to document all activities regarding the contract duration estimated in a report, highlighting objectives, scope limitations, the executed contract time estimation, its analysis and comparison with project designer's estimation, and conclusions and recommendations.

Chapter 5: Case Studies

The *Production Rate Resource*'s gathered database of calculated averages for Low, Mean, and High production rates was tested by conducting two contract time determinations on actual TXDOT projects. After calculating these durations, the contract time estimations were compared with TXDOT estimator's results. This task serves as a validation of the gathered data and allows to look for improvements to the resource.

It is important to note that at the time these case studies were conducted, the *Production Rate Resource*'s database contained only 27 work items with data provided from five publicly available sources. The findings of these case studies led to the resource's improvement, increasing its scope to 59 work items with data provided from six sources.

The contract time determination process recommended in Section 4.7 served as a guideline to conduct these case studies. The effort's objectives and scope limitations were first established. Then, two case studies pertaining to two TXDOT highway construction projects resulted in the calculation of their contract time estimations. Each case study contains a project description, the description of the followed process for concluding estimation results, the comparison of each case study's results with TXDOT estimator's results, and conclusions and recommendations for each project.

5.1 CASE STUDY OBJECTIVES

The main objective for conducting case studies is to test the *Production Rate Resource*'s database on actual TXDOT highway construction projects by analyzing the applicability of the data and comparing the results to identify significant differences and improvements. The following, more specific, objectives will help fulfill the main objective:

- Estimate the contract duration of two TXDOT projects using the *Production Rate Resource*'s gathered information as the main reference for production rate data.

- Compare the resulting contract time determinations with project design teams' estimations to identify significant differences between each process and their results.
- Conclude findings that would promote the improvement of the *Production Rate Resource*.

5.2 CONTRACT TIME DETERMINATION LIMITATIONS

The procedures used to conduct the contract time determinations of both case studies are guided by the steps detailed in the recommended process specified in Section 4.7 of this report.

In order to conduct an adequate contract time determination, detailed plans and documentation identifying activity quantities must be provided for each of the projects analyzed. If such information creates a logical, identifiable, and well-interpreted construction sequence, then it is more likely to achieve a proper contract time determination. Other relevant factors such as crews, equipment to be used, and site conditions play a big role in achieving this goal. If the above factors are not clearly specified, the estimator will have to rely on assumptions and potential misinformation when creating a rational outcome. Therefore, the result of this process hinges on the information provided to the estimator, as well as the estimator's interpretation and assumptions of such documents in regards to each project.

The resulting contract duration estimations refer to two specific TXDOT projects: 1) US80 IH635 and 2) US287. Project plans and specifications – including the construction sequences and Traffic Control Plans (TCP) – and the contract time estimate sheets provided by TXDOT for analysis in these case studies may or may not be final versions due to revisions before contract letting. For case study 1, the used version of the US 80 Plans of Proposed State Highway Improvement was signed by registrant on May 12, 2016, and was

provided for this study on May 13, 2016. US 80 Contract Time Estimate sheet is dated on January 14, 2015 and was provided for this study on June 22, 2016. For case study 2, the used version of the US 287 Plans of Proposed State Highway Improvement was signed by registrant on November 20, 2015, and was provided for this study on June 27, 2016. US 287 Contract Time Estimate sheet was signed by Professional Engineer on October 24, 2016 and was provided for this study on November 21, 2016.

The results and comparison analysis are limitedly based on the aforementioned documents. Activities not perceivable in such documentation are excluded from this task.

The primary source of production rates is the *Production Rate Resource* (PR Resource) and the averages calculated for each production rate level (low, mean, and high) for each activity. At the time the case studies were conducted, the Production Rate Resource was under development. The early stage version used contained only 27 work items and did not include production rate data from Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration*.

If a particular activity is not included in the *Production Rate Resource*'s database, then the following five sources were used as reference for the analysis. These sources – in order of reference priority – are: TXDOT *Contract Time Determination System* (TXCTDS), *Highway Production Rate Information System* (HYPRIS), *Oklahoma Contract Time Determination System* (OKCTDS), *Kentucky Contract Time Determination System* (KYCTDS), *RSMeans Heavy Construction Cost Guide 2016* (RSMeans), and Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration* (FLDOT).

As for the tools needed for the case studies, the only computer programs used were Microsoft Excel and Microsoft Project. All tables, calculations, precedence networks, Gantt charts, and Linear Sequence Models are conducted through these programs.

5.4 CASE STUDY 1: US 80 HIGHWAY IMPROVEMENT PROJECT

5.4.1 Project Description

The project to be addressed in the first case study is the Texas Department of Transportation State Highway Improvement project of US 80 in the Dallas County (CCSJ: 0095-02-102, etc.). It consists of the improvements and construction of frontage roads and ramps along the south east sector of the IH635 and US80 intersection (IH635: from station 1017+92.59 to 1067+76.91; US80: from station 331+82.40 to 366+51.36). These activities include:

- IH635 northbound Gross Road Exit and Entrance ramps.
- Intersection of these ramps at Gross Road.
- IH635 northbound Frontage Road from Gross Road to US80 eastbound Frontage Road.
- US80 eastbound Frontage Road from IH635 northbound Frontage Road intersection to Galloway Avenue.
- New US80 eastbound Galloway Exit ramp.
- Demolition of old US80 eastbound Galloway Exit ramp.

5.4.1.1 Project Documents and Plans

A complete set of the project plans was supplied for this case study, detailing most – if not all – aspects of the project. Of particular interest for the purpose of contract time determination are the following items: project layout; proposed typical sections; specification data; general estimate and quantities; work item summaries; sequence of construction; Traffic Control Plan; roadway details; drainage details; bridge specifications.

Additionally, a summary of major activities and quantities specified by construction sequence phases are shown in Table 4.

Table 4: Major project activities and quantities provided by TXDOT

TASK #	Description	Quantity	Unit
1	Initial Traffic Control Phase 1	1	LS
2	Erosion Ctrl - Phase 1	3,087	SY
3	Detours Widening Phase 1	1	LS
4	Prep ROW	3	AC
5	Temporary Drainage/Shoring	690	SY
6	Remove old Pavement	1,821	SY
7	Excavation	5,840	CY
8	New Box Culvert Extension	108	LF
9	Storm Sewer Pipes & TEP	935	LF
10	Storm Sewer Inlets/Manholes	39	EA
11	Embankment	223	CY
12	Flex Base	5,821	SY
13	HMAC Base	5,821	SY
14	Concrete Pavement	5,022	SY
15	Block Sod/CMT	19,430	SY
16	Small Signs	4	EA
17	Pavement Markings	6,867	LF
18	Final Clean-up Phase 1	11	STA
19	Initial Traffic Control Phase 2	1	LS
20	Erosion Ctrl - Phase 2	14,436	SY
21	Detours Widening Phase 2	1	LS
22	Prep ROW	16	AC
23	Remove old Pavement	6170	SY
24	Remove Old drainage Structure	160	LF
25	Excavation	36340	CY
26	Channel Excavation/Grading	800	CY
27	New Box Culverts (2,3,4)	485	LF
28	Storm Sewer Pipes & TEP	825	LF
29	Storm Sewer Inlets/Manholes	14	EA
30	Bridge Structure	1	LS
31	Cofferdam	178	SY
32	Piling	165	LF
33	Footings	43	CY
34	Caps & Bents	57	CY
35	Wingwalls	275	SF
36	Beams	718	LF
37	Bridge Deck	84	CY
38	Bridge Curb/curbs	74	LF
39	Embankment	10,280	CY
40	Flex Base	18,882	SY
41	HMAC Base	18,882	SY
42	Concrete Pavement	17,147	SY
43	Block Sod/CMT	6,747	SY
44	Intersections/ Signals PT	1	EA
45	Small Signs	1	EA
46	Pavement Markings	12,066	LF
47	Final Clean-up Phase 2	40	STA
48	Initial Traffic Control Phase 3	1	LS
49	Erosion Control - Phase 3	10,910	SY
50	Detour widening - Phase 3	1	LS
51	Prep ROW	10	AC
52	Temporary Drainage/Shoring	12	SY
53	Remove old Pavement	12,381	SY
54	Remove old Driveways	1,164	SY
55	Remove Old drainage Structure	866	LF
56	Excavation	18,030	CY
57	Exist. Bridge Class Culvert Ext.	51	LF
58	Storm Sewer Pipes & TEP	2,087	LF
59	Storm Sewer Inlets/Manholes	8	EA
60	Embankment	4,628	CY
61	Flex Base	21,201	SY
62	HMAC Base	21,201	SY
63	Concrete Pavement	19,518	SY
64	Block Sod/CMT	3,138	SY
65	Intersections/ Signals PT	1	EA
66	Small Signs	4	EA
67	Pavement Markings	3,925	LF
68	Final Clean-up	37	STA

5.4.1.2 Construction Sequence and Traffic Control Plan

Since most of the project consists of ramps and frontage road improvements, traffic plays an important factor in its construction sequence. Hence, a large part of the construction sequence is determined by the Traffic Control Plan (TCP) as specified in the project documentation. Such TCP dictates for the project to be delivered in three phases, each of these containing various stages. These phases include the following sectors:

- Phase 1 – IH 635 northbound Gross Road Exit Ramp (11 Stations, 5 Stages).
- Phase 2 – IH 635 northbound Gross Road Entrance Ramp & Frontage Road (38 stations, 3 Stages).
- Phase 3 – US 80 Frontage Road (36 stations, 5 Stages).

Appendix B shows the Construction Sequence description and specifications extracted from the project's documents.

5.4.2 Contract Time Determination

To initiate the contract time determination of the IH635 US80 Frontage Road improvement project, all available documentation was gathered. These included project plans as described in Section 5.4.1 of this report. These documentation and plans were then studied and analyzed in order to identify important information for the contract time determination, such as the construction sequence of the project, major work activities, construction methods to be implemented, and estimated quantities for each activity.

Further information was requested in order to better visualize activity quantities divided in the correspondent construction sequence phases and stages. Due to this request, Table 4 (Section 5.4.1.1) was supplied by the project's design team.

5.4.2.1 Analysis of Construction Sequence and TCP

Perhaps the most important aspect for determining the contract duration of this and any project is understanding the construction sequence and traffic control plan (TCP). As described in Chapter 2 of this report, the TCP is a major factor due to the nature of the project. The improvement efforts of three entrance/exit ramps and approximately 3600ft of existing US80 Frontage Road call for the imminent need for an adequate TCP. As a result, the project construction sequence is divided into 3 phases, each with their own set of stages specified as follows:

- Phase 1 – IH 635 northbound Gross Road Exit Ramp (11 Stations):
 - Stage 1 – Detour Widening for Gross Road Exit Ramp traffic.
 - Stage 2 – Gross Road Exit Ramp Right Side.
 - Stage 3 – Right Thru-Lane portion of Gross Road Exit Ramp.
 - Stage 4 – Gross Road Exit Ramp Left Side.
 - Stage 5 – Construct Large Island at Gross Road intersection.
- Phase 2 – IH 635 northbound Gross Road Entrance Ramp & Frontage Road (38 stations):
 - Stage 1 – Detour Widening for Gross Road Entrance Ramp traffic.
 - Stage 2 – Gross Road Entrance Ramp.
 - Stage 3 – IH 635 Frontage Road from Gross Road intersection to US 80 eastbound merge.
- Phase 3 – US 80 Frontage Road (36 stations):
 - Stage 1 – Detour Widening for US 80 Frontage Road traffic.
 - Stage 2 – US 80 Frontage Road Right Lane.
 - Stage 3 – US 80 Frontage Road Left & Middle Lanes, including new Galloway Ave. Exit Ramp.

- Stage 4 – US 80 Frontage Road Left & Middle Lane Portion.
- Stage 5 – Remove Old Galloway Ave. Exit Ramp.

It is also stated that even though these three phases correspond to three different physical sectors, this sequence should be respected and no phase is to initiate until the previous phase is complete.

One particular aspect of this sequence is that traffic affects every phase and stage of the project except for phase 2 stage 3, consisting of the construction of a new portion of IH635 northbound frontage road. This suggests that the construction of this particular stage could start simultaneously with phase 2 stages 1 or 2, or even during phase 1. However, for the purpose of this contract time determination and respecting the statement described in the previous paragraph, that consideration was ignored.

Another identified aspect of phase 2 stage 3 is the demand for a 74ft bridge to be constructed. For ease of analysis and considering that different activities can be separated in three distinct sectors, this particular stage was divided into three sub-stages:

- Phase 2 stage 3 – A: IH 635 northbound Frontage Road before bridge (Stations from 1029+00 to 1040+00).
- Phase 2 stage 3 – B: IH 635 northbound Frontage Road bridge area (Stations from 1040+00 to 1051+00).
- Phase 2 stage 3 – C: IH 635 northbound Frontage Road after bridge (Stations from 1051+00 to 1067+00).

5.4.2.2 Work Breakdown Structure and Quantity Allocation

With the information gathered, a Work Breakdown Structure (WBS) was needed in order to address the major activities in each phase and stage of the construction sequence. Therefore, the identified major activities were organized in accordance to each phase and

stage in an assumed chronological order. Each stage required traffic control activities at the beginning and clean-up activities at the end due to traffic logistics.

The next step was to identify and separate activity quantities in different stages. The information gathered only reflected quantities divided by phases, not by phase stages. These quantities were the result of dividing the obtained quantities based on plan observations – most importantly from Project Layout, TCP, and Proposed Typical Sections plans – and assuming approximate work area percentages for each stage. The following example illustrates this process: For phase 2 in the sector between stations 1029+00.00 and 1040+00.00 of IH635 northbound frontage road, roadway construction quantities are given. To divide these by stages, it was observed that the Gross Road entrance ramp (phase 2 stage 2) only represents one lane of the construction area while IH 635 Frontage Road (phase 2 stage 3 – A) is constituted by two lanes. Hence, the division of roadway construction activity quantities was assumed as approximately 40% for phase 2 stage 2 and 60% for phase 2 stage 3 – A.

It is to be noted that the utilized activity quantities were not identical to the ones provided by TXDOT (Table 4) as such information was used to complement quantity data when project documentation – and its interpretation – were not conclusive in identifying particular activities and quantities.

Appendix C reflects the established WBS for each construction sequence phase detailing the quantities for each activity in each phase and stage.

5.4.2.3 Identifying Production Rate Sources and Levels, and Activity Duration Calculation

Once the WBS is established, the idea is to find the duration, in working days, of each major activity identified. To conduct the appropriate calculation, daily production rates are required for each activity. These were primarily extracted from the *Production*

Rate Resource in order to attempt to fulfill the task's objectives. However, since this analysis did not cover all identified major activities, other sources were required to expand the pool of production rates. Therefore, the sources used were expanded to those covered in the mentioned analysis. These – in order of reference priority – are: TXCTDS, HYPRIS, OKCTDS, KYCTDS, and RSMeans. Since all HYPRIS activities were included in the *Production Rate Resource* and no major project activities were identified from the KYCTDS respecting the given reference priority order, these two sources were discarded from this task.

Once the source was selected for each activity, a production rate level was identified. These were categorized in three levels on each source: low/minimum (identified with the letter L in calculation tables in Appendixes D and E), mean (identified with the letter M), and high/maximum (identified with the letter H). The selection of the level depended primarily on activity circumstances for each stage and was subject to the estimator's interpretation. As a result, most activity levels were given a Mean production rate level, followed by Low/Minimum and High/Maximum respectively, as shown in Table 5.

Table 5: Case study 1 Percentage Distribution of activity level selection

Level	Percent selected
High/Maximum	9.8%
Mean	72.4%
Low/Minimum	17.8%

Finally, a simple division calculation of activity quantities by the respective production rate yielded the duration in working days for each activity. This result was always rounded up to the nearest integer stating that each activity, for duration estimation

purposes, was to be given a number of whole days for its execution. This also allows for inclusion of crew and equipment preparation, mobilization, and demobilization.

5.4.2.4 Established Assumptions

At this point, all established assumptions have been documented, including the fulfillment of all previous steps as well as assumptions regarding project logistics. This process accounts for estimation results while allowing room for considerations that may not be covered by this contract estimation. The established assumptions for this case study are:

- A Buffer Time of 1 day was allocated at the beginning or end of each stage, allowing for a phase/stage adjustment period. This period does not include Traffic Control and Cleanup as both are considered as major activities in our WBS.
- All materials and equipment are at the jobsite and all contractor crews are available at starting times of each stage.
- No Mobilization and Demobilization time - at the beginning, between phases, and end – is included in the contract time determination.
- No rain days or weather delays are considered for this contract duration estimation. TXDOT establishes a 22% additional factor in regard to weather delays. This factor was not included, but will be discussed in Section 5.4.3 comparisons.
- Working days per week and vacations are not considered as the calculation results will be expressed in total working days. For contract duration in weeks and months, the results should be converted according to 5 working days per week or 20 working days per months.

- A duration of 1 day has been assigned to those activities for which no production rate information was found in the aforementioned sources and are believed to represent low quantities.
- There are no modifications to the construction sequence and TPC and all construction is to be executed in order of specified phases and stages.
- The work sequence and controlling activities within each phase and stage was assumed under the estimator's judgment.
- Non-critical path activities are excluded from the duration calculation (e.g. Remove minor structures and traffic signals; Construct culvert wing walls; Electrical services).
- All critical path activities are given complete (rounded up) number of days for execution.
- No initiation of activities after a completion percentage of the preceding activity is considered. Critical path activities are to start after its preceding activity is fully complete (after complete number of days assigned to the previous activity). This assumption was assigned due to software limitations and the observation that most activities lasted only one or two days.

5.4.2.5 Linear Scheduling Model (LSM)

At this stage of the task, enough information was gathered to create a Linear Scheduling Model (LSM) using Microsoft Excel software. The LSM was used to facilitate construction sequence visualization and understanding. Sample sheets of the LSM established is available in Appendix F. However, a complete LSM is not included in this report since its size requires enlarged printing and would not fit or be visualized adequately.

The LSM graphs express the number of working days in the horizontal axis with the description of each activity listed below this axis, each located at the column corresponding to the activity's starting working day. The vertical axis represents the stations of the roadway section addressed, with a copied sketch of this section to the left of the graph with the sole purpose of orientating activity locations. The graphed lines represent the production rate of each activity in relation to the stationed area of the activity.

The complete LSM constitutes 5 Microsoft Excel sheets, described as follows:

- Sheet 1: phase 1: all stages.
- Sheet 2: phase 2: stages 1, 2, and 3 – A.
- Sheet 3: phase 2: stage 3 – B.
- Sheet 4: phase 2: stage 3 – C.
- Sheet 5: phase 3: all stages.

Throughout all LSM sheets, red graph lines represent the transition of stages, blue lines are critical path activities, green lines are activities identified as to be executed in parallel to the critical path, and orange lines are the activities with no production rate information found and assigned one working day durations.

5.4.2.6 Nominal Contract Time

The nominal contract time is determined by the sum of all WBS activity working days, assuming that each activity in the WBS is part of the critical path with each starting after full completion of its predecessor. For ease of analysis, the number of working days was first calculated at a stage level, followed by a phase level, and finally at a project level. This project nominal contract time is exclusively in working days, and all considerations and assumptions from Section 5.4.2.4 apply to the results. Table 6 shows the results of the nominal contract time estimation by phases and stages. A complete table expressing the

duration of each activity in the nominal contract time estimation can be found in Appendix

D.

Table 6: Nominal contract duration – stages, phases, and project

IH635 US 80 FR Project

Contract Duration Summary

	Nominal Schedule
Phase 1 - IH 635 Gross Road Exit Ramp	
Stage 1 - Detour Widening	8
Stage 2 - Gross Road Exit Ramp Right Side	30
Stage 3 - Right Thru-Lane portion	9
Stage 4 - Gross Road Exit Ramp Left Side	18
Stage 5 - Large Island	6
Phase 1 Total	71
Phase 2 - IH 635 Gross Road Entrance Ramp & FR	
Stage 1 - Detour Widening	15
Stage 2 - Gross Road Entrance Ramp	16
Stage 3 - FR Before Bridge (1029+00 - 1040+00)	34
Stage 3 - FR Bridge Area (1040+00 - 1051+00)	40
Stage 3 - FR After Bridge (1051+00 - 1067+00)	38
Phase 2 Total	143
Phase 3 - US 80 FR	
Stage 1 - Detour Widening	8
Stage 2 - US80 FR Right Lane	42
Stage 3 - US80 FR Left & Middle Lanes	41
Stage 4 - US80 FR Left & Middle Lane Portion	12
Stage 5 - Remove Galloway Ave. Exit Ramp	9
Phase 3 Total	112
	Nominal Schedule
Project Total Working Days	326

5.4.2.7 Accelerated Contract Time

After calculating the nominal contract time, the results were scrutinized in order to identify activities that can be executed in parallel and which should not be considered part of the critical paths of each stage. Also to be identified were activities that yielded 1 day of duration, yet due to particular circumstances wouldn't take much time from a whole working day. The reason for highlighting these activities is to develop an accelerated, more accurate contract duration.

The LSM, the detailed nominal schedule, and the original project plans were revised to find these activities. In order to declare an activity as executed in parallel, each should meet the following criteria:

- Parallel activities require different crews, tools, and equipment than those of critical path activities.
- The physical work space for such activities is not shared with critical path activities.
- There must be complete interdependency from critical path activities.
- These activities are assumed to be accommodated by the project's subcontracting plan.

Tables 7 to 9 highlight these identified parallel activities as well as the commanding critical path activities to be executed simultaneously, resulting in a number of working days saved from the nominal schedule. The number of working days executed by parallel activities totals 53 days.

Table 7: Case study 1 Activities identified in parallel – Phase 1

Activities in Parallel		Critical Path Activities	Working days saved
Phase 1			
Stage 1			
-			
Stage 2			
TEP	Storm Sewer Pipes &	Excavation, Culvert 1	4
	Storm Sewer Inlets	Excavation, Culvert 1, Storm Sewer Pipes	4
	Prime coat	Flex base, 4" Superpave (Should not take whole day)	1
	Pavement Markings	Compost Topsoil	1
	Construct Island	Conc. Curb, Compost Topsoil	1
	Small Signs	Compost Topsoil	1
Stage 3			
	Prime coat	Flex base, 4" Superpave (Should not take whole day)	1
	4"Superpave	Flex base, HES Concrete (Should not take whole day)	1
Stage 4			
TEP	Storm Sewer Pipes &	Excavation	2
	Storm Sewer Inlets	Storm Sewer Pipes	1
	Pavement Markings	Compost Topsoil	1
Stage 5			
	Small Signs	Con. Curb, Construct Island	1
Phase 1 Total			19

Table 8: Case study 1 Activities identified in parallel – Phase 2

Activities in Parallel		Critical Path Activities	Working days saved
Phase 2			
Stage 1			
Embankment	Excavation		1
Stage 2			
Embankment	Excavation		1
Compost Topsoil	Pavement Markings		1
Stage 3 – A			
Storm Sewer Pipes & TEP	Excavation, Culvert 2		5
Storm Sewer Inlets	Storm Sewer Pipes, Excavation, Culvert 2		3
Compost Topsoil	Intersection/ Signals PT		1
Pavement Markings	Intersection/ Signals PT		1
Stage 3 – B			
Embankment	Prestressed concrete girders, Reinforced concrete slab		4
Pavement Markings	Compost Topsoil		1
Stage 3 – C			
Storm Sewer Pipes & TEP	Excavation, Embankment		2
Storm Sewer Inlets	Storm Sewer Pipes, Excavation, Embankment		1
Pavement Markings	Compost Topsoil		1
Phase 2 Total			22

Table 9: Case study 1 Activities identified in parallel – Phase 3

Activities in Parallel	Critical Path Activities	Working days saved
Phase 3		
Stage 1		
-		
Stage 2		
Storm Sewer Pipes & TEP	Excavation, Culvert 4	2
Storm Sewer Inlets	Storm Sewer Pipes, Excavation, Culvert 4	2
Compost Topsoil	Pavement Markings	2
Stage 3		
Compost Topsoil	Pavement Markings	1
Stage 4		
Embankment	Excavation	1
Prime Coat	Should not take whole day; 1 week closure limit	1
4" Superpave	Should not take whole day; 1 week closure limit	1
Stage 5		
Small Signs	Intersection/ Signals PT	1
Compost Topsoil	Intersection/ Signals PT	1
Phase 3 Total		12

The accelerated contract duration was calculated by deducting the sum of the durations of parallel activities for each stage. Once the deductions are implemented, phase durations and the total project duration are calculated, resulting in the summary expressed in Table 10. Appendix E contains the detailed accelerated contract time highlighting the parallel activities.

Table 10: Summary of case study 1 contract time determination results

IH635 US 80 FR Project
Contract Duration Summary

	Nominal Schedule	Accelerated Schedule
Phase 1 - IH 635 Gross Road Exit Ramp		
Stage 1 - Detour Widening	8	8
Stage 2 - Gross Road Exit Ramp Right Side	30	18
Stage 3 - Right Thru-Lane portion	9	7
Stage 4 - Gross Road Exit Ramp Left Side	18	14
Stage 5 - Large Island	6	5
Phase 1 Total	71	52
Phase 2 - IH 635 Gross Road Entrance Ramp & FR		
Stage 1 - Detour Widening	15	14
Stage 2 - Gross Road Entrance Ramp	16	14
Stage 3 - FR Before Bridge (1029+00 - 1040+00)	34	24
Stage 3 - FR Bridge Area (1040+00 - 1051+00)	40	35
Stage 3 - FR After Bridge (1051+00 - 1067+00)	38	34
Phase 2 Total	143	121
Phase 3 - US 80 FR		
Stage 1 - Detour Widening	8	8
Stage 2 - US80 FR Right Lane	42	36
Stage 3 - US80 FR Left & Middle Lanes	41	40
Stage 4 - US80 FR Left & Middle Lane Portion	12	9
Stage 5 - Remove Galloway Ave. Exit Ramp	9	7
Phase 3 Total	112	100
	Nominal Schedule	Accelerated Schedule
Project Total Working Days	326	273

As a final result for our contract time estimation, the accelerated schedule was accepted as it is believed to include an adequate critical path of activities for the addressed project. Such contract time totals 273 working days. If we consider 5 working day weeks, the contract duration would be 55 weeks (54.6 rounded up). Similarly, considering about 20 working days per month, the contract duration totals 13.65 months. None of these consider any delay factors as mentioned in Section 5.4.2.4 as established assumptions.

5.4.3 Comparison of Results

Once the contract duration estimation was calculated, the project design team's estimation was provided in a contract time estimate sheet for result comparison. Appendix G contains the provided TXDOT estimation results. Table 11 shows a summary of this contract time estimate sheet, expressing the number of working days per phase and a total contract duration of the project.

Table 11: Case study 1 Summary of TXDOT contract time estimation results

Phase Description	TXDOT Estimation
Phase 1 - IH 635 Gross Road Exit Ramp	42
Phase 2 - IH 635 Gross Road Entrance Ramp & FR	144
Phase 3 - US 80 FR	88
Project Total Working Days	274

After calculating the total contract time, a 22% additional factor was applied, resulting in 334.28 days. This number rounded up to 335 is the number of working days expressed in the project's bid proposal form. Furthermore, the contract time estimate of 334.28 days is divided by 21 days concluding an approximate duration of 16 months.

For the purposes of the following comparison, all factors will be excluded and the raw result of 274 working days will be used.

5.4.3.1 Overall Results

Table 12 shows an overall comparison of working day calculations by phases and project total, highlighting the difference in number of days and percentage.

Table 12: Overall comparison of TXDOT and case study 1 estimations

Phase Description	TXDOT	Case Study	Difference	Difference %
Phase 1 - IH 635 Gross Road Exit Ramp	42	52	10	23.81%
Phase 2 - IH 635 Gross Road Entrance Ramp & FR	144	121	-23	-15.97%
Phase 3 - US 80 FR	88	100	12	13.64%
Project Total Working Days	274	273	-1	-0.36%

The contract duration comparison, while yielding almost identical total contract durations (just a difference of one day, - 0.36%), reflects significant working day differences at a phase level. As for phase 1, the case study yielded 10 days more (+23.81%) than TXDOT's estimation, a difference that could be considered of great significance. Phases 2 and 3 narrowed the gap as there was a difference of 23 days less (-15.97%) for phase 2 and 12 days more (+13.64%) for phase 3. These are due to several factors in perception, criteria, and information.

The most identifiable difference factors include the critical paths chosen, the consideration and interpretation of the construction sequence and TCP, differences in activity quantities, and differences in the production rates used.

5.4.3.2 Construction Sequence and Traffic Control Plan Consideration and Interpretation

When studied in detail, there are big differences between both estimations regarding the adaptation of the construction sequence and TCP to the contract time calculation. TXDOT only considers the construction sequence at a phase level – leaving out specifications by stages - while the case study's estimation considers each activity within each phase.

TXDOT's estimation groups activities and quantities by phases without separating these further into stages. All activities – and their quantities – for the 5 stages of phase 1 are grouped into phase 1 activities. The same happens for the 3 stages in phase 2 and the 5 stages of phase 3. It only considers one traffic controls activity at the beginning of each phase and one final clean-up activity at the end of each phase.

Meanwhile, this case study's contract duration considers each stage within each phase. While the duration of each activity calculated per phase may be similar to the sum of these durations at a stage level, the stage level calculation should yield more days per activity due to the complete days round up operation used (also used in TXDOT's estimation at a phase level). Furthermore, it considers a traffic control activity and a clean-up activity at the beginning and end of each stage, resulting in a significant increase in working days per phase. This fact could explain a big part of the difference in phase 1. TXDOT considers 2 working days of traffic controls and 1 day for clean-up, totaling 3 days for such activities. This case study's estimation, considering all phase 1 stages, assumes 6 working days of traffic controls and 5 working days of cleanup totaling 11 days. This results in a difference of 8 days, accounting for 19.05% of TXDOT's estimation for phase 1.

Additionally, the case study considers a buffer time of one day at the beginning or end of each stage to allow for unaccounted factors, such as reorganizing for stage changes, contractor availability, equipment mobilization, etc. For phase 1, it considers 5 days of buffer time (1 for each stage), accounting for 11.90% of TXDOT's estimation. There is no similar consideration perceived in TXDOT's estimation.

These major differences show that TXDOT's estimation could be longer if it were to consider dividing activities into construction sequence and TCP stages, and assigning traffic controls and clean-up for each stage. This consideration should result in a more accurate contract duration.

5.4.3.3 Critical Paths

The case study's estimation does not consider an activity as started unless the previous commanding critical path activity is completely finished. Either an activity is executed completely and accounted in the sum of working days or it is considered to be done in parallel – or not part of the critical path – and excluded from the calculation. In contrast, TXDOT's estimation shows critical path activities starting at a completion percentage of its preceding activity. This was not considered in this task primarily for a lack of need: 54.11% of activities (at a stage level) were granted a duration of one working day and 26.03% were assigned two working days. That is, 80.14% of the activities at a stage level take between just one and two working days of duration. Meanwhile, this same statistic for the TXDOT contract time is 36.77% at a phase level (17.65% one working day activities, 19.12% two working day activities).

This occurs for two main reasons. First, studying activities at a phase level yields longer activity durations, allowing the possibility of identifying if activities initiate prior to the full completion of its preceding activity. Second, there are differences in activity

quantities and production rates that conclude different durations. Quantity and production rate differences will be discussed in the Sections 5.4.3.4 and 5.4.3.5.

Another interesting aspect is the differences in the activities selected. There are some activities that this case study's contract estimation considers that are excluded from TXDOT's analysis, and vice versa. The activities excluded from TXDOT's analysis that are included in this task are:

- 4" Superpave base in TON – Considers Hot Mixed Asphalt Concrete (HMAC) in SY instead.
- Prime coating.
- Concrete curbs.
- High Early Strength (HES) concrete – Quantities considered within concrete pavement quantities. Nonetheless, production rates for HES concrete used in the case study were significantly different from those used for concrete pavement.

As for the activities excluded from the case study that are considered in TXDOT's contract time estimation, these are:

- HMAC (SY) – Considers 4" Superpave base (TON) instead. Should not make much difference as the production rates used for 4" Superpave were those of Hot Mixed Asphalt. However, the unit difference complicates comparison.
- Remove drainage structures.
- Bridge structure (Lump Sum) – Considers the construction of bridge elements individually.
- Cofferdams – Overlooked by the estimator, would have accounted for 1 working day (quantity: 178SY; Production rate level: M; Production rate: 200; Working days: 1; Source: TXCTDS).

5.4.3.4 Quantity Differences

The quantities used in the case study were mainly interpreted and extracted from project plans and specifications. Those that were harder to identify were found on the supplied major activities and quantities table (Table 4), which accords with those in TXDOT's contract time estimation. Hence, a majority of quantities were different – due to different project information interpretation, assumptions, and access to additional knowledge and conditions – while some quantities are the same – extracted from TXDOT estimation's quantities (Table 4).

For comparison purposes, the case study's quantities were summed by phases. That is, all quantities from a same activity from different stages within a given phase are summed to reflect quantities at a phase level. This result would allow for direct comparison with TXDOT's estimation quantities. Tables 13 to 15 express this comparison, yielding a column with quantity differences and quantity difference percentages. Note that not applicable (N/A) values were assigned when there were inconsistencies in units.

Table 13: TXDOT and case study 1 quantity allocation comparison – Phase 1

Description	TXDOT		Case Study		Quant. Delta	Quant. Delta %
	Unit	Quantity	Unit	Quantity		
Phase 1						
Initial Traffic Control Phase 1	LS	1	LS	5	4	400.00%
Erosion Ctrl - Phase 1	SY	3087	SY	3087	0	0.00%
Detour Widening Phase 1	LS	1	TON	120	N/A	N/A
Prep ROW	AC	3	AC	3	0	0.00%
Temporary Drainage/Shoring	SY	690	SY	690	0	0.00%
Remove Old Pavement	SY	1821	SY	2818	997	54.75%
Excavation	CY	5940	CY	4082	-1858	-31.28%
New Box Culvert Extension	LF	108	LF	109	1	0.93%
Storm Sewer Pipes & TEP	LF	936	LF	695	-241	-25.75%
Storm Sewer	EA	39	EA	11	-28	-71.79%
Inlets/Manholes						
Embankment	CY	223	CY	693	470	210.76%
Flex Base	SY	5821	SY	5851	30	0.52%
HMAC Base/ Superpave	SY	5821	TON	1288	N/A	N/A
Concrete Pavement	SY	5022	SY	5323	301	5.99%
Block Sod/CMT	SY	18430	SY	19430	1000	5.43%
Small Signs	EA	4	EA	4	0	0.00%
Pavement Markings	LF	6867	LF	3078	-3789	-55.18%
Final Clean-up Phase 1	STA	11	STA	11	0	0.00%

Table 14: TXDOT and case study 1 quantity allocation comparison – Phase 2

Description	TXDOT		Case Study		Quant. Delta	Quant. Delta %
	Unit	Quantity	Unit	Quantity		
Phase 2						
Initial Traffic Control Phase 2	LS	1	LS	3	2	200.00%
Erosion Ctrl - Phase 2	SY	14436	SY	14436	0	0.00%
Detour Widening Phase 2	LS	1	TON	155	N/A	N/A
Prep ROW	AC	16	AC	16	0	0.00%
Remove Old Pavement	SY	6170	SY	16070	9900	160.45%
Remove old Drainage structure	LF	160	LF	-	N/A	N/A
Excavation	CY	36340	CY	27351.4	-8988.6	-24.73%
Channel excavation/Grading	CY	800	CY	800	0	0.00%
New Box Culverts (2, 3, 4)	LF	465	LF	324	-141	-30.32%
Storm Sewer Pipes & TEP	LF	825	LF	975	150	18.18%
Storm Sewer Inlets/Manholes	EA	14	EA	7	-7	-50.00%
Bridge Structure	LS	1	LS	-	N/A	N/A
Cofferdam	SY	178	SY	-	N/A	N/A
Piling	LF	165	LF	165	0	0.00%
Footings	CY	43	CY	43	0	0.00%
Caps & Bents	CY	57	CY	57	0	0.00%
Wing walls	SF	275	SF	275	0	0.00%
Beams	LF	718	LF	718	0	0.00%
Bridge Deck	CY	84	CY	84	0	0.00%
Bridge Curb/Handrails	LF	74	LF	149	75	101.35%
Embankment	CY	10280	CY	12607	2327	22.64%
Flex Base	SY	18882	SY	18881	-1	-0.01%
HMAC Base/ Superpave	SY	18882	TON	4153	N/A	N/A
Concrete Pavement	SY	17147	SY	16846	-301	-1.76%
Block Sod/CMT	SY	6747	SY	37617	30870	457.54%
Intersections/ Signals PT	EA	1	EA	1	0	0.00%
Small Signs	EA	1	EA	-	N/A	N/A
Pavement Markings	LF	12086	LF	11550	-536	-4.43%
Final Clean-up Phase 2	STA	40	STA	40	0	0.00%

Table 15: TXDOT and case study 1 quantity allocation comparison – Phase 3

Description	TXDOT		Case Study		Quant. Delta	Quant. Delta %
	Unit	Quantity	Unit	Quantity		
Phase 3						
Initial Traffic Control Phase 3	LS	1	LS	5	4	400.00%
Erosion Ctrl - Phase 3	SY	10910	SY	10910	0	0.00%
Detour Widening Phase 3	LS	1	TON	395	N/A	N/A
Prep ROW	AC	10	AC	10	0	0.00%
Temporary Drainage/Shoring	SY	12	SY	12	0	0.00%
Remove Old Pavement	SY	12381	SY	17896	5515	44.54%
Remove old Driveway	SY	1164	SY	2000	836	71.82%
Remove old Drainage structure	LF	886	LF	-	N/A	N/A
Excavation	CY	18030	CY	13367	-4663	-25.86%
Exist Bridge Class Culvert Ext	LF	51	LF	162	111	217.65%
Storm Sewer Pipes & TEP	LF	2087	LF	2087	0	0.00%
Storm Sewer Inlets/Manholes	EA	8	EA	8	0	0.00%
Embankment	CY	4628	CY	5674	1046	22.60%
Flex Base	SY	21201	SY	19892	-1309	-6.17%
HMAC Base/ Superpave	SY	21201	TON	4375	-16826	-79.36%
Concrete Pavement	SY	19518	SY	18276	-1242	-6.36%
Block Sod/CMT	SY	3138	SY	20674	17536	558.83%
Intersections/ Signals PT	EA	1	EA	1	0	0.00%
Small Signs	EA	4	EA	2	-2	-50.00%
Pavement Markings	LF	3925	LF	29556	25631	653.02%
Final Clean-up	STA	37	STA	35	-2	-5.41%

Observations of this table suggest significant differences in the quantities used. These may be due to different access levels of information, perhaps implying that it is more likely for TXDOT estimators to have more information than that provided for this case study. Furthermore, it could be the result of misinterpreting information and/or overlooking important activities and quantities in diverse sectors of the project, whether they be from this estimation, TXDOT's estimation, or both.

5.4.3.5 Production Rate Differences

There are also notable differences in the production rates used. Similar to the quantities comparison, Tables 16 to 18 compare production rates from both estimations yielding a column with production rate differences and production rate difference percentages. Note that not applicable (N/A) values were assigned when there were inconsistencies in units and when there was no production rate information found in the *Production Rate Resource* and its sources.

Table 16: TXDOT and case study 1 production rate comparison – Phase 1

Description	TXDOT		Case Study		Daily Rate Delta	Daily Rate Delta %
	Unit	Daily Rate	Unit	Daily Rate		
Phase 1						
Initial Traffic Control Phase 1	LS	0.5	LS	0.5	0	0.00%
Erosion Ctrl - Phase 1	SY	1330	SY	2500	1170	87.97%
Detour Widening Phase 1	LS	0.25	TON	883	N/A	N/A
Prep ROW	AC	3	AC	3	0	0.00%
Temporary Drainage/Shoring	SY	40	SY	-	N/A	N/A
Remove Old Pavement	SY	2000	SY	1000	-1000	-50.00%
Excavation	CY	1900	CY	920	-980	-51.58%
New Box Culvert Extension	LF	35	LF	99	64	182.86%
Storm Sewer Pipes & TEP	LF	300	LF	145	-155	-51.67%
Storm Sewer Inlets/Manholes	EA	10	EA	2	-8	-80.00%
Embankment	CY	200	CY	654	454	227.00%
Flex Base	SY	3000	SY	3539	539	17.97%
HMAC Base/ Superpave	SY	4000	TON	884	N/A	N/A
Concrete Pavement	SY	3000	SY	2700	-300	-10.00%
Block Sod/CMT	SY	2000	SY	7000	5000	250.00%
Small Signs	EA	5	EA	10	5	100.00%
Pavement Markings	LF	10000	LF	3915	-6085	-60.85%
Final Clean-up Phase 1	STA	30	STA	30	0	0.00%

Table 17: TXDOT and case study 1 production rate comparison – Phase 2

Description	TXDOT		Case Study		Daily Rate Delta	Daily Rate Delta %
	Unit	Daily Rate	Unit	Daily Rate		
Phase 2						
Initial Traffic Control Phase 2	LS	0.5	LS	0.5	0	0.00%
Erosion Ctrl - Phase 2	SY	1330	SY	2500	1170	87.97%
Detour Widening Phase 2	LS	0.25	TON	883	N/A	N/A
Prep ROW	AC	3	AC	3	0	0.00%
Remove Old Pavement	SY	2000	SY	2000	0	0.00%
Remove old Drainage structure	LF	15	LF		N/A	N/A
Excavation	CY	1900	CY	2795	895	47.11%
Channel excavation/Grading	CY	200	CY	920	720	360.00%
New Box Culverts (2, 3, 4)	LF	200	LF	99	-101	-50.50%
Storm Sewer Pipes & TEP	LF	300	LF	145	-155	-51.67%
Storm Sewer Inlets/Manholes	EA	10	EA	2	-8	-80.00%
Bridge Structure	LS	0.025	LS		N/A	N/A
Cofferdam	SY	100	SY		N/A	N/A
Piling	LF	200	LF	370	170	85.00%
Footings	CY	10	CY	27	17	170.00%
Caps & Bents	CY	7	CY	8.3	1.3	18.57%
Wing walls	SF	125	SF	124	-1	-0.80%
Beams	LF	200	LF	702	502	251.00%
Bridge Deck	CY	10	CY	14	4	40.00%
Bridge Curb/Handrails	LF	200	LF	150	-50	-25.00%
Embankment	CY	200	CY	654	454	227.00%
Flex Base	SY	3000	SY	3539	539	17.97%
HMAC Base/ Superpave	SY	4000	TON	884	N/A	N/A
Concrete Pavement	SY	3000	SY	2700	-300	-10.00%
Block Sod/CMT	SY	2000	SY	7000	5000	250.00%
Intersections/ Signals PT	EA	0.03	EA	0.33	0.3	1000.00%
Small Signs	EA	5	EA		N/A	N/A
Pavement Markings	LF	10000	LF	3915	-6085	-60.85%
Final Clean-up Phase 2	STA	30	STA	30	0	0.00%

Table 18: TXDOT and case study 1 production rate comparison – Phase 3

Description	TXDOT		Case Study		Daily Rate Delta	Daily Rate Delta %
	Unit	Daily Rate	Unit	Daily Rate		
Phase 3						
Initial Traffic Control	LS	0.5	LS	0.5	0	0.00%
Phase 3						
Erosion Ctrl - Phase 3	SY	1330	SY	2500	1170	87.97%
Detour Widening Phase 3	LS	0.25	TON	883	N/A	N/A
Prep ROW	AC	3	AC	3	0	0.00%
Temporary						
Drainage/Shoring	SY	40	SY	-	N/A	N/A
Remove Old Pavement	SY	2000	SY	3000	1000	50.00%
Remove old Driveway	SY	75	SY	3000	2925	3900.00%
Remove old Drainage structure	LF	15	LF	-	N/A	N/A
Excavation	CY	1900	CY	2794	894	47.05%
Exist Bridge Class Culvert						
Ext	LF	35	LF	99	64	182.86%
Storm Sewer Pipes & TEP	LF	300	LF	145	-155	-51.67%
Storm Sewer						
Inlets/Manholes	EA	10	EA	2	-8	-80.00%
Embankment	CY	200	CY	2654	2454	1227.00%
Flex Base	SY	3000	SY	3539	539	17.97%
HMAC Base/ Superpave	SY	4000	TON	884	N/A	N/A
Concrete Pavement	SY	3000	SY	2700	-300	-10.00%
Block Sod/CMT	SY	2000	SY	7000	5000	250.00%
Intersections/ Signals PT	EA	0.03	EA	0.33	0.3	1000.00%
Small Signs	EA	5	EA	10	5	100.00%
Pavement Markings	LF	10000	LF	9607	-393	-3.93%
Final Clean-up	STA	30	STA	30	0	0.00%

As observed from the tables, production rate differences range from -80% to +3900%, and generally reflect that most of the production rates used in the case study were much higher than those used by TXDOT. This most likely suggests that the production rates used for this case study were higher than what the project demanded.

This difference could be due to the production rate level selection. As mentioned previously in this report, 9.8% of rates for this case study were given a High (H) level, 72.4% were given a Mean (M) level, and 17.8% were given a Low (L) level. Data in the table suggests that perhaps more production rates should have been addressed L levels, which would result in lower production rates and, therefore, longer activity durations and contract time estimation.

A very simple example is Embankment in phases 2 and 3. TXDOT's estimation expresses a daily rate of 200CY/day for this activity while this case study addressed level M with a production rate of 2,654CY/day (*Production Rate Resource*). This number is 1,227% more than that of TXDOT's estimation. If addressed a level L (such as in phase 1), the daily rate would have been 654CY/day. This number, while still being 227% higher than TXDOT's production rate, may be more appropriate for the equipment that is used for such work. No equipment information for such work was provided and, therefore, was assigned a Level M. This leads to the conclusion that TXDOT's estimators possess more information – and more experience – for the analysis of certain activities.

Another observation is the variance from levels in certain activities and the incompatibility to TXDOT's production rates. Take excavation, for example. In phase 1, excavation was assigned a level L in the case study, expressing a 920CY/day production rate. In phases 2 and 3, this same activity was assigned a level M which resulted in 2795CY/day. On the other hand, TXDOT's estimation assigns a daily rate of 1900CY/day for excavation in all phases. That is, for this particular activity, a production rate of 51.58% under TXDOT's daily rate if assigned a level L while a rate of 47.11% over TXDOT's rate when assigned a level M. This can be due to limitations in generalizing conditions, such as the equipment used and crews, into just 3 levels of production rates - Low, Mean, and High – of the *Production Rate Resource* without considering values between the three levels;

and to TXDOT's potential knowledge of equipment to be used and their ability to pinpoint more appropriate production rates without level limitations. This also hints that a production rate difference of $\pm 50\%$ could be common in different sources, and should be further studied.

As for other high production rate differences, such as in remove old driveway and intersections/ signals PT, these may have been the result of errors and should be further analyzed for correction.

5.4.4 Case Study 1 Conclusions

A contract time determination of the IH635 US80 highway improvement project was conducted using Production Rate Resource and its supporting references.

The process followed a detailed methodology, starting with a detailed examination of the available plans and documents, a thorough understanding of the construction sequence and TCP, and the development of a WBS of critical-path activities. The *Production Rate Resource* and its supporting references were then consulted to select the appropriate production rates for each activity in order to calculate a working day duration. Identification of parallel activities that should not be part of the critical path led to the development of an accelerated schedule. Necessary assumptions that pertain to included and excluded analysis considerations were also documented.

The analysis resulted in a contract duration estimate of 273 working days. These 273 working days are the sum of all phase duration totals, which were: Phase 1: 52 working days, Phase 2: 121 working days, and Phase 3: 100 working days.

The TXDOT engineer provided their estimate for comparison purposes, which indicated 274 working days of contract time. The issues considered in the analysis of differences were the overall results, both at a phase and project level; the construction

sequence and TCP inclusion and interpretation; and assumed activity quantity and production rate differences.

The contract time estimates were surprisingly close with a difference of 1 day. However, when compared at a phase level, significant differences were found: Phase 1 was estimated at 23.81% longer than TXDOT's estimation, while Phase 2 was estimated at 15.97% shorter, and Phase 3 was estimated at 13.64% longer. This suggested that the methods used by both estimations were considerably different.

The first difference identified was that TXDOT's estimation did not allocate activity quantities by phase stages, but rather limited their calculation to the phase level. Since stages further categorize the project into detailed sequential sub-phases, the effects of traffic controls, clean-ups, and activity initiations and demobilizations are more evident. This approach should result in a more accurate contract duration.

There were also differences in the selected critical path activities and sequences. A significant difference was the number of activities with only one or two working days. In the case study, these activities accounted for 80.14% of the critical path, compared to 36.77% in TXDOT's estimation.

When comparing activity installed quantities, evident differences were found. These may have resulted from misinterpreting project documentation.

When the assumed activity production rates were compared, several inconsistencies were identified. In general, this case study's assumed production rates were considerably higher than those used in TXDOT's analysis. This may have resulted from limitations in the restricted three level production rate selection process, as well as from TXDOT's experience and access to more information.

5.4.5 Case Study 1 Recommendations

Allocating activity quantities by stage level in TXDOT's estimation is recommended. The estimation would consider the effects of stage level traffic controls, clean-ups, and activity initiations and demobilizations, yielding a more accurate contract duration.

Further project documentation analysis is suggested to confirm that the activity quantities used for the contract time determination are accurate, since considerable differences in the estimation comparison were discovered. A review confirming these quantities could identify the accuracy of these assumed quantities and determine the confidence of the results.

Major production rate differences suggest that the production rate selection process should be revised, as these were considerably higher production rates than those of TXDOT's estimation. 72.4% of project activities were assigned a Mean (M) level. While Low (L) levels may still be higher production rates than the ones used in TXDOT's estimation, the important differences suggest that assigning more L level activities should yield more accurate results. Since the level selection process is the result of project document interpretations and assumptions, more information regarding activity production rate factors, such as crews and equipment to be used, should be collected to adequately analyze and confirm the production rate levels selected.

5.5 CASE STUDY 2: US 287 HIGHWAY IMPROVEMENT PROJECT

5.5.1 Project Description

The project to be addressed in case study 2 is the State of Texas Department of Transportation State Highway Improvement project of US 287 in Ellis County (STP 2016 (739) MM, CCSJ: 0172-08-053). The project covers 4.442 miles of US 287 from station 1040+44.03 to station 1274+97.79. It consists of the widening of the 2-lane undivided highway to a 4-lane urban freeway with grade separated interchanges and 1 to 4 lane frontage roads. The project scope includes the following activities:

- US 287 Northbound and Southbound Frontage Road construction.
- US 287 Northbound and Southbound Main Lane expansion.
- Northbound and Southbound Exit and Entrance ramps.
- Three grade separated intersections on Main Lanes.
- Three bridges for all Southbound and Northbound Main Lanes and Frontage Roads.
- Ten culvert extensions.

5.5.1.1 Project Documents and Plans

A complete set of the project plans was supplied for this task, detailing most – if not all – aspects of the project. Of particular interest for the purpose of contract time determination are the following items:

- Project layout.
- Proposed typical sections.
- Sequence of construction.
- Traffic Control Plan.
- Specification data.

- General estimate and quantities.
- Work item summaries of major activities analyzed:
 - Earthwork.
 - Roadway and driveway.
 - Removal.
 - Permanent pavement markings.
 - Inlet, storm sewers, and manholes.
 - Culverts.
 - Storm water pollution prevention plan (SW3P).
 - Retaining walls.
 - Illumination.
 - Signs.
 - Bridges and overpasses.
- Roadway details.
- Drainage details.
- Bridge specifications.

5.5.1.2 Construction Sequence and Traffic Control Plan

Since the project consists of improving and expanding a transited highway, traffic plays an important factor in its construction sequence. Hence, the Traffic Control Plan (TCP) determines a large part of the construction sequence as specified in the project documentation. Such TCP dictates for the project to be delivered in three phases, each of these containing various sub-phases. These sub-phases are described as follows:

- Sub-phase 1A: US287 Northbound Frontage Road construction, including bridges.

- Sub-phases 1B and 1C: Simultaneous phases. Road intersection work with US 287 Northbound Frontage Road.
- Sub-phase 2A: US287 Main Lanes construction, including bridges and overpasses.
- Sub-phase 2B: US287 Southbound Frontage Road construction, including bridges.
- Sub-phase 2C: Road intersection work with US 287 Main Lanes and Southbound Frontage Road.
- Sub-phase 2D: Road intersection work with US 287 Southbound Frontage Road.
- Phase 3: Phase 1A work area final pavement, and SH34 – S287 entrance ramp.

Appendix H shows the Construction Sequence description and specifications extracted from the project's documents.

5.5.2 Contract Time Determination

To initiate the contract time determination of the US287 highway improvement project, all available documentation was gathered. These included the project plans as described in Section 5.5.1 of this report. These documentation and plans were then studied and analyzed in order to identify important information for the contract time determination, such as the construction sequence of the project, major work activities, construction methods to be implemented, and estimated quantities for each activity.

Information regarding types and number of crews and equipment for each activity was not available upon request. Therefore, the estimator made assumptions regarding activity drivers and number of crews depending on the work zone size, activity quantities, and the possibility of stacking of trades.

5.5.2.1 Analysis of Construction Sequence and TCP

Perhaps the most important aspect for determining the contract duration of this and any project is understanding the construction sequence and traffic control plan (TCP). As

described in Section 5.5.1.2 of this report, the TCP is a major factor due to the nature of the project. The Main Lane expansions and the inclusion of both Frontage Roads, while incorporating three bridges and three grade separated intersections over actively transited roads call for the imminent need of an adequate TCP. As a result, the project construction sequence is divided into three phases and a total of six sub-phases:

- Phase 1A: Northbound Frontage Road, including:
 - Temporary detours #1 and #8.
 - Culverts C4, C5, C6, and C7 (Upstream section).
 - Northbound Main Lane portions:
 - From Sta. 1072+67.66 to Sta. 1089+83.
 - From Sta. 1176+62 to Sta. 1192+30.
 - From Sta. 1232+65 to Sta. 1252+72.
 - Northbound ramps:
 - Ensign road to US287 Northbound Main Lane entrance ramp.
 - Sterilite road to US287 Northbound Main Lane entrance ramp.
 - US287 Northbound Main Lane to Sterilite road exit ramp.
 - Northbound Frontage Road including widening.
 - Northbound Frontage Road retaining walls.
 - Storm sewers.
 - Driveways.
 - Safety lighting.
 - Northbound Frontage Road bridges:
 - Cummins Creek.
 - Cummins Creek Tributary 1.
 - Cummins Creek Tributary 2.

- Northbound Frontage Road intersection portions.
- Old Alma road half-width portion (Sta. 10+00 to Sta. 23+00).
- Phases 1B and 1C:
 - Remaining portions of Northbound Frontage Road intersections:
 - Ensign road.
 - Oak Grove road.
 - Sterilite road.
 - Complete construction of Old Alma road.
 - Temporary detours #2, #4, and #7.
 - Temporary traffic signals.
 - Temporary pavement markings.
- Phase 2A: US287 Northbound and Southbound Main Lanes, including:
 - Complete construction of US287 Southbound Main Lanes.
 - Remaining portions of US287 Northbound Main Lanes.
 - Northbound Frontage Road portions:
 - From Sta. 2063+00 to Sta. 2088+64.
 - From Sta. 2176+02 to Sta. 2191+33.
 - From Sta. 2236+11 to Sta. 2267+51.
 - Culverts C3 (Upstream section); C4, C5, C6, and C7 (Downstream sections); C2A, C8A, C8B, and C8C (Upstream and downstream sections).
 - US287 Main Lane retaining walls.
 - Storm sewers.
 - Safety lighting.
 - US287 Northbound and Southbound Main Lane bridges and overpasses:
 - Ensign road.

- Cummins Creek.
 - Oak Grove road.
 - Cummins Creek Tributary 1.
 - Sterilite road.
 - Cummins Creek Tributary 2.
- Portions of Southbound Frontage Road intersections.
- Northbound ramps:
 - US287 Northbound Main Lane to Ensign Road exit ramp.
- Phase 2B: Southbound Frontage Road, including:
 - Culverts C1, C2, and C3 (Downstream section).
 - Southbound Frontage Road.
 - Southbound ramps:
 - US287 Southbound Main Lane to Ensign Road exit ramp.
 - Ensign road to US287 Southbound Main Lane entrance ramp.
 - US287 Southbound Main Lane to Sterilite road exit ramp.
 - Sterilite road to US287 Southbound Main Lane entrance ramp.
 - US287 Northbound Main Lane Portion (Sta. 1252+72 to Sta. 1259+15).
 - Storm sewers.
 - Driveways.
 - Safety lighting.
 - Southbound Frontage Road bridges:
 - Cummins Creek.
 - Cummins Creek Tributary 1.
 - Cummins Creek Tributary 2.
 - Southbound Frontage Road intersection portions.

- Phases 2C and 1D:
 - Remaining portions of Northbound Frontage Road intersections:
 - Ensign road.
 - Oak Grove road.
 - Sterilite road.
 - Permanent pavement markings.
- Phase 3:
 - Southbound ramps:
 - SH34 to US287 Southbound Main Lane entrance ramp.
 - Remaining portion of Southbound Frontage Road pavement (adjacent to SH34 – US287 entrance ramp).
 - Final pavement of roadway construction in phase 1A (Northbound Frontage Road).
 - Final Clean-up.

It is also assumed that even though these three phases correspond to three different physical areas, this sequence should be respected and no phase is to initiate until the previous phase is complete.

It is important to note that Main Lane traffic will be active throughout the project with deviations and controlled detours in each sub-phase. Traffic will also be controlled at the Ensign Road, Oak Grove road, and Sterilite road intersections.

Another meaningful observation is the amount of bridge construction that the project demands. Its execution includes three bridges and three grade separated intersections over Ensign Road, Oak Grove road, and Sterilite road. The bridges have spans over both Main Lanes and Frontage roads, while the overpasses have spans over the Main

Lanes. This observation highlights the importance of bridge construction in the project and a high likelihood that this activity plays a big role in the Critical Path.

5.5.2.2 Work Breakdown Structure

With the information gathered, a Work Breakdown Structure (WBS) was needed in order to address the major activities in each sub-phase of the construction sequence. Therefore, the identified major activities were organized in accordance to each sub-phase in an assumed chronological order. Each sub-phase required traffic control activities at the beginning and clean-up activities at the end due to traffic logistics. Furthermore, a phasing allowance was implemented for every shift between sub-phases, of 1 or 3 working days depending on the preceding sub-phase's duration (1 working day for relatively short sub-phases and 3 working days for relatively long sub-phases).

The next step was to identify and separate activity quantities into the different sub-phases of the project. The information gathered only reflected quantities for each activity, while at most dividing quantities by project stations. Yet, there was no direct specification as to what portion of an activity's quantities was to be executed during a specific sub-phase. Therefore, the quantities for each sub-phase were the result of dividing the quantities obtained from plan observations – most importantly from Project Layout, TCP, and Proposed Typical Sections plans – and assuming approximate work area percentages for each stage. For example, a simple division for most roadway construction sectors (divided in Main Lane stations) was to assume that 25% of activity quantities should be allocated to the Northbound Frontage Road, 50% to the two Main Lanes, and 25% to the Southbound Frontage Road. Hence, the most common allocation for these activities were 25% for sub-phase 1A (Northbound Frontage Road), 50% for sub-phase 2A (Northbound and Southbound Main Lanes), and 25% for sub-phase 2B (Southbound Frontage Road). These

percentages varied depending on project stations and the estimator's observations of plans and specifications.

When assessing the quantities for bridge construction activities, the estimator analyzed each bridge and overpass separately. This allowed the estimator to study the number of crews and equipment assigned for bridge construction and the possibility of bridges constructed in parallel within each sub-phase. The following activities were considered for the construction analysis and duration calculation of each bridge:

- Drill shaft.
- Abutments.
- Bents.
- Beam erection.
- RC Slab.
- Bridge rail.

Furthermore, the estimator included two buffer times for bridge construction work: the first one is one working day allocated between Drill shaft and Abutments corresponding to equipment mobilization, and the second one is seven working days of concrete curing time after Bents construction before loading the bridge structure in Beam erection activities. Each of the aforementioned activities were assumed as executed in sequence for the construction of each bridge and overpass.

Appendixes I and J reflect the established WBS for each construction sequence phase detailing the quantities for each activity in each sub-phase, and the quantities allocated for the construction of each bridge and overpass.

5.5.2.3 Identifying Production Rate Sources and Levels, and Activity Duration Calculation

Once the WBS is established, the idea is to find the duration, in working days, of each major activity identified. To conduct the appropriate calculation, daily production rates are required for each activity. These were primarily extracted from the *Production Rate Resource* in order to attempt to fulfill the task's objectives. However, since this analysis did not cover all identified major activities at the time of the study, other sources were required to expand the pool of production rates. Therefore, the sources used were expanded to those covered in the mentioned analysis. These – in order of reference priority – are: TXCTDS, HYPRIS, OKCTDS, KYCTDS, and RSMeans. Furthermore, the estimator encountered the need to include an additional source: *Florida Department of Transportation's Guideline for Establishing Construction Contract Duration* (FLDOT). FLDOT's database includes production rates for some activities not considered in the aforementioned sources, such as Erosion Control and Sidewalks. FLDOT is considered the last resource in the order of reference priority.

Once the source was selected for each activity, the estimator analyzed the activity drivers. The main drivers considered were: work zone size, relative quantities of the activity, number and size of crews, and the equipment used for each activity. Since no information regarding crew and equipment requirements was provided, the estimator assumed multiple crews for the activities depending on the work zone size and quantity of the activity in a subjective manner. For this same reason, the activity driver analysis was based primarily on the first two mentioned drivers.

Having analyzed activity drivers, a production rate level was identified for each activity. These were categorized in three levels on each source: low/minimum (identified with the letter L in calculation tables in Appendixes K through N), mean (identified with

the letter M), and high/maximum (identified with the letter H). The selection of the level depended primarily on activity drivers for each sub-phase and was subject to the estimator's interpretation. As a result, most activity levels were given a mean (M) production rate level. This supposition was based on the fact that most activities had enough working space and relative quantities to execute their work uninterrupted by physical limitations and other trades, yet working with average production crews and equipment as there is no information at hand that would suggest high production rates. Table 19 shows the percentage distribution of activity level selection for each sub-phase:

Table 19: Case study 2 Percentage Distribution of activity level selection

Level	Percent selected
High/Maximum	1.7%
Mean	86.7%
Low/Minimum	11.6%

Finally, a simple division calculation of activity quantities by the respective production rate yielded the duration in working days for each activity. In the case of activities having multiple crews assumed for the project, the production rate was multiplied by the number of crews, hence reducing each activity's duration. The result was always rounded up to the nearest integer stating that each activity, for duration estimation purposes, was to be given a number of whole days for its execution. This also allowed for inclusion of crew and equipment preparation, mobilization, and demobilization.

Appendixes K through N show tables of the WBS with each activity's production rate level selection, the recorded production rate from the selected source for each activity, the number of crews assumed, and every activity's calculated duration.

5.5.2.4 Established Assumptions

At this point, all established assumptions have been documented, including the fulfillment of all previous steps as well as assumptions regarding project logistics. This process regards to contract time determination results while allowing room for considerations that may not be covered by this estimation. The established assumptions are stated below:

General Assumptions:

- The allocation of activity quantities by sub-phases was assumed by the estimator based on the plans and specifications provided, his interpretation of these documents, and the main work location and work zone size of the activities.
- A Phasing Allowance time (as specified in KYCTDS) of 1 or 3 working days was established between each sub-phase, depending on the duration of the preceding sub-phase. This period does not include Traffic Control and Cleanup as both of these activities are considered as major activities in our WBS.
- All materials and equipment are at the jobsite and all contractor crews are available at starting times of each stage.
- No Mobilization and Demobilization time - at the beginning, between phases, and end – is included in the contract time determination, with the exclusion of a mobilization buffer time during bridge construction.
- No rain days or weather delays are considered for this contract duration estimation.
- Working days per week and holidays are not considered as the calculation results will be expressed in total working days. For contract duration in weeks and months, the results should be converted according to 5 working days per week or 20 working days per month.

- A duration of 5 working days has been assigned for each unit of activities for which no production rate information was found in the aforementioned sources.
- There are no modifications to the construction sequence and TPC and all construction is to be executed in order of specified phases and sub-phases.
- The work sequence and controlling activities within each sub-phase was assumed under the estimator's judgment.
- Non-critical path activities are excluded from the duration calculation.
- All critical path activities are given complete (rounded up) number of working days for execution.

Productivity drivers and technology based assumptions:

- Concrete pavement activities are assumed to conform slip formed execution.
- As interpreted from the project layout, work zone sizes are big enough as to allow simultaneous activities.
- Average production crews and equipment are utilized for the execution of each activity.
- Quality and compliance inspections were not considered in contract time determination calculations.
- Excavation and embankment activities are not executed with rock materials.
- Earth material for embankment activities is accessible and available.

Bridge construction assumptions:

- Bridge construction was analyzed separately due to the complexity and number of activities while allowing for parallel bridge construction within each sub-phase. Each bridge is included in the WBS and precedence network as a lump sum activity.
- One working day was assigned as an equipment mobilization buffer time after drill shaft activities.

- Seven working days were assigned for concrete curing time after the construction of Bents and prior to Beam erection for each bridge.
- The estimator assumed 6 bridge construction crews for the execution of the following activities: Abutments, Bents, RC slab, and Bridge rail. Each bridge is assumed to be executed in crew pairs, assigning three pairs working simultaneously within each sub-phase.
- The estimator assumed 3 equipment crews for Drill shaft and Beam erection activities, presuming one drilling machine and one crane per crew. Each of these equipment crews are to work alongside each bridge construction crew pair executing these activities on the bridges that each crew pair constructs.
- Figures 11, 12, and 13 illustrate the bridges that are assumed to be executed by each crew pair.

Figure 11: Assumption of bridges assigned to each crew pair - Sub-phase 1-A

Figure 12: Assumption of bridges/overpasses assigned to each crew pair - Sub-phase 2-A

Figure 13: Assumption of bridges assigned to each crew pair - Sub-phase 2-B

5.5.2.5 Creating a Precedence Network and Reflecting Results in Gantt Chart

The next step in our methodology dictates the formation of a precedence network. For assistance and facilitation purposes, the estimator relied on the use of Microsoft Project software to conduct this activity. The precedence network included every activity considered in the WBS and is subject to all assumptions recorded in Section 5.5.2.4 of this report. Taking the aforementioned considerations, the estimator pursued the contract time determination of the US287 project using the critical path method. Activities were assigned successors and predecessors forming several project activity paths that depicted the interpreted project scope from initiation to completion. The critical path, or the path of activities with longest duration, determined the project's contract duration.

Table 20 shows the main activities that drive the critical path for each sub-phase.

Table 20: Case study 2 Activities that drive the critical path in each phase

Phase	Activities that Drive Critical Path
Phase 1	
Phase 1A	NB FR Roadway construction
Phase 1B and 1C	NB FR Intersections
Phase 2	
Phase 2A	12 ML Bridges/overpasses construction
Phase 2B	SB FR Roadway construction
Phase 2C	SB FR Intersections
Phase 2D	SB FR Intersections
Phase 3	Ramp SH34-S287-E

It is important to note the following observations:

- The Microsoft Project precedence network calculation for the contract duration is of 568.5 working days.
- Roadway construction commanded the critical path over bridge construction in sub-phase 1A.
- Despite the construction of retaining walls, the construction of 12 bridges and overpasses commanded the critical path over retaining walls and roadway construction in sub-phase 2A.
- Similar to sub-phase 1A, roadway construction commanded the critical path over bridge construction in sub-phase 2B.

Appendix O illustrates the US287 project precedence network developed in MS Project. The critical path is highlighted in red in the Gantt chart.

5.5.2.6 Depicting the Critical Path and Determining the Contract Duration

Once the critical path was identified, the critical path activities were extracted and recorded in a table in sequential order. The estimator also included each activity's

predecessor in the path and the completion percentage of the preceding activities with the intent to adjust each activity's duration in order to work with complete numbers of working days. This was done by rounding up to the nearest integer the duration of preceding activities that did not require 100% completion. Tables 21, 22, and 23 show the aforementioned calculations, yielding a final contract duration result.

Table 21: Case study 2 critical path activities – Phase 1

CP Activity ID Num.	Name	Duration (W. days)	Predecessor ID Num.	Predecessor % Complete
1	Phase 1	141		
1A	Phase 1A	127		
1A.1	Erosion CTRL (SW3P)	3		
1A.2	Construct detour widening (Asphalt pavement)	1	1A.1	100%
1A.3	Initial Traffic controls	4	1A.2	100%
1A.4	Prep ROW	9	1A.3	100%
1A.5	Excavation	22	1A.4	100%
1A.6	Storm Sewer pipes & TEP	9	1A.5	100%
1A.7	Storm sewer Inlets/Manholes	7	1A.6	50%
1A.8	Flex base	12	1A.7	100%
1A.9	Prime coat	4	1A.8	100%
1A.10	HMA 64-22	35	1A.9	50%
1A.11	HMA 70-22 (1")	5	1A.10	100%
1A.12	Railing	11	1A.11	100%
1A.13	Clean-up Phase 1A	8	1A.12	100%
1A.14	Phasing allowance 1A	3	1A.13	100%
1BC	Phase 1B and 1C	14	1A.12	100%
1BC.1	Traffic controls	1	1A.12	100%
1BC.2	Flex base	1	1BC.1	100%
1BC.3	Prime coat	1	1BC.2	100%
1BC.4	Concrete pavement	4	1BC.3	100%
1BC.5	Concrete Medians	5	1BC.4	100%
1BC.6	Clean-up 1B and 1C	1	1BC.5	100%
1BC.7	Phasing allowance 1B and 1C	1	1BC.6	100%

Table 22: Case study 2 critical path activities – Phase 2

CP Activity ID Num.	Name	Duration (W. days)	Predecessor ID Num.	Predecessor % Complete
	US287 Project	570		
2	Phase 2	409	1	100%
2A	Phase 2A	237	1BC.7	100%
2A.1	Erosion CTRL (SW3P)	4	1BC.7	100%
2A.2	Initial Traffic controls	4	2A.1	100%
2A.3	Remove asphalt pavement	26	2A.2	100%
2A.4	Excavation	40	2A.3	50%
2A.5	Oak Grove O.P NBML	45	2A.4	15%
2A.6	Oak Grove O.P SBML	45	2A.5	100%
2A.7	Cummins CK Trib 1 NBML	39	2A.6	100%
2A.8	Cummins CK Trib 1 SBML	41	2A.7	100%
2A.9	Embankment (C1) 2	10	2A.8	50%
2A.10	Approach slab	30	2A.9	100%
2A.11	Pavement markings	9	2A.10	100%
2A.12	Clean-up 2A	8	2A.11	100%
2A.13	Phasing allowance	3	2A.12	100%
2B	Phase 2B	150	2A.12	100%
2B.1	Erosion CTRL (SW3P)	3	2A.12	100%
2B.2	Initial Traffic controls	2	2B.1	100%
2B.3	Prep ROW	9	2B.2	100%
2B.4	Excavation	21	2B.3	100%
2B.5	Storm Sewer pipes & TEP	11	2B.4	100%
2B.6	Storm sewer Inlets/Manholes	10	2B.5	50%
2B.7	Flex base	13	2B.6	100%
2B.8	Prime coat	4	2B.7	100%
2B.9	HMA 64-22	39	2B.8	50%
2B.10	HMA 70-22 (2")	11	2B.9	100%
2B.11	Concrete curb and gutter	18	2B.10	100%
2B.12	Lighting	5	2B.11	100%
2B.13	Clean-up 2B	8	2B.12	100%
2B.14	Phasing allowance 2B	3	2B.13	100%
2C	Phase 2C	9	2B.12	100%
2C.1	Traffic controls	1	2B.12	100%
2C.2	Flex base	1	2C.1	100%
2C.3	Concrete pavement	4	2C.2	100%
2C.4	Pavement Markings	1	2C.3	100%
2C.5	Clean-up 2C	1	2C.4	100%
2C.6	Phasing allowance 2C	1	2C.5	100%
2D	Phase 2D	13	2C.6	100%
2D.1	Traffic controls	1	2C.6	100%
2D.2	Flex base	1	2D.1	100%
2D.3	Concrete pavement	4	2D.2	100%
2D.4	Concrete Medians	5	2D.3	100%
2D.5	Clean-up 2D	1	2D.4	100%
2D.6	Phasing allowance 2D	1	2D.5	100%

Table 23: Case study 2 critical path activities – Phase 3

CP Activity ID Num.	Name	Duration (W. days)	Predecessor ID Num.	Predecessor % Complete
3	Phase 3	20	2	100%
3.1	Erosion CTRL (SW3P)	1	2D.6	100%
3.2	Initial Traffic controls	1	3.1	100%
3.3	Prep ROW	1	3.2	100%
3.4	Embankment (C1)	2	3.3	100%
3.5	Flex base	1	3.4	100%
3.6	HMA 64-22	1	3.6	100%
3.7	HMA 70-22 (1")	5	3.6	-300%
3.8	Permanent pavement markings	4	3.7	100%
3.9	Final Clean-up	8	3.8	100%

The final contract duration calculated was a total of 570 working days. Table 24 summarizes the contract time determination calculations showing the resulting project and sub-phase durations.

Table 24: Case study 2 contract time determination summary

Phase / Sub-Phase	Stations	Main Work Locations	Duration (working days)
Phase 1			
Phase 1A	232	287 NB FR	127
Phase 1B and 1C	25	NB FR Intersections and Detour Widenings	14
Total Phase 1			141
Phase 2			
Phase 2A	232	US287 ML	237
Phase 2B	232	287 SB FR	150
Phase 2C	25	US287 ML and SBFR Intersections	9
Phase 2D	25	SB FR Intersections	13
Total Phase 2			409
Phase 3	232	Phase 1 Final Asphalt Pavement, Ramp SH34-S287-E	20
Total Phase 3			20
Total Project CTD			570

5.5.3 Comparison of Results

Once the contract duration estimation was calculated, the project design team's estimation was provided in a contract time estimate sheet (Appendix P) for results comparison. Table 25 shows a summary of this contract time estimate sheet, expressing the number of working days per phase and a total contract duration of the project.

Table 25: TXDOT contract time determination summary

Phase / Sub-Phase	Stations	Duration (working days)
Phase 1		207
Phase 1A	232	181
Phase 1B and 1C	25	33
Phase 2		398
Phase 2A	232	315
Phase 2B	232	152
Phase 2C	25	27
Phase 2D	25	6
Phase 3	232	78
Total Project CTD		621

TXDOT's total contract time determination is of 621 working days. As it can be perceived in the previous table, the sum of the sub-phases totals does not add up to the mentioned number. This is due to the fact that they did not assume sub-phases to be executed in sequential order and had several sub-phases executed in parallel.

The estimation's critical path starts with the execution of sub-phase 1A, where construction of retaining walls is the critical path commanding the sequence over roadway construction. The critical path shifts to sub-phases 1B and 1C after conclusion of retaining walls, yet prior to finishing seeding and landscape activities of sub-phase 1A. At sub-phase

2A, the longest activities represent bridge construction. However, bridge construction is considered executed in parallel to retaining walls followed by seeding and landscape. After conclusion of the latter activities the critical path continues to sub-phase 2B while sub-phase 2A bridges are completed in parallel. Sub-phase 2B's longest activity path is roadway construction, slightly longer than bridge construction at this stage of the project. After sub-phase 2B roadway construction, sub-phases 2C, 2D, and 3 are executed in sequential order. However, the critical path of the project is driven by topsoil installation and seeding and landscape activities for sub-phase 2B. After the conclusion of these activities, the critical path shifts to final project cleanup in phase 3 to reach final completion.

Table 26 summarizes the critical path activities for TXDOT's estimation.

Table 26: Critical path activities for TXDOT estimation

CP Activity ID Num.	Name	Duration (W. days)	Predecessor ID Num.	Predecessor % Complete
	US287 TCP	621 days		
1	Phase 1A	181 days		
2	Install SW3P Items for Phase	3 days		
4	Construct temporary detour #1 and #8	5 days	2	
8	Embankment	27 days	3	
12	Construct retaining walls	160 days	8	10%
22	Phase 1B and 1C	33 days		
23	Install traffic control items for phase	2 days	12	
24	Construct detours #2, #4, & #7	6 days	23	
26	Construct flex base	2 days	24	
27	Construct asphalt base	2 days	26	
28	Construct concrete pavement	2 days	27	
29	Place PPM	19 days	28	
30	Phase 2A	315 days		
31	Instal SW3P items for phase	3 days	29	
32	Install traffic control items for phase	3 days	31	
34	Embankment	66 days	32	
38	Construct retaining walls	186 days	34	20%
46	Install topsoil	55 days	38	80%
47	Seeding and landscaping	55 days	46	40%
48	Phase 2B	152 days		
49	Install traffic control items for phase	2 days	47	
51	Embankment	31 days	49	
52	Construct storm sewer	22 days	51	10%
53	Construct inlets and manholes	8 days	52	10%
58	Construct asphalt base	36 days	53	
59	Construct asphalt surface pavement	19 days	58	
61	Install topsoil	59 days	59	80%
62	Seeding and landscaping	59 days	61	40%
74	Phase 3	78 days		
81	Final Clean-up	16 days	62	100%

5.5.3.1 Overall Results Comparison

Table 27 shows an overall comparison of working day calculations by phases and project total, highlighting the difference in number of working days and percentage.

Table 27: Overall comparison between TXDOT and Case study 2 estimations

Phase / Sub-Phase	Stations	TxDOT Duration (working days)	Case Study Duration (working days)	Delta	Delta %
Phase 1		207	141	-66	-31.88%
Phase 1A	232	181	127	-54	-29.83%
Phase 1B and 1C	25	33	14	-19	-57.58%
Phase 2		398	409	11	2.76%
Phase 2A	232	315	237	-78	-24.76%
Phase 2B	232	152	150	-2	-1.32%
Phase 2C	25	27	9	-18	-66.67%
Phase 2D	25	6	13	7	116.67%
Phase 3	232	78	20	-58	-74.36%
Total Project CTD		621	570	-51	-8.21%

The contract duration comparison, while yielding a considerably close total contract duration difference (51 working day, - 8.21%), reflects significant working day dissimilarities at a sub-phase level. Sub-phases 1A, 2A, and 2B are highlighted in Table 9 to express the importance in length that these stages represent. While the total duration of sub-phase 2B is very close in both estimations (difference of 2 working days, - 1.32%), the difference in phases 1A and 2A are considerably apart. For sub-phase 1A, this task's estimator accounted for 54 working days less than TXDOT's estimation (-29.83%). Similarly, in sub-phase 2A this task's estimator calculated 78 working days less than TXDOT's estimators (-24.76%).

The most identifiable difference factors include the critical paths chosen, the consideration and interpretation of the construction sequence and TCP, differences in activity quantities, and differences in the production rates used.

5.5.3.2 Construction Sequence and Traffic Control Plan Consideration and Interpretation

When studied in detail, there are notable differences between both estimations regarding the adaptation of the construction sequence and TCP to the contract time duration. The most meaningful difference is that TXDOT allows for the critical path to shift prior to a previous sub-phase concludes while this case study task established the full completion of a preceding sub-phase prior to the next sub-phase's initiation.

If TXDOT's estimation would have followed the same sequence rule used in this report's task, then TXDOT's estimation would be closer to 753 working days, and this task's estimation would be about 24.3% less than TXDOT's. This is an overall number more consistent with the differences that the sub-phase level comparison yielded. The following sections will analyze critical path, quantity, and production rate differences, which will express further explanation for the considerable resulting differences.

5.5.3.3 Differences in Considered Activities for Analysis

An interesting aspect to consider is the differences in the activities selected for each estimation. There are some activities considered in this case study's contract estimation that are excluded from TXDOT's analysis, and vice versa. The activities excluded from TXDOT's analysis that are included in this case study are shown in Tables 28, 29 and 30.

Table 28: Case study 2 activities not considered in TXDOT estimation – Phase 1

	Activities
Phase 1A	Remove concrete pavement
	Remove asphalt pavement
	Temporary Shoring
	Riprap
	Temporary Shoring
	Embankment (C2)
	Approach slab
	Railing
	Prime coat
	Concrete curb and gutter
	Bridge Sidewalk
	Sidewalk
	Lighting
	Small signs
	Overhead Signs
	Temp pavement markings
	Clean-up
	Phasing allowance
Phase 1B & 1C	Prime coat
	Superpave 70-22 (1")
	Concrete medians
	Small signs
	Seeding and landscape
	Clean-up
	Phasing allowance

Table 29: Case study 2 activities not considered in TXDOT estimation – Phase 2

	Activities
Phase 2A	Prep ROW
	Remove asphalt pavement
	Temporary Shoring
	Riprap
	Temporary Shoring
	Embankment (C2)
	Approach slab
	Railing
	Prime coat
	Concrete curb and gutter
	Sidewalk
	Small signs
	Overhead signs
	Lighting
	Pavement markings
	Clean-up
	Phasing allowance
Phase 2 B	Erosion CTRL (SW3P)
	Prep ROW
	Remove asphalt pavement
	Temporary Shoring
	Riprap
	Culvert extensions
	Approach slab
	Prime coat
	Concrete curb and gutter
	Railings
	Bridge Sidewalk
	Sidewalks
	Small signs
	Lighting
	Pavement markings
	Clean-up
	Phasing allowance
Phase 2C	Prime coat
	Clean-up
	Phasing allowance
Phase 2D	Prime coat
	Concrete medians
	Small signs
	Pavement Markings
	Clean-up
	Phasing allowance

Table 30: Case study 2 activities not considered in TXDOT estimation – Phase 3

	Activities
Phase 3	Prep ROW
	Excavation
	Embankment (C1)
	Prime coat
	Small signs
	Lighting
	Seeding and landscape

Furthermore, Table 31 depicts the activities considered in case study 2's estimation that were excluded from TXDOT's calculations:

Table 31: TXDOT activities not considered in Case study 2 estimation

	Activities
Phase 1A	Construct concrete pavement
	Install Topsoil
Phase 2A	Construct concrete pavement
	Install Topsoil
Phase 2 B	Construct concrete pavement
	Install Topsoil
Phase 2C	Construct asphalt base
Phase 2D	Construct asphalt base

The number of total major activities considered were considerably higher in the case study calculation, with 148 activities compared to TXDOT's 73. That is a difference of 75 considered activities, and 102% more activities considered by this estimation. If we narrow our scope to the activities that represented each critical path (analyzed in section 5.5.3.4 of this report), the case study estimation accounts for 69 critical path activities while TXDOT concludes only 25, yielding a difference of 44 more activities (+176%) in this task.

5.5.3.4 Critical Path Differences

Acknowledging the differences regarding critical path shifts prior to the conclusion of preceding phases, an interesting comparison perspective is to compare the longest path activities for each sub-phase and the different activities that shape the critical paths. Table 32 shows the activities that drive the critical path in both estimations.

Table 32: Activities that drive the critical paths of TXDOT and Case study 2 estimations

Phase / Sub-Phase	TxDOT Estimation Activities that drives CP	Case Study Estimation Activities that drives CP
Phase 1		
Phase 1A	Roadway construction	Retaining walls
Phase 1B and 1C	Intersections	Intersections / PPM
Phase 2		
Phase 2A	Bridge construction	Retaining walls / Seeding and landscape
Phase 2B	Roadway construction	Roadway construction / Seeding and landscape
Phase 2C	Intersections	Intersections / PPM
Phase 2D	Intersections	Intersections
Phase 3	Ramp construction	Ramp construction / PPM

The following descriptions narrate the differences between both estimations regarding the critical paths within each sub-phase and how these activities are reflected in the project's critical path.

- Sub-phase 1A:
 - The critical path in TXDOT's estimation is mainly driven by the construction of retaining walls. Meanwhile, the case study accounts for roadway construction as the main activity that drives the critical path in phase 1A. This difference is primarily due to quantity allocation for each phase. For construction of retaining walls, TXDOT's estimation allocates

42,962 SF for sub-phase 1A while this task's estimation accounts for only 2,118 SF. Project documents led to believe that a vast majority of the retaining wall work was to be allocated to sub-phase 2A.

- The case study considers that a portion of roadway construction has to be concluded after construction of retaining walls since these are designed to support the Northbound Frontage Road (observation based on interpretation of plans and specifications). Meanwhile, TXDOT's estimation represents roadway construction to conclude prior to retaining wall construction. The revision of this activity sequence is recommended based on plans observations.
- The second nearest path does account for roadway construction work in TXDOT's estimation, although it is not the defining path to the sub-phase's conclusion.
- Sub-phase 1B starts prior to the 100% completion of Seeding & landscape activities in sub-phase 1A, an assumption not accounted for in this task's estimation.
- The case study considers railing installation as part of the critical path.
- Sub-phases 1B and 1C:
 - Both estimations incorporate sub-phases 1B and 1C as one combined sub-phase for analysis.
 - TXDOT's estimation considers construction detour as a critical path activity while the case study considers it in parallel to pavement construction.

- The longest activity in sub-phases 1B and 1C for TXDOT's estimation is Pavement markings (Place PPM). There is a significant difference in quantity allocation for this activity when compared with the case study.
- While pavement construction commands the rest of the longest path for both estimations, TXDOT's durations in these activities double the durations of the case study's estimation.
- Sub-phase 2A:
 - Despite differences in quantification approach, both estimations agree that the bridge construction path commands the longest path in sub-phase 2A. However, the path that defines the transition to sub-phase 2B in TXDOT's estimation is formed by retaining wall construction, topsoil installation, and seeding and landscape while bridge construction work is concluded in parallel with sub-phase 2B. In the case study, retaining walls construction is a parallel activity while seeding and landscape belongs to the critical path.
 - Roadway construction is a parallel path in both estimations. However, this task considers that a portion of roadway construction has to be concluded after construction of retaining walls since these are designed to support both Northbound and Southbound Main Lanes (observation based on interpretation of plans and specifications). Meanwhile, TXDOT's estimation represents roadway construction to conclude prior to retaining wall construction. The revision of this activity sequence is recommended based on observations.
 - In TXDOT's estimation, bridge construction starts immediately after traffic controls installation. In the case study analysis, removing asphalt pavement and excavation succeed traffic controls and precede bridge construction.

- Approach slabs and pavement markings are in the critical path for this task's estimation, while TXDOT does not include these activities in their analysis.
- Sub-phase 2B:
 - For this case study, storm sewer pipes and inlets and manholes are part of the longest path while in TXDOT's estimation these activities are not considered predecessors to roadway construction.
 - According to TXDOT's estimation, bridge construction is projected to conclude one day after asphalt pavement installation. However, the project's critical path shifts to sub-phase 2C after concrete pavement work in intersections (not considered in the case study) while bridge and roadway work are concluded in parallel with sub-phase 2C. Meanwhile, the case study determined that roadway construction drives the critical path for this sub-phase.
 - The case study accounts for lighting activities after roadway construction and prior to cleanup and phasing allowance prior to shifting to sub-phase 2C.
 - Also, concrete curb and gutter is part of the case study's critical path.
 - TXDOT's estimation has topsoil installation and seeding and landscape as the final longest path activities for sub-phase 2B. However, these start after pavement activities are 80% complete. Since pavement activities start while sub-phase 2C is already underway, topsoil installation and seeding and landscape take place in parallel with sub-phases 2C, 2D, and 3, and in fact command the project's critical path preceding the project's final clean-up.
- Sub-phase 2C:

- Similar to sub-phases 1B and 1C, pavement markings play a big part of sub-phase 2C's critical path. The main difference maker for both estimations is in quantities.
- Both estimations coincide that roadway construction commands the critical path for this sub-phase.
- Sub-phase 2D:
 - The only difference observed is the case study's inclusion of concrete medians to its critical path.
- Phase 3:
 - The case study accounts for excavation and embankment while TXDOT's estimation does not.
 - Both estimations coincide that roadway construction is part of the critical path.
 - Both estimations coincide that pavement markings are part of the critical path, although have considerable differences in quantities.
 - There are differences in quantities for pavement surface activities. These differences may be due to different interpretations on sub-phase 1A asphalt final layer pavement. However, this fact does not represent any difference as 4 of the 5 days of the activity's duration are considered executed in parallel in this case study while TXDOT only accounts for one day for pavement surface.
 - Final project clean-up succeeds pavement markings for phase 3 in the case study.

5.5.3.5 Quantity Differences

The quantities used for the case study task were completely extracted from project plans and specifications and allocated under the estimator's interpretations. However, a majority of quantities were different from TXDOT's estimation. This may be due to different project information interpretation, assumptions, and access to additional knowledge and conditions.

For comparison purposes, the similar activities considered by both estimations were recorded in Tables 33 through 36 depicting the units used for each estimation, the quantities considered, the difference in quantities, and the percentage difference for the considered quantities for each sub-phase.

Table 33: TXDOT and case study 2 quantity allocation comparison – Phase 1

	Activities	TxDOT		Case Study		Quantity Comparison	
		Units	Quantities	Units	Quantities	Delta	Delta %
Phase 1 A	Erosion CTRL (SW3P)	DAY	3.00	LF	7,662.00	Dif. Units	Dif. Units
	Construct detour widening (Asphalt pavement)	DAY	5.00	TON	431.46	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	3.00	LS	1.00	Dif. Units	Dif. Units
	Prep ROW	DAY	5.00	AC	50.00	Dif. Units	Dif. Units
	Excavation	CY	37,244.00	CY	60,924.00	23,680.00	63.58%
	Culvert extensions	LF	2,889.00	LF	1,356.50	-1,532.50	-53.05%
	Storm Sewer pipes & TEP	LF	7,715.00	LF	2,518.00	-5,197.00	-67.36%
	Storm sewer Inlets/Manholes	EA	30.00	EA	13.00	-17.00	-56.67%
	Embankment (C1)	CY	185,829.00	CY	191,928.75	6,099.75	3.28%
	MSE walls	SF	42,963.00	SF	2,118.00	-40,845.00	-95.07%
	Flex base	SY	96,516.00	CY	40,163.05	Dif. Units	Dif. Units
	HMA 64-22	TON	41,983.00	TON	30,264.00	-11,719.00	-27.91%
	HMA 70-22 (1")	TON	8,567.00	TON	4,037.63	-4,529.38	-52.87%
	Bridge Construction	LS	3.00	LS	3.00	0.00	0.00%
	Seeding and landscape	SY	116,941.00	SY	105,891.50	-11,049.50	-9.45%
Phase 1 B and 1 C	Traffic controls	DAY	2.00	LS	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,555.00	CY	2,008.15	Dif. Units	Dif. Units
	Superpave 64-22	TON	1,545.00	TON	1,513.20	-31.80	-2.06%
	Concrete pavement	SY	3,476.00	SY	10,445.67	6,969.67	200.51%
	Construct detour widening (Asphalt pavement)	DAY	6.00	TON	396.61	Dif. Units	Dif. Units
	Pavement Markings	LF	92,163.00	LF	8,002.50	-84,160.50	-91.32%

Table 34: TXDOT and case study 2 quantity allocation comparison – Sub-phase 2A

Activities		TxDOT		Case Study		Quantity Comparison	
		Units	Quantities	Units	Quantities	Delta	Delta %
Phase 2 A	Erosion CTRL (SW3P)	DAY	3.00	SY	9,987.00	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	3.00	LS	1.00	Dif. Units	Dif. Units
	Excavation	CY	91,625.00	CY	109,457.00	17,832.00	19.46%
	Culvert extensions	LF	4,506.00	LF	3,822.50	-683.50	-15.17%
	Storm Sewer pipes & TEP	LF	8,362.00	LF	15,210.00	6,848.00	81.89%
	Storm sewer Inlets/Manholes	EA	69.00	EA	87.00	18.00	26.09%
	Embankment (C1)	CY	457,168.00	CY	401,603.00	-55,565.00	-12.15%
	MSE walls	SF	50,025.00	SF	90,888.00	40,863.00	81.69%
	Flex base	SY	150,558.00	CY	85,291.50	Dif. Units	Dif. Units
	HMA 64-22	TON	65,427.00	TON	63,349.50	-2,077.50	-3.18%
	HMA 70-22 (2")	TON	15,488.00	TON	17,168.00	1,680.00	10.85%
	Bridge/OP construction	LS	12.00	LS	12.00	0.00	0.00%
	Seeding and landscape	SY	197,945.00	SY	229,799.50	31,854.50	16.09%

Table 35: TXDOT and case study 2 quantity allocation comparison – Sub-phases 2B, 2C, and 2D

Activities		TxDOT		Case Study		Quantity Comparison	
		Units	Quantities	Units	Quantities	Delta	Delta %
Phase 2 B	Initial Traffic controls	DAY	2.00	LS	1.00	Dif. Units	Dif. Units
	Excavation	CY	42,682.00	CY	57,668.50	14,986.50	35.11%
	Storm Sewer pipes & TEP	LF	6,518.00	LF	2,999.00	-3,519.00	-53.99%
	Storm sewer Inlets/Manholes	EA	23.00	EA	20.00	-3.00	-13.04%
	Embankment (C1)	CY	212,963.00	CY	208,727.75	-4,235.25	-1.99%
	Flex base	SY	96,700.00	CY	45,031.83	Dif. Units	Dif. Units
	HMA 64-22	TON	42,022.00	TON	33,670.50	-8,351.50	-19.87%
	HMA 70-22 (2")	TON	9,185.00	TON	9,295.25	110.25	1.20%
	Bridge Construction	LS	3.00	LS	3.00	0.00	0.00%
	Seeding and landscape	SY	209,873.00	SY	122,139.50	-87,733.50	-41.80%
Phase 2 C	Traffic controls	DAY	2.00	LS	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,859.00	CY	459.40	Dif. Units	Dif. Units
	Concrete pavement	SY	3,776.00	SY	10,445.67	6,669.67	176.63%
	Pavement Markings	LF	85,247.00	LF	4,001.25	-81,245.75	-95.31%
Phase 2 D	Traffic controls	DAY	2.00	LS	1.00	Dif. Units	Dif. Units
	Flex base	SY	2,818.00	CY	459.40	Dif. Units	Dif. Units
	Concrete pavement	SY	2,748.00	SY	10,445.67	7,697.67	280.12%

Table 36: TXDOT and case study 2 quantity allocation comparison – Phase 3

Activities		TxDOT		Case Study		Quantity Comparison	
		Units	Quantities	Units	Quantities	Delta	Delta %
Phase 3	Erosion CTRL (SW3P)	DAY	2.00	SY	100.00	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	2.00	LS	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,183.00	CY	1,308.60	Dif. Units	Dif. Units
	HMA 64-22	TON	1,383.00	TON	774.00	-609.00	-44.03%
	HMA 70-22 (1")	TON	338.00	TON	4,321.13	3,983.13	1178.44%
	Permanent pavement markings	LF	67,025.00	LF	32,010.00	-35,015.00	-52.24%
	Clean-up	STA	235.00	STA	232.00	-3.00	-1.28%

Observations of this table suggest significant differences in the quantities used. These may be due to different access levels to information, perhaps implying that it is more likely for TXDOT estimators to have more information than the provided for this case study task. Furthermore, it could be the result of misinterpreting information and/or overlooking important activities and quantities in diverse sectors of the project, whether they be from this case study's estimation, TXDOT's estimation, or both.

Important activities of note that affected the overall results for both estimations regarding quantities are:

- Retaining walls: The case study allocated only 2,118 SF for sub-phase 1A compared to TXDOT's 42,963 SF. This difference of around 40,000 SF is balanced with the allocated quantities for sub-phase 2A, where the case study's estimator assigns 90,888 SF compared to TXDOT's 50,025 SF. This difference in allocation can be based on access to project information and different interpretation of plans and construction sequence. This task's estimator assumed that most of the MSE wall construction was attributed to the Northbound and Southbound Main Lanes (to be executed in sub-phase 2A), while just a small fraction retaining the Northbound Frontage Road (sub-phase 1A).

- Asphalt pavement surface (HMA 70-22): In sub-phase 1A, the difference in this activity is around 4,000 Ton, a difference that is then balanced with the quantities allocated to phase 3. This illustrates a difference in interpreting the allocation of the final 1" pavement layer in phase 3 of the roadway constructed in sub-phase 1A (predominantly Northbound Frontage Road) for the case study's analysis. It seems like TXDOT's estimation did not conduct the analysis with the same criteria as it allocates 100% of the activity's quantities in the aforementioned sector to sub-phase 1A.
- Excavation: Overall, excavation yielded higher quantities for the case study. However, excavation was considered a parallel activity in both estimations particularly because embankment quantities are much higher than excavation quantities, assuming the need of material from external sites to complete the project.
- Embankment: A significantly important activity accounting for the quantities required for this project. The quantity differences for embankment range from 1.99% to 12.15%, a small number considering that the case study makes up for such difference allocating retaining wall embankment activities separately (activity embankment (C2)).
- Concrete pavement: The quantity differences for this activity can be explained by the fact that TXDOT's estimation allocated a portion of concrete pavement quantities to sub-phases 1A, 2A, and 2B – mainly dedicated to main lanes and frontage roads construction. Meanwhile, the case study's estimator allocated most of this activity's quantities to sub-phases 1B, 1C, 2C, and 2D, where the work is more focused on intersection pavement.

- Pavement markings: The case study's estimator distributed pavement marking activities – whether temporary or permanent pavement markings – to all sub-phases of the project. TXDOT's estimation shows that permanent pavement marking activities are executed in sub-phases 1B, 1C, 2C, and 3.
- Bridge construction: Analyzed separately in section 5.5.3.7 of this report.

5.5.3.6 Production Rate Differences

There are also notable differences in the production rates used. Similar to the quantities comparison, Tables 37 through 40 compare production rates from both estimations yielding a column with production rate differences and production rate difference percentages. For the case study's production rates, the assigned number is multiplied by the assumed number of crews, yielding higher production rates and differences when assigned more than one crew for an activity.

Table 37: TXDOT and case study 2 production rate comparison – Phase 1

Activities		TxDOT		Case Study				PR Comparison	
		Units	Units/Day	Units	Units/Day	# of Crews	Total PR	Delta	Delta %
Phase 1 A	Erosion CTRL (SW3P)	DAY	1.00	LF	3,000.00	1	3,000.00	Dif. Units	Dif. Units
	Construct detour widening (Asphalt pavement)	DAY	1.00	TON	883.00	1	883.00	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	1.00	LS	0.25	1	0.25	Dif. Units	Dif. Units
	Prep ROW	DAY	1.00	AC	6.00	1	6.00	Dif. Units	Dif. Units
	Excavation	CY	7,000.00	CY	2,794.00	1	2,794.00	-4,206.00	-60.09%
	Culvert extensions	LF	100.00	LF	99.00	2	198.00	98.00	98.00%
	Storm Sewer pipes & TEP	LF	300.00	LF	145.00	2	290.00	-10.00	-3.33%
	Storm sewer Inlets/Manholes	EA	3.00	EA	2.00	1	2.00	-1.00	-33.33%
	Embankment (C1)	CY	7,000.00	CY	2,654.14	2	5,308.28	-1,691.72	-24.17%
	MSE walls	SF	270.00	SF	452.80	1	452.80	182.80	67.70%
	Flex base	SY	3,000.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	HMA 64-22	TON	1,200.00	TON	883.00	1	883.00	-317.00	-26.42%
	HMA 70-22 (1")	TON	500.00	TON	883.00	1	883.00	383.00	76.60%
	Bridge Construction	LS	0.04	LS	0.08	1	0.08	0.04	94.59%
	Seeding and landscape	SY	3,600.00	SY	4,000.00	2	8,000.00	4,400.00	122.22%
Phase 1 B and 1 C	Traffic controls	DAY	1.00	LS	1.00	1	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,000.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	Superpave 64-22	TON	1,200.00	TON	883.00	1	883.00	-317.00	-26.42%
	Concrete pavement	SY	3,000.00	SY	2,765.00	1	2,765.00	-235.00	-7.83%
	Construct detour widening (Asphalt pavement)	DAY	1.00	TON	883.00	1	883.00	Dif. Units	Dif. Units
	Pavement Markings	LF	5,000.00	LF	9,607.00	1	9,607.00	4,607.00	92.14%

Table 38: TXDOT and case study 2 production rate comparison – Sub-phase 2A

Activities		TxDOT		Case Study				PR Comparison	
		Units	Units/Day	Units	Units/Day	# of Crews	Total PR	Delta	Delta %
Phase 2 A	Erosion CTRL (SW3P)	DAY	1.00	SY	3,000.00	1	3,000.00	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	1.00	LS	0.25	1	0.25	Dif. Units	Dif. Units
	Excavation	CY	7,000.00	CY	2,794.00	1	2,794.00	-4,206.00	-60.09%
	Culvert extensions	LF	100.00	LF	99.00	2	198.00	98.00	98.00%
	Storm Sewer pipes & TEP	LF	300.00	LF	145.00	2	290.00	-10.00	-3.33%
	Storm sewer Inlets/Manholes	EA	3.00	EA	2.00	2	4.00	1.00	33.33%
	Embankment (C1)	CY	7,000.00	CY	2,654.14	2	5,308.28	-1,691.72	-24.17%
	MSE walls	SF	270.00	SF	452.80	2	905.60	635.60	235.41%
	Flex base	SY	3,000.00	CY	3,539.00	2	7,078.00	Dif. Units	Dif. Units
	HMA 64-22	TON	1,200.00	TON	883.00	2	1,766.00	566.00	47.17%
	HMA 70-22 (2")	TON	500.00	TON	883.00	2	1,766.00	1,266.00	253.20%
	Bridge/OP construction	LS	0.04	LS	0.07	1	0.07	0.03	81.76%
	Seeding and landscape	SY	3,600.00	SY	4,000.00	2	8,000.00	4,400.00	122.22%

Table 39: TXDOT and case study 2 production rate comparison – Sub-phases 2B, 2C, and 2D

Activities		TxDOT		Case Study				PR Comparison	
		Units	Units/Day	Units	Units/Day	# of Crews	Total PR	Delta	Delta %
Phase 2 B	Initial Traffic controls	DAY	1.00	LS	0.50	1	0.50	Dif. Units	Dif. Units
	Excavation	CY	7,000.00	CY	2,794.00	1	2,794.00	-4,206.00	-60.09%
	Storm Sewer pipes & TEP	LF	300.00	LF	145.00	2	290.00	-10.00	-3.33%
	Storm sewer Inlets/Manholes	EA	3.00	EA	2.00	1	2.00	-1.00	-33.33%
	Embankment (C1)	CY	7,000.00	CY	2,654.14	2	5,308.28	-1,691.72	-24.17%
	Flex base	SY	3,000.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	HMA 64-22	TON	1,200.00	TON	883.00	1	883.00	-317.00	-26.42%
	HMA 70-22 (2")	TON	500.00	TON	883.00	1	883.00	383.00	76.60%
	Bridge Construction	LS	0.04	LS	0.08	1	0.08	0.03	82.05%
Phase 2 C	Seeding and landscape	SY	3,600.00	SY	4,000.00	2	8,000.00	4,400.00	122.22%
	Traffic controls	DAY	1.00	LS	1.00	1	1.00	Dif. Units	Dif. Units
	Flex base	SY	1,500.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	Concrete pavement	SY	3,000.00	SY	2,765.00	1	2,765.00	-235.00	-7.83%
Phase 2D	Pavement Markings	LF	5,000.00	LF	9,607.00	1	9,607.00	4,607.00	92.14%
	Traffic controls	DAY	1.00	LS	1.00	1	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,000.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	Concrete pavement	SY	3,000.00	SY	2,765.00	1	2,765.00	-235.00	-7.83%

Table 40: TXDOT and case study 2 production rate comparison – Phase 3

Activities		TxDOT		Case Study				PR Comparison	
		Units	Units/Day	Units	Units/Day	# of Crews	Total PR	Delta	Delta %
Phase 3	Erosion CTRL (SW3P)	DAY	1.00	SY	3,000.00	1	3,000.00	Dif. Units	Dif. Units
	Initial Traffic controls	DAY	1.00	LS	1.00	1	1.00	Dif. Units	Dif. Units
	Flex base	SY	3,000.00	CY	3,539.00	1	3,539.00	Dif. Units	Dif. Units
	HMA 64-22	TON	1,200.00	TON	883.00	1	883.00	-317.00	-26.42%
	HMA 70-22 (1")	TON	3,000.00	TON	883.00	1	883.00	-2,117.00	-70.57%
	Permanent pavement markings	LF	5,000.00	LF	9,607.00	1	9,607.00	4,607.00	92.14%
	Clean-up	STA	15.00	STA	30.00	1	30.00	15.00	100.00%

Observations of this table suggest significant differences in the production rates used, ranging from -70.57% to +253.20%. These may be due to different access levels to information, perhaps implying that it is more likely for TXDOT estimators to have more information than that provided for this case study task. Furthermore, in the case study's estimation, the number of crews played an important role as a production rate multiplier significantly increasing the number for many activities. It is important to note that the

assignment of crews was based on the activity's work zone size and relative quantities as the main drivers as established in section 5.5.2.3 of this report.

Important activities of note that affected the overall results for both estimations regarding production rates are:

- Excavation: The production rate for excavation activities was considerably lower for the case study's estimation (-60.09%). This is due to the assumption that there is no need for higher production on excavation as a parallel activity to embankment when earth material is expected to continuously arrive from external sites.
- Embankment: The difference of -24.17% is considered within an appropriate range for this activity considering the number of crews assigned in the case study. If the number of crews were to increase to 3 for this activity, the case study's production rate would be 13.75% higher than TXDOT's production rate. While it is a closer number, the assumption of assigning more or less crews is subjective to the estimator. In sub-phase 2A (construction of both Northbound and Southbound Main Lanes), it would be reasonable to increase the production rate based on crews and work zone size. Making the same assumption for sub-phases 1A and 2B (construction of Frontage Roads) may require further analysis. Regardless, the production rate is subject to the number of crews and equipment assigned to the activity. Another option would have been to have a High level production rate selected from the *Production Rate Resource*. The case study's data would have reflected a production rate of 7,000 CY/Day, which is coincidentally exact to TXDOT's number for embankment.
- Retaining walls (MSE walls): The only production rate source that provided information on MSE walls was HYPRIS. The mean production rate from this source – used for this task – is 67.70% higher than TXDOT's production rate. In

sub-phase 2A, this number increases to 235.41% due to assignment of 2 crews. This was assumed given the great quantity number for this activity in the aforementioned sub-phase.

- Asphalt pavement surface (HMA 70-22): In sub-phases 1A and 2B, the mean production rate selected in the case study is 76.60% higher than the one used by TXDOT. Assigning a Low level production rate from the *Production Rate Resource* (420 Ton/Day) would have yielded a much closer number to TXDOT's production rate. However, the relative quantities and work zone size for this activity support the estimator's choice of a Mean level. In sub-phase 2A, the case study's number of crews for this activity is doubles, increasing the difference to 253.20%. This selection is supported by the considerable work zone size.
- Seeding and landscape: The Mean level production rate of 4,000 SY/Day is close to TXDOT's 3,600 SY/Day. However, the assumption of doubling up the number of crews in the case study increased the difference to a 122.22% higher production rate. This selection is supported by the considerable work zone size.
- Pavement markings: The production rate used by the Task's estimator was of 9,607 LF/Day, the *Production Rate Resource's* Mean level production rate for this activity. This number is almost twice the rate used in TXDOT's estimation.
- Bridge construction: Analyzed separately in section 5.5.3.7 of this report.

5.5.3.7 Bridge Construction Analysis Differences

Bridge construction activities were analyzed differently in both estimations. The two main differences lie in the activities considered for analysis and the number of crews assigned for these activities with the possibility of working in parallel.

TXDOT's estimation only considered three sequential activities for bridge construction executed in the following order: Construct drilled shaft; Construct concrete columns, caps, and bents; and Construct deck – Total depth. The quantities of these activities for all bridges within a sub-phase were summed and considered for each as a whole activity. For example, for Construct drilled shaft activity for sub-phase 1A, TXDOT's estimation sums all quantities from the three bridges constructed in this sub-phase – Cummins Creek Northbound Frontage Road, Cummins Creek Tributary 1 Northbound Frontage Road, and Cummins Creek Tributary 2 Northbound Frontage Road – and allocates the total number into one Construct drilled shaft activity. They do the same for activities Construct concrete columns, caps, and bents, and Construct deck – Total depth without bridge construction division. Once the preceding activity is 100% complete, the following activity starts in the bridge construction sequence.

Meanwhile, the case study's estimator proposes 3 crew pairs to work in each sub-phase, allowing to build bridges in parallel and not limiting the initiation of an activity within one bridge until after the conclusion of the preceding activity for all bridges within a sub-phase. Furthermore, the case study analyzes 6 activities plus a total of 8 days of buffer time for each bridge. Specific details on these statements and assumptions are explained in Sections 5.5.2.2 and 5.5.2.4 of this report.

Since only one activity (Drilled shaft construction) is comparable for both estimations, analyzing quantity and production rate comparisons can be misleading. However, a viable comparison option is a lump sum observation analysis. If we sum the three sequential activities for bridge construction, we can calculate TXDOT's total duration for bridge within each sub-phase. This calculation is expressed in the Table 41.

Table 41: Bridge construction duration by sub-phase in TXDOT estimation

	Activity	Duration
Phase 1A	Construct drilled shaft	9
	Construct concrete columns, caps, and bents	18
	Construct deck - Total depth	45
	Total duration	72
Phase 2A	Construct drilled shaft	51
	Construct concrete columns, caps, and bents	64
	Construct deck - Total depth	194
	Total duration	309
Phase 2B	Construct drilled shaft	10
	Construct concrete columns, caps, and bents	18
	Construct deck - Total depth	43
	Total duration	71

If we compare these total durations for bridge construction within each sub-phase to the number calculated in the case study (perceivable in Appendix Q), we can calculate a comparable production rate of portion of bridge constructed per day, the difference in durations and the difference in production rates between each estimation. Table 42 depicts this analysis.

Table 42: Bridge construction duration and production rate comparison

Sub-phase	Num. of bridges	TxDOT		Case Study		Duration delta	Duration delta %	PR delta %
		Duration	Daily Rate	Duration	Daily Rate			
1A	3	72	0.0417	37	0.0811	-35	-48.61%	94.59%
2A	12	309	0.0388	170	0.0706	-139	-44.98%	81.76%
2B	3	71	0.0423	39	0.0769	-32	-45.07%	82.05%

This table concludes that the assumptions undertaken by the case study's estimator for bridge construction yield shorter durations within each sub-phase when compared to TXDOT's estimation. The durations range from 44.98% to 48.61% shorter. This

conclusion can also be interpreted from a production rate standpoint. If we compare the calculated production rates, the case study's determination estimates considerably higher production rates than TXDOT's analysis, ranging from 81.76% to 94.59% higher productivity.

5.5.4 Case Study 2 Conclusions

A contract time determination of the US287 highway improvement project was conducted using the *Production Rate Resource* and its supporting references.

The process followed a detailed methodology, starting with a thorough examination of the available plans and documents, an exhaustive understanding of the construction sequence and TCP, and the development of a WBS of major construction activities. The *Production Rate Resource* and its supporting references were then consulted to select the appropriate production rate for each activity in order to calculate their durations in working days. In addition to these references, the estimator included the use of FLDOT as a supplementary source.

Considering the number of bridges and overpasses in the project, the estimator analyzed bridge construction activities separately from the WBS. Each bridge was studied individually and reflected in the WBS as a whole activity. The estimator also assumed the designation of multiple crews working in pairs at each bridge for concurrent construction.

Creating a precedence network and its illustration through a Gantt chart led to identifying a critical path. This path's duration resulted in the estimated contract duration. Necessary assumptions that pertain to included and excluded analysis considerations were also documented.

The analysis resulted in a contract duration estimate of 570 working days. These 570 working days are the sum of all phase duration totals, which were: phase 1: 141 working days, phase 2: 409 working days, and phase 3: 20 working days.

The TXDOT engineer's estimate was provided for comparison purposes, and indicated 621 working days of contract time. The issues considered in the analysis of differences were the overall results, both at a sub-phase and project level; the construction sequence and TCP inclusion and interpretation; and assumed activity quantity and production rate differences.

The contract time estimates were considerably close with an overall difference of 8.21%. However, when compared at a sub-phase level, significant differences were found. Analyzing the project's three longest, most important sub-phases, sub-phase 1A was estimated in the case study at 29.83% shorter duration than TXDOT's estimation, sub-phase 2A was estimated at 24.76% shorter, and sub-phase 2B was estimated very close with a 1.32% difference. These results suggested that the methods used by both estimations were considerably different.

The first difference identified was that TXDOT's estimation did not assume that succeeding sub-phases will be constructed in sequential order, but rather allowed their initiation prior to full completion of preceding sub-phases. This perspective allowed for several sub-phases to be assumed as executed in parallel, leading to project final clean-up after completion of sub-phase 2B instead of phase 3's preceding activities. If TXDOT's estimation represented sub-phases as executed in sequential order, the result would have been calculated at around 753 working days and the case study's estimation would be of about 23.4% shorter duration. This project difference would be more consistent with the differences calculated at a sub-phase level analysis.

There were also differences in the critical path activities and sequences. A significant discrepancy was the number of critical path activities considered by each estimation. The case study accounted for 69 critical path activities, while TXDOT's calculation considered only 25, a difference of 44 activities.

As for the activities that drive the critical path within each sub-phase, TXDOT's estimation calculates that construction of retaining walls drive the critical path in sub-phases 1A and 2A. Meanwhile, the case study's results reflect that roadway construction activities command the critical path in sub-phase 1A, and bridge construction guides the path in sub-phase 2A. While TXDOT's estimation coincides that bridge construction is the longest path of activities in sub-phase 2A, the critical path shifts to sub-phase 2B after construction of retaining walls.

The allocation of activity quantities for each sub-phase is a significant difference between both estimations. The importance of retaining wall activities in sub-phase 1A for TXDOT's estimation can be explained by differences in quantity allocation as the case study assigns the variance in quantity for this activity in sub-phase 2A. These discrepancies may have been the result of misinterpreting project documentation.

When the used activity production rates were compared, several differences were identified. In the particular case of considered critical path activities, the case study's assumed production rates were considerably higher than those used in TXDOT's analysis. This may have resulted from more TXDOT information and experience in assigning production rates, as well as the case study's limitations in the production rate level selection process and the impact represented by the assumed number of crews.

5.5.5 Case Study 2 Recommendations

Sub-phase construction sequences represented a major difference between both estimations. While the case study assumed that every sub-phase should initiate after full completion of the previous sub-phase, TXDOT's calculation allowed for particular sub-phases to initiate prior to its predecessor's completion. The revision of this interpretation of the construction sequence and TCP is recommended for more accurate results and comparisons.

An important characteristic that stood out from observations of TXDOT's contract time estimate is that roadway construction activities are projected to conclude prior to the construction of the retaining walls designed to support the given roadways. It is recommended that TXDOT estimators should review this particular construction sequence and its impact in the project's critical path.

Further project documentation analysis is suggested to confirm that the activity quantities used for the case study's contract time determination are accurate, since considerable differences in the allocation of quantities by sub-phases were discovered when compared to TXDOT's estimation. A review confirming these quantity allocations could identify the accuracy of these assumed quantities and determine the confidence of the results.

Major production rate differences suggest that the production rate selection should be revised, as these were considerably higher production rates than those used in TXDOT's estimation, particularly for critical path activities. 86.7% of project activities were assigned a Mean (M) level. However, the information provided did not support the selection of different production rate levels. The assumption of multiple crews also played a factor in increasing production rates. Since the level selection process and the assignment of the number of crews for each activity are the result of project document interpretations and

assumptions, more information regarding activity production rate drivers, such as crews and equipment to be used, should be collected to adequately analyze and confirm the production rate levels selected.

5.6 IMPROVEMENTS TO THE PRODUCTION RATE RESOURCE

After conducting two contract time estimations of two TXDOT highway construction projects, the *Production Rate Resource* was improved based on findings related to the activities and sources used. It is important to remember that at the time both case studies were initiated the *Production Rate Resource* only contained 27 work items with production rate information from five sources. The revised version now contains 59 work items with data extracted from six sources. This section explains these improvements in detail.

5.6.1 Findings on Activities Used in Case Studies

The 27 work items included in the *Production Rate Resource* at the time the case studies were conducted were not sufficient production rate data as to cover all activities included in each WBS. Analyzing the percentages of production rate information that come from the different sources used in the case study tasks allows us to understand important production rate information missing from the resource. High percentages of data provided by other sources highlight the need for the resource's expansion. Table 43 summarizes the percentage of WBS activities with production rate data provided by the different sources in both case studies.

Table 43: Percentage of production rate data extracted from the different sources for both case studies

	Case study 1	Case study 2
PR Resource	51.6%	40.9%
TXCTDS	30.3%	26.0%
HYPRIS	0.0%	1.3%
OKCTDS	2.2%	6.5%
KYCTDS	0.0%	3.9%
RSMeans	7.3%	6.5%
FLDOT	N/A	4.5%
None	8.6%	10.4%

As visualized in Table 43, the *Production Rate Resource* provided data for 51.6% of activities in case study 1, and just 40.9% of activities in case study 2. The estimator relied on other sources 39.8% of the time in case study 1, and 48.7% in case study 2.

When the estimator relied on other sources, it is important to remember the methodology's order of resource priority. The methodology's reference order is 1) the *Production Rate Resource*, 2) TXCTDS, 3) HYPRIS, 4) OKCTDS, 5) KYCTDS, 6) RSMeans, and 7) FLDOT. If a work item is not found in the *Production Rate Resource*, the subsequent sources are referenced, extracting data from the first source in the order that contains the desired work item. For a particular example, in Table 43, case study 2 data revealed that 3.9% of the production rates used were extracted from KYCTDS. This means that 3.9% of the activities in case study 2 were not found in any of the previous sources in the reference order (*Production Rate Resource*, TXCTDS, HYPRIS, and OKCTDS), but was found in KYCTDS's baseline, and thus the subsequent sources (RSMeans and FLDOT) did not need to be consulted. Note that this number does not indicate that 3.9% of case 2 activities were not found in the production rate baselines from the subsequent sources, rather that these sources were not referred since the activity was found in KYCTDS.

Furthermore, the estimator did not find production rate data for 8.6% and 10.4% of activities in case studies 1 and 2, respectively.

5.6.2 Expanding the Resource to Include All TXCTDS Work Items

As observed in Table 43, relying on TXCTDS data not yet included in the *Production Rate Resource* occurred in 30.3% and 26.0% of the WBS activities in case studies 1 and 2, respectively. This realization is a significant indication that the *Production Rate Resource* required work item additions, and led to the incorporation of all work items that had not been included yet from TXCTDS. This addition included work items for which no production rate information was found in any of the other considered sources.

It is important to note that these relatively high percentages do not mean that the production rate data for these activities could be found exclusively from TXCTDS, rather that TXCTDS was the first source in the reference order in our methodology, and therefore the subsequent sources didn't need to be consulted for their data. Nonetheless, once each work item is included in the *Production Rate Resource*, the respective item worksheets are filled with the data provided by all the considered production rate sources.

5.6.3 Adding Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration* as a Source

The addition of Florida Department of Transportation's *Guideline for Establishing Construction Contract Duration* (FLDOT) as a sixth source of production rate data resulted from its use in case study 2.

Acknowledging that the *Production Rate Resource* and its supporting sources at the time did not contain all activities considered important in the WBS, such as Erosion Control and Sidewalks, the estimator looked for outside sources to fill the gaps. FLDOT provided an extended database that comprised 345 work items, including 26 also covered in

TXCTDS's production rate baseline. Within these 345 work items, the estimator found production rate data for work items Erosion Control and Sidewalks, which were activities included in case study 2's WBS.

This realization led to the source's inclusion. This addition required a modified item worksheet prototype to include a sixth publicly available production rate source column. All previously recorded item worksheets were recreated using this new prototype, which was later used for further work item inclusions. Furthermore, work items Erosion Control and Sidewalks were included to the *Production Rate Resource* at this time.

5.6.4 Including Specific Work Items

Other specific and important WBS work items were found in the remaining sources in the reference order as their data was consulted in 9.5% of the activities in case study 1, and 18.2% in case study 2. For the inclusion of these important work items, each was individually analyzed for its addition to the *Production Rate Resource*. Table 44 was assembled depicting in what case study was each work item used and which sources provide production rate data pertaining these work items.

Table 44: Specific work items used in both case studies included in supporting production rate sources

Work Items	Case study 1	Case study 2	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	# of sources
Riprap	✓	✓		✓		✓	✓	3
MSE walls		✓	✓			✓		2
Prime coating	✓	✓					✓	1
Lighting		✓		✓	✓	✓	✓	4
Guardrails		✓		✓	✓	✓		3
Abutment		✓	✓	✓			✓	3
Approach slabs		✓		✓		✓		2
Phasing allowance	✓	✓		✓	✓			2

All of the work items in Table 44 were included with the exception of Prime coating. Only one source provides data for this work item and thus does not meet the minimum 2 source requirement. This should not be alarming since, despite being included in both case studies, this activity should take less than a working day in duration prior to the commencement of succeeding pavement activities.

Of important note are the following work items:

- Mechanically Stabilized Earth walls (MSE walls): This work item is considered of notable importance despite only being covered in two sources. In case study 2, this work item was estimated to account for 106 working days even though it belonged in a parallel sequence to the critical path, and was considered in the critical path in TXDOT's estimation.
- Lighting: Although this activity can commonly be considered a parallel activity and of relatively short durations, four sources include the work item in their production rate data, hinting its possible impact in highway construction projects.

- Phasing allowance: This work item is used as a buffer time when altering from one phase of a project to the next. Its inclusion in OKCTDS and KYCTDS suggests the impact phase shifting has on a project. It was used in both case study estimations to account for mobilization and reorganization between every stage and sub-phase.

Chapter 6: Conclusions and Recommendations

6.1 CONCLUSIONS

The research's objective of creating a resource compiling production rate data for highway construction activities was achieved. Through the process documented in this thesis report, the *Production Rate Resource* was developed, tested, and improved.

The work began with a literature review that researched and recollected data from five production rate sources in the public domain and identified the work items these considered in common with TXCTDS's baseline. The findings reveal that each of these sources contained at least 19 different work items contemplated in TXCTDS, and that 43 TXCTDS work items are included in at least one more source. Furthermore, several work items missing from the TXCTDS were identified in these five sources and were considered important for contract time determination procedures.

The methodology implemented for developing the resource contains detailed steps that include: gathering publicly available information, selecting the appropriate production rate sources, organizing their production rate data by creating item worksheets, testing the recollected data in actual contract time estimations of highway construction projects, and improving and assembling the data into creating the *Production Rate Resource*.

With the first data gathered – comprised of 27 work items – two case studies were conducted to calculate contract durations of actual TXDOT highway construction projects. The goal of this task was to test the gathered production rate data and look for potential improvements. Both calculations were the result of a documented methodology that yielded working day durations with a difference of 0.39% for case study 1 and 8.21% for case study 2 when compared to TXDOT's contract time estimations. Despite the close results, multiple differences were found in an in-depth analysis, such as construction

sequence interpretations, critical path activities, quantity allocations within a project's phases, and dissimilar production rates assumed for each work item. Furthermore, specific case study conclusions and recommendations were documented.

Case study findings on the specific work items used allowed for improvements of the resource's database. These improvements encompassed expanding the database to include all TXCTDS work items, adding FLDOT as a supplementary production rate source, and incorporating other work items needed for conducting the case studies' contract duration estimations.

Finally, the *Production Rate Resource* was assembled as a Microsoft Excel workbook that contains: 1) an introduction tab explaining the purpose and content of the resource, 2) a sources tab detailing the publicly available systems and databases that provided the resource's production rate data, 3) a summary sheet gathering the most important production rate data in one single table, and 4) item worksheets detailing the recollected production rate data of the 59 work items included in the resource, expressing calculated averages, visual aid graphics, and scope descriptions from the original sources.

6.2 RECOMMENDATIONS

Although the calculated averages of the initial 27 work items were tested in the two case studies, the production rate averages in the final version of the *Production Rate Resource* – containing 59 Work items – have not yet been tested in actual contract time estimations. The remaining work items constitute new production rate averages – in all low, mean, and high levels – that should be tested in a real contract time estimation despite perhaps being considered of less importance than the initial 27 work items. Furthermore, the addition of FLDOT as a sixth source has slightly varied the initial 27 work items'

calculated averages. Consequently, conducting a contract time estimation using the latest version of the *Production Rate Resource* is recommended.

The *Production Rate Resource* should also be tested as a reference tool for TXCTDS and other DOT's contract time determination systems. These systems are composed of different methodologies and analysis criteria from the processes followed in the conducted case studies. Such task would further validate the purpose of the resource, analyzing if it effectively facilitates estimators' appropriate production rate selection.

Acknowledging that production rates may vary over time due to technology and equipment improvements among other factors, the *Production Rate Resource* should be updated over time with the latest production rate data provided by the six data sources. Furthermore, the resource can be improved by incorporating additional production rate information from authoritative sources available in the public domain.

Appendices

APPENDIX A: PRODUCTION RATE RESOURCE

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Appendix A-1: Introduction Tab Content

Production Rate Resource: Introduction

The Production Rate Resource is designed to provide a user-friendly reference of production rate data for highway construction activities, mainly for contract time determination purposes. Its content encompasses 59 work items considered important for estimating contract durations, extracted from six sources available in the public domain. These sources are:

- Texas Department of Transportation's Contract Time Determination System (TXCTDS)
- Highway Production Rate Information System (HYPRIS)
- Oklahoma Department of Transportation's Contract Time Determination System (OKCTDS)
- Kentucky Contract Time Determination System (KYCTDS)
- Florida Department of Transportation Guideline for Establishing Construction Contract Duration (FLDOT)
- RSMeans Heavy Construction Cost Data 2016 (RSMeans)

This resource's work item sheets provide Low, Mean, and High production rates as defined in the original sources and calculated averages for each of these three levels. Assisted with visual aids, the user can compare the production rates and is free to choose an appropriate rate from either the calculated averages or from any of the mentioned sources if considered more appropriate to an activity's particularities and characteristics (such as site and weather conditions, type and size of the project, crews and equipment used, etc.).

The contents of this resource include:

- An introduction.
- A production rate sources sheet that explains the interpretation and extraction of data from each source.
- A summary sheet that provides:
 - All included work items identified by TXDOT specification numbers.
 - Production rate data for each work item consistent with the specified unit of measurement.
- Item worksheets that express:
 - Work Item TXDOT number, description, and unit of measurement.
 - Low, Mean, and High production rates from original sources.
 - Calculated Low, Mean, and High production rate averages.
 - Column chart for visual comparison of production rates.
 - Box plot chart depicting the production rate ranges for Low, Mean, and High levels.
 - Scope definitions table with inclusions and exclusions as defined in original sources.

Appendix A-2: Sources Tab Content

Production Rate Resource: Sources of production rates

TXCTDS

- Publication: Hancher, D.E., McFarland, W., and Alabay, R.T., Construction Contract Time Determination, Texas Transportation Institute, Texas A&M University System Research Report No: 1262-1F, Nov 1992.
- System: TXDOT Contract Time Determination System (TXCTDS).
- Production Rates: Extracted from Table 3.3 of the publication, where:
 - Low production rates: Extracted from the "Low" column.
 - Mean production rates: Extracted from the "Average" column.
 - High production rates: Extracted from the "High" column.
- Scope table information: Extracted from the work item definitions given in section 3.4 of the publication.

HYPRIS:

- Publication: O'Connor, J.T., Chong W.K., Huh Y., and Kuo Y., Development of Improved Information for Estimating Construction Time, Center for Transportation Research, The University of Texas at Austin, Texas Department of Transportation, Research Report No: 0-4416-1, Oct 2004..
- System: Highway Production Rate Information System (HYPRIS).
- Production Rates: Extracted either from Table 3.9 of the publication or from the original observation box plots in Figures 3.1 to 3.21 of the publication.
 - When extracted from Table 3.9 of the publication:
 - Low production rates: Extracted from the "Min" column, defined as the lowest production rate in research observations.
 - Mean production rates: Extracted from the "Mean" column, defined as calculated by the sum of observed production rates divided by the total number of data points.
 - High production rates: Extracted from the "Max" column, defined as the highest production rate in research observations.
 - When extracted from the box plots in Figures 3.1 to 3.21 of the publication:
 - Low production rates: the lowest observation value, excluding outliers and extremes.
 - Mean production rates: the mean value of observations.
 - High production rates: the highest observation value, excluding outliers and extremes.
- Scope table information: Extracted from the Work Item Description sheets within the HYPRIS system, with supporting information from Tables 3.4 to 3.7, and Appendix F of the publication.

OKCTDS

- Publication: Jeong, H.S., Oberlender, G.D., Atreya, S.K., and Akella, V., Development of an Improved System for Contract Time Determination, Oklahoma State University, Research Report No: AA-5-17837, May 2007.
- System: Oklahoma Contract Time Determination System (OKCTDS).
- Production Rates: Extracted from Table 5.5 of the publication, where:
 - Low production rates: Extracted from the "Min Rate" column, defined as the minimum value in a controlling activity's production rate range.
 - Mean production rates: Extracted from the "Avg Rate" column, defined as the average value in a controlling activity's production rate range.
 - High production rates: Extracted from the "Max Rate" column, defined as the maximum value in a controlling activity's production rate range.
- Scope table information: Extracted from activity definitions in the Oklahoma Department of Transportation 2009 Standard Specifications Book.

KYCTDS

- Publication: Werkmeister, R.F., Luscher, B.L., and Hancher, D.E., Kentucky Contract Time Determination System, University of Kentucky Research Foundation, Kentucky Transportation Center, Research Record KYSPR-99-195, 2000.
- System: Kentucky Contract Time Determination System (KYCTDS).
- Production Rates: Extracted from Table 4 of the publication, where:
 - Low production rates: Extracted from the "Lower Limit" column, defined as the lower limit of the reasonable range for an activity's production rate.
 - Mean production rates: Extracted from the "Average Value" column, defined as the average default production rate for an activity.
 - High production rates: Extracted from the "Upper Limit" column, defined as the upper limit of the reasonable range for an activity's production rate.
- Scope table information: Extracted from the activity descriptions given in Appendix B of the publication.

FLDOT

- Publication: Florida Department of Transportation (2010). Guidelines for Establishing Construction Contract Duration.
- System: No contract time determination system identified.
- Production Rates: Extracted from Excel Spreadsheet downloaded from link within publication, where:
 - Low production rates: Extracted from the "LOW" columns, described as "typically used on projects where there are large numbers of intersections, driveways, high congested traffic and a large number of existing utilities which may interfere with the proposed construction".
 - Mean production rates: Extracted from the "AVE" columns, described as "typically used in projects where there are minimum existing utilities, low to medium traffic volume/congestion with minimal intersections and driveways".
 - High production rates: Extracted from the "HIGH" columns, described as "typically used on rural and limited access facilities".
- Scope table information: Extracted from the Scope of Work Definitions section of the publication.

RSMeans

- Publication: Hale, D. et al., Heavy Construction Cost Data 2016, 30th annual edition, RSMeans, The Gordian Group, 2015.
- System: No contract time determination system identified.
- Production Rates: Extracted from the "Daily Output" column for each activity in the publication, where:
 - Low production rates: The minimum "Daily Output" value of a detailed sub item among all sub items considered applicable for a particular work item.
 - Mean production rates: The average (arithmetic mean) of "Daily Outputs" expressed by all sub items considered applicable for a particular work item.
 - High production rates: The maximum "Daily Output" value of a detailed sub item among all sub items considered applicable for a particular work item.
- Scope table information: Extracted from the "RSMeans Data" descriptions given for each considered sub item in the publication.

Appendix A-3: Summary Tab Content

Production Rate Resource: Summary sheet

TXDOT Work Item #	Work Item Description	Units	TXCTDS			HYPRIS			OKCTDS			KYCTDS			FLDOT			RSMeans			Averages		
			Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High	Low	Mean	High
-	Erect temporary bridge	Days	10	15	25	-	-	-	-	-	-	5	8	10	-	-	-	-	-	-	8	12	18
-	Phasing allowance	Days	-	-	-	-	-	-	1	2	5	1	3	5	-	-	-	-	-	-	1	3	5
100-1	Preparing Right of way - Clear and Grub	Acres	1	3	6	-	-	-	Inconsistent Units			1	3	6	1	-	10	0.1	2.4	10	0.8	2.8	8.0
104-1	Removing concrete - Remove old curb and gutter	LF/Day	600	1200	2000	-	-	-	-	-	-	-	-	-	-	-	-	275	380	528	438	790	1264
104-2	Removing concrete - Remove old Sidewalks	SY/Day	350	700	1100	-	-	-	-	-	-	-	-	-	1500	2500	3500	112	185	350	654	1128	1650
105	Remove old pavement	SY/Day	1000	2000	3000	-	-	-	1200	1900	2600	-	-	-	-	-	600	200	441	690	800	1447	1723
110	Excavation	CY/Day	1200	3400	7000	199	1163	3558	1800	2825	7000	1000	5000	10000	900	3800	7500	65	1887	14800	861	3013	8310
110-1	Rock Excavation	CY/Day	500	1100	1500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	500	1100	1500
132	Embankment	CY/Day	1200	3500	7000	249	1097	3000	-	-	-	800	4000	8000	-	-	-	1300	3309	10000	887	2977	7000
164	Seeding and landscaping	SY/Day	2000	4000	7000	-	-	-	7,744	11,616	18,392	2000	4000	7000	-	23500	-	-	-	-	3915	10779	10797
247	Flexible Base	SY/Day	1500	3000	4500	526	2725	5624	Inconsistent Units			Inconsistent Units			-	-	-	3800	4891	6000	1942	3539	5375
260	Lime Treated Base	SY/Day	2000	4000	6000	82	1563	3722	1900	2500	4600	-	-	-	-	-	-	1550	1683	1800	1383	2437	4031
276	Cement Treatment	SY/Day	1500	3000	4500	1416	4050	6500	-	-	-	-	-	-	-	-	-	960	1037	1100	1292	2696	4033
292	Hot mix asphalt base	TON/Day	500	1200	2000	-	-	-	270	1000	1700	500	1200	2000	-	-	-	1000	1235	1400	568	1159	1775
316	Asphalt surface treatment	SY/Day	30000	50000	70000	-	-	-	-	-	-	-	-	-	20000	-	25000	-	-	-	25000	50000	47500
340	Hot mixed asphalt	TON/Day	500	1200	2000	158	817	1460	440	900	1600	400	1000	1500	-	-	-	290	502	900	358	884	1492
354	Milling/Planing	SY/Day	5000	10000	14000	-	-	-	-	-	-	-	-	-	-	8000	-	4000	7071	12500	4500	8357	13250
358	Asphalt pavement repair	SY/Day	100	200	300	-	-	-	-	-	-	Inconsistent Units			-	-	-	-	-	-	100	200	300
360	Concrete Pavement	SY/Day	1000	3000	5000	462	1253	2154	600	1640	2400	1000	4000	8000	-	5000	-	1550	2986	5300	922	2980	4571
361	Concrete pavement repair	SY/Day	50	100	200	-	-	-	-	-	-	10	30	50	-	-	-	-	-	-	30	65	125
400-1	Excavation and backfill for structures - Cofferdams	SY/Day	100	200	300	-	-	-	-	-	-	Inconsistent Units			100	200	300	28	62	193	76	154	264
409	Piling	LF/Day	200	300	400	200	450	1,150	90	257	700	200	300	600	200	300	400	220	547	720	185	359	662
416	Drilled Shaft Foundations	LF/Day	-	-	-	40	112	279	60	120	200	-	-	-	200	300	400	5	265	700	76	199	395
420-1	Concrete structures - Footing	CY/Day	10	15	20	3	16	30	-	-	-	-	-	-	10	20	30	28	49	75	13	25	39
420-2	Concrete structures - Column - Square	CY/Day	4	7	10	8	26	40	1.75	2.5	3.3	-	-	-	4	8	12	9	17	34	5	12	20
420-3	Concrete structures - Column - Round	CY/Day	4	7	10	2.5	8	15	1.75	2.5	3.3	-	-	-	4	8	12	12	28	75	5	11	23
420-4	Concrete structures - Caps	CY/Day	4	7	10	1	8	19	1.75	2.5	3.3	-	-	-	4	8	12	-	10	-	3	7	11
420-5	Concrete structures - Abutment	CY/Day	-	-	-	Inconsistent Units			2.9	3.8	5.6	-	-	-	-	-	-	-	-	23	2.9	3.8	14.3
420-6	Concrete Structures - Approach slab	SY/Day	-	-	-	-	-	-	65	220	490	-	-	-	Inconsistent Units			-	-	-	65	220	490
422	Reinforced Concrete Slab - Bridge deck	SF/Day	162	385	756	305	895	2,157	600	730	900	-	-	-	162	423	756	3500	4250	5000	946	1337	1914
423-1	Reinforced concrete retaining wall	SF/Day	100	150	200	-	-	-	-	-	-	500	1000	1500	100	150	200	150	198	232	213	375	533
423-2	MSE wall	SF/Day	-	-	-	225	453	1164	-	-	-	-	-	-	500	750	-	-	-	-	363	602	1164
425	Beam Erection	LF/Day	150	200	250	200	1,550	2,800	400	575	800	200	600	800	250	425	600	440	587	800	273	656	1008
432	Riprap	TON/Day	-	-	-	-	-	-	40	480	800	-	-	-	185	-	750	600	700	800	275	590	783
450-1	Railing - Guardrails	LF/Day	-	-	-	-	-	-	400	1000	1800	1000	1500	2000	200	1000	1500	75	474	960	419	994	1565
450-2	Railing - Handrails	LF/Day	150	200	300	-	-	-	-	-	-	-	-	-	150	225	300	-	-	-	150	213	300
462-1	Precast concrete box culverts	LF/Day	-	-	-	14	132	328	-	-	-	-	-	-	50	100	150	67	104	140	44	112	206
462-2	Cast in place Concrete Box Culverts	CY/Day	10	15	20	9	25	58	25	60	95	10	30	50	20	50	80	Inconsistent Units			15	36	61
464	Reinforced Concrete Pipe	LF/Day	100	200	300	9	116	283	50	110	190	100	200	300	100	-	400	16	100	192	63	145	278
465	Inlets and Manholes	EA/Day	1	2	3	0.2	1.8	4	-	1	1.5	-	-	-	-	-	4	1	2.1	4.1	0.7	1.7	3.3
466	Head walls and wing walls	SF/Day	100	150	200	14	35	92	125	290	370	-	-	-	100	150	200	Inconsistent Units			85	156	216
496-1	Removing structures - Remove old Drainage/Utility Str.	LF/Day	100	300	500	-	-	-	-	-	-	-	-	-	-	-	-	112	202	350	106	251	425
496-2	Removing structures - Remove old structures	Days	1	3	5	-	-	-	-	-	-	1	3	5	-	-	-	-	-	-	1	3	5
496-3	Removing structures - Remove temporary bridges	Days	5	10	15	-	-	-	-	-	-	2	4	8	-	-	-	-	-	-	4	7	12
496-4	Removing structures - Major Structure Demolition	Days	5	10	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10	20
496-5	Removing structures - Bridge demolition	Days	5	15	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	15	30

502	Initial traffic control	Days	1	2	4	-	-	-	-	-	-	1	2	4	-	-	-	-	-	-	1	2	4
506-1	Erosion Control - Silt Fence	LF/Day	-	-	-	-	-	-	-	-	-	-	-	-	750	1500	3000	-	1300	-	750	1400	3000
506-2	Erosion Control - Filter Fabric	SY/Day	-	-	-	-	-	-	-	-	-	-	-	-	-	2500	-	515	1827	2500	515	2164	2500
508	Detour	Days	3	6	12	-	-	-	-	-	-	3	6	12	-	-	-	-	-	-	3	6	12
514	Barriers	LF/Day	500	1000	1500	89	1366	2676	-	-	-	300	500	800	200	300	400	160	270	380	250	687	1151
529	Conc. curb, gutter, and combined	LF/Day	300	500	1000	128	871	1580	500	800	1400	300	500	1000	400	600	800	200	934	2200	305	701	1330
531	Sidewalks	LF/Day	50	80	120	-	-	-	-	-	-	-	-	-	Inconsistent Units			-	-	-	50	80	120
610/613	Roadway illumination assemblies - Lighting	EA/Day	-	-	-	-	-	-	1	2	3	1	2	3	-	-	10	2	3.2	4.4	1.3	2.4	5.1
644	Small signs	EA/Day	10	20	30	-	-	-	-	-	-	20	30	40	10	20	30	-	-	-	13	23	33
650	Overhead signs	EA/Day	1	1.5	3	-	-	-	-	-	-	1	2	3	0.2	-	0.7	-	-	-	0.7	1.8	2.2
680	Major traffic signals	EA/Day	0.2	0.3	0.7	-	-	-	Inconsistent Units			0.05	0.07	0.1	-	-	-	-	-	-	0.1	0.2	0.4
666/668	ReflectORIZED pavement markings	LF/Day	5000	10000	20000	-	-	-	5000	10000	18000	5000	10000	20000	-	2000	-	660	8431	20000	3915	8086	19500
738	Cleaning and sweeping highways - Final Clean-up	Days	Inconsistent Units			-	-	-	1	3	4	5	10	15	-	7	-	-	-	-	3	7	10

Appendix A-4: Item Worksheets

Work Item #	Work Item	Unit of measurement
-	Erect temporary bridge	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	Days	No production rate information from source	No production rate information from source	Days
Low	10			5			8
Mean	15			8			12
High	25			10			18

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout and construction of a temporary bridge structure and related appurtenances for a highway construction project	No production rate information from source	No production rate information from source	All activities required to erect a temporary bridge for a project	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	Days	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
-	Phasing allowance	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	Days	Days	No production rate information from source	No production rate information from source	Days
Low			1	1			1
Mean			2	3			3
High			5	5			5

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	Phasing allowance	Number of days allocated to allow the project to be completed in phases	No production rate information from source	No production rate information from source
Exclusions	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	N/A	N/A	Days	Days	N/A	N/A
Conversions	N/A	N/A	Not needed	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
100-1	Preparing Right of way - Clear and Grub	Acres

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Acres	No production rate information from source	Days	Acres	Acres	Acres	Acres
Low	1		1.5	1	1	0.1	0.8
Mean	3		4	3		2.4	2.8
High	6		6.2	6	10	10	8

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal of top soil, small trees, minor physical objects and other vegetation from the construction site using mechanical equipment	No production rate information from source	Clearing, grubbing, removing, and disposing of vegetation and debris Protecting vegetation specified to remain	Site clearance of all obstacles prior to start of construction	The removal of top soil, small trees, minor physical objects and other vegetation from the construction site using mechanical equipment	Cut and chip light trees; Grub stumps and remove; Clearing brush with brush saw, by hand, with dozer, ball and chain or brush rake; Brush mowing, tractor w/rotary mower
Exclusions	No specific exclusions identified in source	No production rate information from source	Items specified for removal	No specific exclusions identified in source	No specific exclusions identified in source	Selective tree removal
Original units	Acres	N/A	Days	Acres	Acres	Acres
Conversions	Not needed	N/A	Not convertible	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
104-1	Removing concrete - Remove old curb and gutter	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	LF/Day	LF/Day
Low	600					275	438
Mean	1,200					380	790
High	2,000					528	1,264

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The breakout and removal of old curb and gutter from the construction site using mechanical equipment	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Curbs, concrete, plain
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source
Original units	LF/Day	N/A	N/A	N/A	N/A	LF/Day
Conversions	Not needed	N/A	N/A	N/A	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
104-2	Removing concrete - Remove old Sidewalks	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	SY/Day	SY/Day
Low	350				1,500	112	654
Mean	700				2,500	185	1,128
High	1,100				3,500	350	1,650

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The breakout and removal of old sidewalks from the construction site using mechanical equipment	No production rate information from source	No production rate information from source	No production rate information from source	Remove sidewalk	Sidewalk removal: Bituminous, Brick, Concrete, Mesh reinforced concrete
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	SY/Day	N/A	N/A	N/A	SY/Day	SY/Day
Conversions	Not needed	N/A	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
105	Remove old pavement	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	SY/Day	No production rate information from source	SY/Day	SY/Day	SY/Day
Low	1,000		1,200			200	800
Mean	2,000		1,900			441	1,447
High	3,000		2,600		600	690	1,723

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The identification, breakout and removal of old pavement from the construction site using mechanical equipment	No production rate information from source	Obliterating specified sections of abandoned road by removing and disposing of pavement surfaces, structures, and other items	No production rate information from source	Remove existing concrete pavement	Pavement removal, bituminous roads Concrete to 6" thick
Exclusions	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	Concrete 7" to 24" thick With hand held air equipment
Original units	SY/Day	N/A	SY/Day	N/A	SY/Day	SY/Day
Conversions	Not needed	N/A	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
110	Excavation	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day
Low	1,200	199	1,800	1,000	900	65	861
Mean	3,400	1,163	2,825	5,000	3,800	1,887	3,013
High	7,000	3,558	7,000	10,000	7,500	14,800	8,310

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal and transporting of in situ soils on the construction site using mechanical equipment	Removing top soil; Excavation from original elevation to the elevation which is at least 6" below the required sub-grade elevation; Disposal of material	Excavation of earth material within the right-of-way.	Includes the excavation and movement of all earth and rock on the construction site.	Excavation - Truck Haul; The removal and transporting of in situ soils on the construction site using mechanical equipment	Trench excavation; Excavating, Bulk Bank Measure; Large Volume Projects; Bulk Excavation w. Dozers
Exclusions	Rock Excavation	Survey & Layout; Access road construction/maintenance; Unsuitable material replacement; Reshaped by blade, sprinkled and rolled for sub-grade surface; Temporary drainage maintenance; Shaping slope; Rock	Muck excavation, rock excavation, and structural excavation	No specific exclusions identified in source	No specific exclusions identified in source	Hand Exc.; Chain trencher, fly wheel trencher, plow; Backfilling; Minor Structures Exc.; Rock removal, Drilling and Blasting; Ripping, Hydraulic Rock Breaking and loading; Clamshells, draglines, scrapers
Original units	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
110-1	Rock Excavation	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	CY/Day
Low	500						500
Mean	1,100						1,100
High	1,500						1,500

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal and transporting of in situ rock deposits on the construction site using mechanical equipment	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Original units	CY/Day	N/A	N/A	N/A	N/A	N/A
Conversions	Not needed	N/A	N/A	N/A	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
132	Embankment	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	No production rate information from source	CY/Day	No production rate information from source	CY/Day	CY/Day
Low	1,200	249		800		1,300	887
Mean	3,500	1,097		4,000		3,309	2,977
High	7,000	3,000		8,000		10,000	7,000

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The placing and compaction of soil on the construction site using mechanical equipment	Construction of roadway embankments, levees and dykes or any designated section of the roadway; Placing materials; Spread material; Sprinkling; Compaction	No production rate information from source	Includes the placement and compaction of all earth and rock fill on the project.	No production rate information from source	Compaction - Riding, Towed
Exclusions	No specific exclusions identified in source	Survey & Layout; Construction access road; Temporary drainage maintenance	No production rate information from source	No specific exclusions identified in source	No production rate information from source	Backfill; Borrow, loading, spreading; Filling; Hauling; Placing material; Airport Compaction; Walk Behind, Rammer Tamper, Water compaction
Original units	CY/Day	CY/Day	N/A	CY/Day	N/A	CY/Day
Conversions	Not needed	Not needed	N/A	Not needed	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
164	Seeding and landscaping	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	SY/Day	SY/Day	SY/Day	No production rate information from source	SY/Day
Low	2,000		7,744	2,000	23,500		3,915
Mean	4,000		11,616	4,000			10,779
High	7,000		18,392	7,000			10,797

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The seeding of grasses, planting of small plants, and the application of protective materials along a highway using production techniques	No production rate information from source	Repairing seedbeds, providing and planting seeds, and seeding for temporary and permanent erosion control	All activities required to place final 25% of seeding on a project	Seeding / Seed and mulch: The seeding of grasses, application of fertilizer and mulch, and cutting into soil	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source
Original units	SY/Day	N/A	Acres/Day	SY/Day	SY/Day	N/A
Conversions	Not needed	N/A	1SY = 2.06612E-04 Acres	Not needed	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
247	Flexible Base	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	SY/Day	CY/Day	Tons/Day	No production rate information from source	SY/Day	SY/Day
Low	1,500	526	160	500		3,800	1,942
Mean	3,000	2,725	310	1,500		4,891	3,539
High	4,500	5,624	775	4,000		6,000	5,375

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The placement and compaction of flexible base material	Placing materials; Spread uniformly & shaping; Blade & shaping; Sprinkle; Compaction; Dry-out (if required)	Providing and placing one or more layers of aggregates, and specified additives, on a prepared subgrade or subbase; Agg Base 10"	Stone base: Placement and compaction of stone on a project.	No production rate information from source	Base Course Drainage Layers
Exclusions	No specific exclusions identified in source	Survey & Layout; Shaping the sub-grade or existing roadbed; Stockpiled; All material tests; Curing; Density tests; Rework caused by failing to achieve required density	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source	Plant Mix Asphaltic Base Course; Macadam Base Course; Bituminous-Stabilized Base Course; Flexible paving
Original units	SY/Day	SY/Day	CY/Day	Tons/Day	N/A	SY/Day
Conversions	Not needed	Not needed	Not convertible	Not convertible	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
260	Lime Treated Base	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	SY/Day	SY/Day	No production rate information from source	No production rate information from source	SY/Day	SY/Day
Low	2,000	82	1,900			1,550	1,383
Mean	4,000	1,563	2,500			1,683	2,437
High	6,000	3,722	4,600			1,800	4,031

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The placement, mixing, and compaction operations involved in the lime stabilization of highway subgrade soils	Cutting and pulverizing; Spread Lime; Mixing; Sprinkling or aerating; Compaction; Finishing; 1st curing and 2nd mixing	Incorporate chemical additives (Lime) into the subgrade to increase the strength of the subgrade soils and to provide structural value for the pavement structure	No production rate information from source	No production rate information from source	Lime Soil Stabilization; Scarifying; Compaction; 2%, 4%, and 6% Mix by weight; 6", 8", and 12" deep
Exclusions	First curing	Survey & Layout; Equipment move in; Transport material; Curing (after finishing); Density tests; Setup blue top	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source
Original units	SY/Day	SY/Day	SY/Day	N/A	N/A	SY/Day
Conversions	Not needed	Not needed	Not needed	N/A	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
276	Cement Treatment	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	SY/Day	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	SY/Day
Low	1,500	1,416				960	1,292
Mean	3,000	4,050				1,037	2,696
High	4,500	6,500				1,100	4,033

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The placement, mixing, and compaction of cement-treated base materials	Placing materials; Spread uniformly & shaping; Blade & shaping; Sprinkle; Compaction; Dry-out (if required)	No production rate information from source	No production rate information from source	No production rate information from source	Bituminous concrete; Cement Soil Stabilization - Including Scarifying and Compaction
Exclusions	No specific exclusions identified in source	Survey & Layout; Shaping the sub-grade or existing roadbed; Stockpiled; All material tests; Curing; Density tests; Rework caused by failing to achieve required density	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source
Original units	SY/Day	SY/Day	N/A	N/A	N/A	SY/Day
Conversions	Not needed	Not needed	N/A	N/A	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
292	Hot mix asphalt base	TON/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	TON/Day	No production rate information from source	TON/Day	TON/Day	No production rate information from source	TON/Day	TON/Day
Low	500		270	500		1,000	568
Mean	1,200		1,000	1,200		1,235	1,159
High	2,000		1,700	2,000		1,400	1,775

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The laydown and compaction of hot mix asphalt concrete base course material	No production rate information from source	Constructing one or more courses of bituminous mixture on the prepared foundation (base)	All activities required to lay the asphalt base then level and wedge for a new or existing road on a project	No production rate information from source	Plant mix asphaltic base courses; Bituminous concrete, 4", 6", 8" and 10" thick
Exclusions	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source
Original units	TON/Day	N/A	TON/Day	TON/Day	N/A	TON/Day
Conversions	Not needed	N/A	Not needed	Not needed	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
316	Asphalt surface treatment	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	No production rate information from source	SY/Day
Low	30,000				20,000		25,000
Mean	50,000						50,000
High	70,000				25,000		47,500

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The application of liquid asphalt to an existing roadway followed by the spreading and rolling of fine aggregate materials to form an improved roadway surface, often referred to as a Chip and Seal operation	No production rate information from source	No production rate information from source	No production rate information from source	Asphalt - Micro-Surfacing	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source
Original units	SY/Day	N/A	N/A	N/A	SY/Day	N/A
Conversions	Not needed	N/A	N/A	N/A	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
340	Hot mixed asphalt	TON/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	TON/Day	TON/Day	TON/Day	TON/Day	No production rate information from source	TON/Day	TON/Day
Low	500	158	440	400		290	358
Mean	1,200	817	900	1,000		502	884
High	2,000	1,460	1,600	1,500		900	1,492

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The laydown and compaction of hot mix asphalt concrete base course material	Lay Hot Mix Asphalt; Compaction (Roller or lightly oiled tamps)	Asphalt Type A. Constructing one or more courses of bituminous mixture on the prepared foundation (roadbed or base). Includes Superpave, Stone Matrix Asphalt, and Rich Bottom Layer.	All activities required to lay asphalt surface on a new or existing road for a project.	No production rate information from source	Plant mixed asphalt paving - Binder Course 1-1/2" to 4" thick; Wearing Course 1" to 3" thick
Exclusions	No specific exclusions identified in source	Survey & Layout; Transport materials; Cleaning surface before applying for tack coat; Shoot tack coat; Plant Mixing; Equipment setup	Asphalt Type B (Considered as separate activity with similar rates)	No specific exclusions identified in source	No production rate information from source	Hauling
Original units	TON/Day	TON/Day	TON/Day	TON/Day	N/A	TON/Day
Conversions	Not needed	Not needed	Not needed	Not needed	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
354	Milling/Planing	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	SY/Day	SY/Day
Low	5,000					4,000	4,500
Mean	10,000				8,000	7,071	8,357
High	14,000					12,500	13,250

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal of the surface level of existing pavements using automated milling or planing equipment	No production rate information from source	No production rate information from source	No production rate information from source	Milling asphalt; The removal of the surface level of existing pavements using automated milling or planing equipment	Cold planing; cleaning asphalt pavmt; Asphalt pave. removal from conc. Base, no haul; Rip; Profile grooving, asphalt pavement; load and sweep
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	SY/Day	N/A	N/A	N/A	SY/Day	SY/Day
Conversions	Not needed	N/A	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
358	Asphalt pavement repair	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	TONS/Day	No production rate information from source	No production rate information from source	SY/Day
Low	100			20			100
Mean	200			50			200
High	300			80			300

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal and placement of sections of unsatisfactory or failed asphalt concrete pavement	No production rate information from source	No production rate information from source	All activities required to patch asphalt surface on a roadway prior to paving for a project	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	SY/Day	N/A	N/A	TONS/Day	N/A	N/A
Conversions	Not needed	N/A	N/A	Not convertible	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
360	Concrete Pavement	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	SY/Day	SY/Day	SY/Day	SY/Day	SY/Day	SY/Day
Low	1,000	462	600	1,000		1,550	922
Mean	3,000	1,253	1,640	4,000	5,000	2,986	2,980
High	5,000	2,154	2,400	8,000		5,300	4,571

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, reinforcing, placing, curing, and jointing of Portland cement concrete pavement	Concrete pavement - Slip formed; Setting string line; Placing dowels; Installing reinforcing steel; Placing joint assemblies; Initial equipment setup; Placing concrete; Finishing	9" Portland cement pavement; Constructing portland cement concrete (PCC) pavement on a prepared base	All activities required to concrete pave the new or existing road on a project.	The layout, reinforcing, placing, curing, and jointing of Portland cement concrete pavement	Slip Form Concrete Pavement, Plain Cement Concrete Pavement, Airports; Includes joints, finish, and curing; 12' pass; Unreinforced; Thickness from 8" to 14"
Exclusions	No specific exclusions identified in source	Survey & Layout; Surface preparation; Equipment move in; Ride quality test; Core test; Unloading reinforcing steel; Curing; Saw cutting	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	24' pass
Original units	SY/Day	SY/Day	SY/Day	SY/Day	SY/Day	SY/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
361	Concrete pavement repair	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	SY/Day	No production rate information from source	No production rate information from source	SY/Day
Low	50			10			30
Mean	100			30			65
High	200			50			125

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal and placement of sections of unsatisfactory or failed portland cement concrete pavement	No production rate information from source	No production rate information from source	All activities required to patch concrete pavement on a roadway prior to paving for a project	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	SY/Day	N/A	N/A	SY/Day	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
400-1	Excavation and backfill for structures - Cofferdams	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SY/Day	No production rate information from source	No production rate information from source	Days	SY/Day	SY/Day	SY/Day
Low	100			5	100	28	76
Mean	200			15	200	62	154
High	300			30	300	193	264

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The installation, dewatering and minor excavation associated with building a cofferdam system for a bridge construction site	No production rate information from source	No production rate information from source	All activities required to construct cofferdams on a project	The installation, dewatering and minor excavation associated with building a cofferdam system for a bridge construction site	Cofferdams, including mobilization and temporary sheeting; Soldier beams and lagging H piles; No Hydrostatic head; Lagging only; Open sheeting no bracing
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	Tie-back method Trench box
Original units	SY/Day	N/A	N/A	Days	SY/Day	SF/Day
Conversions	Not needed	N/A	N/A	Not convertible	Not needed	1 SF = 0.11111 SY

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
409	Piling	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low	200	200	90	200	200	220	185
Mean	300	450	257	300	300	547	359
High	400	1,150	700	600	400	720	662

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The instalation of piling for bridge foundations	The instalation of piling for bridge foundation Includes equipment setup	Providing and placing reinforcing steel, concrete-filled steel shell piles, and pipe piles. Defines piles as steel H-piles, sheet piles, steel shell piles, or precast concrete piles	All activities required for piling for a bridge on a project.	The instalation of piling for bridge foundations	Cylinder - 50' Long, 12" to 66" Diam; Square - 40' long, 10" to 24" thick; Square - 60' long, 10" to 12" thick; Octagonal - 40' long, 14" to 24" thick
Exclusions	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	Pile Caps Mobilization
Original units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
416	Drilled Shaft Foundations	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	LF/Day	LF/Day	No production rate information from source	LF/Day	LF/Day	LF/Day
Low		40	60		200	5	76
Mean		112	120		300	265	199
High		279	200		400	700	395

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	From equipment setup, drilling, casing, handling and placing of reinforcement, handling and placing of concrete and tub removal	Constructing drilled shafts and providing and placing reinforcing steel and concrete	No production rate information from source	Drilled shaft	Fixed End Caisson Piles - Excavation, concrete, 50 lb. reinforcing per C.Y.; up to 50' deep; 18" to 84" diam.; in stable ground, wet ground, and soft rocks and medium hard shales; Drilled concrete piers and shafts - 8" to 18" diam
Exclusions	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	Mobilization, Boulder removal, Disposal, Bell excavation, Rock excavation, 50' to 200' deep, casing left in place, other than 50 lb. rein., Steel I Beam cores, Load and haul excess
Original units	N/A	LF/Day	LF/Day	N/A	LF/Day	LF/Day
Conversions	N/A	Not needed	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-1	Concrete structures - Footing	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	No production rate information from source	No production rate information from source	CY/Day	CY/Day	CY/Day
Low	10	3			10	28	13
Mean	15	16			20	49	25
High	20	30			30	75	39

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge footings	Excavation; Dewatering; Exc.protection work; False work; Installing and inspecting form & rebar; Handling and placing of concrete; Pile cap	No production rate information from source	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge footings	Forms (4 uses), grade 60 rebar, concrete (Portland cement Type I), placement and finishing; Footings (3000 psi), spread, strip unreinforced and reinforced
Exclusions	No specific exclusions identified in source	Site preparation; Preparation of rebar, forms; Curing; Weather protection of placed concrete; Removal of forms; Finishing of structure surface; Removal of false work	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	CY/Day	CY/Day	N/A	N/A	CY/Day	CY/Day
Conversions	Not needed	Not needed	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-2	Concrete structures - Column - Square	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	CY/Day	No production rate information from source	CY/Day	CY/Day	CY/Day
Low	4	8	1.8		4	9	5
Mean	7	26	2.5		8	17	12
High	10	40	3.3		12	34	20

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge columns	False work; Installation of form and rebar; Inspection of forms and rebar; Handling and placing concrete	Form/ Pour Columns and Caps; Providing, placing, finishing, and curing concrete in bridges, culverts, and other structures	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge columns	Forms, grade 60 rebar, concrete (Portland cement Type I), placement & finishing; Columns, square (4000 psi); 12"x12", 16"x16", 24"x24", 36"x36"; Up to 1%, 2%, and 3% reinf.
Exclusions	No specific exclusions identified in source	Site preparation; Preparation of rebar & forms; Curing; Weather protection of placed concrete; Removal of forms; Finishing of structure surface; Removal of false work; Installing drainage pipe	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	CY/Day	CY/Day	CY/Day	N/A	CY/Day	CY/Day
Conversions	Not needed	Not needed	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-3	Concrete structures - Column - Round	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	CY/Day	No production rate information from source	CY/Day	CY/Day	CY/Day
Low	4	2.5	1.8		4	12	5
Mean	7	8	2.5		8	28	11
High	10	15	3.3		12	75	23

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge columns	False work; Installation of form and rebar; Inspection of forms and rebar; Handling and placing concrete	Form/ Pour Columns and Caps. Providing, placing, finishing, and curing concrete in bridges, culverts, and other structures	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge columns	Forms, grade 60 rebar, concrete (Portland cement Type I), placement & finishing; Columns, round (4000 psi); 12", 16", 20", 24", and 36" diam; Up to 1%, 2%, and 3% reinf.
Exclusions	No specific exclusions identified in source	Site preparation; Preparation of rebar & forms; Curing; Weather protection of placed concrete; Removal of forms; Finishing of structure surface; Removal of false work; Installation of drainage pipe	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	CY/Day	CY/Day	CY/Day	N/A	CY/Day	CY/Day
Conversions	Not needed	Not needed	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-4	Concrete structures - Caps	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	CY/Day	No production rate information from source	CY/Day	CY/Day	CY/Day
Low	4	1	1.8		4		3
Mean	7	8	2.5		8	10	7
High	10	19	3.3		12		11

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge caps	False work; Installation of form and rebar; Inspection of forms and rebar; Handling and placing concrete	Form/ Pour Columns and Caps. Providing, placing, finishing, and curing concrete in bridges, culverts, and other structures	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge caps	Pier Caps including shoring
Exclusions	No specific exclusions identified in source	Site preparation; Preparation of rebar & forms; Curing; Weather protection of placed concrete; Removal of forms; Finishing of structure surface; Removal of false work; Installing drainage pipe; Non-metal form	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	CY/Day	CY/Day	CY/Day	N/A	CY/Day	CY/Day
Conversions	Not needed	Not needed	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-5	Concrete structures - Abutment	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	Each/Day	CY/Day	No production rate information from source	No production rate information from source	CY/Day	CY/Day
Low		0.1	2.9				2.9
Mean		0.2	3.8				3.8
High		0.5	5.6			23	14.3

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	Base (abutment cap) & backwall; False work, if any; Installation of form and rebar; Inspection of forms and rebar; Handling and placing concrete; Wingwalls or headwalls, if any	Rebars, Forming, and Concrete. Providing, placing, finishing, and curing concrete in bridges, culverts, and other structures	No production rate information from source	No production rate information from source	Abutment Concrete in place, no reinforcing
Exclusions	No production rate information from source	Site preparation; Preparation of rebar and forms; Curing; Weather protection of placed concrete; Removal of forms; Finishing of structure surface; Removal of false work; Installation of drainage pipe; Rip rap; Piles/Drill shafts; Backfilling	No specific exclusions identified in source	No production rate information from source	No production rate information from source	Footings
Original units	N/A	Days/Each	CY/Day	N/A	N/A	CY/Day
Conversions	N/A	(Each/Day) = 1/(Day/Each)	Not needed	N/A	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
420-6	Concrete Structures - Approach slab	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	SY/Day	No production rate information from source	CY/Day	No production rate information from source	SY/Day
Low			65				65
Mean			220		15		220
High			490				490

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	Constructing concrete approach slabs	No production rate information from source	Approach slabs	No production rate information from source
Exclusions	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No production rate information from source
Original units	N/A	N/A	SY/Day	N/A	CY/Day	N/A
Conversions	N/A	N/A	Not needed	N/A	Not convertible	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
422	Reinforced Concrete Slab - Bridge deck	SF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SF/Day	SF/Day	SF/Day	No production rate information from source	SF/Day	SF/Day	SF/Day
Low	162	305	600		162	3,500	946
Mean	385	895	730		423	4,250	1,337
High	756	2,157	900		756	5,000	1,914

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge decks. Includes time for all components; precast plank under slab.	False work; Installing system form; Reinforcing steel; Prestress work required; Inspection; Handling & placing of concrete; Joints & cork liner work; Temporary rail or screed supports	Rebars, Forming, and Concrete. Providing, placing, finishing, and curing concrete in bridges, culverts, and other structures	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete bridge decks. Includes time for all components; precast plank under slab.	Concrete in place Bridge Decks, including finish and cure, 8" thick; Beam supported forms and Stay in place metal slab forms
Exclusions	No specific exclusions identified in source	Site preparation; Equipment move in; Bridge rail work; Bridge protective assembly; Drainage pipe work; Waterproofing & pavement; Remove false work; Curing; Weather protection of placed concrete; Post Tensioning	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	CY/Day	SF/Day	SF/Day	N/A	CY/Day	SF/Day
Conversions	SF/Day (Assuming 6" to 12" thick slabs)	Not needed	Not needed	N/A	SF/Day (Assuming 6" to 12" thick slabs)	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
423-1	Reinforced concrete retaining wall	SF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SF/Day	No production rate information from source	No production rate information from source	SF/Day	SF/Day	SF/Day	SF/Day
Low	100			500	100	150	213
Mean	150			1,000	150	198	375
High	200			1,500	200	232	533

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for cast in place reinforced concrete retaining walls	No production rate information from source	No production rate information from source	All activities required to construct retaining walls for a project	The layout, excavation, forming, reinforcing, placing, curing, and removing forms for cast in place reinforced concrete retaining walls	Concrete gravity wall w. vertical face, w/o reinf.; Reinforced concrete cantiliver, including reinf. From 6' to 10' high; level & 33° slope embankment; Exc. & backfill
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	SF/Day	N/A	N/A	SF/Day	SF/Day	LF/Day
Conversions	Not needed	N/A	N/A	Not needed	Not needed	SF/Day (using specified wall heights)

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
423-2	MSE wall	SF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	SF/Day	No production rate information from source	No production rate information from source	SF/Day	No production rate information from source	SF/Day
Low		225			500		363
Mean		453			750		602
High		1,164					1,164

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	The grading and compacting of foundation to removal of placing tie strips on only precast MSE walls	No production rate information from source	No production rate information from source	Walls - MSE walls	No production rate information from source
Exclusions	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source
Original units	N/A	SF/Day	N/A	N/A	SF/Day	N/A
Conversions	N/A	Not needed	N/A	N/A	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
425	Beam Erection	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low	150	200	400	200	250	440	273
Mean	200	1,550	575	600	425	587	656
High	250	2,800	800	800	600	800	1,008

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	Erection of premanufactured bridge beams by crane.	Equipment setup; Handling beam(s) for erection in site; Erection; False work and bracing	Providing and placing precast, prestressed beams.	All activities required to install concrete beams for a bridge on a project.	Superstructure Precast beams	Precast Structural Pretensioned Concrete - Precast beams; 20' to 40' beams; L shaped - 12"x20" to 24"x52"; Rectangular - 12"x20" to 24"x52"; T shaped - 12"x20" to 24"x52"
Exclusions	No specific exclusions identified in source	Erection planning; Site preparation; Equipment move in; Fabricating beam; Transporting beam from off-site; Storage of beam; Traffic controls; Temporary rail or screed support; Steel; Connection with bents	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	Beams/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	LF/Day (using specified beam lengths)

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
432	Riprap	TON/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	TON/Day	No production rate information from source	TON/Day	TON/Day	TON/Day
Low			40		185	600	275
Mean			480			700	590
High			800		750	800	783

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	Final Erosion Control - Riprap, filter blanket Providing and placing riprap for slope protection	No production rate information from source	Riprap - Dumped and Placed	Random, broken stone, Dumped, 50, 100, and 300 lb.
Exclusions	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	Sand bags, Gabion mats and baskets	Machine placed (not included due to inconsistent units)
Original units	N/A	N/A	TON/Day	N/A	TON/Day	TON/Day
Conversions	N/A	N/A	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
450-1	Railing - Guardrails	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low			400	1,000	200	75	419
Mean			1,000	1,500	1,000	474	994
High			1,800	2,000	1,500	960	1,565

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	Constructing guardrail, end treatment, posts, blockouts, & other appurtenances	All activities required to install guardrail on a project	Guardrail - Furnish & Install	Approach railings; Bridge railings; Vehicle guide rails: Corrugated steel, Timber, Cable, Steel box beam
Exclusions	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	End anchors	End sections; Wrap around end; Anchorage units; Breakaway wood posts
Original units	N/A	N/A	LF/Day	LF/Day	LF/Day	LF/Day
Conversions	N/A	N/A	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
450-2	Railing - Handrails	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	No production rate information from source	No production rate information from source	No production rate information from source	LF/Day	No production rate information from source	LF/Day
Low	150				150		150
Mean	200				225		213
High	300				300		300

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for cast in place reinforced concrete bridge handrails	No production rate information from source	No production rate information from source	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for cast in place reinforced concrete bridge handrails	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source
Original units	LF/Day	N/A	N/A	N/A	LF/Day	N/A
Conversions	Not needed	N/A	N/A	N/A	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
462-1	Precast concrete box culverts	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	LF/Day	No production rate information from source	No production rate information from source	LF/Day	LF/Day	LF/Day
Low		14			50	67	44
Mean		132			100	104	112
High		328			150	140	206

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	Excavation & dewatering; Exc. protection; Shaping & bedding; Box handling from storage to work zone; Laying; Joining & insulating joints; Connections to existing structure(s); Inspection; Backfilling	No production rate information from source	No production rate information from source	Concrete Box Culverts (Precast)	Box culverts, precast, base price, 8' long, 6'x3' to 12'x8'
Exclusions	No production rate information from source	Equipment(s) move in; Site preparation; Disposal of exc.; Testing; Storage & shipment of box; Removal of old structure; Safety & treatment; Wingwall work	No production rate information from source	No production rate information from source	No specific exclusions identified in source	Excavation Backfill
Original units	N/A	LF/Day	N/A	N/A	LF/Day	LF/Day
Conversions	N/A	Not needed	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
462-2	Cast in place Concrete Box Culverts	CY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day	LF/Day	CY/Day
Low	10	9	25	10	20	10	15
Mean	15	25	60	30	50	13	36
High	20	58	95	50	80	16	61

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The excavation, installation, and backfilling of cast in place concrete box culverts on the construction site	The excavation, installation, and backfilling of drainage or sewer pipe system on the construction site using cast in place culverts	Constructing concrete culverts. RCB's (Reinforced Concrete Boxes); Extend/ install 4'x2', 3'x3', etc.	Includes all activities involved in the construction of box culverts on the project	The excavation, installation, and backfilling of cast in place concrete box culverts on the construction site	Box culverts, cast in place, 6'x6', 8'x8', and 12'x12'
Exclusions	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	Excavation Backfill
Original units	CY/Day	CY/Day	CY/Day	CY/Day	CY/Day	LF/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not convertible

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
464	Reinforced Concrete Pipe	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low	100	9	50	100	100	16	63
Mean	200	116	110	200		100	145
High	300	283	190	300	400	192	278

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The excavation, installation, and backfilling of drainage or sewer pipe system on the construction site using manufactured pipe	Excavation & dewatering; Trench exc. protection; Shaping & bedding; Pipe handling from storage yard; Laying pipe; Joining & insulating joints; Inspection; Connections to existing structure or pipe(s)	Installing new or removing and reinstalling existing pipe conduits. Includes excavation, bedding, laying of pipe, joining, backfilling, jacking	Excavation, installation and backfill for drainage pipe on the project.	Pipe installation Storm sewers Temporary pipe Trench drain	Water Supply Concrete Pipe - 12" to 144" diam; Sewage/ Drainage Collection - 12" to 96" diam; Classes 2, 3, 4, and 5; no gaskets, with gaskets; Reinforced Elliptical, Slotted Pipes
Exclusions	No specific exclusions identified in source	Survey & Layout; Equipment(s) move in; Site preparation; Disposal of excavation; Removing old pipe(s); Safety end treatment; Testing	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	Excavation Backfill With flare end
Original units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
465	Inlets and Manholes	EA/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	EA/Day	EA/Day	EA/Day	No production rate information from source	EA/Day	EA/Day	EA/Day
Low	1	0.2				1	0.7
Mean	2	1.8	1			2.1	1.7
High	3	4	1.5		4	4.1	3.3

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The installation of premanufactured inlets and manholes for drainage and sewer systems on the construction	Excavation & dewatering; Trench exc. protection; Shaping & bedding; Concrete handling & drying; formwork & rebar placing (if CIP); Placing precast units (if precast); Installing joints; Inspection; Connections to existing structure or pipe(s)	Constructing manholes, drop or curb inlets, junction boxes, or similar structures using precast concrete units, brick masonry, or cast-in-place concrete	No production rate information from source	The installation of premanufactured manholes for drainage and sewer systems	Concrete, cast in place and precast, 4', 6', and 8' deep
Exclusions	Cast in place inlets and manholes	Survey & Layout; Site preparation; Mobilization; Disposal of excavation; Removing old pipe(s); Testing; Backfilling; (Limit to stage 1: Extension)	No specific exclusions identified in source	No production rate information from source	Inlets	Slab tops Brick and Concrete blocks Depths over 8'
Original units	EA/Day	EA/Day	EA/Day	N/A	EA/Day	EA/Day
Conversions	Not needed	Not needed	Not needed	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
466	Head walls and wing walls	SF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	SF/Day	SF/Day	SF/Day	No production rate information from source	SF/Day	CY/Day	SF/Day
Low	100	14	125		100		85
Mean	150	35	290		150	20	156
High	200	92	370		200		216

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete wing walls for bridges	False work; Installation of forms and rebar; Inspection of forms and rebar; Handling and placing of concrete; Apron	Form, rebars, pour concrete, strip forms.	No production rate information from source	The layout, forming, reinforcing, placing, curing, and removing forms for reinforced concrete wing walls for bridges	Walls, stems and wing walls
Exclusions	No specific exclusions identified in source	Site preparation; Preparation of rebar & forms; Weather protection of placed concrete; Curing; Removal of forms; Surface finishing; Installation of drainage pipe; Removal of false work; Precast concrete panel; Safety covers / Safety edn treatment	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	SF/Day	SF/Day	SF/Day	N/A	SF/Day	CY/Day
Conversions	Not needed	Not needed	Not needed	N/A	Not needed	Not convertible

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
496-1	Removing structures - Remove old Drainage/Utility Str.	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	LF/Day	LF/Day
Low	100					112	106
Mean	300					202	251
High	500					350	425

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The breakout and removal of old drainage and utility systems from the construction site using mechanical equipment	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Pipe removal, sewer/water; Steel, welded connections; Concrete pipe & end pieces; Ductile iron; Plastic; Copper; Cast iron; Vent cast iron
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Fittings, Catch basins, manholes, fire hydrants
Original units	LF/Day	N/A	N/A	N/A	N/A	LF/Day
Conversions	Not needed	N/A	N/A	N/A	N/A	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
496-2	Removing structures - Remove old structures	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	Days	No production rate information from source	No production rate information from source	Days
Low	1			1			1
Mean	3			3			3
High	5			5			5

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The demolition and removal of the materials for small structures (single-story wood buildings, storage sheds, fences, road signs, etc.) from the right of way of new projects	No production rate information from source	No production rate information from source	All activities required to remove any existing structures due to bridge construction from a project	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	Days	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
496-3	Removing structures - Remove temporary bridges	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	Days	No production rate information from source	No production rate information from source	Days
Low	5			2			4
Mean	10			4			7
High	15			8			12

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The demolition and removal of all materials for a temporary bridge structure and related appurtenances for a highway construction project	No production rate information from source	No production rate information from source	All activities required to remove a temporary bridge from the project site	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	Days	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
496-4	Removing structures - Major Structure Demolition	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Days
Low	5						5
Mean	10						10
High	20						20

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The demolition & removal of the materials for large structures (multi-story buildings, retaining walls, towers, underground tanks, etc.) from the right of way of new projects	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	N/A	N/A	N/A
Conversions	Not needed	N/A	N/A	N/A	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
496-5	Removing structures - Bridge demolition	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Days
Low	5						5
Mean	15						15
High	30						30

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The demolition and removal of the materials for an existing bridge structure and related appurtenances (approaches, gates, signals, etc.)	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	N/A	N/A	N/A
Conversions	Not needed	N/A	N/A	N/A	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
502	Initial traffic control	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	Days	No production rate information from source	No production rate information from source	Days
Low	1			1			1
Mean	2			2			2
High	4			4			4

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The establishment of the initial traffic control system components (barricades, flashers, signs, flagpersons, etc.) necessary on a new project prior to the start up of construction operations	No production rate information from source	No production rate information from source	Setup time for traffic control system prior to start of construction	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	Days	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
506-1	Erosion Control - Silt Fence	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	LF/Day	LF/Day	LF/Day
Low					750		750
Mean					1,500	1,300	1,400
High					3,000		3,000

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Erosion Control - Silt Fence	Silt Fence, install and maintain, remove
Exclusions	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	N/A	N/A	N/A	N/A	LF/Day	LF/Day
Conversions	N/A	N/A	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
506-2	Erosion Control - Filter Fabric	SY/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	SY/Day	SY/Day
Low						515	515
Mean					2,500	1,827	2,164
High						2,500	2,500

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	Erosion Control - Filter Fabric	Rolled Erosion Control Mats and Blankets: Jute mesh, Polyethylene geomatrix, Paper biodegradable mesh, Plastic netting, Revegetation mat, Polypropylene mesh, Tobacco netting
Exclusions	No production rate information from source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	Paper mulch, Soil sealant, Hay bales
Original units	N/A	N/A	N/A	N/A	SY/Day	SY/Day
Conversions	N/A	N/A	N/A	N/A	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
508	Detour	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Days	No production rate information from source	No production rate information from source	Days	No production rate information from source	No production rate information from source	Days
Low	3			3			3
Mean	6			6			6
High	12			12			12

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The establishment of initial traffic detour system components (Traffic barriers, temporary pavement run-arounds or crossovers, etc.) necessary on a new project prior to construction start up	No production rate information from source	No production rate information from source	All activities required providing a diversion for traffic from the construction site	No production rate information from source	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	Days	N/A	N/A	Days	N/A	N/A
Conversions	Not needed	N/A	N/A	Not needed	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
514	Barriers	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	LF/Day	No production rate information from source	LF/Day	LF/Day	LF/Day	LF/Day
Low	500	89		300	200	160	250
Mean	1,000	1,366		500	300	270	687
High	1,500	2,676		800	400	380	1,151

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout and installation of precast concrete traffic barriers	Slip form bridge rail; Anchorage to the structure, if any; Casting	No production rate information from source	Barrier walls, slip form; All activities required to construct barrier walls on a project. This includes forming, pouring, and curing	Concrete barrier walls	Jersey concrete barriers 10' & 20' Long; Median, precast concrete, 3'-6" high, 2' wide, single and double face; Cast in place, steel forms; Slipformed.
Exclusions	No specific exclusions identified in source	Equipment setup; Cleaning site after work; Removal of old railing; Temporary railing; Material handling and setting in site; Rebar setting; Protective work for railing	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	Highway sound barriers
Original units	LF/Day	LF/Day	N/A	LF/Day	LF/Day	LF/Day / Ea./Day
Conversions	Not needed	Not needed	N/A	Not needed	Not needed	LF/Day (using specified lengths)

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
529	Conc. curb, gutter, and combined	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low	300	128	500	300	400	200	305
Mean	500	871	800	500	600	934	701
High	1,000	1,580	1,400	1,000	800	2,200	1,330

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The layout and construction of new roadway curb and gutter using automated equipment	From setting up string line/ placing concrete to finishing	Constructing integral curb, combined curb and gutter, asphalt curbing, and header curbing	All activities required to construct curbs and gutters on a project	The layout and construction of new roadway curb and gutter using automated equipment or forms and hand finish	Cast in place Concrete Curbs and Gutters - wood forms, steel forms, machine formed, straight, median mall; Precast Concrete Curbs and Gutters
Exclusions	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source
Original units	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Conversions	Not needed	Not needed	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
531	Sidewalks	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	No production rate information from source	No production rate information from source	No production rate information from source	SY/Day	No production rate information from source	LF/Day
Low	50				300		50
Mean	80						80
High	120				800		120

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	Bridge curbs, walks: The layout, forming, reinforcing, placing, curing and removing forms for reinforced concrete bridge curbs and walkways.	No production rate information from source	No production rate information from source	No production rate information from source	Concrete and asphalt sidewalks	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source
Original units	LF/Day	N/A	N/A	N/A	SY/Day	N/A
Conversions	Not needed	N/A	N/A	N/A	Not convertible	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
610/613	Roadway illumination assemblies - Lighting	EA/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	No production rate information from source	No production rate information from source	EA/Day	EA/Day	EA/Day	EA/Day	EA/Day
Low			1	1		2	1.3
Mean			2	2		3.2	2.4
High			3	3	10	4.4	5.1

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	No production rate information from source	No production rate information from source	Electrical Lighting Works Providing and installing roadway and sign lighting luminaires	All activities required to install luminaries on a project	Lighting - Poles	Roadway lighting: Roadway Luminaire, Roadway LED luminaire
Exclusions	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	Pull & Junction boxes Highway standard	Parking lighting, Area lighting
Original units	N/A	N/A	Poles/Day	EA/Day	EA/Day	EA/Day
Conversions	N/A	N/A	1 Pole/Day = 1 EA/Day	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
644	Small signs	EA/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	EA/Day	No production rate information from source	No production rate information from source	EA/Day	EA/Day	No production rate information from source	EA/Day
Low	10			20	10		13
Mean	20			30	20		23
High	30			40	30		33

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The installation of small highway information and warning signs mounted on metal posts driven into soil along a highway	No production rate information from source	No production rate information from source	Sheet signs: All activities required to install sheet signs for a project	The installation of small highway information and warning signs mounted on metal posts driven into soil along a highway	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source
Original units	EA/Day	N/A	N/A	EA/Day	EA/Day	N/A
Conversions	Not needed	N/A	N/A	Not needed	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
650	Overhead signs	EA/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	EA/Day	No production rate information from source	No production rate information from source	EA/Day	EA/Day	No production rate information from source	EA/Day
Low	1			1	0.2		0.7
Mean	1.5			2			1.8
High	3			3	0.7		2.2

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The installation of large highway information and directional signs mounted on metal frames over a highway	No production rate information from source	No production rate information from source	Panel signs: All activities required to install panel signs for a project	Large signs; Overhead signs: The installation of large highway information and directional signs mounted on metal frames over a highway	No production rate information from source
Exclusions	Footings and poles that support the frame	No production rate information from source	No production rate information from source	No specific exclusions identified in source	Footings and poles that support the frame	No production rate information from source
Original units	EA/Day	N/A	N/A	EA/Day	EA/Day	N/A
Conversions	Not needed	N/A	N/A	Not needed	Not needed	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
680	Major traffic signals	EA/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	EA/Day	No production rate information from source	Total Days	EA/Day	No production rate information from source	No production rate information from source	EA/Day
Low	0.2		2	0.05			0.1
Mean	0.3		3	0.07			0.2
High	0.7		3	0.1			0.4

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The installation of automated traffic signals and their support systems at highway intersections	No production rate information from source	No production rate information from source	All activities required to install a traffic signal intersection on a project	No production rate information from source	No production rate information from source
Exclusions	Footings for the supports	No production rate information from source	No production rate information from source	No specific exclusions identified in source	No production rate information from source	No production rate information from source
Original units	EA/Day	N/A	N/A	Days/Intersection	N/A	N/A
Conversions	Not needed	N/A	N/A	EA = 1/Days	N/A	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
666/668	Reflectorized pavement markings	LF/Day

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	LF/Day	No production rate information from source	LF/Day	LF/Day	LF/Day	LF/Day	LF/Day
Low	5,000		5,000	5,000		660	3,915
Mean	10,000		10,000	10,000	2,000	8,431	8,086
High	20,000		18,000	20,000		20,000	19,500

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The application of thermoplastic pavement marking materials to a highway pavement	No production rate information from source	Permanent signs and striping	All activities required to mark the new or existing pavement on a project.	Traffic stripe (skip or solid); The application of paint or thermoplastic pavement marking materials to a highway pavement	Painted pavement markings - Acrylic & Thermoplastic; white or yellow; Plastic pavement markings - Thermoplastic; white or yellow; Gore lines, Arrows, and Letters
Exclusions	Markings made using paint or reflectors	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	Temporary paint; Glass beads; Airport painting markings; Pavement parking markings
Original units	LF/Day	N/A	LF/Day	LF/Day	LF/Day	LF/Day
Conversions	Not needed	N/A	Not needed	Not needed	Not needed	Not needed

*Production rates with inconsistent units are excluded from average calculations and charts

Work Item #	Work Item	Unit of measurement
738	Cleaning and sweeping highways - Final Clean-up	Days

Rate Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans	Average
Units	Sta/Day	No production rate information from source	Days	Days	Days	No production rate information from source	Days
Low	10		1	5			3
Mean	30		3	10	7		7
High	50		4	15			10

Scope Table	TXCTDS	HYPRIS	OKCTDS	KYCTDS	FLDOT	RSMeans
Inclusions	The removal of debris, dirt and other construction materials from a highway pavement and adjacent right of way at the end of a project	No production rate information from source	Removing from the right-of-way all machinery, equipment, surplus and discarded materials, rubbish, temporary structures, stumps or portions of trees; Cut all brush and weeds	All work required to complete all activities of the project	Demobilize / Punchlist / Clean-up	No production rate information from source
Exclusions	No specific exclusions identified in source	No production rate information from source	No specific exclusions identified in source	No specific exclusions identified in source	No specific exclusions identified in source	No production rate information from source
Original units	Sta/Day	N/A	Days	Days	Weeks	N/A
Conversions	Not convertible	N/A	Not needed	Not needed	1 week = 7 days	N/A

*Production rates with inconsistent units are excluded from average calculations and charts

APPENDIX B: US 80 & IH 635 PROJECT SEQUENCE OF CONSTRUCTION

<u>US 80 & IH 635 SEQUENCE OF CONSTRUCTION</u>			
<p>GENERAL CONSTRUCTION:</p> <p>ALL SIGNS SHALL BE IN ACCORDANCE TO THE TEXAS MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (TMUTCD) 2014 EDITION, STANDARD HIGHWAYS SIGN DESIGNS FOR TEXAS (SHSD) 2014 EDITION, AND TEXAS STANDARD SPECIFICATIONS (SPEC BOOK) 2014 EDITION.</p> <p>PLACE AND MAINTAIN ALL ADVANCE WARNING SIGNS, TRAFFIC CONTROL PLAN SIGNS, TEMPORARY SIGNALIZATION, PAVEMENT MARKINGS, BARRICADES, AND OTHER TRAFFIC CONTROL DEVICES AS SHOWN IN THE PLANS. REFER TO THE BC STANDARDS, COMPLIANT WORK ZONE TRAFFIC CONTROL DEVICE LIST, APPLICABLE STANDARDS AND SPECIFICATIONS, OR AS DIRECTED BY THE ENGINEER.</p> <p>CONSIDER SIGNS, BARRICADES, AND OTHER WARNING DEVICES SHOWN AS A MINIMUM. PROVIDE ADDITIONAL DEVICES AS REQUIRED BY FIELD CONDITIONS OR AS DIRECTED BY THE ENGINEER.</p> <p>INSTALL AND MAINTAIN ALL EROSION CONTROL MEASURES AS SHOWN ON THE STORMWATER POLLUTION PREVENTION PLAN (SWPP) LAYOUTS FOR EACH PHASE. CONTRACTOR IS EXPECTED TO MAINTAIN POSITIVE DRAINAGE AT ALL TIMES DURING CONSTRUCTION ACTIVITIES. CONTRACTOR SHALL BE IN COMPLIANCE WITH ALL ENVIRONMENTAL AGREEMENTS AND COMMITMENTS UNTIL THE PROJECT IS COMPLETED AND AS DEFINED IN THE CONTRACT.</p> <p>COMPLETE CONSTRUCTION DETOURS AS SHOWN ON THE PLANS. ALL CONSTRUCTION DEBRIS SHALL BE REMOVED AND CLEANED FROM THESE AREAS BEFORE THE WORK DAY CONCLUDES.</p> <p>BEFORE SWITCHING TRAFFIC TO THE FOLLOWING STAGE, ALL ADVANCE WARNING SIGNS AND TRAFFIC CONTROL DEVICES SHALL BE READIED AND PLACE IN POSITION UNTIL COMPLETION. CERTIFIED FLAGGERS SHALL BE HANDLING TRAFFIC SAFELY DURING THESE ACTIVITIES. PROVIDE NOTIFICATION TO THE ENGINEER.</p> <p>CONTRACTOR IS EXPECTED TO COMMUNICATE AND COORDINATE WITH UTILITY COMPANIES IN ADVANCE FOR UTILITY LOCATIONS.</p>			
<p><u>IH 635: GROSS ROAD EXIT RAMP: PHASE 1 STAGES 1-5</u></p> <p><u>FOR THIS PROJECT, THE SEQUENCE OF CONSTRUCTION WILL FOLLOW THIS ORDER: THE GROSS ROAD EXIT RAMP, THE GROSS ROAD ENTRANCE RAMP, THE IH 635 FRONTAGE ROAD AND BRIDGE, AND THE US 80 FRONTAGE ROAD AND RAMPS CONSTRUCTION.</u></p> <p>THE CONTRACTOR SHALL INSTALL ALL ADVANCE WARNING SIGNS AND TRAFFIC CONTROL DEVICES AS SHOWN ON THE PLANS FOR ALL STAGES. ALL PREPARATION WORK, STRUCTURES, STORM SEWER, DRAINAGE, SIDEWALK, REMOVALS, MEDIAN, EARTHWORK, TEMPORARY PAVEMENT MARKINGS, AND TEMPORARY/PERMANENT EROSION CONTROL MEASURES SHALL BE COMPLETED WITHIN THE STAGE WHERE THE CONSTRUCTION WORK IS BEING COMPLETED ANY DEVIATION FROM THE PLANS SHALL BE APPROVED BY THE ENGINEER.</p> <p>THE CONTRACTOR WILL DETERMINE THE APPROPRIATE STAGE FOR INSTALLATION OF ALL PROPOSED STORM SEWER LOCATIONS AND DITCHWORK. REFER TO ALL THE REVELANT PLAN SHEETS.</p> <p>FOR WORK ON OR NEAR THE GROSS ROAD INTERSECTION, THE CONTRACTOR SHALL SET-UP THE TRAFFIC CONTROL PLAN ALONG GROSS ROAD AS SHOWN IN THE PLANS. ANY CHANGE TO THE TCP WILL NEED TO BE APPROVED BY THE ENGINEER.</p>			
<p>~ PHASE 1 STAGE 1</p> <p>THE PROJECT BEGINS AT GROSS ROAD EXIT RAMP. FOR THIS PHASE, CONSTRUCTION DETOUR WIDENING FOR THE LEFT SHOULDER SHALL BE COMPLETED. SEE THE PLANS FOR ALL REMOVAL AND RELOCATION ITEMS THAT ARE REQUIRED FOR THIS STAGE BEFORE PAVEMENT IS LAID. ENSURE THAT ALL TRAFFIC CONTROL DEVICES ARE SET-UP ACCORDING TO THE PLANS AT THE BEGINNING AND END OF EACH DAY FOR ALL PHASES.</p>			
<p>~ PHASE 1 STAGE 2</p> <p>DURING THIS STAGE, MAJORITY OF THE PROPOSED RIGHT SIDE OF THE RAMP INCLUDING CULVERT #1, THE RIGHT TURN LANE, RIDGEVIEW STREET THRU-LANE, AND THE SMALL ISLAND SHALL BE BUILT UP TO THE CONSTRUCTION JOINTS. TRAFFIC WILL BE ON THE LEFT SIDE OF THE RAMP, ANY FIELD ADJUSTMENTS TO THE TCP SHALL BE APPROVED BY THE ENGINEER.</p>			
<p>~ PHASE 1 STAGE 3</p> <p>FOR THIS STAGE, THE REMAINING PORTION OF THE RIGHT THRU-LANE USING HIGH EARLY STRENGTH CONCRETE (HES), AND THE TEMPORARY CONSTRUCTION WIDENING (ASPHALT) SHALL BE COMPLETED. TRAFFIC WILL REMAIN ON THE LEFT SIDE OF THE RAMP, AND THE RIGHT-TURN LANE WILL BE OPENED FOR TRAFFIC TO MAKE THE RIGHT TURN MOVEMENT.</p>			
<p>~ PHASE 1 STAGE 4</p> <p>DURING THIS STAGE, THE LEFT SIDE OF THE RAMP INCLUDING THE MIDDLE LANE AND THE LEFT LANE SHALL BE CONSTRUCTED. TRAFFIC WILL BE TRAVELING ON THE COMPLETED RIGHT SIDE OF THE RAMP. ALL CONSTRUCTION DEBRIS SHALL BE THOROUGHLY REMOVED ONCE THIS PHASE COMMENCES.</p>			
<p>~ PHASE 1 STAGE 5</p> <p>FOR THIS FINAL STAGE FOR PHASE 1, THE LARGE ISLAND WILL BE COMPLETED. THE EXIT RAMP RIGHT THRU-LANE WILL REMAIN CLOSED UNTIL THE IH 635 FRONTAGE ROAD IS OPENED FOR TRAFFIC. SEE PHASE 2 STAGE 1 FOR DETAILS. ALL CONSTRUCTION DEBRIS SHALL BE REMOVED.</p>			
<p><u>IH 635: GROSS ROAD ENTRANCE RAMP AND FRONTAGE ROAD: PHASE 2 STAGES 1-3</u></p> <p>THE CONTRACTOR SHALL INSTALL ALL ADVANCE WARNING SIGNS AND TRAFFIC CONTROL DEVICES AS SHOWN ON THE PLANS FOR ALL STAGES. ALL PREPARATION WORK, STRUCTURES, STORM SEWER, DRAINAGE, SIDEWALK, REMOVALS, MEDIAN, EARTHWORK, TEMPORARY PAVEMENT MARKINGS, AND TEMPORARY/PERMANENT EROSION CONTROL MEASURES SHALL BE COMPLETED WITHIN THE STAGE WHERE THE CONSTRUCTION WORK IS BEING COMPLETED ANY DEVIATION FROM THE PLANS SHALL BE APPROVED BY THE ENGINEER.</p>			
<p>THE CONTRACTOR WILL DETERMINE THE APPROPRIATE STAGE FOR INSTALLATION OF ALL PROPOSED STORM SEWER LOCATIONS AND DITCHWORK.</p>			
<p>FOR WORK ON OR NEAR THE GROSS ROAD INTERSECTION, THE CONTRACTOR SHALL SET-UP THE TRAFFIC CONTROL PLAN ALONG GROSS ROAD AS SHOWN IN THE PLANS. ANY CHANGE TO THE TCP WILL NEED TO BE APPROVED BY THE ENGINEER.</p>

Signature of Registrant P.E. Date

Texas Department of Transportation

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US 80 & IH 635
SEQUENCE OF CONSTRUCTION

SCALE: N.T.S.		SHEET 1 OF 2	
DESIGN	FILE NO.	PROJECT NO.	PROJECT NAME
MJK	6	SEE TITLE SHEET	US 80
CHECK	STATE	DISTRICT	COUNTY
VB	TEXAS	DAL	DALLAS
CONTR.	SECTION	JOB	
MOH	0095	02	102, etc.

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US 80 & IH 635 SEQUENCE OF CONSTRUCTION

*GROSS ROAD MEDIAN WORK SHOULD BE COMPLETED AT THE END OR BETWEEN PHASE 1 STAGE 5 OR AT THE END OF PHASE 2 STAGE 1, BEFORE TRAFFIC IS ROUTED TO THE TEMPORARY ENTRANCE RAMP.

~ PHASE 2 STAGE 1

THE TEMPORARY ENTRANCE RAMP SHALL BE COMPLETELY BUILT FOR USE IN PHASE 2 STAGE 2. DURING THIS STAGE, D1-NBFR-1 AND SSIPE-NBFR-1 WILL BE INSTALLED, TEMPORARY INLETS AND DITCHES, AND THE MAINLANE STRUCTURE WILL BE EXTENDED. SEE APPLICABLE SHEETS FOR DETAILS. INSTALL TOP DEVICES, INSTALL DRAINAGE STRUCTURES, COMPLETE REMOVALS AS SHOWN, AND PREPARE ROADBED BEFORE ASPHALT IS LAID AS SHOWN IN THE PLANS AND ACCORDING TO SPECIFICATIONS. TRAFFIC WILL REMAIN ON THE EXISTING ENTRANCE RAMP WHILE THIS PHASE IS BEING EXECUTED.

~ PHASE 2 STAGE 2

THE PROPOSED GROSS ENTRANCE RAMP WILL BE FULLY CONSTRUCTED AND A PORTION OF THE IH 635 FRONTAGE ROAD WILL BE BUILT UP TO THE CONSTRUCTION JOINTS FOR THIS STAGE. TRAFFIC WILL BE ROUTED TO THE TEMPORARY ENTRANCE RAMP COMPLETED IN PHASE 2 STAGE 1.

*BEFORE TRAFFIC IS SWITCHED ONTO THE GROSS ENTRANCE RAMP, GROSS ROAD MEDIAN WORK, PERMANENT PAVEMENT MARKINGS, AND PERMANENT SIGNALIZATION MUST BE COMPLETED ALONG GROSS ROAD AND THE ENTRANCE RAMP.

~ PHASE 2 STAGE 3

THE IH 635 FRONTAGE ROAD ALONG WITH THE BRIDGE, DRAINAGE STRUCTURES, AND SIDEWALK ELEMENTS, SHALL BE COMPLETELY BUILT UP TO THE CONSTRUCTION JOINT DURING THIS STAGE. TRAFFIC WILL REMAIN ON THE NEWLY CONSTRUCTED GROSS ENTRANCE RAMP.

*THE IH 635 FRONTAGE ROAD WILL REMAIN CLOSED TO THE PUBLIC WHILE THE US 80 FRONTAGE ROAD AND RAMP IS CONSTRUCTED.

US 80 FRONTAGE ROAD AND RAMP: PHASE 3 STAGES 1-5

THE CONTRACTOR SHALL INSTALL ALL ADVANCE WARNING SIGNS AND TRAFFIC CONTROL DEVICES AS SHOWN ON THE PLANS FOR ALL STAGES. ALL PREPARATION WORK, STRUCTURES, STORM SEWER, DRAINAGE, SIDEWALK, REMOVALS, MEDIAN, EARTHWORK, TEMPORARY PAVEMENT MARKINGS, AND TEMPORARY/PERMANENT EROSION CONTROL MEASURES SHALL BE COMPLETED WITHIN THE STAGE WHERE THE CONSTRUCTION WORK IS BEING COMPLETED ANY DEVIATION FROM THE PLANS SHALL BE APPROVED BY THE ENGINEER.

THE CONTRACTOR WILL DETERMINE THE APPROPRIATE STAGE FOR INSTALLATION OF ALL PROPOSED STORM SEWER LOCATIONS AND DITCHWORK. REFER TO ALL THE RELEVANT PLAN SHEETS.

FOR WORK ON OR NEAR THE GALLOWAY AVENUE INTERSECTION, THE CONTRACTOR SHALL SET-UP THE TRAFFIC CONTROL PLAN ALONG GALLOWAY AVENUE AS SHOWN IN THE PLANS. ANY CHANGE TO THE TCP WILL NEED TO BE APPROVED BY THE ENGINEER.

*FOR PHASE 3 STAGE 1, SEE THE DETOUR TRAFFIC CONTROL PLAN FOR GALLOWAY AVENUE RAMP CLOSURE AS SHOWN IN THE PLANS. THE DETOUR TCP SHALL BE IN PLACE TEMPORARILY WHILE CONSTRUCTION WIDENING WORK IS NEAR THE EXISTING GALLOWAY EXIT RAMP (APPROX. STA.362+00 TO STA.366+72). WORK IS LIMITED TO A WEEKEND CLOSURE. SCHEDULING SHALL BE COORDINATED WITH ENGINEER. THE DETOUR TCP SHALL BE REMOVED ONCE PHASE 3 STAGE 1 WORK IS COMPLETED.

*FOR PHASE 3 STAGE 4 AND STAGE 5, SEE THE DETOUR TRAFFIC CONTROL PLAN FOR GALLOWAY AVENUE RAMP CLOSURE AS SHOWN IN THE PLANS. THE DETOUR TCP WILL REMAIN UNTIL STAGE 4 IS COMPLETED AND THE PERMANENT SIGNAGE AND PAVEMENT MARKINGS ARE INSTALLED. PHASE 3 STAGE 4 (APPROX. STA.362+00 TO STA.366+72) CONSTRUCTION IS LIMITED TO ONE WEEK. THE DETOUR SIGNS SHALL BE REMOVED AT THE DISCRETION OF THE ENGINEER.

~ PHASE 3 STAGE 1

CONSTRUCTION BEGINS ON THE EXISTING US 80 FRONTAGE ROAD. DURING THIS STAGE, TEMPORARY CONSTRUCTION DETOUR WIDENING FOR THE LEFT SHOULDER SHALL BE COMPLETED. SEE THE PLANS FOR ALL REMOVAL ITEMS THAT ARE REQUIRED FOR THIS STAGE BEFORE PAVEMENT IS LAID. IH 635 FRONTAGE ROAD WILL REMAIN CLOSED TO THE PUBLIC. ENSURE THAT ALL TRAFFIC CONTROL DEVICES ARE SET-UP ACCORDING TO THE PLANS AT THE BEGINNING AND END OF EACH DAY.

~ PHASE 3 STAGE 2

BUILD THE FRONTAGE ROAD SHARED-USE RIGHT LANE AND REMAINING SECTION OF IH 635 FRONTAGE ROAD, ALL DRIVEWAYS, AND SIDEWALK ELEMENTS FOR THIS STAGE; SEE ALL APPLICABLE SHEETS FOR THIS WORK. US 80 FRONTAGE ROAD TRAFFIC WILL BE REROUTED TO LEFT LANE AND THE TEMPORARY PAVEMENT WIDENING SECTION WHILE WORK IS BEING COMPLETED.

~ PHASE 3 STAGE 3

THE FRONTAGE ROAD LEFT LANE AND MIDDLE LANE WILL BE BUILT CONCURRENTLY UP TO THE CONSTRUCTION JOINT. THE PROPOSED GALLOWAY AVENUE EXIT RAMP TIES TO THE EXISTING US 80 DIRECT CONNECTOR AND THE FRONTAGE ROAD, IT WILL BE CONSTRUCTED DURING THIS STAGE. TRAFFIC WILL BE ROUTED TO THE RIGHT LANE OF THE FRONTAGE ROAD. TRAFFIC WILL REMAIN ON THE US 80 DIRECT CONNECTOR RAMP BUT SLIGHTLY SHIFTED LEFT ON THE RAMP. THE EXISTING GALLOWAY AVENUE EXIT RAMP WILL REMAIN OPEN TO TRAFFIC.

~ PHASE 3 STAGE 4

THE REMAINING SECTIONS OF THE MIDDLE LANE AND LEFT LANE SHALL BE COMPLETED USING HIGH EARLY STRENGTH CONCRETE (HES) DURING THIS STAGE FROM THE CONSTRUCTION JOINT TO GALLOWAY AVENUE. THE EXISTING GALLOWAY EXIT RAMP SHALL BE CLOSED TO TRAFFIC FOR THE REMAINING STAGES OF THE FRONTAGE ROAD CONSTRUCTION. THE NEWLY CONSTRUCTED GALLOWAY EXIT RAMP AND THE IH 635 FRONTAGE ROAD WILL BE OPENED FOR TRAFFIC; HOWEVER, THIS SHALL BE COORDINATED WITH THE ENGINEER.

~ PHASE 3 STAGE 5

REMOVE THE EXISTING GALLOWAY AVENUE EXIT RAMP, COMPLETE SIDESLOPE GRADING, INSTALL REMAINING DRAINAGE STRUCTURES, AND INSTALL GUARDRAIL ELEMENTS AS SHOWN ON THE PLANS. USE CERTIFIED FLAGGERS TO GET EQUIPMENT IN AND OUT OF THE WORK ZONE SAFELY.

FINISHING:

INSTALL ALL PERMANENT SIGNS, PAVEMENT MARKINGS, AND PERMANENT EROSION CONTROL MEASURES AS SHOWN IN THE PLANS OR AS DIRECTED BY THE ENGINEER.

REMOVE REMAINING TRAFFIC CONTROL DEVICES AND APPLICABLE ADVANCE WARNING SIGNS.

PERFORM FINAL CLEAN-UP TO THE APPROVAL OF THE ENGINEER.

AS DIRECTED BY THE ENGINEER, OPEN THE US 80 AND IH 635 FRONTAGE ROADS TO THE TRAVELING PUBLIC.

Signature of Registrant P.E. Date _____

US 80 & IH 635 SEQUENCE OF CONSTRUCTION

SCALE: N.T.S.		SHEET 2 OF 2	
DESIGN	MJK	FEDERAL AID PROJECT NO.	114354
DRAWN	MJK	SEE TITLE SHEET	US 80
CHECK	VB	STATE	TEXAS
CHECK	MDH	DISTRICT	DAL
		COUNTY	DALLAS
		SECTION	102, etc.
		JOB	
			43

APPENDIX C: US 80 & IH 635 PROJECT WBS

Phase 1 - IH 635 Gross Road Exit Ramp

Stations: 11

	Activities	Units	Quantities
Stage 1	Initial Traffic controls	LS	1
Detour Widening	Erosion CTRL	SY	3087
Stations: 11	Prep ROW	AC	3
	Construct detour widening (Asphalt pavement)	TON	120
	Clean-up	STA	11
Stage 2	Traffic controls	LS	1
Gross Road Exit Ramp	Remove pavement	SY	938
Right Side	Excavation	CY	2653.3
Stations: 11	Temporary Drainage/Shoring	SY	690
	Culvert 1	LF	109
	Storm Sewer pipes & TEP	LF	505
	Storm sewer Inlets/Manholes	EA	8
	Embankment	CY	450.45
	Flex Base	SY	3218.05
	Prime coat	GAL	643.5
	4" superpave	TON	708.4
	Concrete pavement	SY	2927.65
	Conc. Curb	LF	569
	Pavement markings	LF	1385.1
	Construct island	SY	27
	Compost topsoil (seed and landscape)	SY	9715
	Small Signs	EA	2
	Clean-up	STA	11
Stage 3	Traffic controls	LS	1
Right Thru-Lane portion	Storm Sewer pipes & TEP	LF	106
Stations: 1	Flex Base	SY	292.55
	Prime Coat	GAL	58.5

	4"Superpave	TON	64.4
	HES concrete	SY	266.15
	Pavement markings	LF	153.9
	Clean-up	STA	1
Stage 4	Traffic controls	LS	1
Gross Road Exit Ramp	Remove pavement	SY	1880
Left Side	Excavation	CY	1428.7
Stations: 11	Storm Sewer pipes & TEP	LF	190
	Storm sewer Inlets/Manholes	EA	3
	Embankment	CY	242.55
	Flex Base	SY	2340.4
	Prime Coat	GAL	468
	4"Superpave	TON	515.2
	Concrete Pavement	SY	2129.2
	Conc. Curb	LF	455.2
	Pavement Markings	LF	1539
	Compost topsoil (seed and landscape)	SY	9715
	Clean-up	STA	11
Stage 5	Traffic controls	LS	1
Large Island	Con. Curb	LF	113.8
Stations: 1	Construct island	SY	500
	Small Signs	EA	2
	Final Clean-up Phase 1	STA	1
Phase 2 - IH 635 Gross Road Entrance Ramp & FR			
Stations: 38			
	Activities	Units	Quantities
Stage 1	Traffic controls	LS	1
Detour Widening	Erosion CTRL	SY	14436
Stations: 10	Prep ROW	AC	3
	Excavation	CY	3646.8
	Embankment	CY	524
	Construct detour widening (Asphalt pavement)	TON	155
	Clean-up	STA	12
Stage 2	Traffic controls	LS	1

Gross Rd Entrance Ramp	Remove old pavement	SY	6170
Stations: 10	Excavation	CY	3646.8
	Embankment	CY	524
	Flex Base	SY	2753
	Prime coat	GAL	551
	Superpave mixtures	TON	606
	Concrete pavement	SY	2464
	Compost topsoil (seed and landscape)	SY	3712
	Pavement markings	LF	1775
	Clean-up	STA	12
Stage 3 – A	Traffic controls	LS	1
IH635 FR Before Bridge	Prep ROW	AC	13
(STA 1029+00 - 1040+00)	Excavation	CY	8546.8
Stations: 11	Culvert 2	LF	162
	Storm Sewer pipes & TEP	LF	680
	Storm sewer	EA	5
	Inlets/Manholes	EA	5
	Embankment	CY	524
	Flex Base	SY	4130
	Prime coat	GAL	826
	Superpave mixtures	TON	908
	Concrete pavement	SY	3696
	Concrete Curb	LF	1401
	Compost topsoil (seed and landscape)	SY	3712
	Intersections/ Signals PT	EA	1
	Pavement markings	LF	1775
Stage 3 – B	Channel excavation/grading	CY	800
IH635 FR Bridge Area	Piling	LF	165
(STA 1040+00 - 1051+00)	Footings	CY	43
Stations: 11	Caps and bents	CY	57
	Wing walls	SF	275
	Embankment	CY	9463

	Prestressed concrete girders	LF	718
	Reinforced concrete slab	CY	84
	Railing	LF	149
	Riprap	CY	16
	Flex Base	SY	4485
	Prime coat	GAL	897
	4" superpave	TON	987
	Concrete pavement	SY	3996
	Conc. Curb	LF	1100
	Pavement markings	LF	2000
	Compost topsoil (seed and landscape)	SY	13782
Stage 3 – C IH635 FR After Bridge (STA 1051+00 - 1067+00) Stations: 16	Remove concrete pavement	SY	4700
	Remove asphalt pavement	SY	5200
	Culvert 3	LF	162
	Excavation	CY	11511
	Embankment	CY	1572
	Storm Sewer pipes & TEP	LF	295
	Storm sewer Inlets/Manholes	EA	2
	Flex Base	SY	7513
	Prime coat	GAL	1503
	Superpave mixtures	TON	1652
	Concrete pavement	SY	6690
	Concrete Curb	LF	1880
	Pavement markings	LF	6000
	Compost topsoil (seed and landscape)	SY	16411
	Clean-up	STA	40
Phase 3 - US 80 FR Stations: 36			
	Activities	Units	Quantities
Stage 1	Erosion CTRL	SY	10910
Detour Widening	Traffic detours	LS	1
Stations: 36	Remove Pavement	SY	2796

	Construct detour widening (Asphalt pavement)	TON	395
Stage 2	Traffic detours	LS	1
US80 FR Right Lane	Prep ROW	AC	5
Stations: 36	Remove Pavement	SY	8500
	Temporary Drainage/Shoring	SY	12
	Culvert 4/5	LF	162
	Excavation	CY	8020
	Storm Sewer pipes & TEP	LF	224
	Storm sewer Inlets/Manholes	EA	3
	Embankment	CY	3404
	Flex Base	SY	10617
	Prime coat	GAL	1887
	4" superpave	TON	2625
	Conc. Curb	LF	2368
	Concrete pavement	SY	10144
	Pavement markings	LF	17700
	Compost topsoil (seed and landscape)	SY	12404
	Clean-up	STA	35
Stage 3	Traffic detours	LS	1
US80 FR	Prep ROW	AC	5
Left & Middle Lanes	Remove pavement	SY	4300
Stations: 31	Excavation	CY	3208
	Storm Sewer pipes & TEP	LF	1863
	Storm sewer Inlets/Manholes	EA	5
	Embankment	CY	1362
	Flex Base	SY	6092
	Prime coat	GAL	1455
	4" superpave	TON	1050
	Conc. Curb	LF	947
	Concrete pavement	SY	6756
	Pavement markings	LF	7114
	Compost topsoil (seed and landscape)	SY	4962
	Clean-up	STA	35
	Buffer Time	LS	1

Stage 4	Traffic detours	LS	1
US80 FR	Remove pavement	SY	2300
Left & Middle L	Excavation	CY	2139
Portion			
Stations: 5	Embankment	CY	908
	Flex Base	SY	3183
	Prime coat	GAL	636
	4" superpave	TON	700
	Conc. Curb	LF	632
	Concrete pavement (HES)	SY	1376
	Pavement markings	LF	4742
	Clean-up	STA	10
Stage 5	Traffic detours	LS	1
Remove Galloway	Remove ramp	SY	2000
Ave.			
Exit Ramp	Small Signs	EA	2
Stations: 10	Intersections/ Signals PT	EA	1
	Compost topsoil (seed and landscape)	SY	3308
	Clean-up	STA	10

APPENDIX D: US 80 & IH 635 PROJECT NOMINAL CONTRACT TIME

Phase 1 - IH 635 Gross Road Exit Ramp							
Stations: 11							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Initial Traffic controls	LS	1	M	2	2	TxCTDS
Detour Widening	Erosion CTRL	SY	3087	M	2500	2	RSMeans
Stations: 11	Prep ROW	AC	3	M	3	1	TxCTDS
	Construct detour widening (Asphalt pavement)	TON	120	M	883	1	PR Resource
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 1 Total						8	
Stage 2	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Road Exit Ramp	Remove pavement	SY	938	L	1000	1	TxCTDS
Right Side	Excavation	CY	2653.3	L	920	3	PR Resource
Stations: 11	Temporary Drainage/Shoring	SY	690			1	-
	Culvert 1	LF	109	M	99	2	PR Resource
	Storm Sewer pipes & TEP	LF	505	M	145	4	PR Resource
	Storm sewer Inlets/Manholes	EA	8	M	2	4	PR Resource
	Embankment	CY	450.45	L	654	1	PR Resource
	Flex Base	SY	3218.05	M	3539	1	PR Resource
	Prime coat	GAL	643.5	M	6000	1	RSMeans
	4" superpave	TON	708.4	M	884	1	PR Resource
	Concrete pavement	SY	2927.65	M	2700	2	PR Resource
	Conc. Curb	LF	569	M	721	1	PR Resource
	Pavement markings	LF	1385.1	L	3915	1	PR Resource
	Construct island	SY	27			1	-
	Compost topsoil (seed and landscape)	SY	9715	H	7000	2	TxCTDS
	Small Signs	EA	2	L	10	1	TxCTDS
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						30	
Stage 3	Traffic controls	LS	1	L	1	1	TxCTDS
Right Thru-Lane portion	Storm Sewer pipes & TEP	LF	106	M	145	1	PR Resource
Stations: 1	Flex Base	SY	292.55	M	3539	1	PR Resource
	Prime Coat	GAL	58.5	M	6000	1	RSMeans
	4"Superpave	TON	64.4	M	884	1	PR Resource
	HES concrete	SY	266.15	L	350	1	OkCTDS
	Pavement markings	LF	153.9	L	3915	1	PR Resource
	Clean-up	STA	1	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 Total						9	
Stage 4	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Road Exit Ramp	Remove pavement	SY	1880	M	2000	1	TxCTDS
Left Side	Excavation	CY	1428.7	L	920	2	PR Resource
Stations: 11	Storm Sewer pipes & TEP	LF	190	M	145	2	PR Resource
	Storm sewer Inlets/Manholes	EA	3	H	3	1	PR Resource
	Embankment	CY	242.55	L	654	1	PR Resource
	Flex Base	SY	2340.4	M	3539	1	PR Resource
	Prime Coat	GAL	468	M	6000	1	RSMeans
	4"Superpave	TON	515.2	M	884	1	PR Resource
	Concrete Pavement	SY	2129.2	M	2700	1	PR Resource
	Conc. Curb	LF	455.2	M	721	1	PR Resource
	Pavement Markings	LF	1539	L	3915	1	PR Resource
	Compost topsoil (seed and landscape)	SY	9715	H	7000	2	TxCTDS
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 4 Total						18	

Phase 1 - IH 635 Gross Road Exit Ramp							
Stations: 11							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 5	Traffic controls	LS	1	L	1	1	TxCTDS
Large Island	Con. Curb	LF	113.8	M	721	1	PR Resource
Stations: 1	Construct island	SY	500			1	-
	Small Signs	EA	2	L	10	1	TxCTDS
	Final Clean-up Phase 1	STA	1	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 5 Total						6	
Phase 1 Total						71	

Phase 2 - IH 635 Gross Road Entrance Ramp & FR							
Stations: 38							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Traffic controls	LS	1	M	2	2	TxCTDS
Detour Widening	Erosion CTRL	SY	14436	M	2500	6	RSMeans
Stations: 10	Prep ROW	AC	3	M	3	1	TxCTDS
	Excavation	CY	3646.8	M	2795	2	PR Resource
	Embankment	CY	524	L	654	1	PR Resource
	Construct detour widening (Asphalt pavement)	TON	155	M	883	1	PR Resource
	Clean-up	STA	12	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 1 Total						15	
Stage 2	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Rd Entrance Ramp	Remove old pavement	SY	6170	M	2000	4	TxCTDS
Stations: 10	Excavation	CY	3646.8	M	2795	2	PR Resource
	Embankment	CY	524	L	654	1	PR Resource
	Flex Base	SY	2753	M	3539	1	PR Resource
	Prime coat	GAL	551	M	6000	1	RSMeans
	Superpave mixtures	TON	606	M	884	1	PR Resource
	Concrete pavement	SY	2464	M	2700	1	PR Resource
	Compost topsoil (seed and landscape)	SY	3712	M	4000	1	TxCTDS
	Pavement markings	LF	1775	L	3915	1	PR Resource
	Clean-up	STA	12	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						16	
Stage 3 - A	Traffic controls	LS	1	L	1	1	TxCTDS
IH635 FR Before Bridge	Prep ROW	AC	13	M	3	5	TxCTDS
(STA 1029+00 - 1040+00)	Excavation	CY	8546.8	M	2795	4	PR Resource
Stations: 11	Culvert 2	LF	162	M	99	2	PR Resource
	Storm Sewer pipes & TEP	LF	680	M	145	5	PR Resource
	Storm sewer Inlets/Manholes	EA	5	M	2	3	PR Resource
	Embankment	CY	524	L	654	1	PR Resource
	Flex Base	SY	4130	M	3539	2	PR Resource
	Prime coat	GAL	826	M	6000	1	RSMeans
	Superpave mixtures	TON	908	H	1437	1	PR Resource
	Concrete pavement	SY	3696	M	2700	2	PR Resource
	Concrete Curb	LF	1401	M	721	2	PR Resource
	Compost topsoil (seed and landscape)	SY	3712	M	4000	1	TxCTDS
	Intersections/ Signals PT	EA	1	M	3 days	3	OkCTDS
	Pavement markings	LF	1775	L	3915	1	PR Resource
Stage 3 - A Total						34	
Stage 3 - B	Channel excavation/grading	CY	800	L	920	1	PR Resource
IH635 FR Bridge Area	Piling	LF	165	M	370	2	PR Resource
(STA 1040+00 - 1051+00)	Footings	CY	43	M	27	2	PR Resource
Stations: 11	Caps and bents	CY	57	H	8.3	7	PR Resource
	Wingwalls	SF	275	M	124	3	PR Resource
	Embankment	CY	9463	M	2654	4	PR Resource
	Prestressed concrete girders	LF	718	M	702	2	PR Resource
	Reinforced concrete slab	CY	84	H	14	6	TxCTDS
	Railing	LF	149	L	150	1	TxCTDS
	Riprap	CY	16			1	-
	Flex Base	SY	4485	M	3539	2	PR Resource
	Prime coat	GAL	897	M	6000	1	RSMeans
	4" superpave	TON	987	H	1437	1	PR Resource
	Concrete pavement	SY	3996	M	2700	2	PR Resource
	Conc. Curb	LF	1100	M	721	2	PR Resource
	Pavement markings	LF	2000	M	9600	1	PR Resource
	Compost topsoil (seed and landscape)	SY	13782	H	7000	2	TxCTDS
Stage 3 - B Total						40	

Phase 2 - IH 635 Gross Road Entrance Ramp & FR							
Stations: 38							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 3 - C	Remove concrete pavement	SY	4700	M	2000	3	TxCTDS
IH635 FR After Bridge	Remove asphalt pavement	SY	5200	M	2000	3	TxCTDS
(STA 1051+00 - 1067+00)	Culvert 3	LF	162	M	99	2	PR Resource
Stations: 16	Excavation	CY	11511	M	2794	5	PR Resource
	Embankment	CY	1572	L	654	3	PR Resource
	Storm Sewer pipes & TEP	LF	295	M	145	2	PR Resource
	Storm sewer Inlets/Manholes	EA	2	M	2	1	PR Resource
	Flex Base	SY	7513	M	3539	3	PR Resource
	Prime coat	GAL	1503	M	6000	1	RSMMeans
	Superpave mixtures	TON	1652	M	884	2	PR Resource
	Concrete pavement	SY	6690	M	2700	3	PR Resource
	Concrete Curb	LF	1880	M	721	3	PR Resource
	Pavement markings	LF	6000	M	9607	1	PR Resource
	Compost topsoil (seed and landscape)	SY	16411	H	7000	3	TxCTDS
	Clean-up	STA	40	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 - C Total						38	
Phase 2 Total							
						143	

Phase 3 - US 80 FR							
Stations: 36							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Erosion CTRL	SY	10910	M	2500	5	RSMeans
Detour Widening	Traffic detours	LS	1	L	1	1	TxCTDS
Stations: 36	Remove Pavement	SY	2796	H	3000	1	TxCTDS
	Construct detour widening (Asphalt pavement)	TON	395	M	883	1	PR Resource
Stage 1 Total						8	
Stage 2	Traffic detours	LS	1	M	2	2	TxCTDS
US80 FR Right Lane	Prep ROW	AC	5	M	3	2	TxCTDS
Stations: 36	Remove Pavement	SY	8500	M	2000	5	TxCTDS
	Temporary Drainage/Shoring	SY	12			1	-
	Culvert 4/5	LF	162	M	99	2	PR Resource
	Excavation	CY	8020	M	2794	3	PR Resource
	Storm Sewer pipes & TEP	LF	224	M	145	2	PR Resource
	Storm sewer Inlets/Manholes	EA	3	M	2	2	PR Resource
	Embankment	CY	3404	M	2654	2	PR Resource
	Flex Base	SY	10617	M	3539	3	PR Resource
	Prime coat	GAL	1887	M	6000	1	RSMeans
	4" superpave	TON	2625	M	884	3	PR Resource
	Conc. Curb	LF	2368	M	721	3	PR Resource
	Concrete pavement	SY	10144	M	2700	4	PR Resource
	Pavement markings	LF	17700	M	9607	2	PR Resource
	Compost topsoil (seed and landscape)	SY	12404	H	7000	2	TxCTDS
	Clean-up	STA	35	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						42	
Stage 3	Traffic detours	LS	1	M	2	2	TxCTDS
US80 FR	Prep ROW	AC	5	M	3	2	TxCTDS
Left & Middle Lanes	Remove pavement	SY	4300	M	2000	3	TxCTDS
Stations: 31	Excavation	CY	3208	M	2794	2	PR Resource
	Storm Sewer pipes & TEP	LF	1863	M	145	13	PR Resource
	Storm sewer Inlets/Manholes	EA	5	M	2	3	PR Resource
	Embankment	CY	1362	M	2654	1	PR Resource
	Flex Base	SY	6092	M	3539	2	PR Resource
	Prime coat	GAL	1455	M	6000	1	RSMeans
	4" superpave	TON	1050	M	884	2	PR Resource
	Conc. Curb	LF	947	M	721	2	PR Resource
	Concrete pavement	SY	6756	M	2700	3	PR Resource
	Pavement markings	LF	7114	M	9607	1	PR Resource
	Compost topsoil (seed and landscape)	SY	4962	H	7000	1	TxCTDS
	Clean-up	STA	35	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 Total						41	
Stage 4	Traffic detours	LS	1	L	1	1	TxCTDS
US80 FR	Remove pavement	SY	2300	H	3000	1	TxCTDS
Left & Middle L Portion	Excavation	CY	2139	M	2794	1	PR Resource
Stations: 5	Embankment	CY	908	M	2654	1	PR Resource
	Flex Base	SY	3183	M	3539	1	PR Resource
	Prime coat	GAL	636	M	6000	1	RSMeans
	4" superpave	TON	700	M	884	1	PR Resource
	Conc. Curb	LF	632	M	721	1	PR Resource
	Concrete pavement (HES)	SY	1376	H	700	2	OkCTDS
	Pavement markings	LF	4742	M	9607	1	PR Resource
	Clean-up	STA	10	M	30	1	TxCTDS
Stage 4 Total						12	

Phase 3 - US 80 FR							
Stations: 36							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 5	Buffer Time	LS	1			1	
Remove Galloway Ave.	Traffic detours	LS	1	L	1	1	TxCTDS
Exit Ramp	Remove ramp	SY	2000	H	3000	1	TxCTDS
Stations: 10	Small Signs	EA	2	L	10	1	TxCTDS
	Intersections/ Signals PT	EA	1	M	3 days	3	OkCTDS
	Compost topsoil (seed and landscape)	SY	3308	H	7000	1	TxCTDS
	Clean-up	STA	10	M	30	1	TxCTDS
Stage 5 Total						9	
Phase 3 Total						112	

APPENDIX E: US 80 & IH 635 PROJECT ACCELERATED CONTRACT TIME

Phase 1 - IH 635 Gross Road Exit Ramp							
Stations: 11							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Initial Traffic controls	LS	1	M	2	2	TxCTDS
Detour Widening	Erosion CTRL	SY	3087	M	2500	2	RSMeans
Stations: 11	Prep ROW	AC	3	M	3	1	TxCTDS
	Construct detour widening (Asphalt pavement)	TON	120	M	883	1	PR Resource
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 1 Total						8	
Stage 2	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Road Exit Ramp	Remove pavement	SY	938	L	1000	1	TxCTDS
Right Side	Excavation	CY	2653.3	L	920	3	PR Resource
Stations: 11	Temporary Drainage/Shoring	SY	690			1	-
	Culvert 1	LF	109	M	99	2	PR Resource
	Storm Sewer pipes & TEP	LF	505	M	145	-	PR Resource
	Storm sewer Inlets/Manholes	EA	8	M	2	-	PR Resource
	Embankment	CY	450.45	L	654	1	PR Resource
	Flex Base	SY	3218.05	M	3539	1	PR Resource
	Prime coat	GAL	643.5	M	6000	-	RSMeans
	4" superpave	TON	708.4	M	884	1	PR Resource
	Concrete pavement	SY	2927.65	M	2700	2	PR Resource
	Conc. Curb	LF	569	M	721	1	PR Resource
	Pavement markings	LF	1385.1	L	3915	-	PR Resource
	Construct island	SY	27			-	-
	Compost topsoil (seed and landscape)	SY	9715	H	7000	2	TxCTDS
	Small Signs	EA	2	L	10	-	TxCTDS
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						18	
Stage 3	Traffic controls	LS	1	L	1	1	TxCTDS
Right Thru-Lane portion	Storm Sewer pipes & TEP	LF	106	M	145	1	PR Resource
Stations: 1	Flex Base	SY	292.55	M	3539	1	PR Resource
	Prime Coat	GAL	58.5	M	6000	-	RSMeans
	4"Superpave	TON	64.4	M	884	-	PR Resource
	HES concrete	SY	266.15	L	350	1	OkCTDS
	Pavement markings	LF	153.9	L	3915	1	PR Resource
	Clean-up	STA	1	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 Total						7	
Stage 4	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Road Exit Ramp	Remove pavement	SY	1880	M	2000	1	TxCTDS
Left Side	Excavation	CY	1428.7	L	920	2	PR Resource
Stations: 11	Storm Sewer pipes & TEP	LF	190	M	145	-	PR Resource
	Storm sewer Inlets/Manholes	EA	3	H	3	-	PR Resource
	Embankment	CY	242.55	L	654	1	PR Resource
	Flex Base	SY	2340.4	M	3539	1	PR Resource
	Prime Coat	GAL	468	M	6000	1	RSMeans
	4"Superpave	TON	515.2	M	884	1	PR Resource
	Concrete Pavement	SY	2129.2	M	2700	1	PR Resource
	Conc. Curb	LF	455.2	M	721	1	PR Resource
	Pavement Markings	LF	1539	L	3915	-	PR Resource
	Compost topsoil (seed and landscape)	SY	9715	H	7000	2	TxCTDS
	Clean-up	STA	11	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 4 Total						14	

Phase 1 - IH 635 Gross Road Exit Ramp							
Stations: 11							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 5	Traffic controls	LS	1	L	1	1	TxCTDS
Large Island	Con. Curb	LF	113.8	M	721	1	PR Resource
Stations: 1	Construct island	SY	500			1	-
	Small Signs	EA	2	L	10	-	TxCTDS
	Final Clean-up Phase 1	STA	1	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 5 Total						5	
Phase 1 Total						52	

Phase 2 - IH 635 Gross Road Entrance Ramp & FR							
Stations: 38							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Traffic controls	LS	1	M	2	2	TxCTDS
Detour Widening	Erosion CTRL	SY	14436	M	2500	6	RSMeans
Stations: 10	Prep ROW	AC	3	M	3	1	TxCTDS
	Excavation	CY	3646.8	M	2795	2	PR Resource
	Embankment	CY	524	L	654	-	PR Resource
	Construct detour widening (Asphalt pavement)	TON	155	M	883	1	PR Resource
	Clean-up	STA	12	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 1 Total						14	
Stage 2	Traffic controls	LS	1	L	1	1	TxCTDS
Gross Rd Entrance Ramp	Remove old pavement	SY	6170	M	2000	4	TxCTDS
Stations: 10	Excavation	CY	3646.8	M	2795	2	PR Resource
	Embankment	CY	524	L	654	-	PR Resource
	Flex Base	SY	2753	M	3539	1	PR Resource
	Prime coat	GAL	551	M	6000	1	RSMeans
	Superpave mixtures	TON	606	M	884	1	PR Resource
	Concrete pavement	SY	2464	M	2700	1	PR Resource
	Compost topsoil (seed and landscape)	SY	3712	M	4000	-	TxCTDS
	Pavement markings	LF	1775	L	3915	1	PR Resource
	Clean-up	STA	12	M	30	1	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						14	
Stage 3 - A	Traffic controls	LS	1	L	1	1	TxCTDS
IH635 FR Before Bridge	Prep ROW	AC	13	M	3	5	TxCTDS
(STA 1029+00 - 1040+00)	Excavation	CY	8546.8	M	2795	4	PR Resource
Stations: 11	Culvert 2	LF	162	M	99	2	PR Resource
	Storm Sewer pipes & TEP	LF	680	M	145	-	PR Resource
	Storm sewer Inlets/Manholes	EA	5	M	2	-	PR Resource
	Embankment	CY	524	L	654	1	PR Resource
	Flex Base	SY	4130	M	3539	2	PR Resource
	Prime coat	GAL	826	M	6000	1	RSMeans
	Superpave mixtures	TON	908	H	1437	1	PR Resource
	Concrete pavement	SY	3696	M	2700	2	PR Resource
	Concrete Curb	LF	1401	M	721	2	PR Resource
	Compost topsoil (seed and landscape)	SY	3712	M	4000	-	TxCTDS
	Intersections/ Signals PT	EA	1	M	3 days	3	OkCTDS
	Pavement markings	LF	1775	L	3915	-	PR Resource
Stage 3 - A Total						24	
Stage 3 - B	Channel excavation/grading	CY	800	L	920	1	PR Resource
IH635 FR Bridge Area	Piling	LF	165	M	370	2	PR Resource
(STA 1040+00 - 1051+00)	Footings	CY	43	M	27	2	PR Resource
Stations: 11	Caps and bents	CY	57	H	8.3	7	PR Resource
	Wingwalls	SF	275	M	124	3	PR Resource
	Embankment	CY	9463	M	2654	-	PR Resource
	Prestressed concrete girders	LF	718	M	702	2	PR Resource
	Reinforced concrete slab	CY	84	H	14	6	TxCTDS
	Railing	LF	149	L	150	1	TxCTDS
	Riprap	CY	16			1	-
	Flex Base	SY	4485	M	3539	2	PR Resource
	Prime coat	GAL	897	M	6000	1	RSMeans
	4" superpave	TON	987	H	1437	1	PR Resource
	Concrete pavement	SY	3996	M	2700	2	PR Resource
	Conc. Curb	LF	1100	M	721	2	PR Resource
	Pavement markings	LF	2000	M	9600	-	PR Resource
	Compost topsoil (seed and landscape)	SY	13782	H	7000	2	TxCTDS
Stage 3 - B Total						35	

Phase 2 - IH 635 Gross Road Entrance Ramp & FR							
Stations: 38							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 3 - C	Remove concrete pavement	SY	4700	M	2000	3	TxCTDS
IH635 FR After Bridge	Remove asphalt pavement	SY	5200	M	2000	3	TxCTDS
(STA 1051+00 - 1067+00)	Culvert 3	LF	162	M	99	2	PR Resource
Stations: 16	Excavation	CY	11511	M	2794	5	PR Resource
	Embankment	CY	1572	L	654	3	PR Resource
	Storm Sewer pipes & TEP	LF	295	M	145	-	PR Resource
	Storm sewer Inlets/Manholes	EA	2	M	2	-	PR Resource
	Flex Base	SY	7513	M	3539	3	PR Resource
	Prime coat	GAL	1503	M	6000	1	RSMMeans
	Superpave mixtures	TON	1652	M	884	2	PR Resource
	Concrete pavement	SY	6690	M	2700	3	PR Resource
	Concrete Curb	LF	1880	M	721	3	PR Resource
	Pavement markings	LF	6000	M	9607	-	PR Resource
	Compost topsoil (seed and landscape)	SY	16411	H	7000	3	TxCTDS
	Clean-up	STA	40	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 - C Total						34	
Phase 2 Total							
						121	

Phase 3 - US 80 FR							
Stations: 36							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 1	Erosion CTRL	SY	10910	M	2500	5	RSMeans
Detour Widening	Traffic detours	LS	1	L	1	1	TxCTDS
Stations: 36	Remove Pavement	SY	2796	H	3000	1	TxCTDS
	Construct detour widening (Asphalt pavement)	TON	395	M	883	1	PR Resource
Stage 1 Total						8	
Stage 2	Traffic detours	LS	1	M	2	2	TxCTDS
US80 FR Right Lane	Prep ROW	AC	5	M	3	2	TxCTDS
Stations: 36	Remove Pavement	SY	8500	M	2000	5	TxCTDS
	Temporary Drainage/Shoring	SY	12			1	-
	Culvert 4/5	LF	162	M	99	2	PR Resource
	Excavation	CY	8020	M	2794	3	PR Resource
	Storm Sewer pipes & TEP	LF	224	M	145	-	PR Resource
	Storm sewer Inlets/Manholes	EA	3	M	2	-	PR Resource
	Embankment	CY	3404	M	2654	2	PR Resource
	Flex Base	SY	10617	M	3539	3	PR Resource
	Prime coat	GAL	1887	M	6000	1	RSMeans
	4" superpave	TON	2625	M	884	3	PR Resource
	Conc. Curb	LF	2368	M	721	3	PR Resource
	Concrete pavement	SY	10144	M	2700	4	PR Resource
	Pavement markings	LF	17700	M	9607	2	PR Resource
	Compost topsoil (seed and landscape)	SY	12404	H	7000	-	TxCTDS
	Clean-up	STA	35	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 2 Total						36	
Stage 3	Traffic detours	LS	1	M	2	2	TxCTDS
US80 FR	Prep ROW	AC	5	M	3	2	TxCTDS
Left & Middle Lanes	Remove pavement	SY	4300	M	2000	3	TxCTDS
Stations: 31	Excavation	CY	3208	M	2794	2	PR Resource
	Storm Sewer pipes & TEP	LF	1863	M	145	13	PR Resource
	Storm sewer Inlets/Manholes	EA	5	M	2	3	PR Resource
	Embankment	CY	1362	M	2654	1	PR Resource
	Flex Base	SY	6092	M	3539	2	PR Resource
	Prime coat	GAL	1455	M	6000	1	RSMeans
	4" superpave	TON	1050	M	884	2	PR Resource
	Conc. Curb	LF	947	M	721	2	PR Resource
	Concrete pavement	SY	6756	M	2700	3	PR Resource
	Pavement markings	LF	7114	M	9607	1	PR Resource
	Compost topsoil (seed and landscape)	SY	4962	H	7000	-	TxCTDS
	Clean-up	STA	35	M	30	2	TxCTDS
	Buffer Time	LS	1			1	
Stage 3 Total						40	
Stage 4	Traffic detours	LS	1	L	1	1	TxCTDS
US80 FR	Remove pavement	SY	2300	H	3000	1	TxCTDS
Left & Middle L Portion	Excavation	CY	2139	M	2794	1	PR Resource
Stations: 5	Embankment	CY	908	M	2654	-	PR Resource
	Flex Base	SY	3183	M	3539	1	PR Resource
	Prime coat	GAL	636	M	6000	-	RSMeans
	4" superpave	TON	700	M	884	-	PR Resource
	Conc. Curb	LF	632	M	721	1	PR Resource
	Concrete pavement (HES)	SY	1376	H	700	2	OkCTDS
	Pavement markings	LF	4742	M	9607	1	PR Resource
	Clean-up	STA	10	M	30	1	TxCTDS
Stage 4 Total						9	

Phase 3 - US 80 FR							
Stations: 36							
	Activities	Units	Quantities	Rate Level	Units/Day	Time (W. days)	Source
Stage 5	Buffer Time	LS	1			1	
Remove Galloway Ave.	Traffic detours	LS	1	L	1	1	TxCTDS
Exit Ramp	Remove ramp	SY	2000	H	3000	1	TxCTDS
Stations: 10	Small Signs	EA	2	L	10	-	TxCTDS
	Intersections/ Signals PT	EA	1	M	3 days	3	OkCTDS
	Compost topsoil (seed and landscape)	SY	3308	H	7000	-	TxCTDS
	Clean-up	STA	10	M	30	1	TxCTDS
Stage 5 Total						7	
Phase 3 Total						100	

APPENDIX F: US 80 & IH 635 PROJECT LSM SHEET SAMPLES

Phase 2 - Stages 1 and 2

APPENDIX G: TXDOT CONTRACT TIME ESTIMATE FOR US 80 & IH 635 PROJECT

Contract Time Estimate														
Rd:	US 80 & IH 635				County:	Dallas								
CSJ:	0095-02-102				Project:									
TASK #	Description	Quantity	Unit	Daily Rate	Duration	Prod Task	% Comp	Prod Task	% Comp	Prod Task	% Comp	Start Day	Finish Day	# DAYS / CELL
1	Initial Traffic Control Phase 1	1	LS	0.5	2							1	2	
2	Erosion Control - Phase 1	3,087	SY	1330	3							1	3	
3	Detouring - Phase 1	1	LS	0.25	4	2	50					3	6	
4	Prep ROW	3	AC	3	1	2	100					4	4	
5	Temporary Drainage/Storage	890	SY	60	18	4	50					5	23	
6	Remove old Pavement	1,821	SY	2000	1	4	75					5	5	
7	Excavation	3,940	CY	1100	4	3	50					14	17	
8	New Box Culvert Extension	103	LF	35	4	7	25					15	18	
9	Storm Sewer Pipes & TEP	536	LF	300	4	7	100					18	21	
10	Storm Sewer Inlets/Manholes	39	EA	10	4	6	50					20	23	
11	Embankment	223	CY	200	2	10	100					24	25	
12	Flex Base	5,821	SY	2000	2	11	50					25	26	
13	HMAC Base	5,821	SY	4000	2	12	75					27	28	
14	Concrete Pavement	5,022	SY	3000	2	13	50					28	29	
15	Block Sot/CMT	19,430	SY	2000	10	14	75					30	39	
16	Small Signs	4	EA	5	1	15	100					40	40	
17	Pavement Markings	6,691	LF	10000	1	14	100					30	30	
18	Final Clean-up Phase 1	11	STA	30	1	16	100	17	100			41	41	
19	Initial Traffic Control Phase 2	1	LS	0.5	2	18	100					42	43	
20	Erosion Control - Phase 2	14,438	SY	1330	11	19	50					43	53	
21	Detouring Phase 2	13.5	0.25	4	20	25						46	49	
22	Prep ROW	6	AC	3	6	20	100					54	59	
23	Remove old Pavement	910	SY	2000	4	21	75					49	52	
24	Remove Old drainage Structure	160	LF	15	11	22	50					57	67	
25	Excavation	30,340	CY	1800	20	23	50					61	70	
26	Channel Excavation/Grading	600	CY	200	4	24	25					60	63	
27	New Box Culverts (2.3.4)	465	LF	200	3	26	100					64	66	
28	Storm Sewer Pipes & TEP	805	LF	300	3	26	100					64	66	
29	Storm Sewer Inlets/Manholes	14.54	EA	10	2	27	50					66	67	
30	Bridge Structure	1	LS	0.025	40	27	50					96	105	
31	Cofferdam	178	SY	100	2	30	55					88	89	
32	Piling	165	LF	200	1	31	25					89	89	
33	Footings	43	CY	10	5	30	55					90	94	
34	Caps & Beels	57	CY	7	8	33	25					92	100	
35	Wingwalls	278	SP	135	3	34	35					96	98	
36	Beams	718	LF	200	4	35	35					98	101	
37	Bridge Deck	84	CY	10	6	36	35					100	108	
38	Bridge Curb/Handrails	74	LF	200	1	37	25					103	103	
39	Embankment	10,285	CY	2000	5	37	100					109	109	
40	Flex Base	19,682	SY	2000	7	39	30					135	141	
41	HMAC Base	19,682	SY	4000	7	40	75					141	145	
42	Concrete Pavement	17,147	SY	3000	6	41	50					144	149	
43	Block Sot/CMT	8,747	SY	2000	4	42	15					145	148	
44	Interchange/ Signs PT	1	EA	0.03	34	42	100					150	183	
45	Small Signs	1	EA	5	1	44	100					184	184	
46	Pavement Markings	12,095	LF	10000	2	43	100					152	151	
47	Final Clean-up Phase 2	42	STA	30	2	45	100	44	100			185	185	
48	Initial Traffic Control Phase 3	1	LS	0.5	2	47	100					187	188	
49	Erosion Control - Phase 3	10,810	SY	1330	8	48	30					188	196	
50	Detouring - Phase 3	1	LS	0.25	4	49	50					193	196	
51	Prep ROW	10	AC	3	4	49	100					197	200	
52	Temporary Drainage/Storage	12	SY	40	1	51	50					199	199	
53	Remove old Pavement	12,381	SY	2000	7	51	75					200	206	
54	Remove Old drainage Structure	1,154	SY	75	16	52	50					199	214	
55	Remove Old drainage Structure	845	LF	15	60	52	50					200	219	
56	Excavation	18,038	CY	1100	10	53	50					220	228	
57	Box Culvert Extension	51	LF	35	2	53	50					230	231	
58	Storm Sewer Pipes & TEP	2,087	LF	300	7	53	100					230	233	
59	Storm Sewer Inlets/Manholes	8	EA	10	1	54	25					233	239	
60	Embankment	4,616	CY	200	24	55	100					235	259	
61	Flex Base	21,201	SY	2000	10	55	50					237	259	
62	HMAC Base	21,201	SY	4000	8	61	75					238	252	
63	Concrete Pavement	19,518	SY	3000	7	62	50					231	237	
64	Block Sot/CMT	3,138	SY	2000	2	63	75					237	238	
65	Interchange/ Signs PT	1	EA	0.03	34	63	100					238	271	
66	Small Signs	1	EA	5	1	64	100					272	272	
67	Pavement Markings	3,925	LF	10000	1	65	100					272	272	
68	Final Clean-up	37	STA	30	2	68	100	65	100			273	274	
69														

Working Days = 274
 Total Working Days = 274 x 1.22 = 334.28 days
 Barricades: 5 day = 21 days per month
 = 334.28 / 21 = 15.92 = 16 months
 Virginia Baldreas
 1/14/15

Contract Time Estimate

Rd: US 80 & IH 635

County: Dallas

CSJ: 0095-02-102

Project:

													2
TASK #	Description	Quantity	Unit	Daily Rate	Duration	Pred Task	% Comp	Pred Task	% Comp	Pred Task	% Comp	Start Day	Finish Day
1	Initial Traffic Control Phase 1	1	LS	0.5	2							1	2
2	Erosion Ctrl - Phase 1	3,087	SY	1330	3							1	3
3	Detours Widening Phase 1	1	LS	0.25	4	2	50					3	6
4	Prep ROW	3	AC	3	1	2	100					4	4
5	Temporary Drainage/Shoring	690	SY	40	18	4	50					5	22
6	Remove old Pavement	1,821	SY	2000	1	4	75					5	5
7	Excavation	5,640	CY	1900	4	5	50					14	17
8	New Box Culvert Extension	108	LF	35	4	7	25					15	18
9	Storm Sewer Pipes & TEP	936	LF	300	4	7	100					18	21
10	Storm Sewer Inlets/Manholes	39	EA	10	4	9	50					20	23
11	Embankment	223	CY	200	2	10	100					24	25
12	Flex Base	5,821	SY	3000	2	11	50					25	26
13	HMAC Base	5,821	SY	4000	2	12	75					27	28
14	Concrete Pavement	5,022	SY	3000	2	13	50					28	29
15	Block Sod/CMT	19,430	SY	2000	10	14	75					30	39
16	Small Signs	4	EA	5	1	15	100					40	40
17	Pavement Markings	6,667	LF	10000	1	14	100					30	30
18	Final Clean-up Phase 1	11	STA	30	1	16	100	17	100			41	41
19	Initial Traffic Control Phase 2	1	LS	0.5	2	18	100					42	43
20	Erosion Ctrl - Phase 2	14,436	SY	1330	11	19	50					43	53
21	Detours Widening Phase 2	1	LS	0.25	4	20	25					48	49
22	Prep ROW	18	AC	3	8	20	100					54	59
23	Remove old Pavement	8170	SY	2000	4	21	75					49	52
24	Remove Old drainage Structure	180	LF	15	11	22	50					57	67
25	Excavation	36340	CY	1900	20	23	50					51	70
26	Channel Excavation/Grading	800	CY	200	4	24	25					60	63
27	New Box Culverts (2,3,4)	485	LF	200	3	25	100					64	68
28	Storm Sewer Pipes & TEP	825	LF	300	3	26	100					64	68
29	Storm Sewer Inlets/Manholes	14	EA	10	2	27	50					66	67
30	Bridge Structure	1	LS	0.025	40	27	50					66	105
31	Cofferdam	178	SY	100	2	30	55					88	89
32	Piling	165	LF	200	1	31	25					89	89
33	Footings	43	CY	10	5	32	55					90	94
34	Caps & Bents	57	CY	7	9	33	25					92	100
35	Wingwalls	275	SF	125	3	34	35					96	98
36	Beams	718	LF	200	4	35	35					98	101
37	Bridge Deck	84	CY	10	9	36	35					100	108
38	Bridge Curb/Handrails	74	LF	200	1	37	25					103	103
39	Embankment	10,280	CY	200	52	37	100					109	160
40	Flex Base	18,882	SY	3000	7	39	50					135	141

39	Embankment	10,280	CY	200	52	37	100					109	180
40	Flex Base	18,882	SY	3000	7	39	50					135	141
41	HMAC Base	18,882	SY	4000	5	40	75					141	145
42	Concrete Pavement	17,147	SY	3000	6	41	50					144	149
43	Block Sod/CMT	8,747	SY	2000	4	42	15					145	148
44	Intersections/ Signals PT	1	EA	0.03	34	42	100					150	183
45	Small Signs	1	EA	5	1	44	100					184	184
46	Pavement Markings	12,086	LF	10000	2	42	100					150	151
47	Final Clean-up Phase 2	40	STA	30	2	45	100	44	100			185	186
48	Initial Traffic Control Phase 3	1	LS	0.5	2	47	100					187	188
49	Erosion Control - Phase 3	10,910	SY	1330	9	48	50					188	196
50	Detour widening - Phase 3	1	LS	0.25	4	49	50					193	196
51	Prep ROW	10	AC	3	4	49	100					197	200
52	Temporary Drainage/Shoring	12	SY	40	1	51	50					199	199
53	Remove old Pavement	12,381	SY	2000	7	51	75					200	206
54	Remove old Driveways	1,164	SY	75	15	51	50					199	214
55	Remove Old drainage Structure	886	LF	15	60	52	50					200	259
56	Excavation	18,030	CY	1900	10	55	50					230	239
57	Exist. Bridge Class Culvert Ext.	51	LF	35	2	55	50					230	231
58	Storm Sewer Pipes & TEP	2,087	LF	300	7	53	100					207	213
59	Storm Sewer Inlets/Manholes	8	EA	10	1	58	25					209	209
60	Embankment	4,628	CY	200	24	59	100					210	233
61	Flex Base	21,201	SY	3000	8	60	50					222	229
62	HMAC Base	21,201	SY	4000	8	61	75					228	233
63	Concrete Pavement	19,518	SY	3000	7	62	50					231	237
64	Block Sod/CMT	3,138	SY	2000	2	63	75					237	238
65	Intersections/ Signals PT	1	EA	0.03	34	63	100					238	271
66	Small Signs	4	EA	5	1	65	100					272	272
67	Pavement Markings	3,925	LF	10000	1	65	100					272	272
68	Final Clean-up	37	STA	30	2	66	80	65	100			273	274

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APPENDIX H: US287 PROJECT SEQUENCE OF CONSTRUCTION

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GENERAL NOTES:

1. REFER TO THE DC STANDARDS, WORK ZONE STANDARDS, TCP STANDARDS, AND THE TEXAS MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES (TMUTCD) FOR DETAILS REGARDING TRAFFIC CONTROL DEVICES USED IN CONSTRUCTION.
2. MODIFY TCP AND CONSTRUCTION PHASING ONLY AS DIRECTED.
3. PLACE ADVANCED WARNING SIGNS ACCORDING TO DC STANDARDS AND STORM WATER POLLUTION PREVENTION (SWPP) DEVICES PRIOR TO THE START OF CONSTRUCTION.
4. PLACE PHASE TRAFFIC CONTROL DEVICES PRIOR MOVING TRAFFIC AND BEGINNING PHASED CONSTRUCTION.
5. REMOVE EXISTING PAVEMENT MARKING AND SIGNS CONFLICTING WITH WORK ZONE PAVEMENT MARKING AND TEMPORARY SIGNS.
6. MAINTAIN SIGNS IN PLACE FOR THE DURATION OF CONSTRUCTION OR UNTIL THE SIGNS ARE REPLACED BY OTHER SIGNING.
7. MAINTAIN EXISTING DRAINAGE.
8. LIMIT TRAFFIC DISRUPTION DURING CONSTRUCTION OF INTERSECTIONS.
9. PROVIDE ACCESS TO PRIVATE PROPERTY AT ALL TIMES. MATERIALS, MAINTENANCE AND LABOR FOR TEMPORARY ACCESS IS SUBSIDIARY.
10. PROVIDE TEMPORARY PAVEMENT WITH A MAXIMUM 10:1 RAMP SLOPE TO TRANSITION BETWEEN EXISTING PAVEMENT AND PROPOSED PAVEMENT CONSTRUCTION.

PHASE 1

PHASE 1A TRAFFIC MAINTENANCE:

US 287 TRAFFIC WILL REMAIN ON EXISTING LANES IN EXISTING CONFIGURATION EXCEPT BETWEEN US 287 STATIONS 1067+38 AND 1071+80 NB US 287 TRAFFIC WILL USE TEMPORARY DETOUR #1 TO OLD ALMA ROAD AND DETOURS 1250+11 AND 1254+48 NB US 287 TRAFFIC WILL USE TEMPORARY DETOUR #8 TO ACCESS US 287.

PHASE 1A WORK SEQUENCE:

1. CONSTRUCT TEMPORARY DETOUR #1 AND TEMPORARY DETOUR #8. MAINTAIN DETOURS AS NEEDED OR AS DIRECTED.
2. SHIFT NB US 287 TRAFFIC ONTO DETOUR #1 AND DETOUR #8. CLOSE NB US 287 BETWEEN STA. 1070+00 AND STA. 1085+00 AND STA. 1240+00 AND STA. 1253+00.
3. CONSTRUCT UPSTREAM SECTION OF CULVERTS C4, C5, C6, AND C7. SEE SHORING DETAILS FOR LIMITS OF PHASE 1 CONSTRUCTION.
4. CONSTRUCT PHASE 1A NB US 287, NB RAMP#S IENS-N287, STE-N287, AND N287-STE), NB FRONTAGE ROAD INCLUDING DRAINAGE, NB FRONTAGE ROAD RETAINING WALLS, STORM SEWER, DRIVEWAYS AND SAFETY LIGHTING. CONSTRUCT DOWNSTREAM STORM SEWER SEGMENTS FIRST AND PROVIDE FOR TEMPORARY DRAINAGE AS SHOWN OR AS DIRECTED. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH 1" OF D-CR HMA TY C AND THE LAST 1" OF D-CR HMA TY C PRIOR TO PLACING PERMANENT PAVEMENT MARKINGS IN PHASE 3.
5. CONSTRUCT PROPOSED NB FRONTAGE ROAD BRIDGES OVER CUMMINS CREEK, CUMMINS CREEK TRIBUTARY #1 AND CUMMINS CREEK TRIBUTARY #2.
6. CONSTRUCT PORTIONS OF NB FRONTAGE ROAD INTERSECTIONS WITH ENSIGN ROAD, OAK GROVE ROAD, AND STERILITE ROAD. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH 1" OF D-CR HMA TY C. CONSTRUCT ANY REQUIRED TEMPORARY PAVEMENT PRIOR TO BEGINNING INTERSECTION CONSTRUCTION. ONCE CONSTRUCTION BEGINS AT AN INTERSECTION, COMPLETE PHASED CONSTRUCTION AND CONTINUE TO THE NEXT PHASE OF INTERSECTION. COMPLETE PHASED CONSTRUCTION AND CONTINUE TO THE NEXT PHASE OF INTERSECTION CONSTRUCTION AS SOON AS POSSIBLE WITH MINIMAL DELAY BETWEEN PHASES. CONSTRUCT INTERSECTIONS IN A MANNER WHICH LIMITS TRAFFIC DISRUPTION OR AS DIRECTED.
7. CONSTRUCT SOUTH SIDE OF OLD ALMA ROAD HALF-WIDTH.

PHASE 1B TO 1C WORK SEQUENCE:

COMPLETE CONSTRUCTION OF THE NB FRONTAGE ROAD INTERSECTIONS AND DETOURS AS OUTLINED BELOW. INTERSECTION PAVEMENT CONSTRUCTED IN THIS PHASE IS NEEDED TO PROVIDE FOR THE CONTINUOUS FLOW OF TRAFFIC THROUGH THE NEWLY CONSTRUCTED NB FRONTAGE ROAD IN THE NEXT PHASE. SEE LAYOUT SHEETS FOR LIMITS.

1. SHIFT INTERSECTION TRAFFIC ONTO PAVEMENT CONSTRUCTED IN PHASE 1A.
2. CONSTRUCT REMAINING PORTIONS OF THE NB FRONTAGE ROAD INTERSECTIONS WITH ENSIGN ROAD, OAK GROVE ROAD AND STERILITE ROAD. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH 1" OF D-CR HMA TY C.
3. COMPLETE CONSTRUCTION OF OLD ALMA ROAD.
4. CONSTRUCT DETOURS #2, #4 AND #7.
5. INSTALL TEMPORARY TRAFFIC SIGNALS.
6. PLACE PERMANENT PAVEMENT MARKINGS AT ENSIGN ROAD, OAK GROVE ROAD AND STERILITE ROAD INTERSECTIONS BETWEEN NORTH SIDE CONSTRUCTION LIMIT AND NB FRONTAGE ROAD INTERSECTION.

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PHASE 2

PHASE 2A TRAFFIC MAINTENANCE:

DURING THIS PHASE, THE US 287 TWO-WAY TRAFFIC WILL BE ROUTED ONTO THE NEWLY CONSTRUCTED PORTIONS OF THE NB MAINLANE AND THE NB FRONTAGE ROAD USING DETOURS #2, #4 AND #7. TRAFFIC WILL UTILIZE NB FRONTAGE ROADS AND DETOURS TO ACCESS INTERSECTIONS. MAINTAIN DETOURS AS NEEDED OR AS DIRECTED.

PHASE 2A WORK SEQUENCE:

1. CONSTRUCT PHASE 2A NB US 287, SB US 287, NB FRONTAGE ROAD, SB FRONTAGE ROAD INTERSECTIONS. US 287 NB AND SB BRIDGES, NB AND SB US 287 RETAINING WALLS, STORM SEWER AND CULVERTS AS OUTLINED BELOW. BRIDGE WORK AND ROADWAY WORK CAN BE CONSTRUCTED CONCURRENTLY OR AS DIRECTED.
1. SHIFT NB AND SB US 287 TRAFFIC TO ROADWAY SEGMENTS CONSTRUCTED IN PHASE 1 USING DETOURS #2, #4 AND #7. SHIFT INTERSECTION TRAFFIC TO PAVEMENT CONSTRUCTED IN PHASE 1 AS SHOWN IN LAYOUT.
2. CONSTRUCT UPSTREAM SECTION OF CULVERT C3. DOWNSTREAM SECTIONS OF CULVERTS C4, C5, C6, AND C7 AND UPSTREAM AND DOWNSTREAM SECTIONS OF CULVERTS C2A, C2B, C2C AND C2D. SEE SHORING DETAILS FOR LIMITS OF PHASE 2 CONSTRUCTION.
3. CONSTRUCT PHASE 2A NB US 287, SB US 287, NB RAMP#S N287-ENS, NB FRONTAGE ROAD, US 287 RETAINING WALLS, STORM SEWER AND SAFETY LIGHTING. CONSTRUCT DOWNSTREAM STORM SEWER SEGMENTS FIRST. PROVIDE FOR TEMPORARY DRAINAGE AS SHOWN OR AS DIRECTED. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH FINAL SURFACE 12" OF D-CR HMA TY C.
4. CONSTRUCT PROPOSED NB AND SB MAINLANE BRIDGES OVER ENSIGN ROAD, CUMMINS CREEK, OAK GROVE ROAD, CUMMINS CREEK TRIBUTARY #1, STERILITE ROAD AND CUMMINS CREEK TRIBUTARY #2.
5. CONSTRUCT PORTIONS OF THE SB FRONTAGE ROAD INTERSECTIONS WITH ENSIGN ROAD, OAK GROVE ROAD AND STERILITE ROAD. CONSTRUCT ANY REQUIRED TEMPORARY PAVEMENT PRIOR TO BEGINNING INTERSECTION CONSTRUCTION. ONCE CONSTRUCTION BEGINS AT AN INTERSECTION, COMPLETE PHASED CONSTRUCTION AND CONTINUE TO THE NEXT PHASE OF INTERSECTION. COMPLETE PHASED CONSTRUCTION AND CONTINUE TO THE NEXT PHASE OF INTERSECTION CONSTRUCTION AS SOON AS POSSIBLE WITH MINIMAL DELAY BETWEEN PHASES. CONSTRUCT INTERSECTIONS IN A MANNER WHICH LIMITS TRAFFIC DISRUPTION OR AS DIRECTED.

PHASE 2B TRAFFIC MAINTENANCE:

TRAFFIC WILL NOT SHIFT DURING THIS PHASE BUT WILL REMAIN ON THE NEWLY CONSTRUCTED PORTIONS OF THE NB MAINLANE AND THE NB FRONTAGE ROAD USING DETOURS #2, #4 AND #7. TRAFFIC WILL UTILIZE NB FRONTAGE ROADS AND DETOURS TO ACCESS INTERSECTIONS. MAINTAIN DETOURS AS NEEDED OR AS DIRECTED.

PHASE 2B TO 2D WORK SEQUENCE:

CONSTRUCT PHASE 2B THROUGH NB US 287, SB FRONTAGE ROAD, SB RAMP#S, SB FRONTAGE ROAD BRIDGES, SB FRONTAGE ROAD INTERSECTIONS, STORM SEWER AND CULVERTS AS OUTLINED BELOW. ROADWAY WORK AND BRIDGE WORK CAN BE CONSTRUCTED CONCURRENTLY OR AS DIRECTED.

1. CONSTRUCT DOWNSTREAM SECTIONS OF CULVERTS C1, C2, AND C3. SEE SHORING DETAILS FOR LIMITS OF PHASE 2 CONSTRUCTION.
2. CONSTRUCT PHASE 2B NB MAIN LANE PROPOSED PAVEMENT.
3. CONSTRUCT PHASE 2B SB FRONTAGE ROAD PROPOSED PAVEMENT, SB RAMP#S IENS-S287, S287-ENS, STE-S287, AND S287-STE), STORM SEWER, DRIVEWAYS AND SAFETY LIGHTING. CONSTRUCT DOWNSTREAM STORM SEWER SEGMENTS FIRST. PROVIDE FOR TEMPORARY DRAINAGE AS SHOWN OR AS DIRECTED. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH FINAL SURFACE 12" OF D-CR HMA TY C.
4. CONSTRUCT PROPOSED SB FRONTAGE ROAD BRIDGES OVER CUMMINS CREEK, CUMMINS CREEK TRIBUTARY #1 AND CUMMINS CREEK TRIBUTARY #2.
5. CONSTRUCT REMAINING PORTIONS OF THE SB FRONTAGE ROAD INTERSECTIONS WITH ENSIGN ROAD, OAK GROVE ROAD AND STERILITE ROAD. FOR CONSTRUCTION OF STERILITE ROAD IN PHASE 2D, USE DETOUR PROVIDED IN THE PLANS.
6. PLACE PERMANENT STRIPING ON NB US 287, SB US 287, SB RAMP#S, NB RAMP#S N287-ENS, SB FRONTAGE ROAD PAVEMENT CONSTRUCTED IN PHASE 2.

PHASE 3

PHASE 3A TRAFFIC MAINTENANCE:

DURING THIS PHASE, TRAFFIC WILL BE SHIFTED TO ITS FINAL POSITION. NB TRAFFIC WILL BE SHIFTED TO THE NB MAIN LANE AND SB TRAFFIC WILL BE SHIFTED TO THE SB MAIN LANE. OPEN NB AND SB FRONTAGE ROADS TO TRAFFIC.

PHASE 3 WORK SEQUENCE:

CONSTRUCT PHASE 3 SB FRONTAGE ROAD, RAMP#S S287-E, AND FINAL OVERLAY OF PAVEMENT CONSTRUCTED IN PHASE 1 AS OUTLINED BELOW.

1. SHIFT ALL TRAFFIC TO ITS FINAL POSITION AND REMOVE TEMPORARY SIGNALS.
2. CONSTRUCT REMAINING PORTION OF SB FRONTAGE ROAD PAVEMENT AT S287-E AND RAMP#S S287-E. CONSTRUCT ASPHALT PAVEMENT FROM FLEX BASE THROUGH FINAL SURFACE 12" OF D-CR HMA TY C. PLACE PERMANENT STRIPING.
3. CONSTRUCT FINAL 1" D-CR HMA TY C OVERLAY PLACE PERMANENT STRIPING ON PAVEMENT CONSTRUCTED IN PHASE 1 WHICH INCLUDES PORTIONS OF NB US 287, SB US 287, NB RAMP#S IENS-N287, STE-N287, AND N287-STE), NB FRONTAGE ROAD AND NB FRONTAGE ROAD INTERSECTIONS. OPEN ALL LANES TO TRAFFIC AT THE END OF EACH DAY AND CONDUCT OVERLAY OPERATION IN A MANNER WHICH LIMITS TRAFFIC DISRUPTION OR AS DIRECTED.
4. CONSTRUCT DOWLED CURB AT ENSIGN ROAD, OAK GROVE ROAD AND STERILITE ROAD INTERSECTIONS.
5. REMOVE ALL TRAFFIC CONTROL DEVICES, TEMPORARY SIGNS AND SWP DEVICES.

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STATE OF TEXAS
M. PAULINE MORRIS
94443
COMMISSIONER
JANUARY 1, 2015

MPMoul
SIGNED BY REGISTERED PROFESSIONAL ENGINEER

Texas Department of Transportation

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US 287 TCP

NARRATIVE

SHEET 1 OF 1			
REGION	REG. NO.	FEDERAL AID PROJECT NO.	RIGHTWAY
06	6	SEE TITLESHEET	US 287
CHECK	STATE	DISTRICT	COUNTY
	TEXAS	DALLAS	ELLIS
CHECK	CONTROL	SECTION	JOB
	0172	08	053

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APPENDIX I: US 287 PROJECT WBS

	Activities	Units	Quantities
Phase 1 A	Erosion CTRL (SW3P)	LF	7,662.00
Stations: 232	Construct detour widening (Asphalt pavement)	TON	431.46
	Initial Traffic controls	LS	1.00
	Prep ROW	AC	50.00
	Remove concrete pavement	SY	3,522.00
	Remove asphalt pavement	SY	13,331.00
	Excavation	CY	60,924.00
	Temporary Shoring	SF	190.50
	Riprap	CY	853.60
	Culvert extensions	LF	1,356.50
	Storm Sewer pipes & TEP	LF	2,518.00
	Storm sewer Inlets/Manholes	EA	13.00
	Embankment (C1)	CY	191,928.75
	Temporary Shoring	SF	5,474.00
	MSE walls	SF	2,118.00
	Embankment (C2)	CY	11,837.00
	Approach slab	CY	192.44
	Railing	LF	2,114.00
	Flex base	CY	40,163.05
	Prime coat	GAL	18,456.55
	HMA 64-22	TON	30,264.00
	HMA 70-22 (1")	TON	4,037.63
	Concrete curb and gutter	LF	15,627.81
	Cummins creek NBFR	LS	1.00
	Cummins Trib 1 NBFR	LS	1.00
	Cummins Trib 2 NBFR	LS	1.00
	Bridge Sidewalk	LF	894.15
	Sidewalk	SY	9,282.19
	Lighting	EA	22.00
	Small signs	EA	28.00
	Overhead Signs	EA	4.00
	Temp pavement markings	LF	32,010.00
	Seeding and landscape	SY	105,891.50
	Clean-up	STA	232.00
	Phasing allowance	DAYS/PHASE	3.00

Phase 1 B and 1			
C	Traffic controls	LS	1.00
Stations: 25	Flex base	CY	2,008.15
	Prime coat	GAL	922.83
	Superpave 64-22	TON	1,513.20
	Superpave 70-22 (1")	TON	201.88
	Concrete pavement	SY	10,445.67
	Concrete medians	SY	243.00
	Construct detour widening (Asphalt pavement)	TON	396.61
	Small signs	EA	41.00
	Seeding and landscape	SY	5,294.58
	Pavement Markings	LF	8,002.50
	Clean-up	STA	25.00
	Phasing allowance	DAYS/PHASE	1.00

	Activities	Units	Quantities
Phase 2 A	Erosion CTRL (SW3P)	SY	9,987.00
Stations: 232	Initial Traffic controls	LS	1.00
	Prep ROW	AC	100.00
	Remove asphalt pavement	SY	101,026.00
	Excavation	CY	109,457.00
	Temporary Shoring	SF	870.00
	Riprap	CY	2,651.00
	Culvert extensions	LF	3,822.50
	Storm Sewer pipes & TEP	LF	15,210.00
	Storm sewer	EA	87.00
	Inlets/Manholes	EA	87.00
	Embankment (C1)	CY	401,603.00
	Temporary Shoring	SF	25,789.00
	MSE walls	SF	90,888.00
	Embankment (C2)	CY	106,533.00
	Approach slab	LS	12.00
	Railing	LF	8,225.00
	Flex base	CY	85,291.50
	Prime coat	GAL	39,135.50
	HMA 64-22	TON	63,349.50
	HMA 70-22 (2")	TON	17,168.00
	Concrete curb and gutter	LF	9,376.69
	Ensign O.P NBML	LS	1.00
	Ensign O.P SBML	LS	1.00

Cummins creek NBML	LS	1.00
Cummins creek SBML	LS	1.00
Oak Grove O.P NBML	LS	1.00
Oak Grove O.P SBML	LS	1.00
Cummins CK Trib 1 NBML	LS	1.00
Cummins CK Trib 1 SBML	LS	1.00
Sterlite O.P NBML	LS	1.00
Sterlite O.P SBML	LS	1.00
Cummins CK Trib 2 NBML	LS	1.00
Cummins CK Trib 2 SBML	LS	1.00
Sidewalk	SY	5,569.31
Small signs	EA	50.00
Overhead signs	EA	13.00
Lighting	EA	15.00
Pavement markings	LF	80,025.00
Seeding and landscape	SY	229,799.50
Clean-up	STA	232.00
Phasing allowance	DAYS/PHASE	3.00

	Activities	Units	Quantities
Phase 2 B Stations: 232	Erosion CTRL (SW3P)	SY	7,373.00
	Initial Traffic controls	LS	1.00
	Prep ROW	AC	50.00
	Remove asphalt pavement	SY	7,963.00
	Excavation	CY	57,668.50
	Temporary Shoring	SF	1,308.50
	Riprap	CY	1,223.40
	Culvert extensions	LF	2,053.00
	Storm Sewer pipes & TEP	LF	2,999.00
	Storm sewer	EA	20.00
	Inlets/Manholes	EA	20.00
	Embankment (C1)	CY	208,727.75
	Approach slab	CY	197.84
	Flex base	CY	45,031.83
	Prime coat	GAL	20,634.24
	HMA 64-22	TON	33,670.50
	HMA 70-22 (2")	TON	9,295.25
	Concrete curb and gutter	LF	25,004.50
	Cummins creek SBFR	LS	1.00
	Cummins Trib 1 SBFR	LS	1.00

	Cummins Trib 2 SBFR	LS	1.00
	Railings	LF	1,731.00
	Bridge Sidewalk	LF	927.08
	Sidewalks	SY	14,851.50
	Small signs	EA	17.00
	Lighting	EA	10.00
	Pavement markings	LF	39,212.25
	Seeding and landscape	SY	122,139.50
	Clean-up	STA	232.00
	Phasing allowance	DAYS/PHASE	3.00
Phase 2 C	Traffic controls	LS	1.00
Stations: 25	Flex base	CY	459.40
	Prime coat	GAL	210.55
	Concrete pavement	SY	10,445.67
	Pavement Markings	LF	4,001.25
	Clean-up	STA	25.00
	Phasing allowance	DAYS/PHASE	1.00
Phase 2 D	Traffic controls	LS	1.00
Stations: 25	Flex base	CY	459.40
	Prime coat	GAL	210.55
	Concrete pavement	SY	10,445.67
	Concrete medians	SY	243.00
	Small signs	EA	45.00
	Pavement Markings	LF	4,001.25
	Clean-up	STA	25.00
	Phasing allowance	DAYS/PHASE	1.00
	Activities	Units	Quantities
Phase 3	Erosion CTRL (SW3P)	SY	100.00
Stations: 232	Initial Traffic controls	LS	1.00
	Prep ROW	AC	3.00
	Excavation	CY	706.50
	Embankment (C1)	CY	4,390.50
	Flex base	CY	1,308.60
	Prime coat	GAL	591.60
	HMA 64-22	TON	774.00
	HMA 70-22 (1")	TON	4,321.13
	Small signs	EA	1.00
	Lighting	EA	1.00

Permanent pavement markings	LF	32,010.00
Seeding and landscape	SY	3,187.50
Clean-up	STA	232.00

APPENDIX J: US 287 PROJECT WBS – BRIDGES AND OVERPASSES

Phase 1A:

Activities	Units	Quantities
Cummins creek NBFR		
Drill shaft	LF	929
Mobilization buffer time		
Abutment	CY	60.8
Bents	CY	40.1
Concrete curing time		
Beam erection	LF	1492.5
RC Slab	SF	12150
Bridge rail	LF	664
Cummins Trib 1 NBFR		
Drill shaft	LF	1009
Mobilization buffer time		
Abutment	CY	64.9
Bents	CY	48.6
Concrete curing time		
Beam erection	LF	1417.5
RC Slab	SF	11542
Bridge rail	LF	648
Cummins Trib 2 NBFR		
Drill shaft	LF	1200
Mobilization buffer time		
Abutment	CY	67.8
Bents	CY	45.4
Concrete curing time		
Beam erection	LF	1224.17
RC Slab	SF	10005
Bridge rail	LF	441

Phase 2A:

Activities	Units	Quantities
<hr/> Ensign O.P NBML		
Drill shaft	LF	788
Mobilization buffer time		
Abutment	CY	61.9
Bents	CY	59.4
Concrete curing time		
Beam erection	LF	1605.53
RC Slab	SF	12904
Bridge rail	LF	713.2
<hr/> Ensign O.P SBML		
Drill shaft	LF	788
Mobilization buffer time		
Abutment	CY	61.9
Bents	CY	62.4
Concrete curing time		
Beam erection	LF	1619.48
RC Slab	SF	13016
Bridge rail	LF	719
<hr/> Cummins creek NBML		
Drill shaft	LF	738
Mobilization buffer time		
Abutment	CY	61.9
Bents	CY	46.6
Concrete curing time		
Beam erection	LF	1492.5
RC Slab	SF	12000
Bridge rail	LF	668
<hr/> Cummins creek SBML		
Drill shaft	LF	954
Mobilization buffer time		
Abutment	CY	61.9
Bents	CY	46.6
Concrete curing time		
Beam erection	LF	1492.5
RC Slab	SF	12000
Bridge rail	LF	668
<hr/> Oak Grove O.P NBML		
Drill shaft	LF	1452

Mobilization buffer time		
Abutment	CY	83.2
Bents	CY	64.4
Concrete curing time		
Beam erection	LF	1852.34
RC Slab	SF	14880
Bridge rail	LF	836
Oak Grove O.P SBML		
Drill shaft	LF	1452
Mobilization buffer time		
Abutment	CY	83.2
Bents	CY	64.4
Concrete curing time		
Beam erection	LF	1852.34
RC Slab	SF	14880
Bridge rail	LF	836
Cummins CK Trib 1 NBML		
Drill shaft	LF	914
Mobilization buffer time		
Abutment	CY	69.8
Bents	CY	71.4
Concrete curing time		
Beam erection	LF	1492.19
RC Slab	SF	12000
Bridge rail	LF	677
Cummins CK Trib 1 SBML		
Drill shaft	LF	1222
Mobilization buffer time		
Abutment	CY	69.4
Bents	CY	64.1
Concrete curing time		
Beam erection	LF	1492.19
RC Slab	SF	12000
Bridge rail	LF	676
Sterlite O.P NBML		
Drill shaft	LF	1358
Mobilization buffer time		
Abutment	CY	64.5
Bents	CY	64.4
Concrete curing time		
Beam erection	LF	1795.2

RC Slab	SF	14427
Bridge rail	LF	721.2
Sterlite O.P SBML		
Drill shaft	LF	1358
Mobilization buffer time		
Abutment	CY	64.5
Bents	CY	68.2
Concrete curing time		
Beam erection	LF	1789.54
RC Slab	SF	14378
Bridge rail	LF	718.9
Cummins CK Trib 2 NBML		
Drill shaft	LF	1086
Mobilization buffer time		
Abutment	CY	58.2
Bents	CY	38.9
Concrete curing time		
Beam erection	LF	936.07
RC Slab	SF	7548
Bridge rail	LF	442.4
Cummins CK Trib 2 SBML		
Drill shaft	LF	967
Mobilization buffer time		
Abutment	CY	58.2
Bents	CY	45.1
Concrete curing time		
Beam erection	LF	948.88
RC Slab	SF	7652
Bridge rail	LF	447.6

Phase 2B:

Activities	Units	Quantities
Cummins creek SBFR		
Drill shaft	LF	1026
Mobilization buffer time		
Abutment	CY	60.8
Bents	CY	46.3
Concrete curing time		
Beam erection	LF	1492.5
RC Slab	SF	12150
Bridge rail	LF	664
Cummins Trib 1 SBFR		
Drill shaft	LF	1080
Mobilization buffer time		
Abutment	CY	72.8
Bents	CY	49.5
Concrete curing time		
Beam erection	LF	1872.64
RC Slab	SF	12704
Bridge rail	LF	708
Cummins Trib 2 SBFR		
Drill shaft	LF	873
Mobilization buffer time		
Abutment	CY	56.8
Bents	CY	45.6
Concrete curing time		
Beam erection	LF	940.78
RC Slab	SF	7681
Bridge rail	LF	439

APPENDIX K: US 287 PROJECT WBS WITH DURATION CALCULATION – PHASE 1

	Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Phase 1 A	Erosion CTRL (SW3P)	LF	7,662.00	H	3000	1	3	FLDOT
Stations: 232	Construct detour widening (Asphalt pavement)	TON	431.46	M	883	1	1	PR Resource
	Initial Traffic controls	LS	1.00	L	0.25	1	4	TXCTDS
	Prep ROW	AC	50.00	H	6	1	9	TXCTDS
	Remove concrete pavement	SY	3,522.00	M	2000	1	2	TXCTDS
	Remove asphalt pavement	SY	13,331.00	M	2000	1	7	TXCTDS
	Excavation	CY	60,924.00	M	2794	1	22	PR Resource
	Temporary Shoring	SF	190.50			1	5	-
	Riprap	CY	853.60	M	62	2	7	RSMMeans
	Culvert extensions	LF	1,356.50	M	99	2	7	PR Resource
	Storm Sewer pipes & TEP	LF	2,518.00	M	145	2	9	PR Resource
	Storm sewer Inlets/Manholes	EA	13.00	M	2	1	7	PR Resource
	Embankment (C1)	CY	191,928.75	M	2654.14	2	37	PR Resource
	Temporary Shoring	SF	5,474.00			1	5	-
	MSE walls	SF	2,118.00	M	452.8	1	5	HYPRIS
	Embankment (C2)	CY	11,837.00	M	2654.14	1	5	PR Resource
	Approach slab	CY	192.44			1	15	-
	Railing	LF	2,114.00	M	200	1	11	TXCTDS
	Flex base	CY	40,163.05	M	3539	1	12	PR Resource
	Prime coat	GAL	18,456.55	M	6000	1	4	RSMMeans
	HMA 64-22	TON	30,264.00	M	883	1	35	PR Resource
	HMA 70-22 (1")	TON	4,037.63	M	883	1	5	PR Resource
	Concrete curb and gutter	LF	15,627.81	M	720.9	2	11	PR Resource
	Cummins creek NBFR	LS	1.00				35	
	Cummins Trib 1 NBFR	LS	1.00				37	
	Cummins Trib 2 NBFR	LS	1.00				37	
	Bridge Sidewalk	LF	894.15	M	80	1	12	TXCTDS
	Sidewalk	SY	9,282.19	M	300	2	16	FLDOT
	Lighting	EA	22.00	M	2	1	11	OKCTDS
	Small signs	EA	28.00	M	20	1	2	TXCTDS
	Overhead Signs	EA	4.00	M	1.5	1	3	TXCTDS
	Temp pavement markings	LF	32,010.00	M	9607	1	4	PR Resource
	Seeding and landscape	SY	105,891.50	M	4000	2	14	TXCTDS
	Clean-up	STA	232.00	M	30	1	8	TXCTDS
	Phasing allowance	DAYS/PHASE	3.00	M	3	1	3	KYCTDS
Phase 1 B and 1 C	Traffic controls	LS	1.00	H	1	1	1	TXCTDS
Stations: 25	Flex base	CY	2,008.15	M	3539	1	1	PR Resource
	Prime coat	GAL	922.83	M	6000	1	1	RSMMeans
	Superpave 64-22	TON	1,513.20	M	883	1	2	PR Resource
	Superpave 70-22 (1")	TON	201.88	M	883	1	1	PR Resource
	Concrete pavement	SY	10,445.67	M	2765	1	4	PR Resource
	Concrete medians	SY	243.00			1	5	-
	Construct detour widening (Asphalt pavement)	TON	396.61	M	883	1	1	PR Resource
	Small signs	EA	41.00	M	20	1	3	TXCTDS
	Seeding and landscape	SY	5,294.58	M	4000	1	2	TXCTDS
	Pavement Markings	LF	8,002.50	M	9607	1	1	PR Resource
	Clean-up	STA	25.00	M	30	1	1	TXCTDS
	Phasing allowance	DAYS/PHASE	1.00	H	1	1	1	KYCTDS

APPENDIX L: US 287 PROJECT WBS WITH DURATION CALCULATION – PHASE 2

	Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Phase 2 A	Erosion CTRL (SW3P)	SY	9,987.00	H	3000	1	4	FLDOT
Stations: 232	Initial Traffic controls	LS	1.00	L	0.25	1	4	TXCTDS
	Prep ROW	AC	100.00	H	6	1	17	TXCTDS
	Remove asphalt pavement	SY	101,026.00	M	2000	2	26	TXCTDS
	Excavation	CY	109,457.00	M	2794	1	40	PR Resource
	Temporary Shoring	SF	870.00			1	5	-
	Riprap	CY	2,651.00	M	62	2	22	RSMeans
	Culvert extensions	LF	3,822.50	M	99	2	20	PR Resource
	Storm Sewer pipes & TEP	LF	15,210.00	M	145	2	53	PR Resource
	Storm sewer Inlets/Manholes	EA	87.00	M	2	2	22	PR Resource
	Embankment (C1)	CY	401,603.00	M	2654.14	2	76	PR Resource
	Temporary Shoring	SF	25,789.00			1	15	-
	MSE walls	SF	90,888.00	M	452.8	2	101	HYPRIS
	Embankment (C2)	CY	106,533.00	M	2654.14	1	41	PR Resource
	Approach slab	LS	12.00		0.2	2	30	-
	Railing	LF	8,225.00	M	200	2	21	TXCTDS
	Flex base	CY	85,291.50	M	3539	2	13	PR Resource
	Prime coat	GAL	39,135.50	M	6000	2	4	RSMeans
	HMA 64-22	TON	63,349.50	M	883	2	36	PR Resource
	HMA 70-22 (2")	TON	17,168.00	M	883	2	10	PR Resource
	Concrete curb and gutter	LF	9,376.69	M	720.9	2	7	PR Resource
	Ensign O.P NBML	LS	1.00				37	
	Ensign O.P SBML	LS	1.00				37	
	Cummins creek NBML	LS	1.00				35	
	Cummins creek SBML	LS	1.00				36	
	Oak Grove O.P NBML	LS	1.00				45	
	Oak Grove O.P SBML	LS	1.00				45	
	Cummins CK Trib 1 NBML	LS	1.00				39	
	Cummins CK Trib 1 SBML	LS	1.00				41	
	Sterlite O.P NBML	LS	1.00				42	
	Sterlite O.P SBML	LS	1.00				42	
	Cummins CK Trib 2 NBML	LS	1.00				34	
	Cummins CK Trib 2 SBML	LS	1.00				33	
	Sidewalk	SY	5,569.31	M	300	1	19	FLDOT
	Small signs	EA	50.00	M	20	1	3	TXCTDS
	Overhead signs	EA	13.00	M	1.5	1	9	TXCTDS
	Lighting	EA	15.00	M	2	1	8	OKCTDS
	Pavement markings	LF	80,025.00	M	9607	1	9	PR Resource
	Seeding and landscape	SY	229,799.50	M	4000	2	29	TXCTDS
	Clean-up	STA	232.00	M	30	1	8	TXCTDS
	Phasing allowance	DAYS/PHASE	3.00	M	3	1	3	KYCTDS

	Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Phase 2 B	Erosion CTRL (SW3P)	SY	7,373.00	H	3000	1	3	FLDOT
Stations: 232	Initial Traffic controls	LS	1.00	M	0.5	1	2	TXCTDS
	Prep ROW	AC	50.00	H	6	1	9	TXCTDS
	Remove asphalt pavement	SY	7,963.00	M	2000	1	4	TXCTDS
	Excavation	CY	57,668.50	M	2794	1	21	PR Resource
	Temporary Shoring	SF	1,308.50			1	5	-
	Riprap	CY	1,223.40	M	62	2	10	RSMMeans
	Culvert extensions	LF	2,053.00	M	99	2	11	PR Resource
	Storm Sewer pipes & TEP	LF	2,999.00	M	145	2	11	PR Resource
	Storm sewer Inlets/Manholes	EA	20.00	M	2	1	10	PR Resource
	Embankment (C1)	CY	208,727.75	M	2654.14	2	40	PR Resource
	Approach slab	CY	197.84			1	15	-
	Flex base	CY	45,031.83	M	3539	1	13	PR Resource
	Prime coat	GAL	20,634.24	M	6000	1	4	RSMMeans
	HMA 64-22	TON	33,670.50	M	883	1	39	PR Resource
	HMA 70-22 (2")	TON	9,295.25	M	883	1	11	PR Resource
	Concrete curb and gutter	LF	25,004.50	M	720.9	2	18	PR Resource
	Cummins creek SBFR	LS	1.00				36	
	Cummins Trib 1 SBFR	LS	1.00				39	
	Cummins Trib 2 SBFR	LS	1.00				33	
	Railings	LF	1,731.00	M	200	1	9	TXCTDS
	Bridge Sidewalk	LF	927.08	M	80	1	12	TXCTDS
	Sidewalks	SY	14,851.50	M	300	2	25	FLDOT
	Small signs	EA	17.00	M	20	1	1	TXCTDS
	Lighting	EA	10.00	M	2	1	5	OKCTDS
	Pavement markings	LF	39,212.25	M	9607	1	5	PR Resource
	Seeding and landscape	SY	122,139.50	M	4000	2	16	TXCTDS
	Clean-up	STA	232.00	M	30	1	8	TXCTDS
	Phasing allowance	DAYS/PHASE	3.00	M	3	1	3	KYCTDS
Phase 2 C	Traffic controls	LS	1.00	H	1	1	1	TXCTDS
Stations: 25	Flex base	CY	459.40	M	3539	1	1	PR Resource
	Prime coat	GAL	210.55	M	6000	1	1	RSMMeans
	Concrete pavement	SY	10,445.67	M	2765	1	4	PR Resource
	Pavement Markings	LF	4,001.25	M	9607	1	1	PR Resource
	Clean-up	STA	25.00	M	30	1	1	TXCTDS
	Phasing allowance	DAYS/PHASE	1.00	H	1	1	1	KYCTDS
Phase 2 D	Traffic controls	LS	1.00	H	1	1	1	TXCTDS
Stations: 25	Flex base	CY	459.40	M	3539	1	1	PR Resource
	Prime coat	GAL	210.55	M	6000	1	1	RSMMeans
	Concrete pavement	SY	10,445.67	M	2765	1	4	PR Resource
	Concrete medians	SY	243.00			1	5	-
	Small signs	EA	45.00	M	20	1	3	TXCTDS
	Pavement Markings	LF	4,001.25	M	9607	1	1	PR Resource
	Clean-up	STA	25.00	M	30	1	1	TXCTDS
	Phasing allowance	DAYS/PHASE	1.00	H	1	1	1	KYCTDS

APPENDIX M: US 287 PROJECT WBS WITH DURATION CALCULATION – PHASE 3

	Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Phase 3	Erosion CTRL (SW3P)	SY	100.00	H	3000	1	1	FLDOT
Stations: 232	Initial Traffic controls	LS	1.00	H	1	1	1	TXCTDS
	Prep ROW	AC	3.00	M	3	1	1	TXCTDS
	Excavation	CY	706.50	M	2794	1	1	PR Resource
	Embankment (C1)	CY	4,390.50	M	2654.14	1	2	PR Resource
	Flex base	CY	1,308.60	M	3539	1	1	PR Resource
	Prime coat	GAL	591.60	M	6000	1	1	RSMeans
	HMA 64-22	TON	774.00	M	883	1	1	PR Resource
	HMA 70-22 (1")	TON	4,321.13	M	883	1	5	PR Resource
	Small signs	EA	1.00	M	20	1	1	TXCTDS
	Lighting	EA	1.00	M	2	1	1	OKCTDS
	Permanent pavement markings	LF	32,010.00	M	9607	1	4	PR Resource
	Seeding and landscape	SY	3,187.50	M	4000	1	1	TXCTDS
	Clean-up	STA	232.00	M	30	1	8	TXCTDS

APPENDIX N: US 287 PROJECT WBS WITH DURATION CALCULATION – BRIDGES

Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Cummins creek NBFR							
Drill shaft	LF	929	M	165	1	6	PR Resource
Mobilization buffer time						1	-
Abutment	CY	60.8	M	3.8	2	8	OKCTDS
Bents	CY	40.1	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.5	M	702	1	3	PR Resource
RC Slab	SF	12150	M	1521	2	4	PR Resource
Bridge rail	LF	664	M	200	2	2	OKCTDS
Cummins creek NBFR Total						35	
Cummins Trib 1 NBFR							
Drill shaft	LF	1009	M	165	1	7	PR Resource
Mobilization buffer time						1	-
Abutment	CY	64.9	M	3.8	2	9	OKCTDS
Bents	CY	48.6	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1417.5	M	702	1	3	PR Resource
RC Slab	SF	11542	M	1521	2	4	PR Resource
Bridge rail	LF	648	M	200	2	2	OKCTDS
Cummins Trib 1 NBFR Total						37	
Cummins Trib 2 NBFR							
Drill shaft	LF	1200	M	165	1	8	PR Resource
Mobilization buffer time						1	-
Abutment	CY	67.8	M	3.8	2	9	OKCTDS
Bents	CY	45.4	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1224.17	M	702	1	2	PR Resource
RC Slab	SF	10005	M	1521	2	4	PR Resource
Bridge rail	LF	441	M	200	2	2	OKCTDS
Cummins Trib 2 NBFR Total						37	

Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Ensign O.P NBML							
Drill shaft	LF	788	M	165	1	5	PR Resource
Mobilization buffer time						1	-
Abutment	CY	61.9	M	3.8	2	9	OKCTDS
Bents	CY	59.4	M	6.3	2	5	PR Resource
Concrete curing time						7	-
Beam erection	LF	1605.53	M	702	1	3	PR Resource
RC Slab	SF	12904	M	1521	2	5	PR Resource
Bridge rail	LF	713.2	M	200	2	2	OKCTDS
Ensign O.P NBML Total						37	
Ensign O.P SBML							
Drill shaft	LF	788	M	165	1	5	PR Resource
Mobilization buffer time						1	-
Abutment	CY	61.9	M	3.8	2	9	OKCTDS
Bents	CY	62.4	M	6.3	2	5	PR Resource
Concrete curing time						7	-
Beam erection	LF	1619.48	M	702	1	3	PR Resource
RC Slab	SF	13016	M	1521	2	5	PR Resource
Bridge rail	LF	719	M	200	2	2	OKCTDS
Ensign O.P SBML Total						37	
Cummins creek NBML							
Drill shaft	LF	738	M	165	1	5	PR Resource
Mobilization buffer time						1	-
Abutment	CY	61.9	M	3.8	2	9	OKCTDS
Bents	CY	46.6	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.5	M	702	1	3	PR Resource
RC Slab	SF	12000	M	1521	2	4	PR Resource
Bridge rail	LF	668	M	200	2	2	OKCTDS
Cummins creek NBML Total						35	
Cummins creek SBML							
Drill shaft	LF	954	M	165	1	6	PR Resource
Mobilization buffer time						1	-
Abutment	CY	61.9	M	3.8	2	9	OKCTDS
Bents	CY	46.6	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.5	M	702	1	3	PR Resource
RC Slab	SF	12000	M	1521	2	4	PR Resource
Bridge rail	LF	668	M	200	2	2	OKCTDS
Cummins creek SBML Total						36	

Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Oak Grove O.P NBML							
Drill shaft	LF	1452	M	165	1	9	PR Resource
Mobilization buffer time						1	-
Abutment	CY	83.2	M	3.8	2	11	OKCTDS
Bents	CY	64.4	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1852.34	M	702	1	3	PR Resource
RC Slab	SF	14880	M	1521	2	5	PR Resource
Bridge rail	LF	836	M	200	2	3	OKCTDS
Oak Grove O.P NBML Total						45	
Oak Grove O.P SBML							
Drill shaft	LF	1452	M	165	1	9	PR Resource
Mobilization buffer time						1	-
Abutment	CY	83.2	M	3.8	2	11	OKCTDS
Bents	CY	64.4	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1852.34	M	702	1	3	PR Resource
RC Slab	SF	14880	M	1521	2	5	PR Resource
Bridge rail	LF	836	M	200	2	3	OKCTDS
Oak Grove O.P SBML Total						45	
Cummins CK Trib 1 NBML							
Drill shaft	LF	914	M	165	1	6	PR Resource
Mobilization buffer time						1	-
Abutment	CY	69.8	M	3.8	2	10	OKCTDS
Bents	CY	71.4	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.19	M	702	1	3	PR Resource
RC Slab	SF	12000	M	1521	2	4	PR Resource
Bridge rail	LF	677	M	200	2	2	OKCTDS
Cummins CK Trib 1 NBML Total						39	
Cummins CK Trib 1 SBML							
Drill shaft	LF	1222	M	165	1	8	PR Resource
Mobilization buffer time						1	-
Abutment	CY	69.4	M	3.8	2	10	OKCTDS
Bents	CY	64.1	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.19	M	702	1	3	PR Resource
RC Slab	SF	12000	M	1521	2	4	PR Resource
Bridge rail	LF	676	M	200	2	2	OKCTDS
Cummins CK Trib 1 SBML Total						41	

Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Sterlite O.P NBML							
Drill shaft	LF	1358	M	165	1	9	PR Resource
Mobilization buffer time						1	-
Abutment	CY	64.5	M	3.8	2	9	OKCTDS
Bents	CY	64.4	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1795.2	M	702	1	3	PR Resource
RC Slab	SF	14427	M	1521	2	5	PR Resource
Bridge rail	LF	721.2	M	200	2	2	OKCTDS
Sterlite O.P NBML Total						42	
Sterlite O.P SBML							
Drill shaft	LF	1358	M	165	1	9	PR Resource
Mobilization buffer time						1	-
Abutment	CY	64.5	M	3.8	2	9	OKCTDS
Bents	CY	68.2	M	6.3	2	6	PR Resource
Concrete curing time						7	-
Beam erection	LF	1789.54	M	702	1	3	PR Resource
RC Slab	SF	14378	M	1521	2	5	PR Resource
Bridge rail	LF	718.9	M	200	2	2	OKCTDS
Sterlite O.P SBML Total						42	
Cummins CK Trib 2 NBML							
Drill shaft	LF	1086	M	165	1	7	PR Resource
Mobilization buffer time						1	-
Abutment	CY	58.2	M	3.8	2	8	OKCTDS
Bents	CY	38.9	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	936.07	M	702	1	2	PR Resource
RC Slab	SF	7548	M	1521	2	3	PR Resource
Bridge rail	LF	442.4	M	200	2	2	OKCTDS
Cummins CK Trib 2 NBML Total						34	
Cummins CK Trib 2 SBML							
Drill shaft	LF	967	M	165	1	6	PR Resource
Mobilization buffer time						1	-
Abutment	CY	58.2	M	3.8	2	8	OKCTDS
Bents	CY	45.1	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	948.88	M	702	1	2	PR Resource
RC Slab	SF	7652	M	1521	2	3	PR Resource
Bridge rail	LF	447.6	M	200	2	2	OKCTDS
Cummins CK Trib 2 SBML Total						33	

Activities	Units	Quantities	Rate Level	Units/Day	# of Crews	Time (W. days)	Source
Cummins creek SBFR							
Drill shaft	LF	1026	M	165	1	7	PR Resource
Mobilization buffer time						1	-
Abutment	CY	60.8	M	3.8	2	8	OKCTDS
Bents	CY	46.3	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1492.5	M	702	1	3	PR Resource
RC Slab	SF	12150	M	1521	2	4	PR Resource
Bridge rail	LF	664	M	200	2	2	OKCTDS
Cummins creek SBFR Total						36	
Cummins Trib 1 SBFR							
Drill shaft	LF	1080	M	165	1	7	PR Resource
Mobilization buffer time						1	-
Abutment	CY	72.8	M	3.8	2	10	OKCTDS
Bents	CY	49.5	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	1872.64	M	702	1	3	PR Resource
RC Slab	SF	12704	M	1521	2	5	PR Resource
Bridge rail	LF	708	M	200	2	2	OKCTDS
Cummins Trib 1 SBFR Total						39	
Cummins Trib 2 SBFR							
Drill shaft	LF	873	M	165	1	6	PR Resource
Mobilization buffer time						1	-
Abutment	CY	56.8	M	3.8	2	8	OKCTDS
Bents	CY	45.6	M	6.3	2	4	PR Resource
Concrete curing time						7	-
Beam erection	LF	940.78	M	702	1	2	PR Resource
RC Slab	SF	7681	M	1521	2	3	PR Resource
Bridge rail	LF	439	M	200	2	2	OKCTDS
Cummins Trib 2 SBFR Total						33	

APPENDIX O: US 287 PROJECT PRECEDENCE NETWORK – GANTT CHART

APPENDIX P: TXDOT CONTRACT TIME ESTIMATE FOR PROJECT US287

Contract Time Estimate														4		# DAYS / CELL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
RD: US 287		County: ELLIS		CSJ: 0172-08-053		Project:

M. Pauline Mone
10-24-2016

Contract Time Estimate

Rd: US 287 County: ELLIS

CSJ: 0172-08-053 Project:

													4
TASK #	Description	Quantity	Unit	Daily Rate	Duration	Prod Task	% Compl	Prod Task	% Compl	Prod Task	% Compl	Start Day	Finish Day
1	US 287 TCP Phase 1A												
2	Install SW3P Items for Phase	3	DAY	1	3							1	3
3	Install Traffic Control Items for Phase	3	DAY	1	3	2	100					4	6
4	Construct Temporary Detours #1 and #8	5	DAY	1	5	2	100					4	8
5	Shift Traffic onto Detours #1 and #8												
6	Prep ROW	5	DAY	1	5	3	100					7	11
7	Excavation	37,244	CY	7000	6	4	100					9	14
8	Embankment	185,829	CY	7000	27	4	100					9	35
9	Construct Storm Sewer	7,715	LF	300	26	7	10	8	10			12	37
10	Construct Inlets and Manholes	30	EA	3	10	9	10					15	24
11	Construct Culverts (Upstream Portions)	2,889	LF	100	29	7	10	8	10			12	40
12	Construct Retaining Walls	42,962	SF	270	160	7	20	8	20			15	174
13	Construct Drilled Shafts(Bridge)	2,228	LF	250	9	4	100					9	17
14	Construct Concrete Columns,Caps,and Bents (Bridge)	172	CY	10	18	13	100					18	35
15	Construct Deck-Total Depth (Bridge)	884	CY	20	45	14	100					36	80
16	Construct Flex Base	96,516	SY	3000	33	8	50	8	50	9	75	32	64
17	Construct Asphalt Base	41,983	TON	1200	35	10	100	16	100			65	99
18	Construct Asphalt Surface Pavement	8,567	TON	500	18	17	100					100	117
19	Construct Concrete Pavement (Cross-Streets)	17,391	SY	3000	6	17	100					100	105
20	Install Topsoil	116,941	SY	3600	33	12	75	18	80			135	167
21	Seeding & Landscape	116,941	SY	3600	33	20	40					149	181
22	US 287 TCP Phase 1B & 1C												
23	Install Traffic Control Items for Phase	2	DAY	1	2	19	100	18	100	12	100	175	176
24	Construct Detours #2, #4 & #7	6	DAY	1	6	23	100					177	182
25	Shift Traffic onto Detours #2, #4, & #7												
26	Construct Flex Base	3,555	SY	3000	2	24	100					183	184
27	Construct Asphalt Base	1,545	TON	1200	2	26	75					185	186
28	Construct Concrete Pavement (Cross-Streets)	3,476	SY	3000	2	27	100					187	188
29	Place PPM	92,163	LF	5000	19	28	100					189	207
30	US 287 TCP Phase 2A												
31	Install SW3P Items for Phase	3	DAY	1	3	29	100					208	210
32	Install Traffic Control Items for Phase	3	DAY	1	3	31	100					211	213
33	Excavation	91,625	CY	7000	14	32	100					214	227
34	Embankment	457,168	CY	7000	66	32	100					214	279
35	Construct Storm Sewer	8,362	LF	300	28	33	10	34	10			221	248
36	Construct Inlets and Manholes	69	EA	3	23	35	10					224	246
37	Construct Culverts (Downstream Portions)	4,506	LF	100	46	33	10	34	10			221	266
38	Construct Retaining Walls	50,025	SF	270	186	33	20	34	20			228	413
39	Construct Drilled Shafts(Bridge)	12,670	LF	250	51	32	100					214	264
40	Construct Concrete Columns,Caps,and Bents (Bridge)	632	CY	10	64	39	100					265	328
41	Construct Deck-Total Depth (Bridge)	3,874	CY	20	194	40	100					329	522
42	Construct Flex Base	150,558	SY	3000	51	33	50	34	50	35	75	247	297
43	Construct Asphalt Base	65,427	TON	1200	55	36	100					247	301
44	Construct Asphalt Surface Pavement	15,488	TON	500	31	43	100					302	332
45	Construct Concrete Pavement (Cross-Streets)	9,738	SY	3000	4	43	100					302	305
46	Install Topsoil	197,945	SY	3600	55	38	80	44	80	45	50	377	431

47	Seeding & Landscape	197,945	SY	3600	55	46	40					399	453
48	US 287 TCP Phase 2B												
49	Install Traffic Control Items for Phase	2	DAY	1	2	47	100					454	455
50	Excavation	42,682	CY	7000	7	49	100					456	462
51	Embankment	212,963	CY	7000	31	49	100					456	486
52	Construct Storm Sewer	6,518	LF	300	22	50	10	51	10			460	481
53	Construct Inlets and Manholes	23	EA	3	8	52	10					463	470
54	Construct Drilled Shafts(Bridge)	2,257	LF	250	10	49	100					456	465
55	Construct Concrete Columns,Caps,and Bents (Bridge)	175	CY	10	18	54	100					466	483
56	Construct Deck-Total Depth (Bridge)	854	CY	20	43	55	100					484	526
57	Construct Flex Base	96,700	SY	3000	33	50	50	51	50			472	504
58	Construct Asphalt Base	42,022	TON	1200	36	53	100					471	506
59	Construct Asphalt Surface Pavement	9,185	TON	500	19	58	100					507	525
60	Construct Concrete Pavement (Cross-Streets)	11,893	SY	3000	4	58	100					507	510
61	Install Topsoil	209,873	SY	3600	59	60	80	59	80			523	581
62	Seeding & Landscape	209,873	SY	3600	59	61	40					547	605
63	US 287 TCP Phase 2C												
64	Install Traffic Control Items for Phase	2	DAY	1	2	60	100					511	512
65	Construct Flex Base	3,859	SY	1500	3	64	100					513	515
66	Construct Asphalt Base	1,677	TON	1200	2	65	100					516	517
67	Construct Concrete Pavement (Cross-Streets)	3,776	SY	3000	2	66	100					518	519
68	Place PPM	85,247	LF	5000	18	67	100					520	537
69	US 287 TCP Phase 2D(STAGES 1&2)												
70	Install Traffic Control Items for Phase	2	DAY	1	2	68	100					538	539
71	Construct Flex Base	2,818	SY	3000	1	70	100					540	540
72	Construct Asphalt Base	1,225	TON	1200	2	71	100					541	542
73	Construct Concrete Pavement (Cross-Streets)	2,748	SY	3000	1	72	100					543	543
74	US 287 TCP Phase 3												
75	Install SW3P Items for Phase	2	DAY	1	2	73	100					544	545
76	Install Traffic Control Items for Phase	2	DAY	1	2	75	100					546	547
77	Construct Flex Base	3,183	SY	3000	2	76	100					548	549
78	Construct Asphalt Base	1,383	TON	1200	2	77	100					550	551
79	Construct Asphalt Surface Pavement	338	TON	3000	1	78	100					552	552
80	Place PPM and Open completed roadway to traffic	67,025	LF	5000	14	79	100					553	566
81	Final Clean-Up	235	STA	15	16	80	100	62	100			606	621
82													
83													
84	6 DAY WORK WEEK												
85	621 WORKING DAYS												
86	757.6 CALENDAR DAYS												
87	BARRICADES: 36 MONTHS												
88	3 00 YEARS												
89													

References

- Atreya, S.K. (2007). Development of an Improved System for Contract Time Determination. Oklahoma State University. Available at: <<http://digital.library.okstate.edu/etd/umi-okstate-2292.pdf>>. Last access: 23 Apr, 2017.
- Federal Highway Administration Legislations and Regulations (2002). FHWA Guide for Construction Contract Time Determination Procedures (TA 5080.15). Available at: <<http://www.fhwa.dot.gov/construction/contracts/t508015.cfm>>. Last access: 22 Apr, 2017.
- Florida Department of Transportation (2010). Guidelines for Establishing Construction Contract Duration. Available at: <<http://www.fdot.gov/construction/SchedulingEng/GuidellinesForEstablishingContractDuration.pdf>>. Last access: 22 Apr, 2017.
- Hale, D. et al. (2015). RSMeans Heavy Construction Cost Data 2016 30th annual edition. Rockland, Massachusetts: The Gordian Group.
- Hancher, D.E., McFarland, W., & Alabay, R.T. (1992). Construction Contract Time Determination (Report No: FHWA/TX-92/1262-1F). Texas Transportation Institute, Texas A&M University System.
- Hancher, D.E., & Werkmeister, R.F. (2000). Kentucky Contract Time Determination System (Report No: KYSPR-99-195). University of Kentucky Research Foundation, Kentucky Transportation Center.
- Herbsman, Z. J., & Ellis, R. (1995). National Cooperative Highway Research Program Synthesis of Highway Practice 215: Determination of Contract Time for Highway Construction Projects. Transportation Research Board, National Research Council. Washington, DC.
- Idaho Transportation Department (2011). Contract Time Determination in Project Development. Available at: <<http://apps.itd.idaho.gov/apps/manuals/ContractTime/files/ContractTimePrintable.pdf>>. Last access: 5 Apr, 2017.
- Illinois Department of Transportation (2010). Bureau of Design and Environment Manual, Chapter Sixty-Six, Contract Processing. Available at: <<https://idot.illinois.gov/Assets/uploads/files/Doing-Business/Manuals-Split/Design-And-Environment/BDE-Manual/Chapter%2066%20Contract%20Processing.pdf>>. Last access: 5 Apr, 2017.

- Iowa Department of Transportation (2016). Letting Guidelines. Available at: <<http://www.iowadot.gov/contracts/LettingGuidelines.pdf>>. Last access: 5 Apr, 2017.
- Jeong, H.S., Oberlender, G.D., Atreya, S.K., & Akella, V. (2007). Development of an Improved System for Contract Time Determination (Report No: FHWA-OK-08-02). Oklahoma State University, Oklahoma Department of Transportation.
- Jiang, Y. (2009). Contract Time Optimization Methodologies for Highway Construction Projects (Report No: FHWA/IN/JTRP-2009/8). Joint Transportation Research Program, Purdue University.
- O'Brien, J.J., & Plotnick, F.L. (2016). CPM in Construction Management. New York: McGraw Hill Education.
- O'Connor, J.T., Chong W.K., Huh Y., & Kuo Y. (2004). Development of Improved Information for Estimating Construction Time (Report No: FHWA/TX-05/0-4416-1). Center for Transportation Research, The University of Texas at Austin, Texas Department of Transportation.
- Office of the Federal Register National Archives and Records Administration (2016). Code of Federal Regulations Title 23 Highways. Available at: <<https://www.gpo.gov/fdsys/pkg/CFR-2016-title23-vol1/pdf/CFR-2016-title23-vol1.pdf>>. Last access: 22 Apr, 2017.
- Oklahoma Department of Transportation Transportation Commission (2009). 2009 Standard Specifications Book. Available at: <http://www.odot.org/c_manuals/specbook/oe_ss_2009.pdf>. Last access: 22 Apr, 2017.
- Texas Department of Transportation (2004). Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges. Available at: <<http://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf>>. Last access: 23 Apr, 2017.
- Texas Department of Transportation. Plans of Proposed State Highway Improvement, US 287, Ellis County, CSJ: 0172-08-053. Signed by registrant on 12 May, 2016.
- Texas Department of Transportation. Plans of Proposed State Highway Improvement, US 80, Dallas County, CCSJ: 0095-02-102. Signed by registrant on 12 May, 2016.
- Texas Department of Transportation (n.d.). Addendum Acknowledgment and Proposal to the Texas Transportation Commission, Control: 0096-02-102, etc., Project: STP 1602(324)MM, Highway US 80, etc., County: Dallas. Available at: <<ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/proposal/p1073226.pdf>>. Last access: 22 Jun, 2016.

- Wisconsin Department of Transportation (2015). Facilities Development Manual, Chapter 19 Section 10. Available at: <<http://wisconsindot.gov/rdwy/fdm/fd-19-10.pdf#fd19-10-1>>. Last access: 5 Apr, 2017.
- Yuksel, I.T. & O'Connor, J.T. (2000). Schedule Compression of an Urban Highway Project Using the Linear Scheduling Method. Center for Transportation Research, The University of Texas at Austin. Available at: <http://library.ctr.utexas.edu/digitized/iacreports/ctr-tti-misc_yuksel.pdf>. Last access: 23 Apr, 2017.