ACTIVITY SEQUENCE LOGICS USING DAILY WORK REPORT DATA

FHWA/MT-20-003/9344-723

Final Report

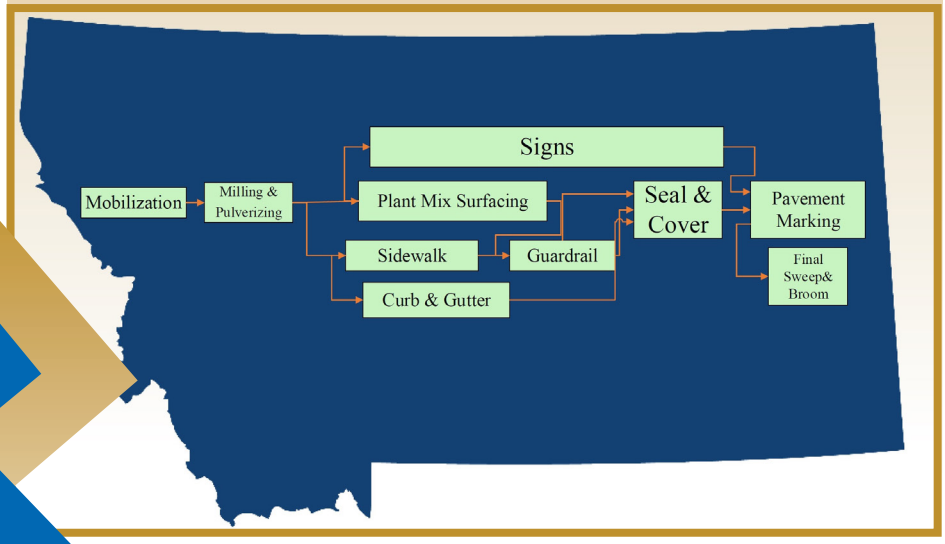
prepared for
THE STATE OF MONTANA
DEPARTMENT OF TRANSPORTATION

in cooperation with
THE U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

August 2020

prepared by
H. David Jeong, Ph.D.
Hamed Alikhani

Texas A&M University
College Station, TX



RESEARCH PROGRAMS

MDT

Activity Sequencing Logics Using Daily Work Report Data

Prepared by

David Jeong, PhD
Professor
Construction Science
Texas A&M University
College Station, TX 77845
&
Hamed Alikhani,
Graduate Research Assistant

Prepared for the
MONTANA DEPARTMENT OF TRANSPORTATION
in cooperation with the
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

September 2020

A report from
Texas A&M University
College Station, TX 77843-3137
Ph: (O) 979-458-9380, (C) 979 – 676-6579
Email: djeong@tamu.edu

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA/MT-20-003/9344-723	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Activity Sequencing Logics Using Daily Work Report Data		**5. Report Date** September 2020 **6. Performing Organization Code**
7. Author(s) H. David Jeong (orcid.org/0000-0003-4074-1869), Hamed Alikhani (orcid.org/0000-0003-2937-2038)		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Texas A&M University, 400 Bizzell St, College Station, TX United States 77843		**10. Work Unit No.** **11. Contract or Grant No.** 9344-723
12. Sponsoring Agency Name and Address Research Programs Montana Department of Transportation (MDT) 2701 Prospect Avenue Helena, MT 59620		**13. Type of Report and Period Covered** Final Report (May 2019 – Sep 2020) **14. Sponsoring Agency Code** 5401

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. This report can be found at https://www.mdt.mt.gov/research/projects/const/production_rates.shtml

16. Abstract

Accurate and reliable project duration estimation is highly dependent upon two major components; a) reasonable production rate estimation of major work items, and b) logical sequencing of those work items. The phase I of the study developed an MS Excel-based production rate estimation tool (PRET). The phase II (this project) has developed construction activity sequence logic diagrams for most common work types in MDT. By analyzing historical daily work report (DWR) data of 730 highway projects stored in AASHTOware Site Manager, the current list of 31 controlling work items has been expanded into 48 items. The new list covers more than 90% of the activities in the database. The same data analysis revealed that there are six most common highway project types in MDT, which include i) overlay (urban), ii) overlay (rural), iii) safety, iv) seal & cover, and v) bridge reconstruction and rehabilitation. These work types account for more than 60% of highway projects in MDT. For each work type, representative as-built schedules were developed from the DWR data, and a construction activity sequence logic diagram was developed to illustrate frequent controlling work items and their sequential relationship. The analysis results were discussed with MDT schedulers to incorporate their practical experience and knowledge into finalizing the list of controlling work items and their sequential relationships. The results of this research project can help MDT quickly identify the most common controlling work items and develop a sequence logic for different types of highway projects. The research findings are expected to significantly improve the accuracy and reliability of MDT's scheduling and project duration estimation efforts. This project will not only allow MDT to be equipped with powerful visual scheduling resources to enhance the current practices but also allow MDT to be one of the leading state DOTs to provide a benchmarking example that other DOTs may follow.

17. Key Words Project scheduling – scheduling – contract time determination – contracting – daily work report – activity sequence analysis – as built schedule analysis – sequence logic diagram – data analysis – information retrieval – research report – technical reports	**18. Distribution Statement** No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161. Enter any other agency mandated distribution statements. Remove NTIS statement if it does not apply.

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 79	**22. Price**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Disclaimer Statement

This document is disseminated under the sponsorship of the Montana Department of Transportation (MDT) and the United States Department of Transportation (USDOT) in the interest of information exchange. The State of Montana and the United States assume no liability for the use or misuse of its contents.

The contents of this document reflect the views of the authors, who are solely responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or official policies of MDT or the USDOT.

The State of Montana and the United States do not endorse products of manufacturers.

This document does not constitute a standard, specification, policy or regulation.

Alternative Format Statement

MDT attempts to provide accommodations for any known disability that may interfere with a person participating in any service, program, or activity of the Department. Alternative accessible formats of this information will be provided upon request. For further information, call 406/444.7693, TTY 800/335.7592, or Montana Relay at 711.

Table of Contents

List of Figures

List of Tables

1. Introduction

The contract time for state highway projects is the maximum time allowed in the contract for completion of all work contained in the contract documents (FHWA, 2002). An accurate contract time determination is crucial to contract administration as the predicted duration, and associated cost forms a basis for budgeting, planning, monitoring, and even litigation purposes (Jeong et al., 2008). Excessive contract time is costly because it extends the construction crew's exposure to traffic, prolongs the inconvenience to the public (an unnecessary increase of road user costs), and subjects motorists to less than desirable safety conditions for longer periods of time. Insufficient contact time results in higher bids, overrun of contract time, increased claims, substandard performance, and safety issues (Jeong et al., 2008). Due to significant importance of contract time determination, title 23 Code of Federal Regulations (CFR) Section 635.121 requires that states should have adequate written procedures for the determination of contract time, and most state DOTs including MDT have a written document describing their procedure to determine a project's contract time.

Accurate and reliable contract time determination is highly dependent upon two major issues; a) production rate estimation of major work items and b) sequencing of those work items. The MDT manual on contract time determination provides the list of major work items and corresponding production rates (MDT, 2008). The manual also provides a general guide on sequencing major work items of highway projects but is not specific enough to be useful for contract time developers.

In Phase I, the AASHTOWare SiteManager's historical project data were obtained and analyzed to develop an MS Excel-based production rate estimation tool (PRET). The PRET uses regression models to estimate production rates of up to 31 major work items and it also shows common statistical measures such as mean, average, 25% and 75% production rates based on the historical data.

In phase II, the SiteManager data were used to identify the most common project work types and the major controlling work items for those project types, and develop as-built schedules. Finally, for each project type, a construction activity logic diagram based on frequent controlling work items was developed.

MDT currently uses the AASHTOWare – SiteManager that includes daily work reports for more than 700 completed projects. The DWR data include information about various project characteristics, the daily quantity of work accomplished for each work item, the start and end date of each work item, labor and equipment usage, weather, etc.

The results of this research project can help MDT quickly identify the most common controlling work items and the proper sequence of them for different types of highway projects. The research results are expected to significantly improve the accuracy and reliability of MDT's scheduling efforts.

1.1 Project objectives and tasks

The overall goal of the Phase II was to develop construction sequence logics for major project types using historical data available in DWR data. The result of the Phase I and Phase II will enhance the MDT's current contract time determination procedure (Figure 1.1).

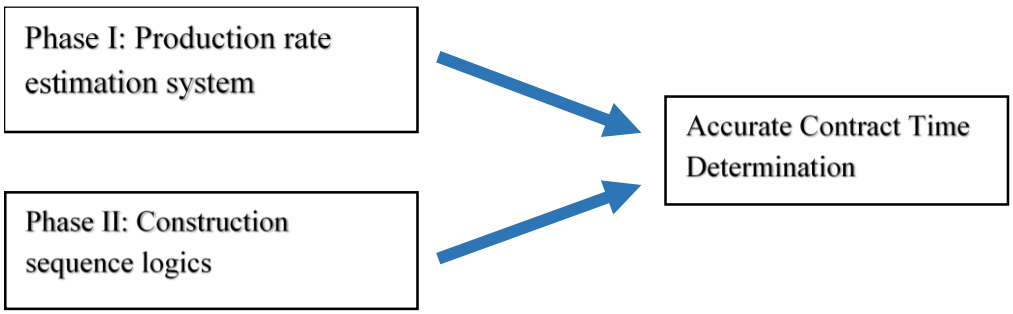


Figure 1.1 Phase II Research Goal

The specific objectives of Phase II are below.

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

To reach the project objectives, five major tasks were accomplished and the final report was organized accordingly.

Task 1: Kick-off Meeting and Review of Historical Daily Work Report Data

The research team conducted the Phase II kick-off meeting with the MDT technical panel members to make a clear mutual understanding of the project objectives and obtained the last ten years of daily work reports (DWR) of MDT highway projects.

Task 2: Analyze As-Built Schedules of Historical Highway Projects

The research team analyzed the DWR data to develop as-built schedules of major work types. A computer algorithm was developed and a Microsoft Excel tool was used to analyze the DWR data to develop an as-built bar-chart schedule for each project. The current list of controlling work items used by MDT was assessed in this task to extend and enhance the list. A common sequence pattern of major work items was identified in this task.

Task 3: Interview with MDT Schedulers and District Engineers

The research team conducted a workshop style meeting with MDT's schedulers to obtain their knowledge on frequent controlling work items, the most common project types, and the dominant sequential pattern of work items. The output of task 2 was discussed with them to validate the results and incorporate the schedulers' comments into developing evidence-based work sequences.

Task 4: Develop Construction Sequence Logic Diagrams

Using the findings from Tasks 2 and 3, the research team developed common activity sequence logic diagrams for major types of highway projects. Discussions and explanations for any variation are described in this report for MDT to make appropriate adjustments in project scheduling. The results from this task will help MDT to determine a more defensible project duration estimation and ultimately contract time with confidence.

Task 5: Training and Implementation

In this task, a training session was provided for the affected MDT personnel to transfer the research findings. A step-by-step process was described using visual examples to explain how activity sequencing logic diagrams can be used in determining a project's schedule. The final report that encompasses all task results, findings, and products was prepared for the panel's review and approval.

1.2 Organization of the report

This report consists of six chapters. Chapter 1 provides an introduction, research objectives and major work tasks. Chapter 2 summarizes a literature review on the project sequence logic identification based on reviews of prior research studies and practices used in other DOTs. Chapter 3 discusses the collected DWR data and analysis results on the as-built schedules extracted from the data. Chapter 4 presents the results of the interviews with MDT schedulers that were conducted to obtain and incorporate their knowledge into the research. Chapter 5 describes construction activity sequence logic diagrams developed in this project. Chapter 6 summarizes the key findings and the value of this research.

2. Literature Review

To determine contract time of a highway project, schedulers develop a pre-construction schedule for the project. Accurate scheduling may result in a more reliable project duration estimation that mitigates the project time uncertainties. To develop a project schedule, project schedulers determine activities and work items, production rates, resources, and sequence logic (Jones, 2009). After determining work items and their durations using production rates, the schedulers logically connect the work items together and arrange them sequentially considering physical constraints, and resource constraints (Jeong et al., 2008). Sometimes the schedulers use activity sequence logic guidelines (MDT, 2008). The schedulers also discuss with the experienced engineers and project managers to identify specific project conditions that may affect the sequence of work items, such as particular geographic characteristics, weather conditions, and soil characteristics, to further adjust the project time estimation (Jeong et al., 2008). The arrangement of work items is determined either using bar charts (Gantt chart) or critical path method (CPM) to finally identify the total project duration. Since the sequence logic guidelines play an essential role in the process of contract time determination, a more accurate and detailed guideline can contribute to more accurate project time estimation.

Controlling work items are major work items that are typically associated with a relatively high amount of work and/or critically influence the duration of the project. Controlling work items may or may not fall into the critical path of the project schedule. They drive the project and are highly likely to fall into the critical path. Therefore, those controlling activities need to be identified first in developing a standard sequence logic.

DOTs across the U.S. have developed different guidelines to identify the common sequence of controlling work items. Hancher et al. (1992) categorized Texas DOT highway projects into thirteen different classes (Table 2.1) and developed a template of activity relationships for each type.

Table 2.1 Different Project Types in Texas DOT

#	**Project type**
1	Seal Coat
2	Overlay
3	Rehabilitate Existing Road
4	Convert Non-Freeway to Freeway
5	Widen Freeway
6	Widen Non-Freeway
7	New Location Freeway
8	New Location Non-Freeway
9	Interchange
10	Bridge Widening/Rehabilitation
11	Bridge Replacement/ New Bridge
12	Upgrade Freeway to Standards
13	Upgrade Non-Freeway to Standards

A bar chart approach was used to develop the activity sequence logic templates because of the popularity of using this approach among Texas DOT's personnel. Table 2.2 and 2.3 show the sequence logic templates for Overlay and Bridge Widening/Rehabilitation respectively. Eight controlling work items were identified for Overlay projects and 16 controlling work items for Bridge Widening/Rehabilitation. Each controlling work item is connected to predecessor and successor work items with a finish-to-start relationship with lag and lead times. For each controlling work item, a production rate is determined and the project scheduler can modify the production rates according to project specific features such as location, traffic conditions, project complexity, soil conditions and quantity of work. After modifying the production rates and identifying work item durations, the predefined relationship between activities is used to develop the project schedule and estimate the project completion date (Hancher et al., 1992).

Table 2.2 Sequence logic template for Overlay projects in Texas DOT (Hancher et al., 1992).

S.No.	Major Work Items	Preceding Activities & Relationship (% complete of predecessors)
1	**Initial traffic control**	
2	**Detour**	1, 100%
3	**Milling/planning**	2, 100%
4	**Pavement repair**	
	A. Asphalt	2, 100%
	B. Concrete	2, 100%
5	Concrete paving	3, 75% ; 4B, 75%
6	Hot mix asphalt surface	3, 75% ; 4A, 75%
7	Permanent pavement marking	5, 100% ;6, 100%
8	Final clean up	7, 100%

Table 2.3 Sequence logic template for Bridge Widening/Rehabilitation projects in Texas DOT (Hancher et al., 1992).

S.No.	Major Work Items	Preceding Activities & Relationship (% complete of predecessors)
1	**Initial traffic control**	
2	**Detour**	1, 100%
3	**ROW Preparations**	2, 100%
	A. Major Structure demolition	
	B. Clear and grub	
	C. Remove old structures (small)	
	D. Remove old pavement	
	E. Remove old curb & gutter	
	F. Remove old sidewalks	
	G. Remove old drainage/ utility structures	
4	**Excavation/ embankment**	
	A. Earth excavation	3, 25%
	B. Rock excavation	3, 25%
	C. Embankment	3, 25%
5	**Bridge structures**	
	A. Erect temporary bridge	1, 100%
	B. Bridge demolition	5A, 100%

Table 2.3 - continued

5	C. Cofferdams	2, 100%; 5B, 100%
	D. Piling	4A, 10%; 4B, 10%; 5C, 1000%
	E. Footings	5D, 75%
	F. Columns, Caps and Bents	5E, 75%
	G. Wingwalls	5F, 50%
	H. Beams (erection only)	5F, 100%
	I. Bridge deck (total depth)	5G, 100%; 5H, 100%
	J. Bridge curbs/ walks	5I, 100%
	K. Bridge handrails	5J, 100%
	L. Remove temporary bridge	5K, 100%
6	**Retaining walls**	4A, 40%; 4C, 40%
7	**Base preparations**	
	A. Lime stabilizations	4, 100%
	B. Flexible base material	7A, 100%
	C. Cement treated base material	7A, 100%
8	**New curb and gutter**	7B, 100%; 7C, 100%
9	**Hot Mix asphalt base**	8, 75%
10	**Concrete paving**	7B, 100%; 7C, 100%
11	**Hot mix asphalt surface**	9, 100%
12	**Precast traffic barriers**	10, 100%; 11, 100%
13	**Permanent signing and traffic signals**	
	A. Small signs	10, 100%; 11, 100%
	B. Overhead signs	10, 100%; 11, 100%
	C. Major traffic signals	10, 100%; 11, 100%
14	**Seeding and landscape**	6, 100%; 10, 50%; 11, 50%
15	**Pavement markings**	10, 100%; 11, 100%; 12, 100%
16	**Final clean up**	5L, 100%; 13, 100%; 14, 100%; 15, 100%

Texas DOT templates contain activity relationship information and show activity overlapping based on lag and lead times. However, such complex relationships may not be useful in projects with different types of activities, since adding or removing an activity from a template will mix up the whole relationship network. Also, it is difficult to modify the activities in the template in case new project characteristics are required for consideration (Jeong et al., 2008).

Werkmeister et al. (2000) developed a system for contract time determination for Kentucky Transportation Cabinet (KyTC) based on the Texas DOT templates. In this system, highway

projects were classified into six project types. Table 2.4 shows these project types and their descriptions.

Table 2.4 Different types of projects in KyTC (Werkmeister et al., 2000)

S.No.	Project type	Project Description
1	Reconstruction Limited Access	This type may revise the profile grade to implement overlay
2	Reconstruction Open Access	This type reconstructs a road utilizing the existing right-of-way
3	New Route	This type constructs a road from point "A" to point "B"
4	Relocation	This is a project type that a section of the road is being reconstructed on new alignment and grade
5	Bridge Rehabilitation	This is a project type that a bridge would be reconstructed
6	Bridge Replacement	This project type constructs a new bridge

Similar to Texas DOT, the KyTC developed an activity sequence template for each project type. Table 2.5 shows a template for Reconstruction, Limited Access. This template includes 38 controlling work items connecting to each other using finish-to-start and start-to-start relationship.

Similar to the Texas DOT study, KyTC templates include complex successor and predecessor relationships. Such a complex system doesn't allow the user to make changes and add or remove work items in the system, since any change would cause disarray in the whole complex network of work items. Also, it is not visually convenient to capture the relationship between activities.

Jeong et al. (2008) developed a contract time determination system for Oklahoma DOT (OKDOT). They divided Oklahoma highway projects into three tiers, based on project complexity and developed sequence logics for all types of project in each tier. For example, they divided the Tier II projects (medium complexity) into eight project types (Table 2.6), and they identified sequence logic using a visual diagram for each project type.

Table 2.5 Sequence logic template for Reconstruction, Limited Access in KyTC (Werkmeister et al., 2000)

S.No.	Major Work Items	Predecessors
1	Initial Traffic Control	
2	Clearing & Grubbing	1
3	Diversion (By-Pass Detour)	1
4	Roadway Excavation	3SS+2,2SS+0
5	Embankment in Place	3SS+2,2SS+0
6	Drainage Pipe	4SS+0,5SS+0
7	Box Culverts, Class A Concrete	2SS+0
8	Erect Temporary Bridge	1
9	Remove Existing Structures	3,8
10	Cofferdams	9
11	Structure Excavation	9,10
12	Piling	10,11SS+0
13	Sub-Structure, Class A Concrete	12SS+0
14	Concrete Beams	13
15	Steel Beams	13
16	Super-Structure, Class AA Concrete	14,15SS+0
17	Remove Temporary Bridge	16
18	Major Retaining Walls	4,5
19	Sub-grade Stabilization	4,5,6SS+0,7SS+0
20	Stone Base	19
21	Drainage Blanket	19
22	Asphalt Base, Leveling, & Wedging	20,21
23	Curb & Gutter	22SS+0,20
24	Entrance Pavement	22SS+0,20
25	Barrier Walls, Slip Form	22SS+0
26	Asphalt Repair	22SS+0
27	Concrete Repair	20
28	Concrete Paving	20,21,23SS+0,24SS+0,27
29	Asphalt Surface	22SS+0,23SS+0,24SS+0,25,26,27
30	Sheet Signs	28,29
31	Panel Signs	28,29
32	Major Traffic Signals	28,29
33	Lighting, Total Installation Luminaries	28,29
34	Guardrail	28,29
35	Finish Seeding	28,29
36	Pavement Marking	28,29
37	Final Clean-Up	17,18,28,29,30,31,32,33,34,35,36
38	Phasing Allowance	37

Table 2.6 Different types of projects in Tier II in OKDOT (Jeong et al., 2008)

S.No.	Project type
1	Reconstruct Existing Alignment/ Rural Interchange
2	Widen/ Reconstruct Existing Alignment
3	Reconstruct City Street
4	Construct Bridges and Approaches
5	Construct Bridge Box and Approaches
6	Intersection Modification
7	Bridge Rehabilitation/Repair
8	Roadway Repair/Overlay

Figure 2.1 shows the sequence logic template for Reconstruct Existing Alignment/ Rural Interchange. In this template, each controlling work item is represented in rectangles and the relationships between work items are represented using arrows. Such visual sequence logic diagrams can overcome drawbacks in previous studies, in that the timely implementation of each activity with regards to other activities can be easily identified.

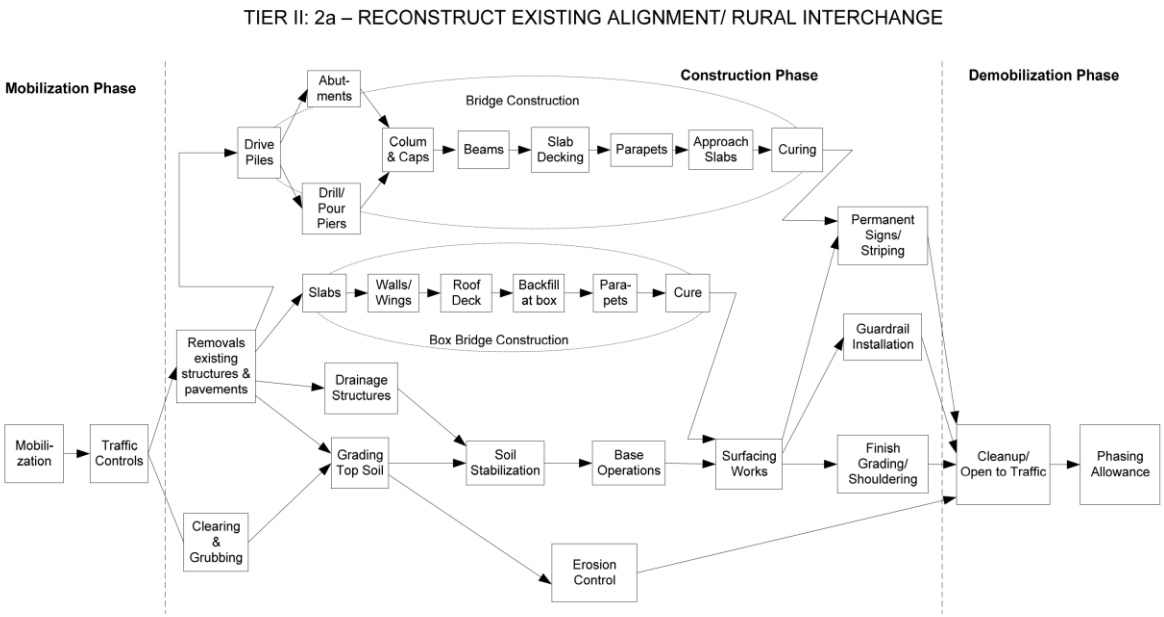


Figure 2.1 Sequence logic template for Reconstruct Existing Alignment/ Rural Interchange in OKDOT (Jeong et al., 2008)

In summary, some DOTs have developed construction sequence logics to help their schedulers estimate project duration. They categorized highway projects into different types and identified

the most common controlling work items in each type. Then, they analyzed real projects and discussed with experienced engineers to develop sequence logic templates for each project type.

Based on the literature review, it was identified that highway projects need to be classified into different common types. Also, frequent controlling work items for each type need to be determined first for building construction logic. It also was identified that using diagrams to display the activity relationship has advantages over using a list of activities and their dependencies.

Based on the key findings from the literature review, this research collected and analyzed MDT DWR data to develop highway project as-built schedules. Then, the projects were classified into five common types, and controlling activities were identified for each type. Sequence logics were then developed for each type using visual diagrams.

3. Review of historical daily work report (DWR) data and analysis of as-built schedules

3.1 Introduction

The last ten years of MDT daily work report (DWR) data were collected and analyzed. Most common highway project types were determined. As-built schedules using historical DWR data were developed to identify the most frequent controlling work items for each major project type, and typical sequence logic. To develop an as-built schedule, it is necessary to identify controlling work items that drive the project schedule and influence the duration of the project. The current list of controlling work items used by MDT was analyzed to identify which major controlling work items might be missing in the list and which items are not necessary to be included in the list. An enhanced list of controlling work items was created to include important controlling items and exclude less important items. The revised list was discussed with MDT schedulers and their practical knowledge was considered in finalizing the list.

An Excel-based tool was developed to develop an as-built schedule for each project. Five types of projects that constitute almost 60% of the total number of projects were identified and five representative projects for each project type were selected to identify the sequence logic of controlling work items. The sample projects are projects that include most of the frequent controlling work items and best represent the characteristics of the project type. These sample projects were analyzed and a dominant sequence pattern of work items was identified for each project type.

3.2 Historical DWR data description

Data obtained from MDT include ten years of historical DWR data of different types of highway projects. Table 3.1 shows the data attributes used in this research project. The data were available in a spreadsheet format.

Table 3.1 Data attributes of the DWR dataset

No.	Description
1	Project #
2	Project type
3	Project location
4	Project contract amount
5	Project start, and end dates
6	Work item code
7	Work Item description
8	Work item implementation date

Table 3.2 displays different types of projects and the number of projects in each type. The DWR dataset includes 730 highway construction and maintenance projects. Some project types are rare such as building (4 projects) and lighting (2 project), while some other project types are very common such as overlay (190 projects) and seal and cover (89 projects).

Table 3.2 Different project types and their frequencies in the DWR dataset

Type of project	Frequency
OVERLAYS	190
RECONSTRUCTION, GRADING	115
SAFETY	100
SEAL & COVER	89
BRIDGE CONSTRUCTION,REHAB AND REMC	58
SLIDES OR SLOPE STABILIZATION	28
SIGNALS	20
GUARDRAIL	17
MICROSURFACING	15
MISCELLANEOUS	12
REHAB (MINOR GRADE & OVERLAY)	12
CRACK SEAL	11
SIGNING	9
DRAINAGE	8
PORTLAND CEMENT CONCRETE PAVEMENT	8
SIDEWALK	8
ENVIRONMENTAL AND WETLAND	6
FENCING	6
BIKE AND PEDESTRIAN	5
BUILDINGS (SCALES, REST AREAS)	4
RUMBLE STRIPS	4
LIGHTING	2
SCOUR PROJECTS	2
WARM MIX BIT SURF	1
Total	**730**

Figure 3.1 shows a bar chart representing the most common project types and their percentages. Most common five project types were selected to develop sequence logic templates. They include overlay, reconstruction, bridge reconstruction and rehabilitation, seal & cover, and safety.

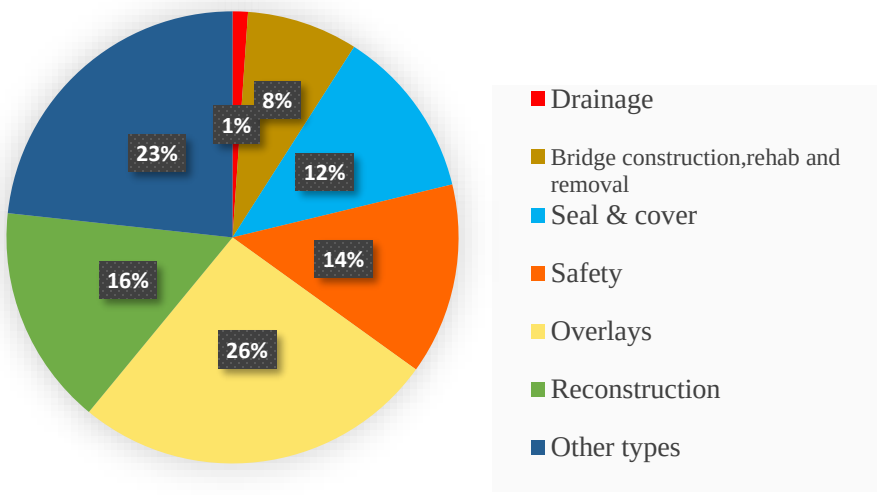


Figure 3.1 The most common project types in MDT

Data of reconstruction projects included numerous work items with scattered dates that make it too complex for analysis and extracting a sequence logic. Therefore, it was decided to take the project type out from consideration and focus on the rest of the four other project types. They include a) overlay, b) safety, c) seal & cover, and d) bridge reconstruction and rehabilitation that account for 60% of all projects. These most common project types identified from DWR data analysis were also discussed and confirmed with the MDT schedulers. However, they mentioned that the overlay projects could be divided into urban and rural types since they have slightly different controlling work items. Detail discussion and comments from MDT schedulers are provided in Chapter 4. Given MDT schedulers' clarification, the final common project types are listed in Table 3.3.

Table 3.3 The final list of common project types

List of the most common project types		**Total number of projects of the type**	**Percentage of the total number of projects over total projects in the database**
1	Overlay (urban)	40	5.5%
2	Overlay (rural)	150	20.5%
3	Seal & cover	89	12.0%
4	Bridge construction, rehabilitation, and removal	58	8.0%
5	Safety	100	14.0%
Total		**437**	**60.0%**

Figure 3.2 shows the timeline of the DWR database and indicates major types of projects and their spread over time. The whole DWR dataset includes highway projects from 2003 to 2018, but the data of the most common project types are from 2008 to 2016.

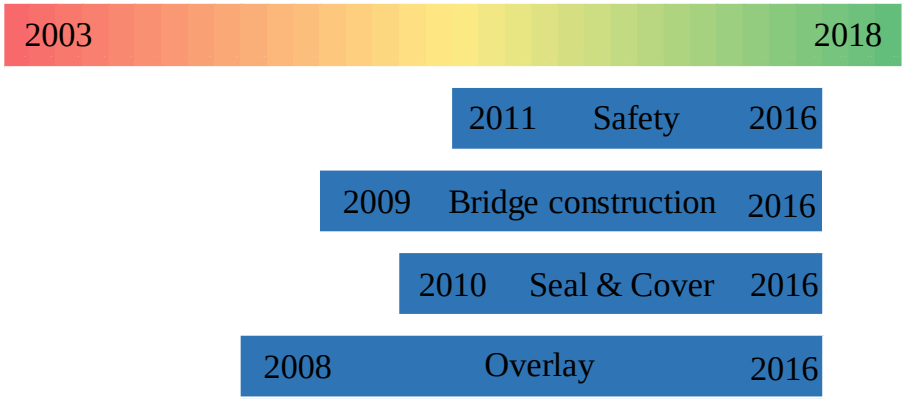


Figure 3.2 The timeline of the DWR dataset

3.3 Extension of the current list of controlling work items

The current list of controlling work items used by MDT was analyzed. Table 3.4 shows the current list. The current list has been revised by adding some new controlling items and consolidating similar items into single items. This revision was made by reviewing controlling work item lists in other DOTs such as Oklahoma DOT (Jeong et al., 2008), Kentucky Transportation Cabinet (Werkmeister et al., 2000), and Texas DOT (Hancher et al., 1992) and reviewing the 2014 MDT standard specifications for road and bridge construction. For example, the item of "Guardrail" usually has been considered as a controlling work item in other DOTs (Werkmeister et al., 2000 and Jeong et al., 2008). Therefore, it was added to the list. The changes were discussed with the MDT schedulers to consider their opinions and reflect their practical experience and make sure the modifications were properly made to develop the final list.

Table 3.4 The current list of controlling work items

No.	Controlling work items
1	BASE-CEMENT TREATED
2	BRIDGE DECK MILLING
3	CLASS A BRIDGE DECK REPAIR
4	COLD MILLING
5	CONCRETE BARRIER RAIL
6	CONCRETE BARRIER RAIL-BRIDGE
7	CONCRETE-CLASS DECK
8	CONCRETE-CLASS OVERLAY
9	SEAL & COVER
10	CRACK SEALING
11	CRUSHED AGGREGATE COURSE
12	CURB AND GUTTER
13	DRAINAGE PIPE (<= 24 IN)
14	DRAINAGE PIPE (> 24 IN)
15	DRILLED SHAFT
16	EXCAVATION-STREET
17	EXCAVATION-UNCLASSIFIED
18	FARM FENCE
19	GUARDRAIL STEEL
20	MICROSURFACING
21	PCCP
22	PLANT MIX SURFACING
23	REIN CONC BOX
24	REINFORCING STEEL
25	REVISE BRIDGE CONCRETE BARRIER
26	RIPRAP
27	SEEDING
28	SIDEWALK
29	SPECIAL BORROW
30	SSPP
31	TOPSOIL-SALVAGING AND PLACING

Table 3.5 shows the final table of extended controlling work items, the previous list and the reason why an item is eliminated or modified from the previous list. The orange cells in the extended list indicate added items and the red cells in the previous list show eliminated items and the reason for elimination is mentioned next to each red cell. Each controlling work item may include one or more pay items. The detailed list of pay items included in each controlling work item is available in Appendix **A**. The extended list was used further in the sequence logic identification.

Table 3.5 The final extended controlling work item list compared with the previous list

#	List of extended controlling work items
1	BASE-CEMENT TREATED
2	BEAMS
3	BRIDGE APPROACH SLAB
4	BRIDGE BACKFILL
5	BRIDGE DECK
6	BRIDGE DECK MILLING
7	BRIDGE DECK REPAIR
8	BRIDGE FOUNDATION
9	BRIDGE PAINTING
10	CLEARING AND GRUBBING
11	CONCRETE BARRIER RAIL
12	CONCRETE BARRIER RAIL-BRIDGE
13	CONCRETE-CLASS OVERLAY
14	COVER
15	CRACK SEALING
16	CRUSHED AGGREGATE COURSE
17	CURB AND GUTTER
18	DECK GROOVING (after curing)
19	DETOURING
20	DRAINAGE PIPE (<= 24 IN)
21	DRAINAGE PIPE (> 24 IN)
22	EARTH WORKS
23	FARM FENCE
24	GEOGRID
25	GEOTEXTILE
26	GUARD RAIL
27	MICROSURFACING
28	MILLING AND PULVERIZING
29	MOBILIZATION
30	PAVEMENT MARKING
31	PCCP
32	PLANT MIX SURFACING
33	REIN CONC BOX
34	REINFORCING STEEL
35	REMOVE EXISTING STRUCTURES
36	RETAINING WALL
37	REVISE BRIDGE CONCRETE BARRIER
38	RIPRAP
39	RUMBLE STRIPS
40	SEEDING
41	SHOULDER GRAVEL
42	SIDEWALK
43	SIGNS
44	SPECIAL BORROW
45	SSPP
46	TOPSOIL-SALVAGING AND PLACING
47	WING WALLS
48	FINAL SWEEP AND BROOM

#	List of previous controlling work items	*Reson why this item doesn't exist in new list*
1	BASE-CEMENT TREATED	
2	BRIDGE DECK MILLING	
3	CLASS A BRIDGE DECK REPAIR	*Aggregated into "Bridge deck repair"*
4	COLD MILLING	*Aggregated into "Miling and pulverizing"*
5	CONCRETE BARRIER RAIL	
6	CONCRETE BARRIER RAIL-BRIDGE	
7	CONCRETE-CLASS DECK	*Removed. So rare in the database*
8	CONCRETE-CLASS OVERLAY	
9	COVER	
10	CRACK SEALING	
11	CRUSHED AGGREGATE COURSE	
12	CURB AND GUTTER	
13	DRAINAGE PIPE (<= 24 IN)	
14	DRAINAGE PIPE (> 24 IN)	
15	DRILLED SHAFT	*Aggregated into "Bridge foundation"*
16	EXCAVATION-STREET	*Aggregated into "Earthworks"*
17	EXCAVATION-UNCLASSIFIED	*Aggregated into "Earthworks"*
18	FARM FENCE	
19	GUARDRAIL STEEL	*Aggregated into "Guardrail"*
20	MICROSURFACING	*Removed. So rare in the database*
21	PCCP	
22	PLANT MIX SURFACING	
23	REIN CONC BOX	
24	REINFORCING STEEL	
25	REVISE BRIDGE CONCRETE BARRIER	
26	RIPRAP	
27	SEEDING	
28	SIDEWALK	
29	SPECIAL BORROW	
30	SSPP	
31	TOPSOIL-SALVAGING AND PLACING	

** Orange cells indicate newly added items and red cells show the removed items from the previous list*

3.4 As-built schedules of the most common project types

The DWR data includes pay items, their implementation dates, project types, and project I.D.s. The extended list of controlling items was used to aggregate pay items into controlling work items. Then, the tool of the pivot table of Microsoft Excel was used to develop an as-built schedule for

each project. Figure 3.3 shows a sample of a Bridge reconstruction project (project ID of 8074001000) that was constructed from Oct. 2015 to Feb. 2016. The rows indicate dates and the columns show controlling work items.

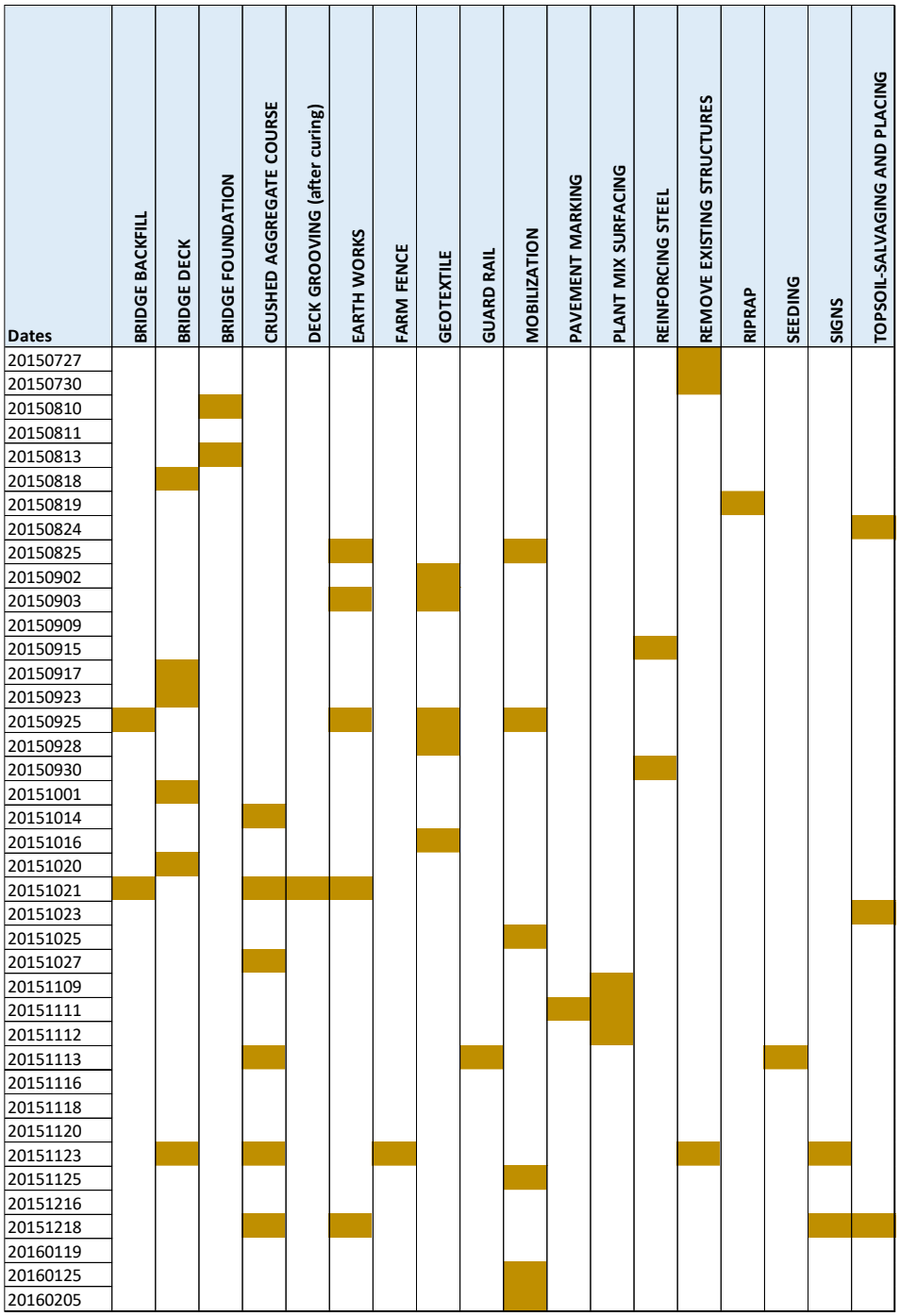


Figure 3.3 A sample of an initial as-built schedule of a bridge reconstruction project

As shown in Figure 3.3, the construction dates for each work item are not continuous and scattered over time. However, in practice, the activities are usually constructed in a continuous manner unless the locations are scattered. The problem of scattered dates was discussed with the MDT schedulers and it was realized that the dates associated with the work items might indicate payment dates as well as construction dates. Given this clarification, it can be inferred that the payment dates for each work item can be evidence of the construction progress of that item. If there are a couple of payment dates for each item, it can be interpreted that the item has been in progress during that period of time. Therefore, to develop a more realistic as-built schedule, the associated dates of each work item that include both construction dates and payment dates were linked together to create a bar chart showing the duration of that work item. Figure 3.4 shows a part of an extracted as-built schedule of a Bridge reconstruction project (project ID: 8074001000) with scattered dates converted to a refined format, including continuous dates by linking the scattered dates together.

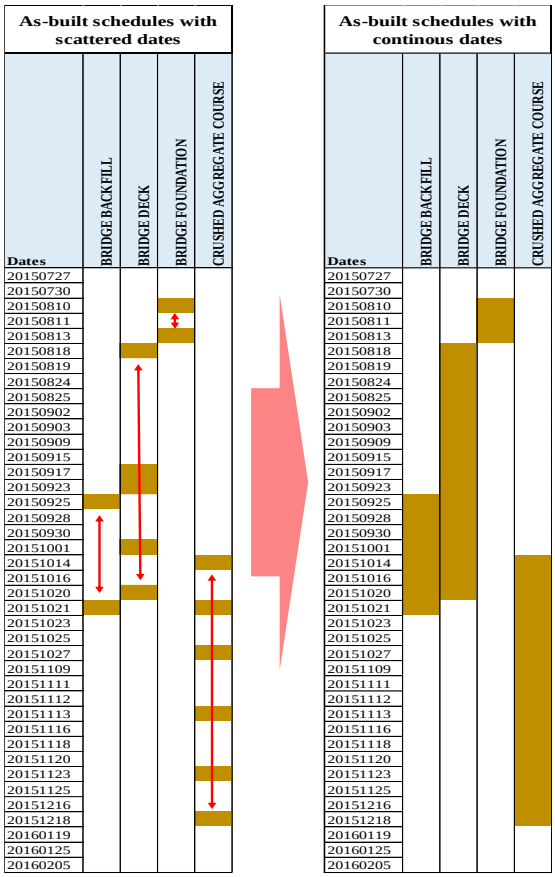


Figure 3.4 A sample of converting DWR data to a continuous and realistic as-built schedule

For each project type, five sample projects were selected to extract and refine as-built schedules. The sample projects from each type best represent the characteristics of the project type and include most of the controlling work items. The refined as-built schedules for those projects are included in Appendix **B**.

3.5 Analysis of construction sequences

The refined as-built schedules were analyzed to extract the sequence of controlling work items. Diagrams showing the sequence and concurrency of work items were developed for sample projects that are accessible in Appendix **C**. Since the results obtained from DWR data are limited to a few representative sample projects, the MDT project schedulers were also asked to draw the work item sequence diagrams based on their practical experience to validate and modify the construction sequence diagrams developed from DWR data analysis. The modified sequential diagrams are final deliverables of this research project, which are discussed in Chapter 5.

4. Discussion with MDT Schedulers

A workshop-style meeting with MDT schedulers was conducted on Dec. 12, 2019, to obtain their knowledge on controlling work items, most common highway project types, and common sequence patterns of controlling work items for the most common project types.

4.1 Controlling work items

The initial draft of the extended list of controlling work items developed from DWR data was discussed with MDT project schedulers. It was identified that some work items in the extended list are major items that have been neglected in the current list of MDT controlling items. Some existing items were determined to be minor items and need to be aggregated with other items. Table 4.1 shows the initial list of controlling work items. The orange cells indicate new work items extracted from DWR data and the white cells are current controlling work items. Table 4.2 shows the schedulers' comments on new work items. It indicates items that need to be kept, removed, and aggregated to another item. For example, the item of "Box beam" is a type of "Guardrail" and it needs to be aggregated to the Guardrail item.

Table 4.1 The initial draft of extended controlling work items

Initial draft of controlling work items			
#	List of Controlling work items	#	List of Controlling work items
1	ASPHALT CEMENT	28	FARM FENCE
2	CONCRETE BARRIER RAIL-BRIDGE	29	BASE PREPARATIONS (Soil Stabilization)
3	BASE-CEMENT TREATED	30	SIGNS
4	BEAMS	31	GUARD RAIL
5	BRIDGE DECK	32	TEMPORARY ACTIVITIES
6	BRIDGE BACKFILL	33	MOBILIZATION
7	RUMBLE STRIPS	34	BRIDGE PAINTING
8	BRIDGE DECK REPAIR	35	PLANT MIX SURFACING
9	CLEARING AND GRUBBING	36	PCCP
10	MILLING AND PULVERIZING	37	BRIDGE APPROACH SLAB
11	COMMERCIAL MIX	38	REIN CONC BOX
12	CONCRETE BARRIER RAIL	39	REINFORCING STEEL
13	COVER	40	REMOVE EXISTING STRUCTURES
14	CRACK SEALING	41	RETAINING WALL
15	CRUSHED AGGREGATE COURSE	42	REVISE BRIDGE CONCRETE BARRIER
16	DRAINAGE PIPE (> 24 IN)	43	RIPRAP
17	DRAINAGE PIPE (<= 24 IN)	44	SEEDING
18	CURB AND GUTTER	45	SHOULDER GRAVEL
19	PAVEMENT MARKING	46	SIDEWALK
20	DETOURING	47	TRAFFIC CONTROL
21	PILING	48	SPECIAL BORROW
22	DRILLED SHAFT	49	STRUCTURE EXCAVATION
23	EMBANKMENT IN PLACE	50	TOPSOIL-SALVAGING AND PLACING
24	EMULSIFIED ASPHALT	51	DECK GROOVING (after curing)
25	EROSION CONTROL	52	WING WALLS
26	EXCAVATION-UNCLASSIFIED		
27	EXCAVATION-STREET		

** Orange cells are new controlling work items from DWR data and white cells are previous controlling work items used by MDT*

Table 4.2 Summary of comments made on extended controlling work items by MDT project schedulers

Items to be added	**Items to be removed**		**Items to be aggregated**
	Item description	**Reason for removal**	
Milling and Pulverizing	Asphalt cement	This item is like an oil in asphalt and is a minor item	Box Beam → aggregate to guardrail
Bridge backfill	Flyash and Hydrate lime	Trivial item	Prestressed beam → aggregate to bridge
Rumble strip	Base preparation	Replace with geotextile stabilization	Commercial mix and plant mix → aggregate to plant
pavement marking	Clean culvert pipe	Trivial item	Piling and drill shaft → aggregate to bridge
Detouring	Erosion control	Trivial item	Embankment, excavation → aggregate to earth work
Mobilization	Emulsified asphalt	Trivial item	
Bridge painting	Traffic control	Does not typically affect the project duration	
Bridge approach slab	Structure excavation	Trivial item	
Remove existing structure	Temporary activities	Does not typically affect the project duration	
retaining wall			
shoulder gravel			
Deck grooving			
Wing walls			

In addition, the MDT schedulers made comments on pay items included in each controlling work item. Table 4.3 shows an example of the initial list of pay items and schedulers' comments for some controlling work items, including bridge deck, bridge deck repair, and bridge deck milling. The pay items included in each work item were then modified according to the schedulers' comments (Table 4.4). The final list of pay items included in each controlling work item is available in Appendix **A**. Table 4.5 shows the final controlling work items that are based on knowledge gained from the literature review, MDT DWR data analysis and practical knowledge of MDT project schedulers. As a result, the total number of controlling activities increased from 31 (previous list used by MDT) to 48 items (the extended list).

Table 4.3 Some of initial controlling items and the coverage of pay items

Controlling work items	**ITEM_DESCCRIPTION**	**Item-Code**	*Schedulers comments*
BRIDGE DECK	BRIDGE DECK CRACK SEAL	552010160	** Bridge Deck Hydrodemolition could be added to Bridge Deck Milling, since it is another form of Bridge Deck Milling*
	BRIDGE DECK HYDRODEMOLITION	552010199	
	BRIDGE DECK SCARIFICATION	552010150	
	BRIDGE DECK TREATMENT	552010430	
	CONCRETE-CLASS DD	551170000	
	CONCRETE-CLASS DD BRIDGE	551020035	** The new Standard Specification (2014) defined new classes for bridge concrete that need to be included in bridge deck:* *•Class Structure, 551020035* *•Class Deck, 551020107* *•Class Overlay, 563000000* *•Class Drilled Shaft, 551020166*
CLASS A BRIDGE DECK REPAIR	BRIDGE DECK REPAIR	552010250	
	BRIDGE DECK REPAIR	552010300	
	BRIDGE DECK REPAIR	552010302	
BRIDGE DECK MILLING	BRIDGE DECK MILLING	552010155	
	BRIDGE DECK MILLING	561020110	

Table 4.4 Modified list of extended controlling items reflecting schedulers' comments

Controlling work items	ITEM_DESCCRIPTION	Item-Code
BRIDGE DECK	BRIDGE DECK CRACK SEAL	552010160
	BRIDGE DECK CRACK SEAL	999552240
	BRIDGE DECK HYDRODEMOLITION	552010199
	BRIDGE DECK SCARIFICATION	552010150
	BRIDGE DECK TREATMENT	552010430
	BRIDGE DECK TREATMENT	552130000
	CONCRETE-CLASS DD	551170000
	CONCRETE-CLASS DD	551175000
	CONCRETE-CLASS DD	551020030
	CONCRETE-CLASS DD BRIDGE	551020035
	CONCRETE-CLASS DD BRIDGE	551175000
	CONCRETE-CLASS DECK	551020107
	CONCRETE-CLASS SD	551410000
	CONCRETE-CLASS SD	551020107
	CONCRETE-CLASS STRUCTURE	551020035
BRIDGE DECK REPAIR	CLASS A BRIDGE DECK POLY REPAIR	552010250
	CLASS A BRIDGE DECK POLY REPAIR	562000000
	CLASS A BRIDGE DECK REPAIR	552010300
	CLASS A BRIDGE DECK REPAIR	552120000
	CLASS A BRIDGE DECK REPAIR	562000020
	CLASS B BRIDGE DECK REPAIR	552010302
	CLASS B BRIDGE DECK REPAIR	562000030
BRIDGE DECK MILLING	BRIDGE DECK MILLING	552010155
	BRIDGE DECK MILLING	561020110

Table 4.5 Final list of extended controlling work items

Final list of extended controlling work items				
#	Item description		#	Item description
1	BASE-CEMENT TREATED		25	GEOTEXTILE
2	BEAMS		26	GUARD RAIL
3	BRIDGE APPROACH SLAB		27	MICROSURFACING
4	BRIDGE BACKFILL		28	MILLING AND PULVERIZING
5	BRIDGE DECK		29	MOBILIZATION
6	BRIDGE DECK MILLING		30	PAVEMENT MARKING
7	BRIDGE DECK REPAIR		31	PCCP
8	BRIDGE FOUNDATION		32	PLANT MIX SURFACING
9	BRIDGE PAINTING		33	REIN CONC BOX
10	CLEARING AND GRUBBING		34	REINFORCING STEEL
11	CONCRETE BARRIER RAIL		35	REMOVE EXISTING STRUCTURES
12	CONCRETE BARRIER RAIL-BRIDGE		36	RETAINING WALL
13	CONCRETE-CLASS OVERLAY		37	REVISE BRIDGE CONCRETE BARRIER
14	SEAL & COVER		38	RIPRAP
15	CRACK SEALING		39	RUMBLE STRIPS
16	CRUSHED AGGREGATE COURSE		40	SEEDING
17	CURB AND GUTTER		41	SHOULDER GRAVEL
18	DECK GROOVING (after curing)		42	SIDEWALK
19	DETOURING		43	SIGNS
20	DRAINAGE PIPE (<= 24 IN)		44	SPECIAL BORROW
21	DRAINAGE PIPE (> 24 IN)		45	SSPP
22	EARTH WORKS		46	TOPSOIL-SALVAGING AND PLACING
23	FARM FENCE		47	WING WALLS
24	GEOGRID		48	FINAL SWEEP AND BROOM

4.2 Frequent controlling work items for each project type

The DWR data has been used to compute the frequency of work items in each project type to identify major controlling work items. If a controlling work item appears in more than 25% of the projects in that type, MDT considers the item as a common work item. To obtain practical knowledge on common work items, the list of work items for each project type was presented to MDT schedulers and asked to identify whether an item is common or not common in each project type. Table 4.7 to Table 4.9 show the frequency analysis results of DWR data and the MDT schedulers' opinions. In some cases, although a work item appears in more than 25% of the projects, MDT schedulers identified that item as an uncommon or an irrelevant item to the project type. For example, Rumble Strip and Crushed Aggregate Course have a frequency of occurrence of 43% and 30% respectively in overlay projects, but MDT schedulers identified them as not common for Urban Overlay projects and not applicable in Rural Projects. Also, there are some cases where the frequency of the item is lower than 25%, but MDT schedulers identified that item

as a common item. For example, Final Sweep & Broom is typically done after all projects to clean up. However, in the Safety project, the frequency of this activity is 12%. The MDT schedulers identified that as a common item in all project types. A probable reason of a few mismatch cases between the frequency analysis results and MDT schedulers' opinion is either some activities have been common in the past, but not anymore in recent projects, or some activities are common in recent project, but were rare in historical projects. In such a few mismatch cases, the expert's opinion obtained from MDT schedulers used as a basis for sequence logic diagrams.

Table 4.6 Frequency analysis of controlling work items (Overlay Projects)

Overlay				
Controlling Work Items	**Frequency**	**Percentage**	**Expert's Opinion (Urban)**	**Expert's Opinion (Rural)**
MOBILIZATION	190	99%	Common	Common
PAVEMENT MARKING	187	98%	Common	Common
MILLING AND PULVERIZING	181	95%	Common	Common
SEAL AND COVER	171	90%	Common	Common
REMOVE EXISTING STRUCTURES	166	87%	Not Applicable	Not Applicable
PLANT MIX SURFACING	156	82%	Common	Common
SIGNS	135	71%	Common	Common
GUARD RAIL	99	52%	Common	Common
RUMBLE STRIPS	83	43%	Not Common	Not Applicable
CRUSHED AGGREGATE COURSE	58	30%	Not Common	Not Applicable
FINAL SWEEP AND BROOM	57	30%	Common	Common
SIDEWALK	36	19%	Common	Not Applicable
CURB AND GUTTER	32	17%	Common	Not Applicable
GEOTEXTILE	30	16%	Not Common	Not Applicable
SPECIAL BORROW	30	16%	Not Common	Not Common
EARTH WORKS	29	15%	Not Common	Not Common
TOPSOIL-SALVAGING AND PLACING	12	6%	Not Applicable	Not Common
FARM FENCE	11	6%	Not Applicable	Not Applicable
Total	**191**	_	_	_

Table 4.7 Frequency analysis of controlling work items (Seal & Cover Projects)

Seal & Cover			
Controlling Work Items	**Frequency**	**Percentage**	**Expert's Opinion**
MOBILIZATION	89	100%	Common
PAVEMENT MARKING	89	100%	Common
SEAL AND COVER	88	99%	Common
REMOVE EXISTING STRUCTURES	43	48%	Not Applicable
CRACK SEALING	30	34%	Common
PLANT MIX SURFACING	30	34%	Not Common
SIGNS	30	34%	Common
FINAL SWEEP AND BROOM	27	30%	Common
MILLING AND PULVERIZING	25	28%	Not Common
GUARD RAIL	22	25%	Not Applicable
CRUSHED AGGREGATE COURSE	13	15%	Not Common
RUMBLE STRIPS	13	15%	Not Applicable
CURB AND GUTTER	5	6%	Not Common
SIDEWALK	5	6%	Not Common
GEOTEXTILE	4	4%	Not Applicable
SHOULDER GRAVEL	4	4%	Not Applicable
EARTH WORKS	2	2%	Not Applicable
TOTAL	**89**	_	_

Table 4.8 Frequency analysis of controlling work items (Safety Projects)

Safety			
Controlling Work Items	**Frequency**	**Percentage**	**Expert's Opinion**
MOBILIZATION	100	100%	Common
REMOVE EXISTING STRUCTURES	78	78%	Not Applicable
SIGNS	70	70%	Common
PAVEMENT MARKING	44	44%	Common
CRUSHED AGGREGATE COURSE	42	42%	Common
EARTH WORKS	40	40%	Common
GUARD RAIL	34	34%	Common
SEAL AND COVER	28	28%	Common
PLANT MIX SURFACING	26	26%	Common
SEEDING	25	25%	Not Applicable
TOPSOIL-SALVAGING AND PLACIN	21	21%	Common
DRAINAGE PIPE (<= 24 IN)	19	19%	Not Applicable
FARM FENCE	13	13%	Not Common
FINAL SWEEP AND BROOM	12	12%	Common
SIDEWALK	11	11%	Not Common
CURB AND GUTTER	9	9%	Not Common
MILLING AND PULVERIZING	8	8%	Not Common
GEOTEXTILE	6	6%	Not Common
RIPRAP	6	6%	Not Applicable
SPECIAL BORROW	6	6%	Not Common
DRAINAGE PIPE (> 24 IN)	2	2%	Not Applicable
Total	**100**	_	_

Table 4.9 Frequency analysis of controlling work items (Bridge Reconstruction & Rehabilitation Projects)

Bridge Reconstruction and Rehabilitation			
Controlling Work Items	**Frequency**	**Percentage**	**Expert's Opinion**
MOBILIZATION	58	100%	Common
REMOVE EXISTING STRUCTURES	54	93%	Common
GUARD RAIL	47	81%	Common
BRIDGE DECK	45	78%	Common
EARTH WORKS	42	72%	Common
CRUSHED AGGREGATE COURSE	39	67%	Common
SIGNS	38	66%	Common
DECK GROOVING (after curing)	37	64%	Common
PAVEMENT MARKING	37	64%	Common
BRIDGE FOUNDATION	34	59%	Common
SEAL AND COVER	33	57%	Common
RIPRAP	31	53%	Common
TOPSOIL-SALVAGING AND PLACING	31	53%	Common
PLANT MIX SURFACING	30	52%	Common
FARM FENCE	28	48%	Common
DRAINAGE PIPE	28	48%	Common
MILLING AND PULVERIZING	21	36%	Common
GEOTEXTILE	17	29%	Common
SPECIAL BORROW	13	22%	Common
RUMBLE STRIPS	12	21%	Common
FINAL SWEEP AND BROOM	10	17%	Common
CLEARING AND GRUBBING	3	5%	Not Applicable
CONCRETE-CLASS OVERLAY	3	5%	Not Applicable
CONCRETE BARRIER RAIL	2	3%	Not Applicable
SIDEWALK	2	3%	Not Applicable
SHOULDER GRAVEL	1	2%	Not Applicable
Total	**58**	_	_

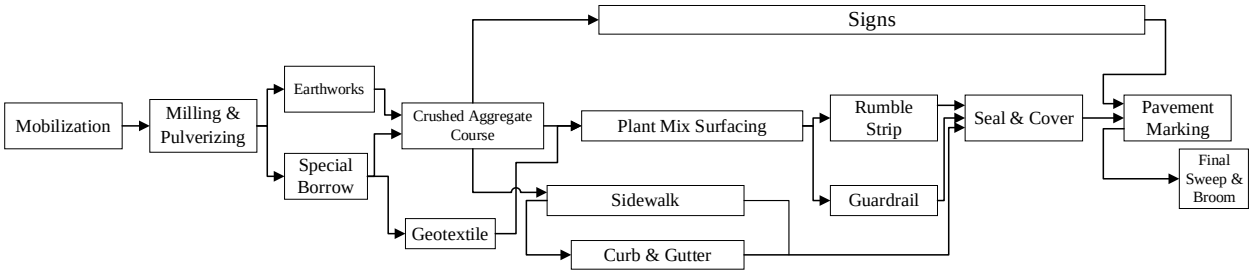
5. Construction Activity Sequence Logic Diagrams

MDT schedulers were asked to draw a typical sequence logic of frequent and common controlling work items for the most common project types. The final construction activity sequence logic diagrams were developed by integrating MDT schedulers' diagrams based on their experience and initial logic diagrams developed from DWR data analysis. The sequence logic diagrams were developed for the five most common project types: a) overlay (urban), b) overlay (rural), c) seal & cover, d) safety and e) bridge reconstruction and rehabilitation. For each project type except for Bridge reconstruction and rehabilitation, two sequence diagrams are developed. The first one (Diagram A) consists of all potential major controlling activities that may include uncommon work items and items that may not be directly relevant to the project type but appeared in historical DWR data. The second one (Diagram B) is the standard sequence logic that includes only the most common activities in each project type.

5.1 Overlay (urban)

Figure 5.1 shows the final activity sequence logic diagrams for urban overlay projects including two diagrams; A) sequence logic for all possible controlling activities and B) standard sequence logic for most common activities that are directly relevant to urban overlay projects. According to the identified sequence logic for all possible activities (Figure 5.1- A), an urban overlay project typically starts off with mobilization followed by milling & pulverizing. Earthworks include the controlling work items of: "excavation-street", "excavation-unclassified", "excavation-muck", and "embankment in place". The special borrow is performed in parallel to earthworks. After that, crushed aggregate course in parallel with geotextile is performed. Plant mix surfacing is performed right after the crushed aggregate course and two activities of the sidewalk and curb & gutter are implemented at the same time. Rumble strip is implemented after the plant mix surfacing and if the project includes a guardrail implementation, it can be constructed at the same time. Seal & cover is performed before pavement marking and is performed after almost all activities are completed. Signs installment can be performed from the early stages of the project in parallel with other controlling work items until the pavement marking. Final sweep and broom is typically performed after the start of pavement marking with a lag time, which is typically the last work item. Figure 5.1 - B shows the sequence logic of the common work items, where uncommon or unrelated work items to the project type are eliminated.

A. Overlay (urban)- All possible major controlling work items



B. Overlay (urban)- Most common work items

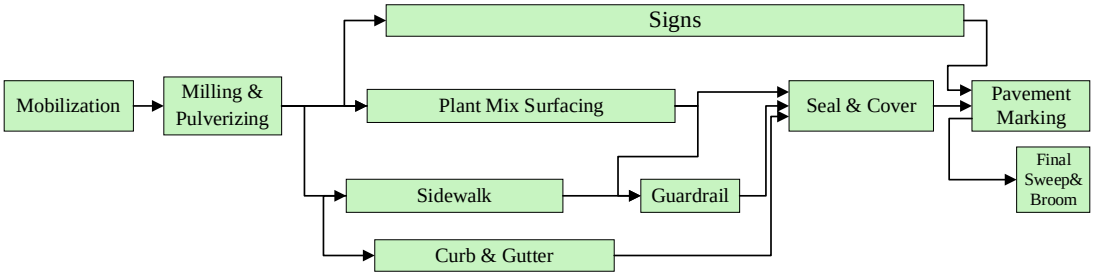
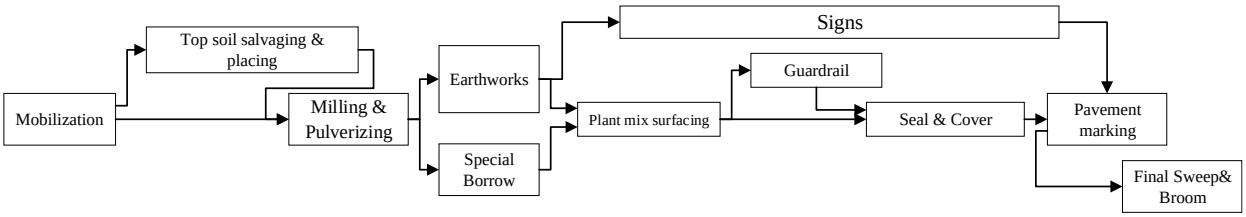


Figure 5.1 Sequence logic diagrams for overlay projects in urban areas

5.2 Overlay (rural)

Figure 5.2 shows the activity sequence logic for overlay projects in rural areas in two parts; A) sequence logic for all possible controlling activities and B) standard sequence logic for most common activities that are directly relevant to rural overlay projects. Compared with overlay projects in urban areas, some controlling work items are more common in rural areas and they include topsoil salvaging & placing and guardrail, while some others are relatively more typical for urban areas such as rumble strip, and sidewalk. In a rural area overlay project, the work item of topsoil salvaging is performed after mobilization and may overlap with milling and pulverizing. The construction logic of other controlling work items is similar to overlay projects in urban areas. Figure 5.2 – B indicates the sequence logic of most common activities, where rare and unrelated activities to the project type are eliminated.

A. Overlay (rural) – All possible work items



B. Overlay (rural) – Most common work items

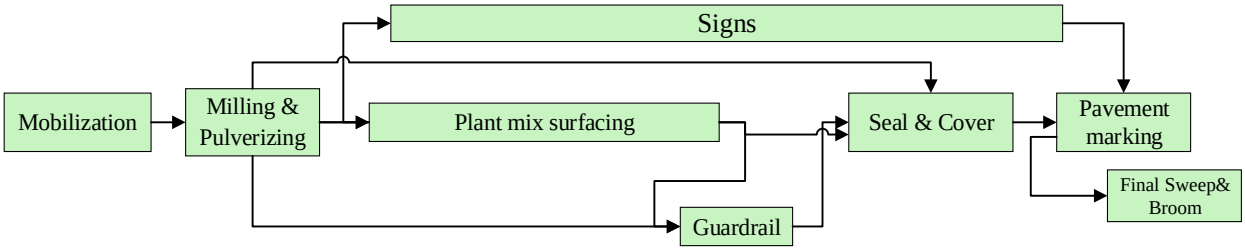
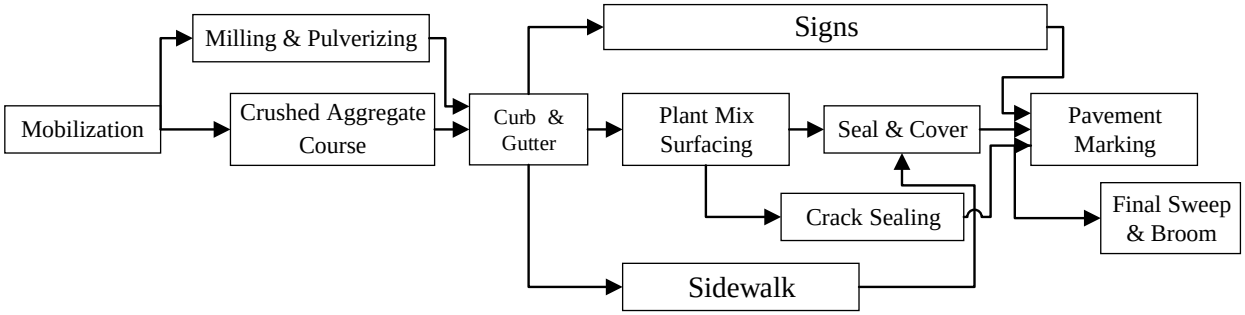


Figure 5.2 Sequence logic diagram for overlay projects in rural areas

5.3 Seal & Cover

Figure 5.3 represents the activity sequence logic diagrams for seal & cover projects; A) sequence logic for all possible controlling activities and B) standard sequence logic for most common activities that are directly relevant to seal & cover projects. As shown in Figure 5.3 – A, seal & cover projects start off with mobilization followed by milling & pulverizing, crushed aggregate course, curb & gutter, plant mix surfacing, seal & cover, pavement marking, and final sweep & broom. This chain of activities is typically the critical path of seal & cover projects. The activity of crack sealing may start before the start of the seal & cover activity but may finish sooner. Sidewalk and signs are implemented concurrently with plant mix surfacing and seal & cover. The project finishes with the final sweep & broom. Figure 5.3 – B indicates the sequence logic of seal & cover projects that just includes the most common activities, where uncommon or unrelated work items to the project type are eliminated.

A. Seal & Cover – All possible work items



B. Seal & Cover – Most common work items

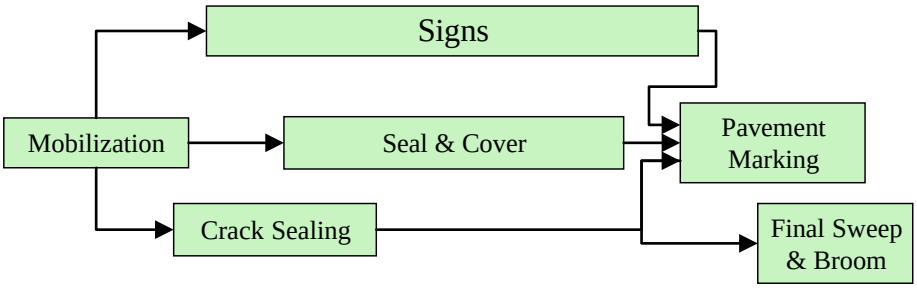
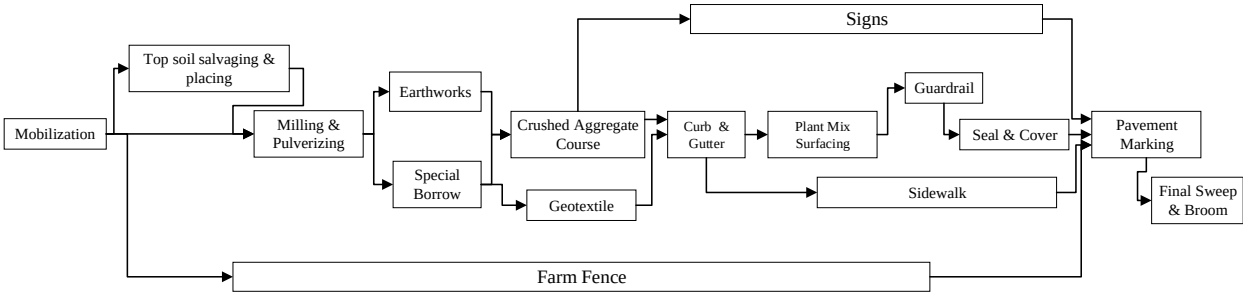


Figure 5.3 Sequence logic diagram for seal & cover projects

5.4 Safety

Figure 5.4 shows the activity sequence logic diagrams for safety projects in two parts; A) sequence logic for all possible major controlling activities and B) sequence logic for common activities that occur most of the time by eliminating uncommon or unrelated controlling items to the project type.

A. Safety – All possible work items



B. Safety – Most common work items

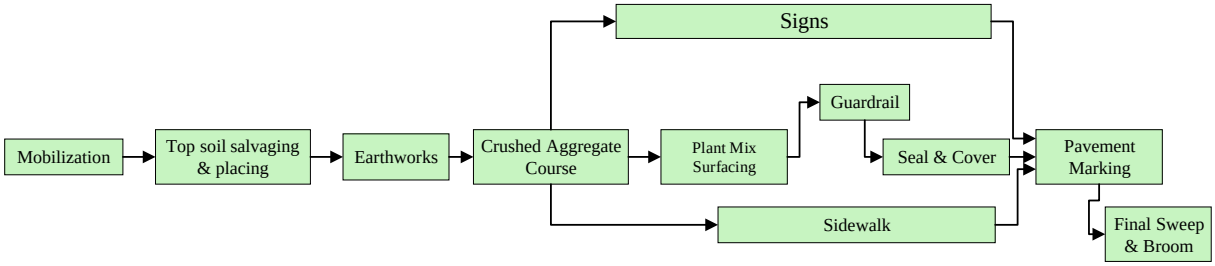


Figure 5.4 Sequence logic diagram for safety projects

5.5 Bridge reconstruction and rehabilitation

Figure 5.5 represents the activity sequence logic for bridge reconstruction and rehabilitation. The overall sequential pattern of work items is similar to the previous project types. However, it includes some additional activities. Drainage pipe can be installed in parallel with earthworks, special borrow, and bridge foundations. The work item of the reinforced concrete deck is implemented at almost the same time. A chain of bridgework items can be performed in parallel with other activities. Riprap installation can be performed at the same time with plant mix surfacing and sidewalk. The project finishes with pavement marking and final sweep & broom.

Bridge reconstruction & rehabilitation – Most common work items

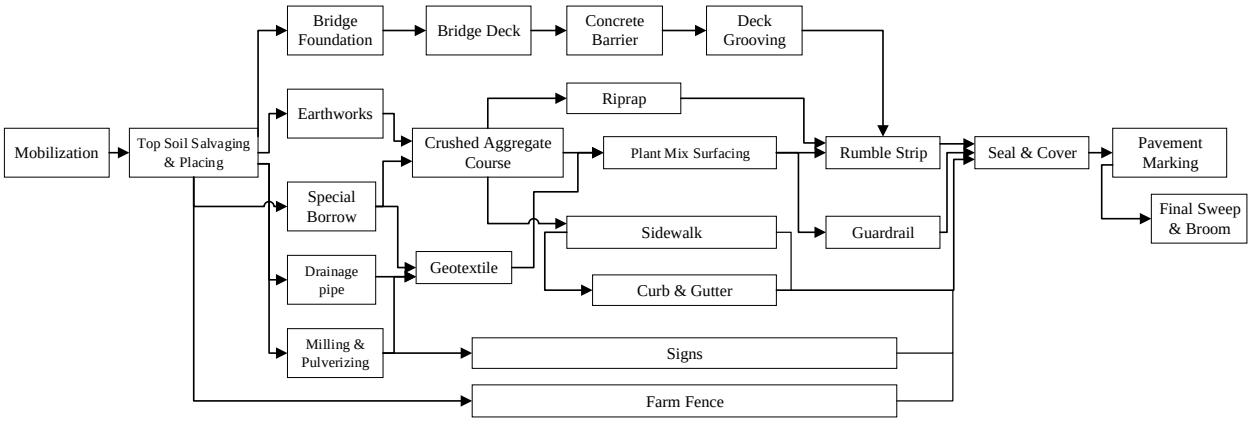


Figure 5.5 Sequence logic diagram for bridge reconstruction and rehabilitation projects

6. Conclusion and recommendations

Construction contract time determination is one of the most important and challenging work tasks as it directly affects the project's completion time and price, contractors' bidding behavior, project's quality, safety, and the inconvenience to the general public. Construction sequence logic development is one of the most challenging processes required in determining construction contract time.

This report provides standard construction sequence logic diagrams for the five most common project types in Montana; a) overlay (urban), b) overlay (rural), c) seal & cover, d) safety, and e) bridge reconstruction and rehabilitation. These visual logic diagrams were developed based on a) a thorough analysis of DWR data from historical highway projects in Montana and b) experience and knowledge obtained from MDT schedulers.

Visual logic diagrams can be powerful resources because they can give schedulers quick and reliable visual aids in finalizing the duration of a project. The diagrams can also be used to train inexperienced schedulers and give them confidence in their contract time estimation. The construction logic diagrams can be used as supplemental components when MDT updates and revise their current contract time determination manual.

Recommendations:

The current list of controlling work items in MDT includes 31 items. By analyzing as-built schedules, the research team identified that the current list doesn't effectively cover controlling activities that may affect the total duration of a project. It was recognized that some controlling work items were missing, and some of the existing items in the current list could be aggregated together into one controlling item. The controlling work items of other DOTs were studied and a discussion with MDT schedulers was conducted to modify the list of controlling work items. The current list of 31 items has been extended to a list of 48 items, where each item may include multiple pay items. A full description of the modification process, the reason for each modification case, and the list of pay items included in each work item is provided in this report. It is recommended that MDT use the new list of controlling work items for their future project scheduling, and contract time determination. It is also recommended that this new list should be included in the MDT's contract time determination manual in the appendix section as formal documentation and easy reference for future users.

The research team identified that the dates that pay items are charged in the Daily Work Reports (AASHTOware SiteManager) may sometimes differ from actual construction dates of the pay items. Some of those dates may include actual payment dates to contractors on the items. Although the research team carefully analyzed many Daily Work Reports to extract reasonable ones, inaccurate reports may lead to inaccurate information on the construction time of activities. The project team recommends that MDT ask contractors to submit an as-built schedule at the completion of a project using the MDT's list of controlling work items, not their own work

breakdown structure used for the project. The accumulation of accurate as-built schedules will lead to more realistic scheduling and time estimation for future projects.

This research project developed standard sequence logic diagrams of major controlling work items for five common highway project types in MDT. The research team recommends MDT schedulers use the diagrams as a supporting resource in estimating an accurate, defensible contract time for their future projects. The diagrams can be used as training material for inexperienced schedulers. It is also recommended that these diagrams are included in the MDT's contract time determination manual in the appendix section as formal documentation and easy reference for future users.

References

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

Hancher, D.E., McFarland, W and Alabay, R.T. (1992), Construction Contract Time Determination, Texas Transportation Institute, Texas A&M University System Research Report 1262-1F

Jeong, H. S., Oberlender, G., Atreya, S., & Akella, V. (2008), Development of an Improved System for Contract Time Determination (Phase I & II) (FHWA-OK-08-02).

Jones, E. F. (2009), Scheduling 101—the basic of best practices. Paper presented at PMI® Global Congress 2009—North America, Orlando, FL. Newtown Square, PA: Project Management Institute.

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

Werkmeister, R.F., Luscher, B.L., and Hancher, D.E., (2000), Kentucky Contract Time Determination System, Transportation Research Record 1712, pp 185-195, 2000

Appendix A: The list of pay items aggregated into controlling activities

Detailed list of controlling work items			
#	**Controlling work items**	**Pay items**	**Item-Code**
1	BASE-CEMENT TREATED	BASE-CEMENT TREATED	304115000
2	BEAMS	PRESTRESSED BEAM-TYPE 4	553030000
		PRESTRESSED BEAM-TYPE A	553010000
		PRESTRESSED BEAM-TYPE M-72	553040000
		PRESTRESSED BEAM-TYPE M-81	553040050
		PRESTRESSED BEAM-TYPE MT-28	553040100
		PRESTRESSED TRI DECK BEAMS	553060000
3	BRIDGE APPROACH SLAB	RAISE BRIDGE APPROACH SLAB	501010550
4	BRIDGE BACKFILL	BRIDGE END BACKFILL	301750000
5	BRIDGE DECK	BRIDGE DECK CRACK SEAL	552010160
		CONCRETE-CLASS STRUCTURE	551020035
		BRIDGE DECK SCARIFICATION	552010150
		BRIDGE DECK TREATMENT	552010430
		CONCRETE-CLASS DD	551170000
		CONCRETE-CLASS DD BRIDGE	551020035
		CONCRETE-CLASS DECK	551020107
		CONCRETE-CLASS SD	551410000
		CONCRETE-CLASS SD	551020107
6	BRIDGE DECK REPAIR	CLASS A BRIDGE DECK POLY REPAIR	552010250
		CLASS A BRIDGE DECK REPAIR	552010300
		CLASS B BRIDGE DECK REPAIR	552010302
7	BRIDGE DECK MILLING	BRIDGE DECK MILLING	552010155
		BRIDGE DECK MILLING	561020110
		BRIDGE DECK HYDRODEMOLITION	552010199

Detailed list of controlling work items

#	Controlling work items	Pay items	Item-Code
8	BRIDGE FOUNDATION	DR STL PILE HP 250 X 62 MM	559332500
		DR STL PILE HP 310 X 110 MM	559333110
		DR STL PILE HP 310 X 79 MM	559333100
		DR STL PILE HP 360 X 152 MM	559333630
		DR STL PILE-HP 12 X 74	559030094
		DR STL PIPE PILE 14 OD X 1/2 IN	559060096
		DR STL PIPE PILE 16 OD X 3/4 IN	559060107
		DR STL PIPE PILE 360 X 9.5 MM	559343060
		DR STL PIPE PILE 406 X 12.7 MM	559344050
		DR STL PIPE PILE 406X12.7 MM	559344050
		DR STL PIPE PILE 457 X 12.7 MM	559344057
		DR STL PIPE PILE 508 X 12.7 MM	559345050
		DR STL PIPE PILE 508X12.7 MM	559345050
		DRILLED SHAFT - 1.22 M	552712200
		DRILLED SHAFT - 2.44 M	552724400
		DRILLED SHAFT - 6.0 FT	552010101
		DRILLED SHAFT CASING - 2.44 M	552762440
		DRILLED SHAFT CASING - 6.0 FT	552010606
		DRILLED SHAFT CASING-1.22 M	552751220
		DRILLED SHAFT CASING-2.44 M	552762440
		DRILLED SHAFT CONCRETE	552701000
		FRN STL PIPE PILE 406X12.7 MM	559244050
		PILE - PREBORE	559500000
		PILE CONICAL DRIVING POINT	559560000
		PILE CUTTING SHOE	559550000
		PILE DRILL AND SOCKET	559040000
		PILE DRIVING POINT	559060300
9	BRIDGE PAINTING	PAINT BRIDGE RAIL	606010694
10	CONCRETE-CLASS OVERLAY	CONCRETE-CLASS OVERLAY	563000000
11	CLEARING AND GRUBBING	CLEARING AND GRUBBING	201310000
12	CONCRETE BARRIER RAIL	CONCRETE BARRIER RAIL	606290000
13	CONCRETE BARRIER RAIL-BRIDGE	BARRIER RAIL-CAST IN PLACE-BR	606300104
		CONCRETE BARRIER RAIL-CAST IN PLACE	606300100

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
14	SEAL AND COVER	COVER - TYPE 1	301440010
		COVER - TYPE 2	301440020
		COVER-TYPE 1	301020718
		COVER-TYPE 2	301020735
15	CRACK SEALING	CRACK SEALING	402020502
16	CRUSHED AGGREGATE COURSE	CRUSHED AGGREGATE COURSE	301270000
17	CURB AND GUTTER	CURB AND GUTTER-CONC	609010200
		CURB AND GUTTER-CONCRETE	609000000
18	DECK GROOVING (after curing)	TRANSVERSE DECK GROOVING	552150000
19	DETOURING	DETOUR-CONST MAINTAIN AND REM	104230000
20	DRAINAGE PIPE (<= 24 IN)	CSP 120 IN 0.109-CTD	603010728
		CSP 24 IN 0.064	603010532
		CSP 300 MM X 2.01 MM	603100320
		CSP 300 MM X 2.01 MM CTD	603100321
		CSP 450 MM X 1.63 MM	603100451
		CSP 450 MM X 2.01 MM	603100460
		CSP 600 MM X 2.01 MM CTD	603100621
		CSP ARCH 128 IN 0.138-CTD	603011305
		CSP IRR 300 MM X 2.01 MM	603110310
		CSP IRR 450 MM X 2.01 MM	603110440
		CSP IRR 600 MM X 1.63 MM	603110616
		CSP IRR 600 MM X 2.01 MM	603110618
		DRAINAGE PIPE 18 IN	603010040
		DRAINAGE PIPE 24 IN	603010048
		DRAINAGE PIPE 300 MM	603003000
		DRAINAGE PIPE ARCH IRR 560 MM	603075600
		DRAINAGE PIPE IRR 300 MM	603033000
		DRAINAGE PIPE IRR 450 MM	603033450
		DRAINAGE PIPE IRR 600 MM	603036000
		RCP 18 IN CLASS 2	603012530
		RCP 24 IN CLASS 2	603012555
		RCP 300 MM CL 5	603403050
		RCP 375 MM CL 5	603406721
		RCP 450 MM CL 2	603404520
		RCP 600 MM CL 2	603406020
		RCP 600 MM CL 3	603406030
		RCP IRR 12 IN CLASS 3	603012805
		RCP IRR 12 IN CLASS 4	603012810
		RCP IRR 24 IN CLASS 2	603012875
		RCP IRR 300 MM CL 4	603443040
		RCP IRR 600 MM CL 2	603446020
		RCP IRR 600 MM CL 4000D	603446060
		RCP IRR 600 MM CL 5	603446050
		RCP SIPHON 24 IN CLASS 2	603013050
		RCP SIPHON 450 MM CL 3	603470430
		RCP SIPHON 600 MM CL 2	603470620
		RCP SIPHON 600 MM CL 3	603470630
		RCPA 560 MM CL 2	603505620
		RCPA 560 MM CL 3	603505630
		RCPA IRR 560 MM CL 3	603446001

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
21	DRAINAGE PIPE (> 24 IN)	CSP 108 IN 0.109	603010720
		CSP 120 IN 0.138-CTD	603010729
		CSP 1200 MM X 1.63 MM	603101216
		CSP 1200 MM X 1.63 MM CTD	603101217
		CSP 1200 MM X 2.01 MM	603101220
		CSP 1200 MM X 2.01 MM CTD	603101221
		CSP 1500 MM X 2.01 MM CTD	603101532
		CSP 1500 MM X 2.01MM	603101530
		CSP 1800 MM X 2.01 MM	603101820
		CSP 2100 MM X 2.01 MM CTD	603102121
		CSP 2400 MM X 2.77 MM	603102427
		CSP 2400 MM X 2.77 MM CTD	603102428
		CSP 2700 MM 2.77 MM	603102728
		CSP 2700 MM X 2.77 MM CTD	603102730
		CSP 3000 MM X 3.51 MM	603103035
		CSP 84 IN 0.079-CTD	603010694
		CSP 900 MM X 2.01 MM CTD	603100921
		CSP 96 IN 0.109-CTD	603010713
		CSP IRR 1050 MM X 2.01 MM	603110935
		CSPA 1240 MM X 2.77 MM	603121127
		CSPA IR 1060 MM X 2.01 MM CTD	603131017
		DRAINAGE PIPE 1050 MM	603011050
		DRAINAGE PIPE 108 IN	603010108
		DRAINAGE PIPE 1200 MM	603012000
		DRAINAGE PIPE 1350 MM	603013500
		DRAINAGE PIPE 1500 MM	603015000
		DRAINAGE PIPE 1800 MM	603018000
		DRAINAGE PIPE 2100 MM	603021000
		DRAINAGE PIPE 2400 MM	603024000
		DRAINAGE PIPE 30 IN	603010056
		DRAINAGE PIPE 36 IN	603010066
		DRAINAGE PIPE 42 IN	603010064
		DRAINAGE PIPE 48 IN	603010068
		DRAINAGE PIPE 54 IN	603010072
		DRAINAGE PIPE 750 MM	603007500
		DRAINAGE PIPE 900 MM	603008900
		DRAINAGE PIPE ARCH 51 IN IRR	603010376
		DRAINAGE PIPE ARCH 1110 MM	603061110
		DRAINAGE PIPE ARCH 1300 MM	603061300
		DRAINAGE PIPE ARCH 1485 MM	603061480
		DRAINAGE PIPE ARCH 1650 MM	603061650
		DRAINAGE PIPE ARCH 1855 MM	603061850
		DRAINAGE PIPE ARCH 22 IN IRR	603010350
		DRAINAGE PIPE ARCH 2235 MM	603062230
		DRAINAGE PIPE ARCH 29 IN	603010152

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
21	DRAINAGE PIPE (> 24 IN)	DRAINAGE PIPE ARCH 36 IN	603010160
		DRAINAGE PIPE ARCH 58 IN	603010180
		DRAINAGE PIPE ARCH 725 MM	603057250
		DRAINAGE PIPE ARCH 73 IN	603010192
		DRAINAGE PIPE ARCH 920 MM	603058800
		DRAINAGE PIPE IRR 1050 MM	603041050
		DRAINAGE PIPE IRR 1200 MM	603041200
		DRAINAGE PIPE IRR 1800 MM	603041800
		DRAINAGE PIPE IRR 750 MM	603037500
		DRAINAGE PIPE IRR 900 MM	603038900
		RCP 1200 MM CL 2	603412020
		RCP 1200 MM CL 5	603412050
		RCP 30 IN CLASS 2	603012610
		RCP 750 MM CL 2	603406500
		RCP 900 MM CL 2	603408920
		RCP IRR 1050 MM CL 2	603450520
		RCP IRR 1200 MM CL 2	603452020
		RCP IRR 1200 MM CL 3	603452030
		RCP IRR 1200 MM CL 4	603452034
		RCP IRR 1200 MM CL 5	603452050
		RCP IRR 1350 MM CL 2	603453520
		RCP IRR 30 IN CLASS 2	603012910
		RCP IRR 36 IN CLASS 2	603012935
		RCP IRR 42 IN CLASS 2	603012955
		RCP IRR 675 MM CL 3	603446725
		RCP IRR 750 MM CL 2	603447520
		RCP IRR 750 MM CL 3	603447530
		RCP IRR 750 MM CL 4	603447540
		RCP IRR 900 MM CL 2	603448920
		RCP SIPHON 900 MM CL 2	603470920
		RCPA 1110 MM CL 3	603511030
		RCPA 1300 MM CL 3	603513030
		RCPA 1485 MM CL 3	603514830
		RCPA 1485 MM CL 4	603514831
		RCPA 1650 MM CL 3	603516530
		RCPA 36 IN CL 3	603013217
		RCPA 725 MM CL 2	603507110
		RCPA 725 MM CL 3	603507230
		RCPA 725 MM CL 4	603507232
		RCPA 920 MM CL 2	603508920
		RCPA 920 MM CL 3	603508930
		RCPA IRR 1110 MM CL 3	603561130
		RCPA IRR 1300 MM CL 3	603513023
		RCPA IRR 1485 MM CL 2	603564820
		RCPA IRR 1485 MM CL 3	603564830

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
22	EARTH WORKS	EMBANKMENT IN PLACE	203300000
		EXCAVATION-MUCK	203160000
		EXCAVATION-STREET	203120000
		EXCAVATION-UNCLASSIFIED	203100000
23	FARM FENCE	FARM FENCE F3W F3M-32 IN WW	607100103
		FARM FENCE TYPE F1M-1200 MM WW	607601125
		FARM FENCE TYPE F1W-1220 MM WW	607601120
		FARM FENCE-PANEL/DOUBLE FW	607212000
		FARM FENCE-PANEL/SINGLE FW	607211000
		FARM FENCE-TYPE F2M-39 IN WW	607100148
		FARM FENCE-TYPE F1W-813 MM WW	607601080
		FARM FENCE-TYPE F2M-813 MM WW	607602800
		FARM FENCE-TYPE F2M-990 MM WW	607602990
		FARM FENCE-TYPE F2W F2M-39 IN WW	607100099
		FARM FENCE-TYPE F2W-1220 MM WW	607602122
		FARM FENCE-TYPE F2W-32 IN WW	607100114
		FARM FENCE-TYPE F2W-813 MM WW	607602813
		FARM FENCE-TYPE F2W-915 MM WW	607602820
		FARM FENCE-TYPE F2W-990 MM WW	607602991
		FARM FENCE-TYPE F3M-32 IN WW	607100152
		FARM FENCE-TYPE F3M-813 MM WW	607603813
		FARM FENCE-TYPE F3M-990 MM WW	607603991
		FARM FENCE-TYPE F3W-32 IN WW	607100149
		FARM FENCE-TYPE F3W-813 MM WW	607603800
		FARM FENCE-TYPE F3W-915 MM WW	607603915
		FARM FENCE-TYPE F3W-990 MM WW	607603990
		FARM FENCE-TYPE F4M	607204100
		FARM FENCE-TYPE F4M 990 MM WW	607604820
		FARM FENCE-TYPE F4W	607204000
		FARM FENCE-TYPE F4W AND F4M	607204200
		FARM FENCE-TYPE F5M	607205100
		FARM FENCE-TYPE F5W	607205000
		FARM FENCE-TYPE F5W & F5M	607100271
		FARM FENCE-TYPE F5W AND F5M	607205200
		FARM FENCE-TYPE F6M	607206100
		FARM FENCE-TYPE F6W	607206000
		FARM FENCE-TYPE FW-990 MM WW	607604816
		FARM FENCE-WOVEN WIRE-1220 MM	607208120
		FARM FENCE-WOVEN WIRE-2134 MM	607208170
		FARM FENCE-WOVEN WIRE-48 IN	607100154

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
22	EARTH WORKS	EMBANKMENT IN PLACE	203300000
24	FINAL SWEEP AND BROOM	FINAL SWEEP AND BROOM	409000000
		FINAL SWEEP AND BROOM	409100000
25	GEOGRID	GEOGRID - BIAXIAL	622610000
		GEOGRID - UNIAXIAL	622610030
26	GEOTEXTILE	GEOTEXTILE STABILIZATION	622220000
27	GUARD RAIL	BOX BEAM BRIDGE APP.SEC.-TYPE 1	557010014
		BOX BEAM DEPART TERM SEC	606010670
		GD RL BOX BEAM OPT TERM SEC	606242000
		GD RL-BOX BEAM TO W-BEAM TRANS	606245000
		GRD RL-BOX BEAM/BR APP-SEC TY 1	606140000
		GRD RL-BOX BEAM/BR APP-SEC TYPE 2	606140005
		GRD RL-BOX BEAM/BR APP-SEC-TYPE 3	606140010
		GUARD RAIL-BOX BEAM	606000200
		GUARD RAIL-NESTED	606000450
		GUARD RAIL-OPTIONAL TERM SECT	606250000
		GUARD RAIL-STEEL	606000000
		GUARD RAIL-STEEL BOX BEAM	606010040
		GUARD RAIL-STEEL/2.1 M POSTS	606000050
		GUARD RAIL-STEEL/7 FOOT POSTS	606010033
		GUARD RAIL-STIFFENED	606000400
		GUARD RAIL-STL INT RDWY TERM SECT	606015000
		GUARD RAIL-STL INT TERM SECT	606015000
		GUARD RAIL-STL/BR APPR-TY 1	606110000
		GUARD RAIL-STL/BR APPR-TY 2	606120000
		GUARD RAIL-STL/BR APPR-TY 3	606130000
		GUARDRAIL END SECTION WIDENING	301020413
		GUARDRAIL-STEEL BOX BEAM	606010040
28	MILLING AND PULVERIZING	COLD MILLING	411000000
		PAVEMENT PULVERIZATION	401320000
29	MOBILIZATION	MOBILIZATION	109200000
30	PAVEMENT MARKING	CURB MARKING-WHITE EPOXY	620010311
		CURB MARKING-YELLOW EPOXY	620010301
		STRIPING-WHITE EPOXY	620110000
		STRIPING-WHITE PAINT	620010000
		STRIPING-YELLOW EPOXY	620120000
		STRIPING-YELLOW PAINT	620020000
		WORDS AND SYMBOLS-WHITE PAINT	620030000
		WORDS AND SYMBOLS-YELLOW EPOXY	620011265
		WORDS AND SYMBOLS-WHITE EPOXY	620011260
		WORDS AND SYMBOLS-YELLOW PAINT	620035000
		WORDS/SYMBOLS-WHITE EPOXY	620130000
		WORDS/SYMBOLS-YELLOW EPOXY	620135000
		YELLOW CURB MARKING EPOXY	620045000

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
31	PCCP	PORT CEM CONC PAVE 9 IN	501010125
32	PLANT MIX SURFACING	COMMERCIAL MIX - PG 58-28	401020023
		COMMERCIAL MIX - PG 64-28	401020506
		COMMERCIAL MIX-3/8 IN-PG 70-28	401020060
		COMMERCIAL MIX-PG 64-28	401020022
		COMMERCIAL MIX-PG 70-28	401020021
		PLANT MIX BIT SURF GR S - 19 MM	401080000
		PLANT MIX BIT SURF GR S-19 MM	401080000
		PLANT MIX BIT SURF GR S-3/4 IN	401020045
		PLANT MIX DITCH	613300105
		PLANT MIX GR D - COMMERCIAL	401040500
		PLANT MIX SURF GR S-3/4 IN	401020045
33	REIN CONC BOX	REIN CONC BOX 16 X 6	603584333
		REIN CONC BOX 1800 MM X 1500 MM	603581815
		REIN CONC BOX 2400 MM X 2400 MM DBL	603582425
		REIN CONC BOX 2400MM X 1200MM	603582412
		REIN CONC BOX 2700MM X 2400MM	603582724
		REIN CONC BOX 3000MM X 3000MM	603583030
		REIN CONC BOX 3000MM X1200MM	603583012
		REIN CONC BOX 3350MM X 2100MM	603583520
		REIN CONC BOX 3600 MM X 2700 MM	603583627
		REIN CONC BOX 3600MM X 2100MM	603583621
		REIN CONC BOX 3600MM X 2400MM	603583624
		REIN CONC BOX 4200 MM X 1200 MM	603584212
		REIN CONC BOX 4300 MM X 2700 MM	603584330
		REIN CONC BOX 4800 MM X 1200 MM DBL	603584341
		REIN CONC BOX 4800 MM X 2400 MM	603584824
		REIN CONC BOX 6 X 4	603013356
		REIN CONC BOX 8 X 5	603013331
		REINFORCED CONCRETE RETAINING WAL	614000120
		REINFORCED SOIL SLOPE	614150000
		REINFORCING STEEL - SEISMIC	555300000
34	REINFORCING STEEL	REINFORCING STEEL	555100000
		REINFORCING STEEL-EPOXY COATED	555200000
		REINFORCING STEEL-SEISMIC	555010400

Detailed list of controlling work items

#	Controlling work items	Pat items	Item-Code
35	REMOVE EXISTING STRUCTURES	RELAY PIPE CULVERT	602020000
		RELOCATE WATER METER	601005601
		REMOVAL AND SALVAGE	617781000
		REMOVE ABUTMENT	202020000
		REMOVE AND RESET EXIST POLE	617801030
		REMOVE AND RESET MISC ITEMS	617800200
		REMOVE AND SALVAGE	617800100
		REMOVE AND SALVAGE CATTLE GUARD	611315000
		REMOVE AND SALVAGE CULVERT	602002000
		REMOVE BITUMINOUS PAVEMENT	202020140
		REMOVE BRIDGE APPROACH SLAB	501010555
		REMOVE CABLE GUARD RAIL	606010120
		REMOVE CURB	202020330
		REMOVE DROP INLET	621011120
		REMOVE GUARDRAIL	606010385
		REMOVE PIPE CULVERT	602010010
		REMOVE PLASTIC STRIPING	620013950
		REMOVE SANDING MATERIAL	202020382
		REMOVE SIGN	619010230
		REMOVE SIGN-GUIDE	619010240
		REMOVE BRIDGE RAIL	557010606
		REMOVE CATTLE GUARD	611310000
		REMOVE CONC BARRIER RAIL	606011150
		REMOVE CONCRETE	202240000
		REMOVE CONCRETE BARRIER RAIL	606830000
		REMOVE CURB AND GUTTER	202230000
		REMOVE CURB INLETS	621011130
		REMOVE DECK	552010031
		REMOVE DELINEATORS	619011250
		REMOVE DROP INLETS	621030000
		REMOVE FENCE	607700000
		REMOVE FENCE-CHAIN LINK	607150020
		REMOVE FIRE HYDRANT	621070000
		REMOVE GUARD RAIL	606800000
		REMOVE GUARD RAIL AND SALV	606010386
		REMOVE HISTORIC MARKER	619706000
		REMOVE IMPACT ATTENUATOR	606011510
		REMOVE IRRIGATION STRUCTURE	202320000
		REMOVE MANHOLES	621010000
		REMOVE MEDIAN CURB	202020360
		REMOVE MISCELLANEOUS ITEMS	202700000
		REMOVE OVERHEAD SIGN STRUCTURE	202020434
		REMOVE PAINT WORDS AND SYMBOLS	620705000
		REMOVE PAVEMENT MARKINGS	620710000
		REMOVE PIPE CULVERTS	602010000
		REMOVE RETAINING WALL	614040000
		REMOVE SIDEWALK	202241000
		REMOVE SIGNS	619700000
		REMOVE SIGNS-GUIDE	619702000
		REMOVE STORM DRAIN	602010011
		REMOVE STRUCTURE	202011000
		REMOVE-CABLE RAIL	606440000

Detailed list of controlling work items

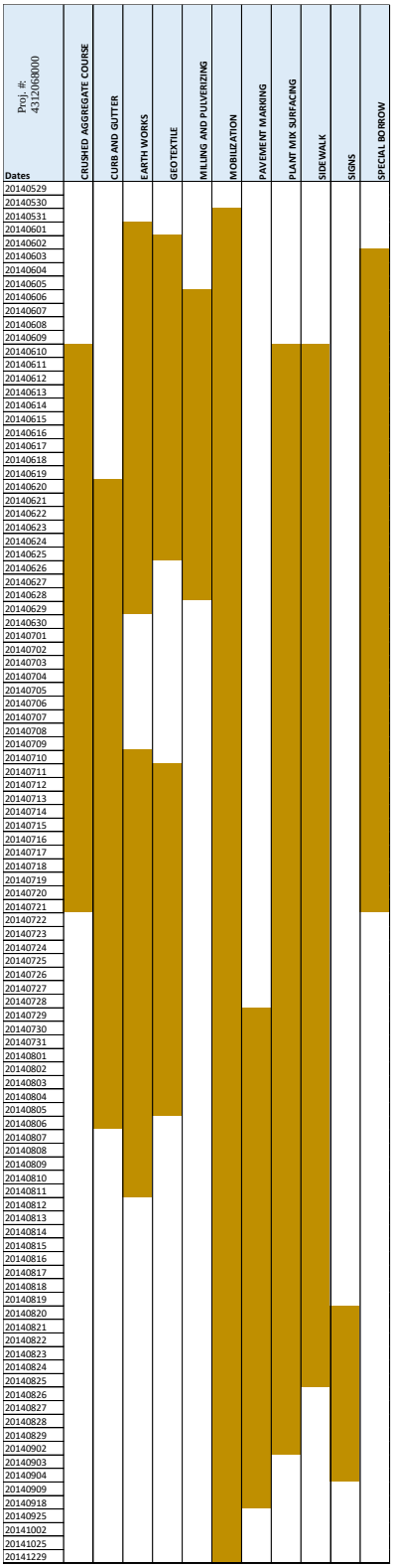
#	Controlling work items	Pat items	Item-Code
37	RETAINING WALL	RETAINING WALL	614000000
38	EVISE BRIDGE CONCRETE BARRIE	REV BRIDGE RAIL-CONC BARRIER	557430000
39	RIPRAP	RIPRAP-CLASS 1 RANDOM	613010000
		RIPRAP-CLASS 2 RANDOM	613020000
		RIPRAP-CLASS 3 RANDOM	613030000
40	RUMBLE STRIPS	CENTERLINE RUMBLE STRIPS-TYPE 2	411011125
		RUMBLE STRIPS	800080000
41	SEEDING	SEEDING AREA NO 1	610110000
		SEEDING AREA NO 13	610134070
		SEEDING AREA NO 2	610120000
		SEEDING AREA NO 3	610130000
		SEEDING AREA NO 4	610100104
		SEEDING AREA NO 5	610134010
		SEEDING AREA NO 7	610134030
		SEEDING AREA NO 8	610134040
		SEEDING AREA NO 9	610134050
		SHOULDER GRAVEL	301020416
42	SIDEWALK	SIDEWALK-CONCRETE 100 MM	608100000
		SIDEWALK-CONCRETE 150MM	608150000
		SIDEWALK-CONCRETE 4 IN	608010020
		SIDEWALK-CONCRETE 6 IN	608010050
43	SIGNS	FRANG SIGN POST BKWY - 3.5 IN RD	619010742
		FRANG SIGN POST BKWY 89 MM RD	619337000
		FRANG SIGN POST BKWY S130X15	619305000
		FRANG SIGN POST BKWY- S4 X 7.7	619010722
		FRANG SIGN POST BKWY-3 IN RD	619010740
		FRANG SIGN POST BKWY-3.5 IN RD (89MM	619010742
		FRANG SIGN POST BKWY-3.5IN RD	619010742
		FRANG SIGN POST BKWY-S5 X 10	619010724
		POLES-TREATED WOOD CLASS 4	619010410
		POSTS-STEEL STRUCTURAL SIGN	619130000
		POSTS-TUBULAR STEEL	619110000
		POSTS-TUBULAR STEEL-SQ-PERF	619140000
		SIGN - INSTALL	619690000
		SIGN-ENTRANCE	855610000
		SIGN-INSTALL	619019010
		SIGNS-ALUM REFL SHEET (I)	619010075
		SIGNS-ALUM REFL SHEET IV	619010086
		SIGNS-ALUM SHEET INCR (I)	619010051
		SIGNS-ALUM SHEET INCR IV	619010058
		SIG-TRAF 1 COLOR-1 WAY 30	617211300
		SIG-TRAF 3 COL-1 WAY 12-12-12	617503130
		SIG-TRAF 3 COL-1 WAY 30-30-30	617231330
		SIG-TRAF 5 COL-1 W 12-12-12-12	617523127
		SIG-TRAF 5 COL-1 W 30-30-30-30	617251330

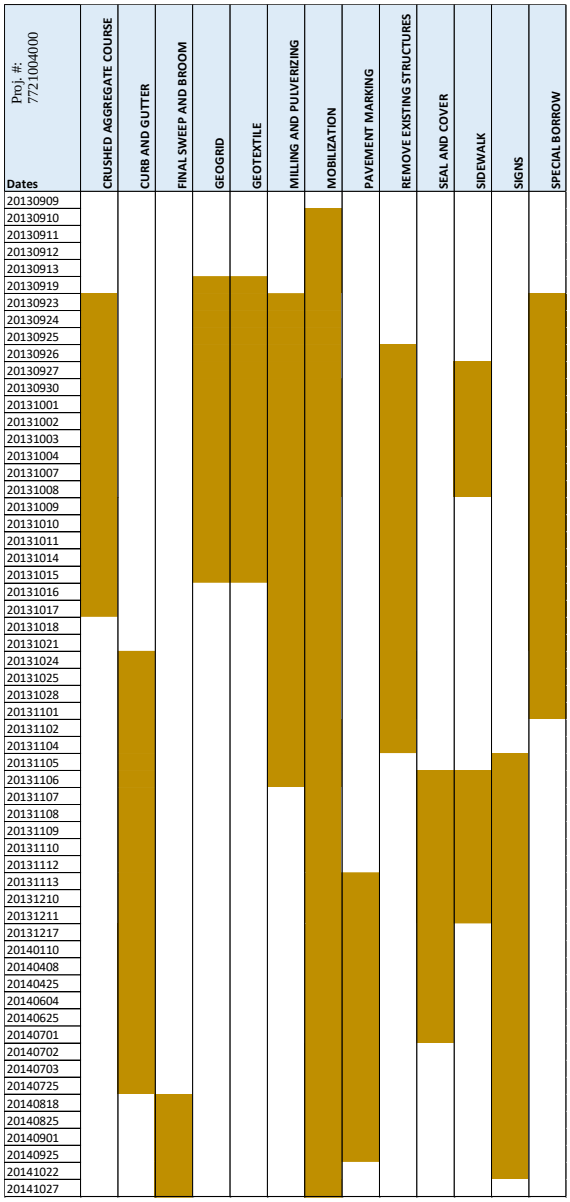
Detailed list of controlling work items

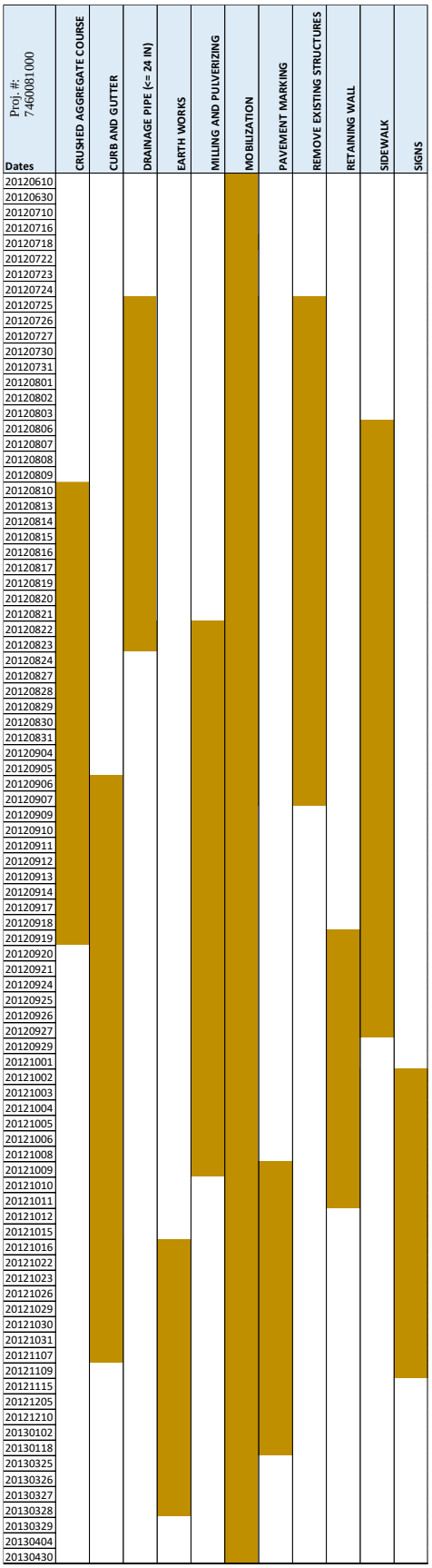
#	Controlling work items	Pat items	Item-Code
44	SPECIAL BORROW	SPECIAL BORROW-EXCAVATION	203210000
		SPECIAL BORROW-NEAT LINE	203220000
45	SSPP	SSPP 120 IN 0.109	603011720
		SSPP 132 IN 0.138-CTD	603011786
		SSPP 150 IN 0.168	603011832
		SSPP 180 IN 0.138-CTD	603011885
		SSPP 3.670 M X 2.82 MM	603236282
		SSPP 3.825 M X 2.82 MM	603237282
		SSPP 3.980 M X 3.56 MM CTD	603240290
		SSPP 4.290 M X 2.82 MM CTD	603242284
		SSPP 84 IN 0.138	603011595
		SSPPA 13 FT 11 IN 0.109-CTD	603012217
		SSPPA 13 FT 5 IN 0.138	603012186
		SSPPA 14 FT 3 IN 0.109 CTD	603012262
		SSPPA 2.340 M X 2.82 MM	603323282
		SSPPA 3.330 M X 2.82 MM	603333282
		SSPPA 4.110 M X 2.82 MM	603341282
		SSPPA 6 FT 9 IN 0.109	603011973
46	OPSOIL-SALVAGING AND PLACIN	TOPSOIL-SALVAGING AND PLACING	203500000
47	WING WALLS	WINGWALLS	551430010

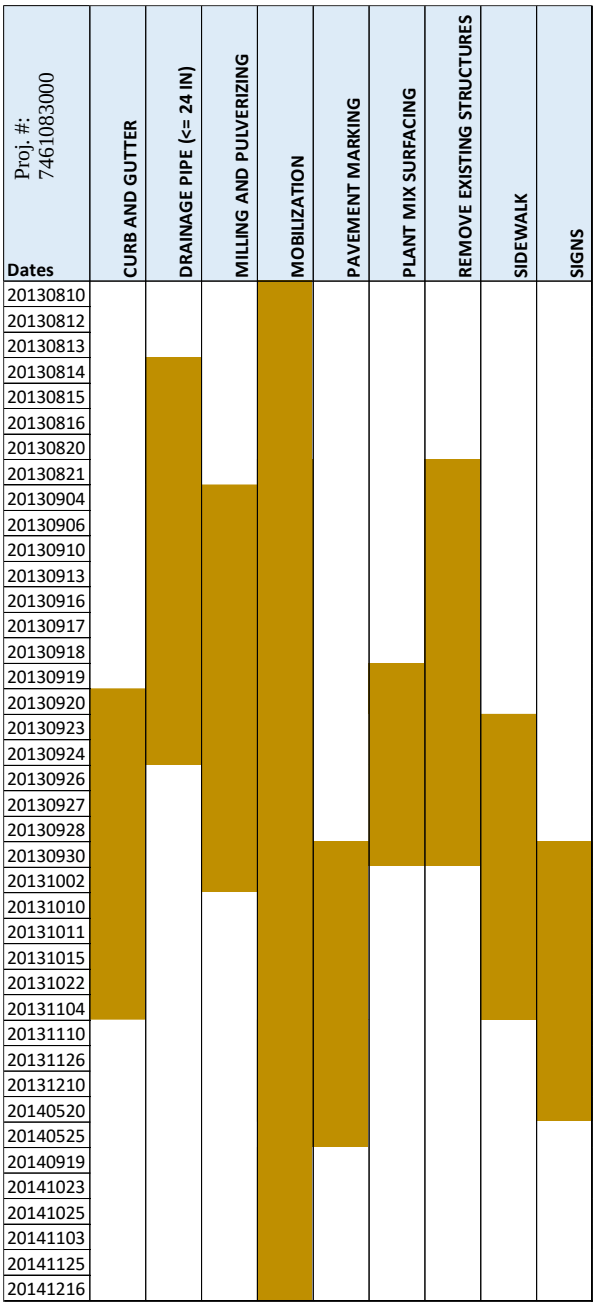
Appendix B: As-built schedules of five representative projects for most common highway project types

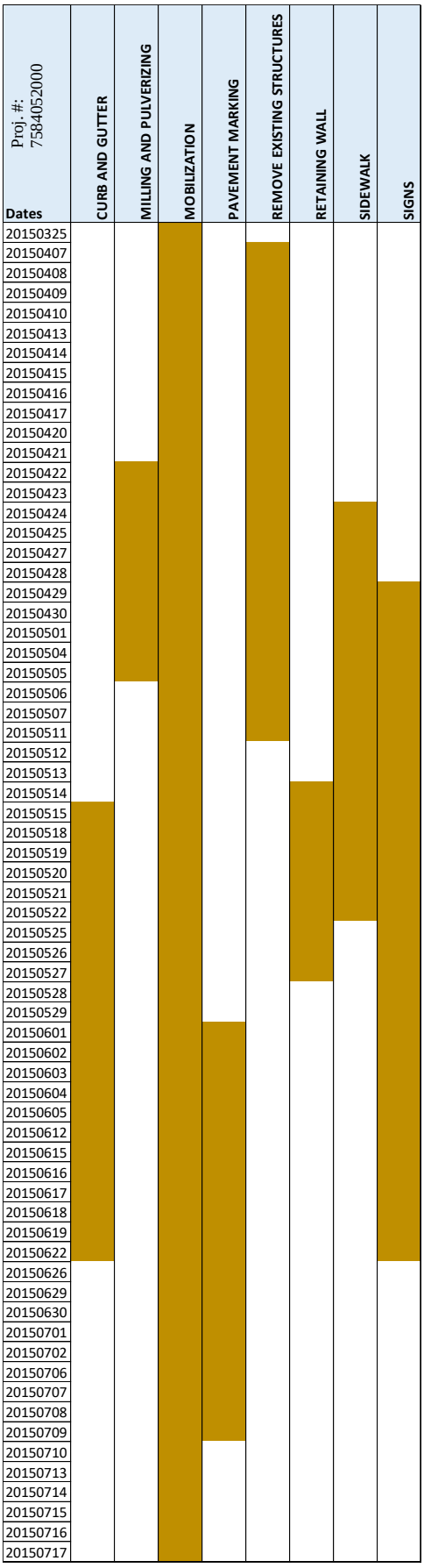
1- Overlay (Urban)



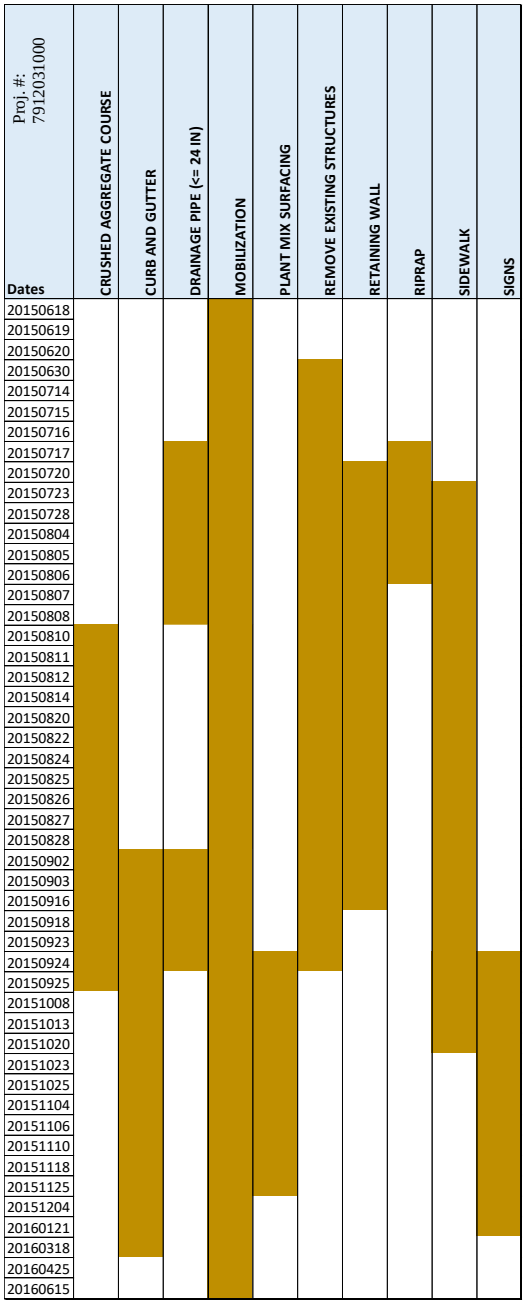


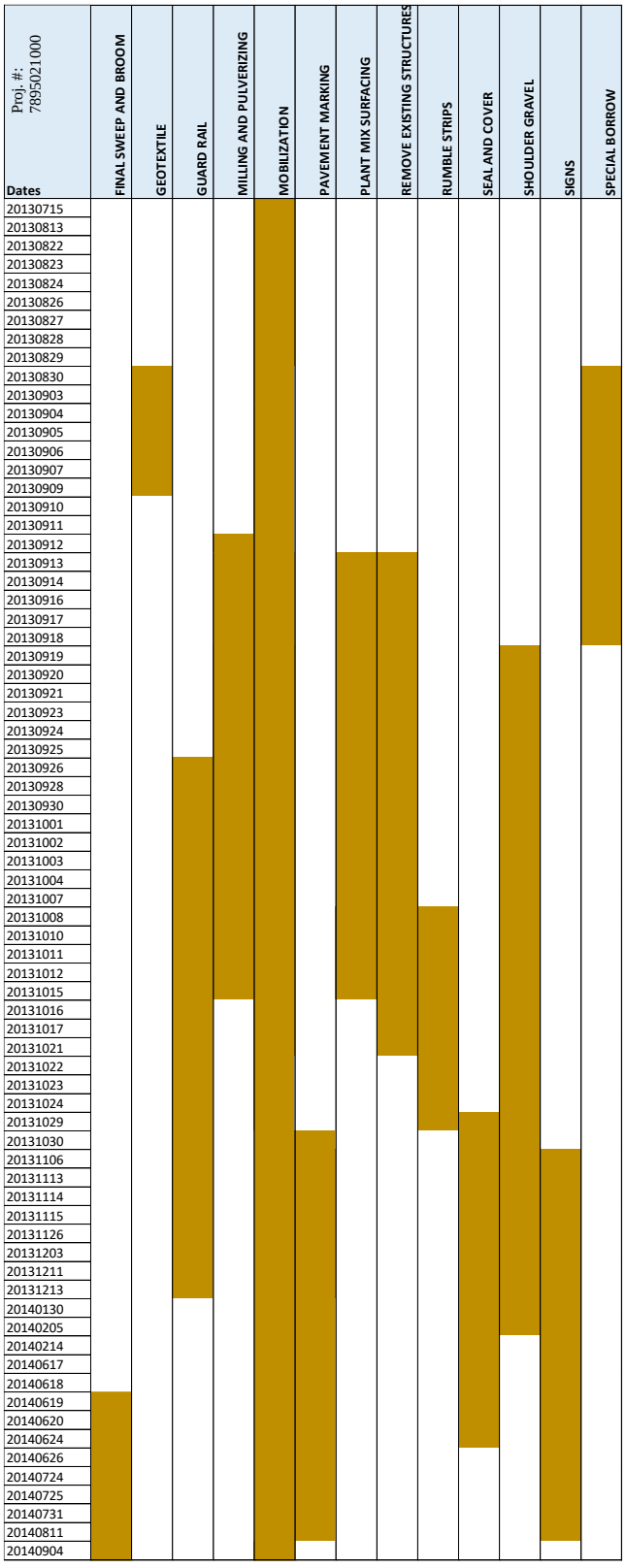

Proj. #: 7460081000
Dates
CRUSHED AGGREGATE COURSE
CURB AND GUTTER
DRAINAGE PIPE (<= 24 IN)
EARTH WORKS
MILLING AND PULVERIZING
MOBILIZATION
PAVEMENT MARKING
REMOVE EXISTING STRUCTURES
RETAINING WALL
SIDEWALK
SIGNS
20120610
20120630
20120710
20120716
20120718
20120722
20120723
20120724
20120725
20120726
20120727
20120730
20120731
20120801
20120802
20120803
20120806
20120807
20120808
20120809
20120810
20120813
20120814
20120815
20120816
20120817
20120819
20120820
20120821
20120822
20120823
20120824
20120827
20120828
20120829
20120830
20120831
20120904
20120905
20120906
20120907
20120909
20120910
20120911
20120912
20120913
20120914
20120917
20120918
20120919
20120920
20120921
20120924
20120925
20120926
20120927
20120929
20121001
20121002
20121003
20121004
20121005
20121006
20121008
20121009
20121010
20121011
20121012
20121015
20121016
20121022
20121023
20121026
20121029
20121030
20121031
20121107
20121109
20121115
20121205
20121210
20130102
20130118
20130325
20130326
20130327
20130328
20130329
20130404
20130430


Proj. #: 7461083000
Dates
CURB AND GUTTER
DRAINAGE PIPE (<= 24 IN)
MILLING AND PULVERIZING
MOBILIZATION
PAVEMENT MARKING
PLANT MIX SURFACING
REMOVE EXISTING STRUCTURES
SIDEWALK
SIGNS
20130810
20130812
20130813
20130814
20130815
20130816
20130820
20130821
20130904
20130906
20130910
20130913
20130916
20130917
20130918
20130919
20130920
20130923
20130924
20130926
20130927
20130928
20130930
20131002
20131010
20131011
20131015
20131022
20131104
20131110
20131126
20131210
20140520
20140525
20140919
20141023
20141025
20141103
20141125
20141216


Proj. #:
7584052000
Dates
CURB AND GUTTER
MILLING AND PULVERIZING
MOBILIZATION
PAVEMENT MARKING
REMOVE EXISTING STRUCTURES
RETAINING WALL
SIDEWALK
SIGNS
20150325
20150407
20150408
20150409
20150410
20150413
20150414
20150415
20150416
20150417
20150420
20150421
20150422
20150423
20150424
20150425
20150427
20150428
20150429
20150430
20150501
20150504
20150505
20150506
20150507
20150511
20150512
20150513
20150514
20150515
20150518
20150519
20150520
20150521
20150522
20150525
20150526
20150527
20150528
20150529
20150601
20150602
20150603
20150604
20150605
20150612
20150615
20150616
20150617
20150618
20150619
20150622
20150626
20150629
20150630
20150701
20150702
20150706
20150707
20150708
20150709
20150710
20150713
20150714
20150715
20150716
20150717

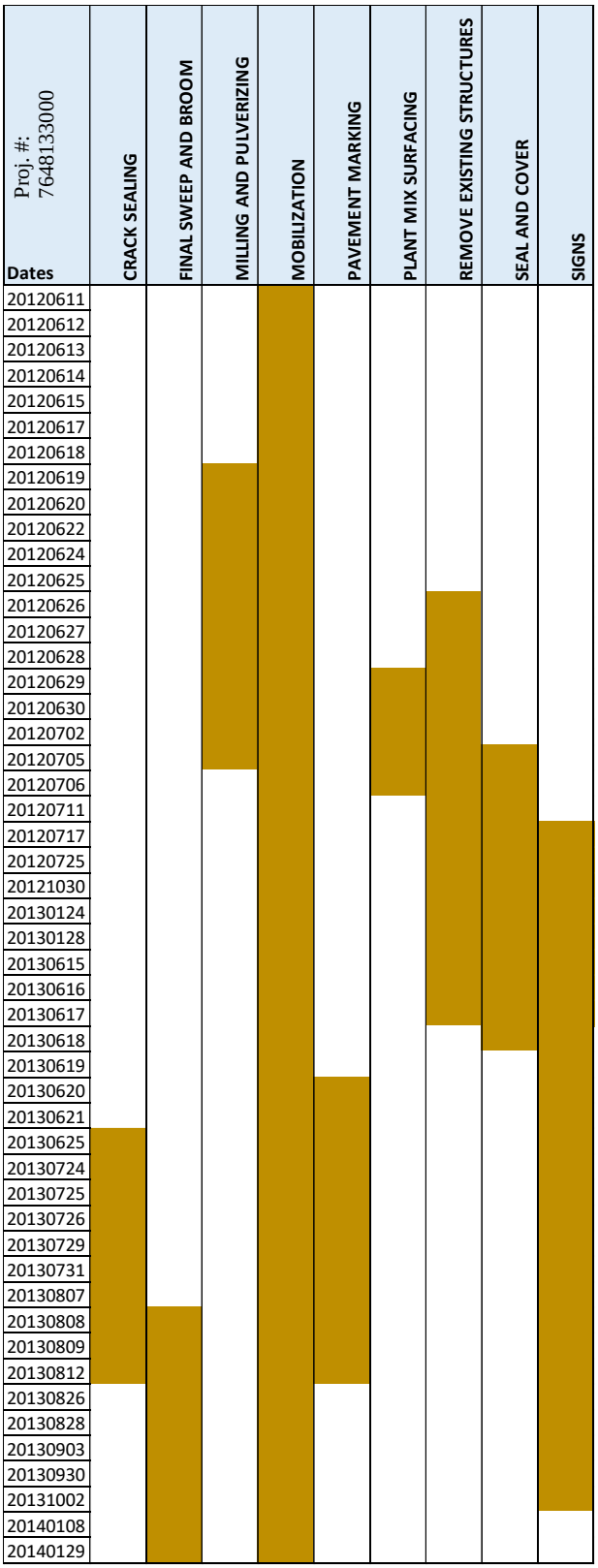
2. Overlay (Rural)





Proj. #: 7941038000 Dates	CRUSHED AGGREGATE COURSE	FINAL SWEEP AND BROOM	GUARD RAIL	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER	SIGNS	SPECIAL BORROW
20140725												
20140825												
20140826												
20140827												
20140828												
20140902												
20140903												
20140905												
20140909												
20140915												
20140916												
20140917												
20140918												
20140919												
20140920												
20140922												
20140923												
20140924												
20140925												
20140929												
20140930												
20141002												
20141006												
20141007												
20141008												
20141009												
20141010												
20141011												
20141013												
20141014												
20141015												
20141016												
20141017												
20141020												
20141023												
20141024												
20141025												
20141113												
20141121												
20141125												
20141204												
20141209												
20141225												
20150123												
20150125												
20150127												
20150427												
20150505												
20150528												
20150622												
20150623												
20150624												
20150625												
20150626												
20150627												
20150708												
20150725												
20150806												
20150818												
20150824												
20150825												
20151002												
20160425												
20160504												
20160523												
20160525												
20160615												
20160616												

Proj. #: 7662004000 Dates	CURB AND GUTTER	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIDEWALK	SIGNS
20130830								
20130910								
20130911								
20130912								
20130916								
20130917								
20130918								
20130920								
20130923								
20130924								
20130925								
20130926								
20130927								
20130930								
20131001								
20131002								
20131003								
20131004								
20131007								
20131008								
20131009								
20131010								
20131015								
20131017								
20131018								
20131022								
20131024								
20131025								
20131031								
20131107								
20131108								
20131109								
20131114								
20131125								
20131202								
20131219								
20140106								
20140129								
20140225								
20140326								
20140429								
20140527								
20140625								
20140627								
20140628								
20140629								
20140630								
20140701								
20140702								
20140731								
20140814								
20140815								
20140829								
20141020								


Proj. #: 7648133000
Dates
CRACK SEALING
FINAL SWEEP AND BROOM
MILLING AND PULVERIZING
MOBILIZATION
PAVEMENT MARKING
PLANT MIX SURFACING
REMOVE EXISTING STRUCTURES
SEAL AND COVER
SIGNS
20120611
20120612
20120613
20120614
20120615
20120617
20120618
20120619
20120620
20120622
20120624
20120625
20120626
20120627
20120628
20120629
20120630
20120702
20120705
20120706
20120711
20120717
20120725
20121030
20130124
20130128
20130615
20130616
20130617
20130618
20130619
20130620
20130621
20130625
20130724
20130725
20130726
20130729
20130731
20130807
20130808
20130809
20130812
20130826
20130828
20130903
20130930
20131002
20140108
20140129

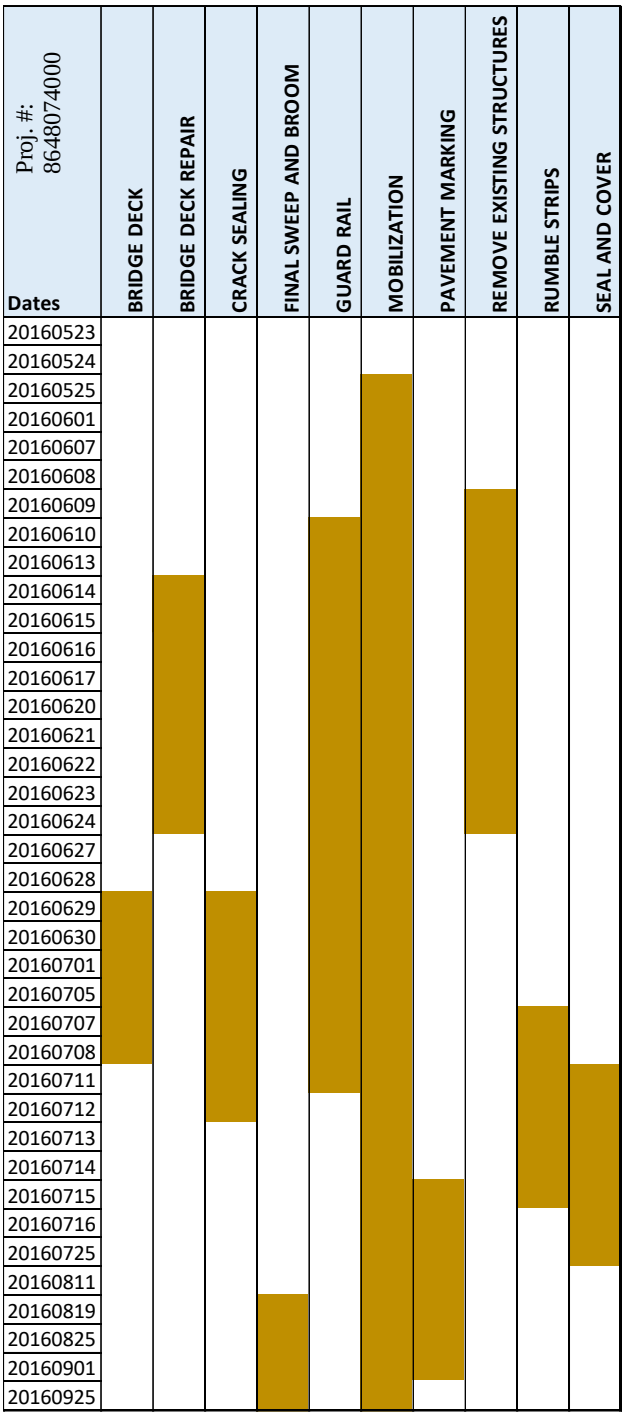
3. Seal & Cover

Proj. #: 7994105000 Dates	CRACK SEALING	FINAL SWEEP AND BROOM	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER
20140606						
20140612						
20140616						
20140620						
20140623						
20140625						
20140701						
20140703						
20140724						
20140725						
20140808						
20140819						
20140825						
20150114						
20150619						
20150622						
20150624						
20150725						
20150803						
20150804						
20150825						
20150924						
20150925						
20151023						

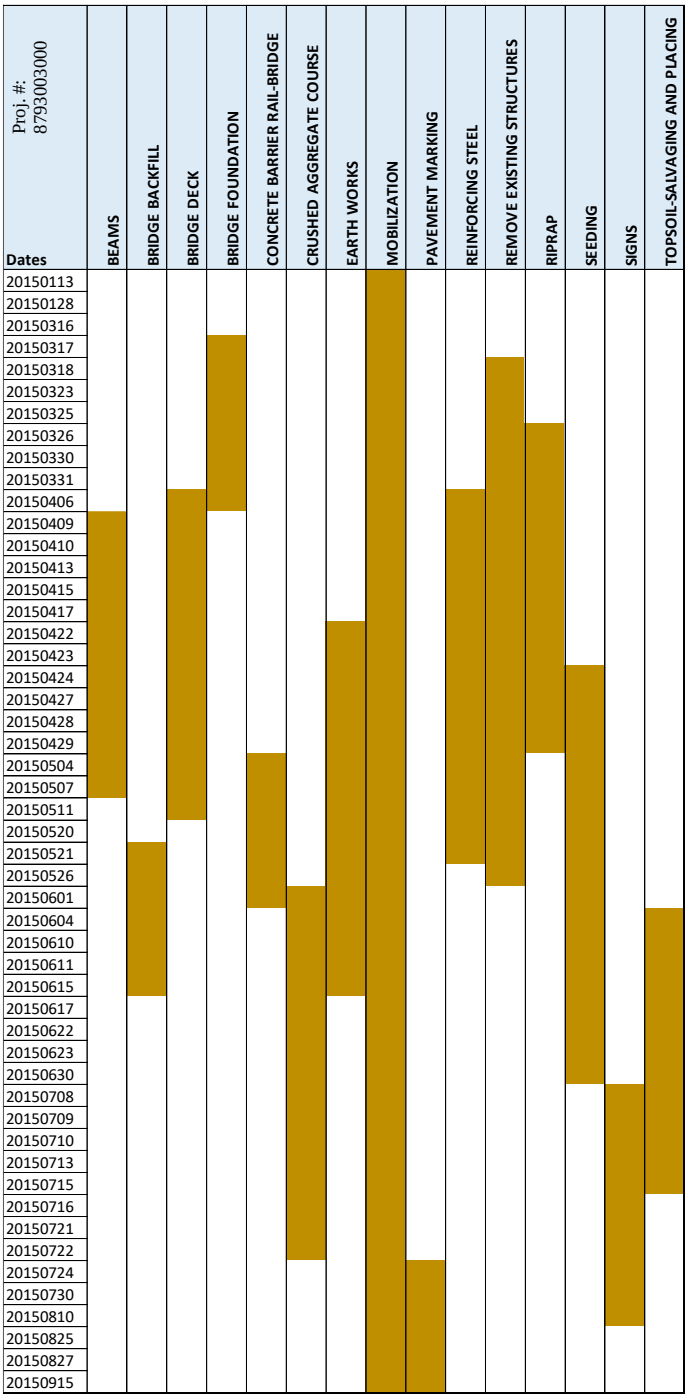
Proj. #: 81620140000 Row Labels	CRACK SEALING	CRUSHED AGGREGATE COURSE	FINAL SWEEP AND BROOM	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIGNS
20140904									
20140905									
20140906									
20140909									
20140910									
20140912									
20140915									
20140925									
20140926									
20140927									
20140929									
20140930									
20141001									
20141002									
20141003									
20141006									
20141007									
20141008									
20141009									
20141025									
20150525									
20150725									
20150730									
20150804									
20150825									
20150925									
20151020									
20151230									
20160104									

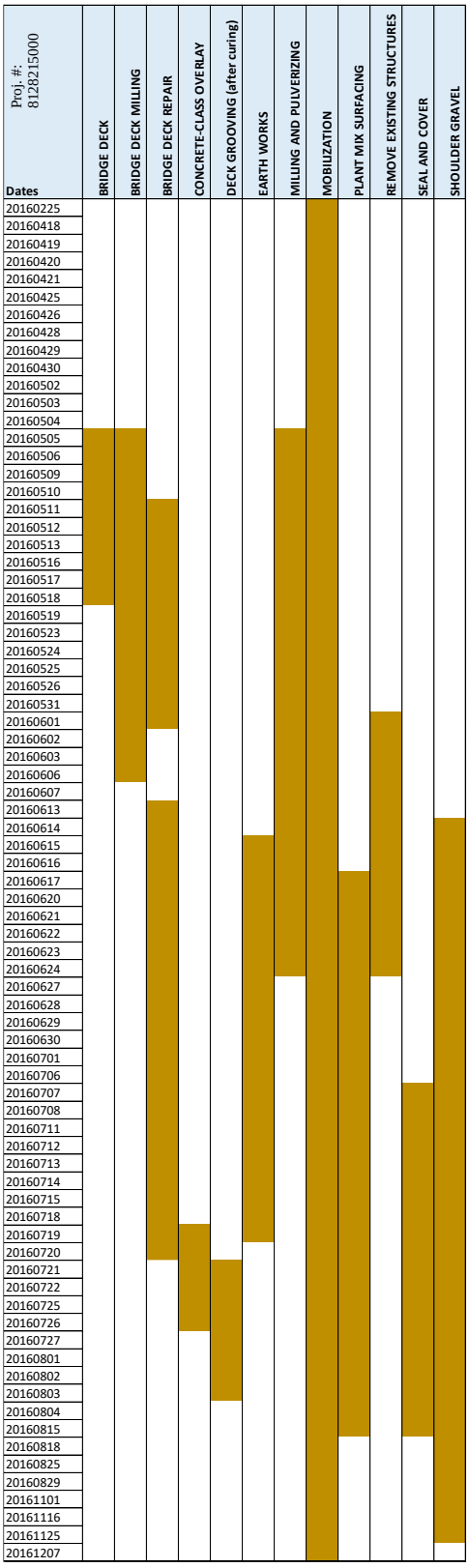
Proj. #: 7639076000 Row Labels	CURB AND GUTTER	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	SEAL AND COVER	SIDEWALK
20120604							
20120605							
20120606							
20120607							
20120608							
20120611							
20120612							
20120613							
20120614							
20120615							
20120618							
20120619							
20120620							
20120621							
20120622							
20120625							
20120626							
20120627							
20120628							
20120629							
20120630							
20120702							
20120703							
20120705							
20120706							
20120709							
20120710							
20120711							
20120712							
20120713							
20120716							
20120717							
20120723							
20120724							
20120725							
20120730							
20120731							
20120814							
20120825							
20120830							
20120904							
20120927							
20121002							
20121010							
20121030							
20121203							
20121206							
20130212							

Proj. #: 8648074000 Row Labels	GUARD RAIL	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER	SIGNS
20120709									
20120710									
20120713									
20120714									
20120716									
20120717									
20120718									
20120719									
20120720									
20120723									
20120724									
20120725									
20120726									
20120727									
20120730									
20120731									
20120803									
20120807									
20120808									
20120809									
20120810									
20120814									
20120911									
20120912									
20120921									
20120928									
20121009									
20121012									
20121015									
20121108									
20121109									
20130405									


Proj. #: 8648074000
Dates
BRIDGE DECK
BRIDGE DECK REPAIR
CRACK SEALING
FINAL SWEEP AND BROOM
GUARD RAIL
MOBILIZATION
PAVEMENT MARKING
REMOVE EXISTING STRUCTURES
RUMBLE STRIPS
SEAL AND COVER
20160523
20160524
20160525
20160601
20160607
20160608
20160609
20160610
20160613
20160614
20160615
20160616
20160617
20160620
20160621
20160622
20160623
20160624
20160627
20160628
20160629
20160630
20160701
20160705
20160707
20160708
20160711
20160712
20160713
20160714
20160715
20160716
20160725
20160811
20160819
20160825
20160901
20160925

4. Bridge reconstruction & rehabilitation



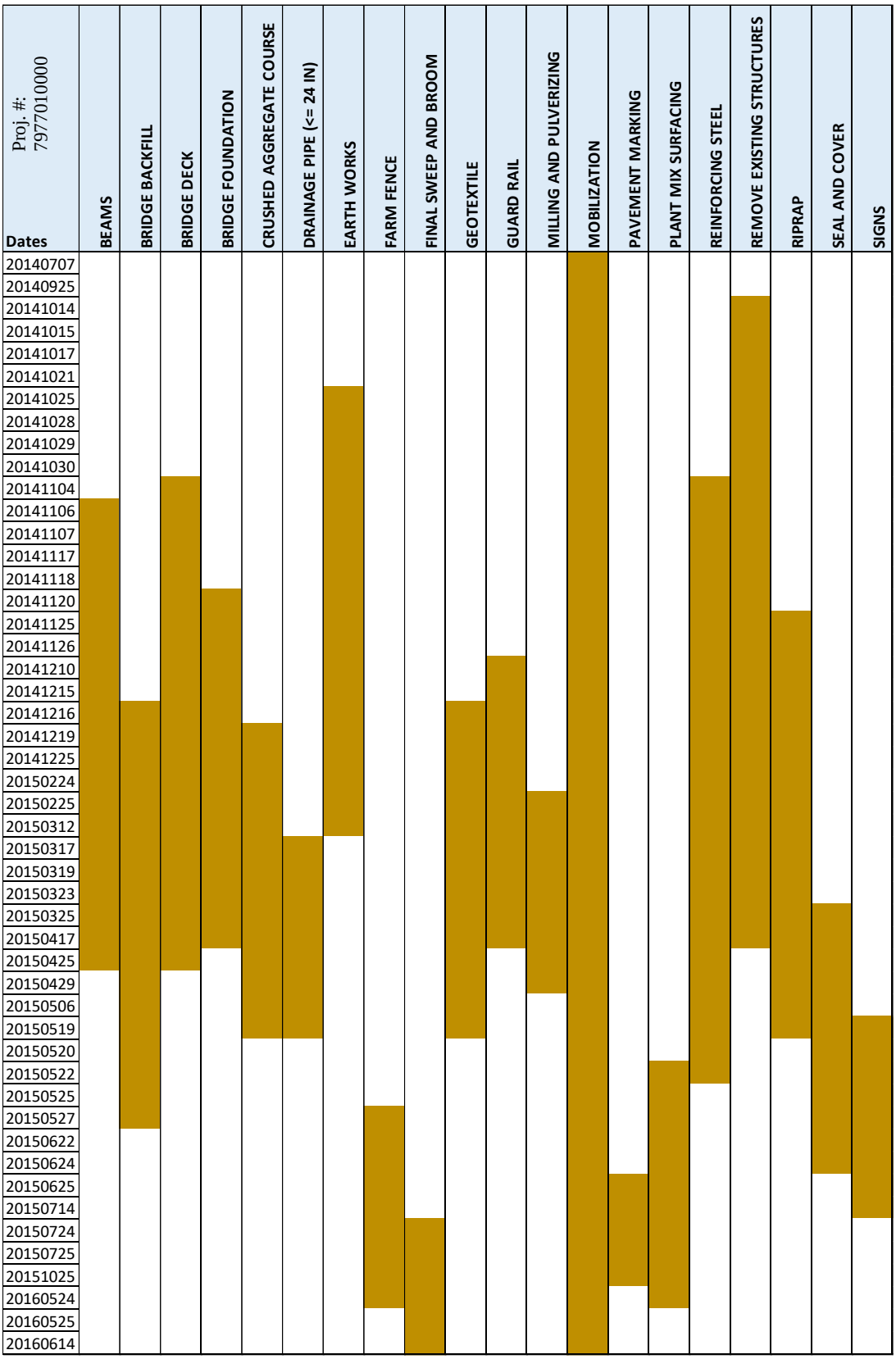


Proj. #: 8100109000

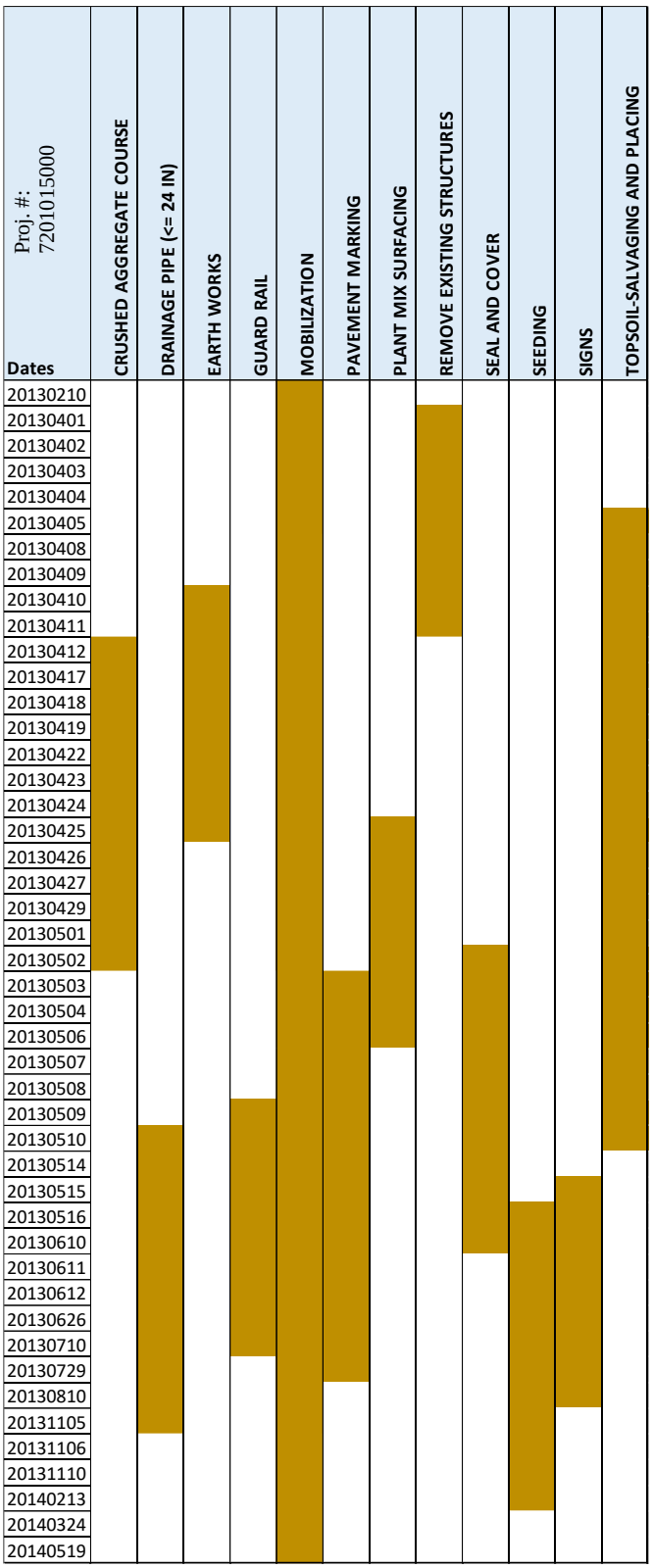
Dates	BRIDGE DECK	BRIDGE DECK MILLING	BRIDGE DECK REPAIR	CONCRETE-CLASS OVERLAY	CRACK SEALING	DECK GROOVING (after curing)	FINAL SWEEP AND BROOM	GUARD RAIL	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER	SIGNS
20150225																
20150309																
20150319																
20150325																
20150402																
20150403																
20150406																
20150408																
20150409																
20150410																
20150414																
20150415																
20150416																
20150417																
20150420																
20150421																
20150424																
20150425																
20150428																
20150430																
20150504																
20150506																
20150507																
20150508																
20150511																
20150512																
20150513																
20150514																
20150515																
20150518																
20150519																
20150520																
20150521																
20150525																
20150526																
20150527																
20150528																
20150529																
20150530																
20150601																
20150602																
20150603																
20150604																
20150605																
20150608																
20150609																
20150610																
20150611																
20150612																
20150615																
20150616																
20150617																
20150618																
20150619																
20150620																
20150622																
20150623																
20150624																
20150625																
20150626																
20150630																
20150707																
20150708																
20150709																
20150710																
20150711																
20150714																
20150717																
20150720																
20150722																
20150723																
20150725																
20150727																
20150728																
20150730																
20150803																
20150804																
20150812																
20150813																
20150825																
20150910																
20150914																
20150925																
20151006																
20151023																
20151025																
20151110																
20151203																

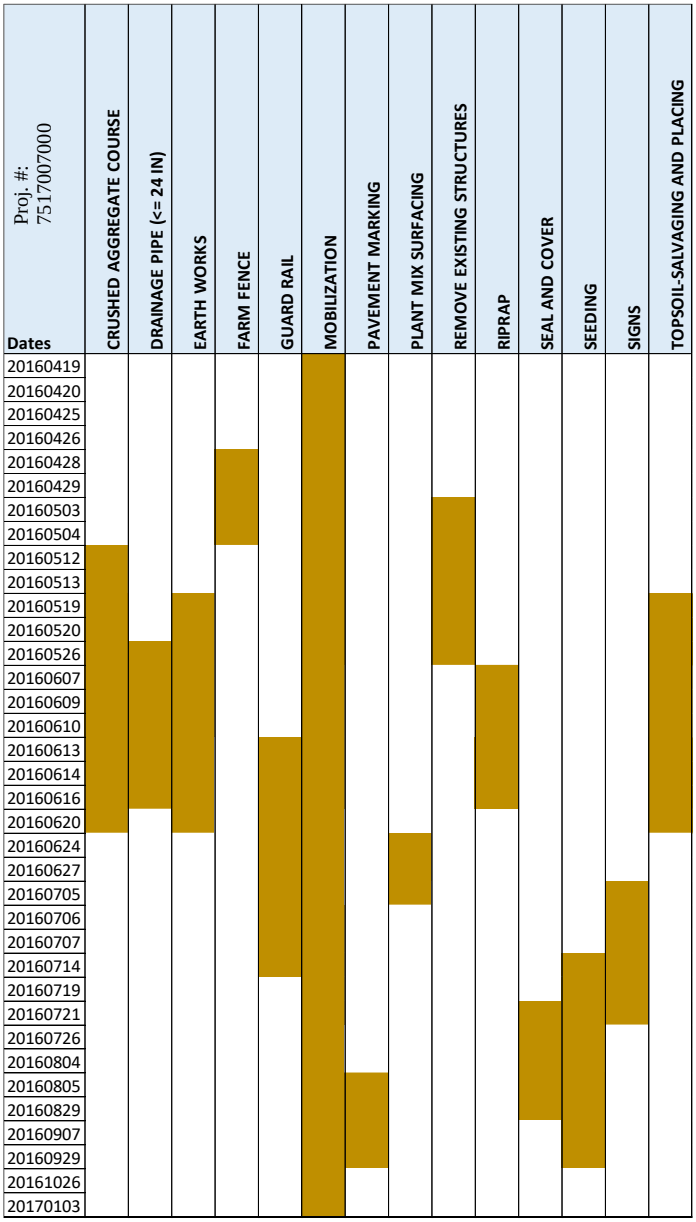
Proj. #: 80740010000

Dates	BRIDGE BACKFILL	BRIDGE DECK	BRIDGE FOUNDATION	CRUSHED AGGREGATE COURSE	DECK GROOVING (after curing)	EARTH WORKS	FARM FENCE	GEOTEXTILE	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	REINFORCING STEEL	REMOVE EXISTING STRUCTURES	RIPRAP	SEEDING	SIGNS	TOPSOIL-SALVAGING AND PLACING
20150727																		
20150730																		
20150810																		
20150811																		
20150813																		
20150818																		
20150819																		
20150824																		
20150825																		
20150902																		
20150903																		
20150909																		
20150915																		
20150917																		
20150923																		
20150925																		
20150928																		
20150930																		
20151001																		
20151014																		
20151016																		
20151020																		
20151021																		
20151023																		
20151025																		
20151027																		
20151109																		
20151111																		
20151112																		
20151113																		
20151116																		
20151118																		
20151120																		
20151123																		
20151125																		
20151216																		
20151218																		
20160119																		
20160125																		
20160205																		


Proj. #:
7977010000
Dates
BEAMS
BRIDGE BACKFILL
BRIDGE DECK
BRIDGE FOUNDATION
CRUSHED AGGREGATE COURSE
DRAINAGE PIPE (<= 24 IN)
EARTH WORKS
FARM FENCE
FINAL SWEEP AND BROOM
GEOTEXTILE
GUARD RAIL
MILLING AND PULVERIZING
MOBILIZATION
PAVEMENT MARKING
PLANT MIX SURFACING
REINFORCING STEEL
REMOVE EXISTING STRUCTURES
RIPRAP
SEAL AND COVER
SIGNS
20140707
20140925
20141014
20141015
20141017
20141021
20141025
20141028
20141029
20141030
20141104
20141106
20141107
20141117
20141118
20141120
20141125
20141126
20141210
20141215
20141216
20141219
20141225
20150224
20150225
20150312
20150317
20150319
20150323
20150325
20150417
20150425
20150429
20150506
20150519
20150520
20150522
20150525
20150527
20150622
20150624
20150625
20150714
20150724
20150725
20151025
20160524
20160525
20160614

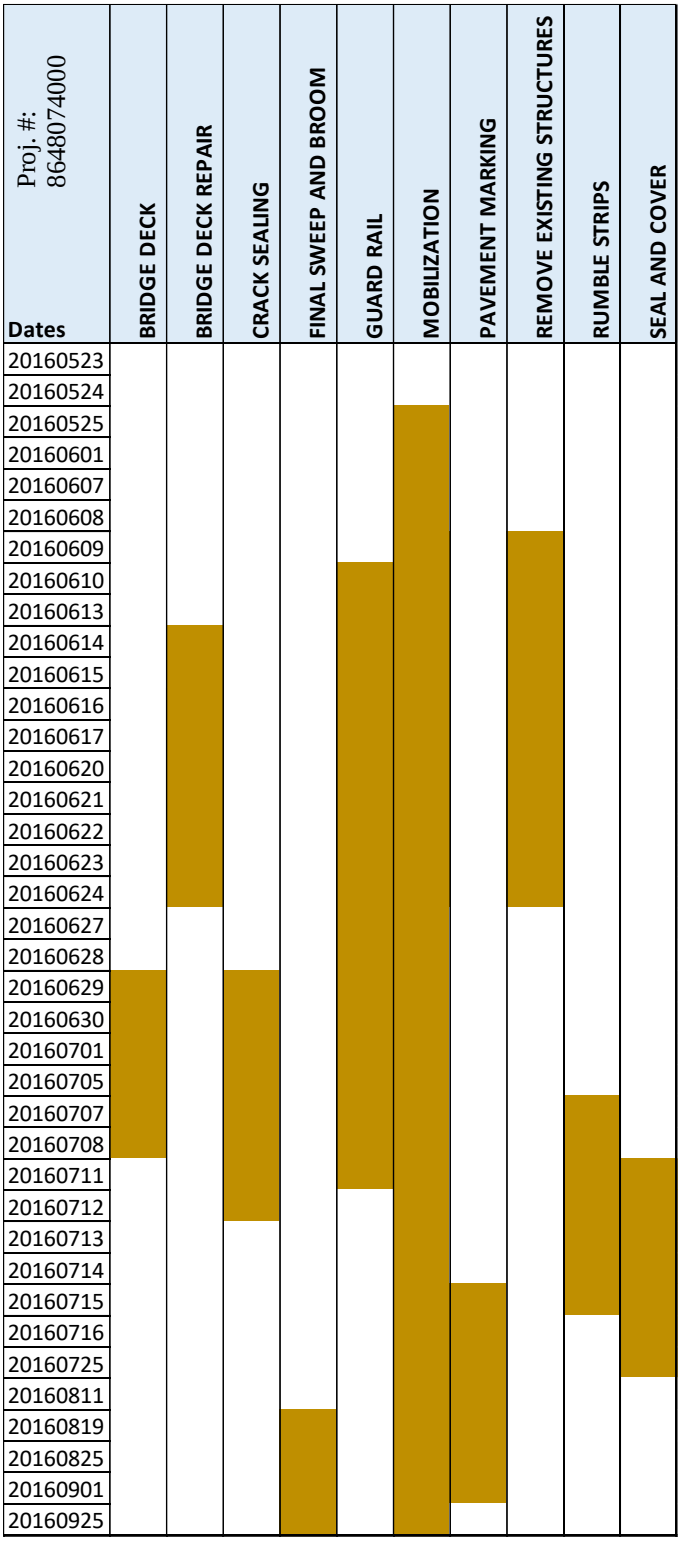
5- Safety


Proj. #: 7201015000
Dates
CRUSHED AGGREGATE COURSE
DRAINAGE PIPE (<= 24 IN)
EARTH WORKS
GUARD RAIL
MOBILIZATION
PAVEMENT MARKING
PLANT MIX SURFACING
REMOVE EXISTING STRUCTURES
SEAL AND COVER
SEEDING
SIGNS
TOPSOIL-SALVAGING AND PLACING
20130210
20130401
20130402
20130403
20130404
20130405
20130408
20130409
20130410
20130411
20130412
20130417
20130418
20130419
20130422
20130423
20130424
20130425
20130426
20130427
20130429
20130501
20130502
20130503
20130504
20130506
20130507
20130508
20130509
20130510
20130514
20130515
20130516
20130610
20130611
20130612
20130626
20130710
20130729
20130810
20131105
20131106
20131110
20140213
20140324
20140519


Proj. #: 7517007000
Dates
CRUSHED AGGREGATE COURSE
DRAINAGE PIPE (<= 24 IN)
EARTH WORKS
FARM FENCE
GUARD RAIL
MOBILIZATION
PAVEMENT MARKING
PLANT MIX SURFACING
REMOVE EXISTING STRUCTURES
RIPRAP
SEAL AND COVER
SEEDING
SIGNS
TOPSOIL-SALVAGING AND PLACING
20160419
20160420
20160425
20160426
20160428
20160429
20160503
20160504
20160512
20160513
20160519
20160520
20160526
20160607
20160609
20160610
20160613
20160614
20160616
20160620
20160624
20160627
20160705
20160706
20160707
20160714
20160719
20160721
20160726
20160804
20160805
20160829
20160907
20160929
20161026
20170103

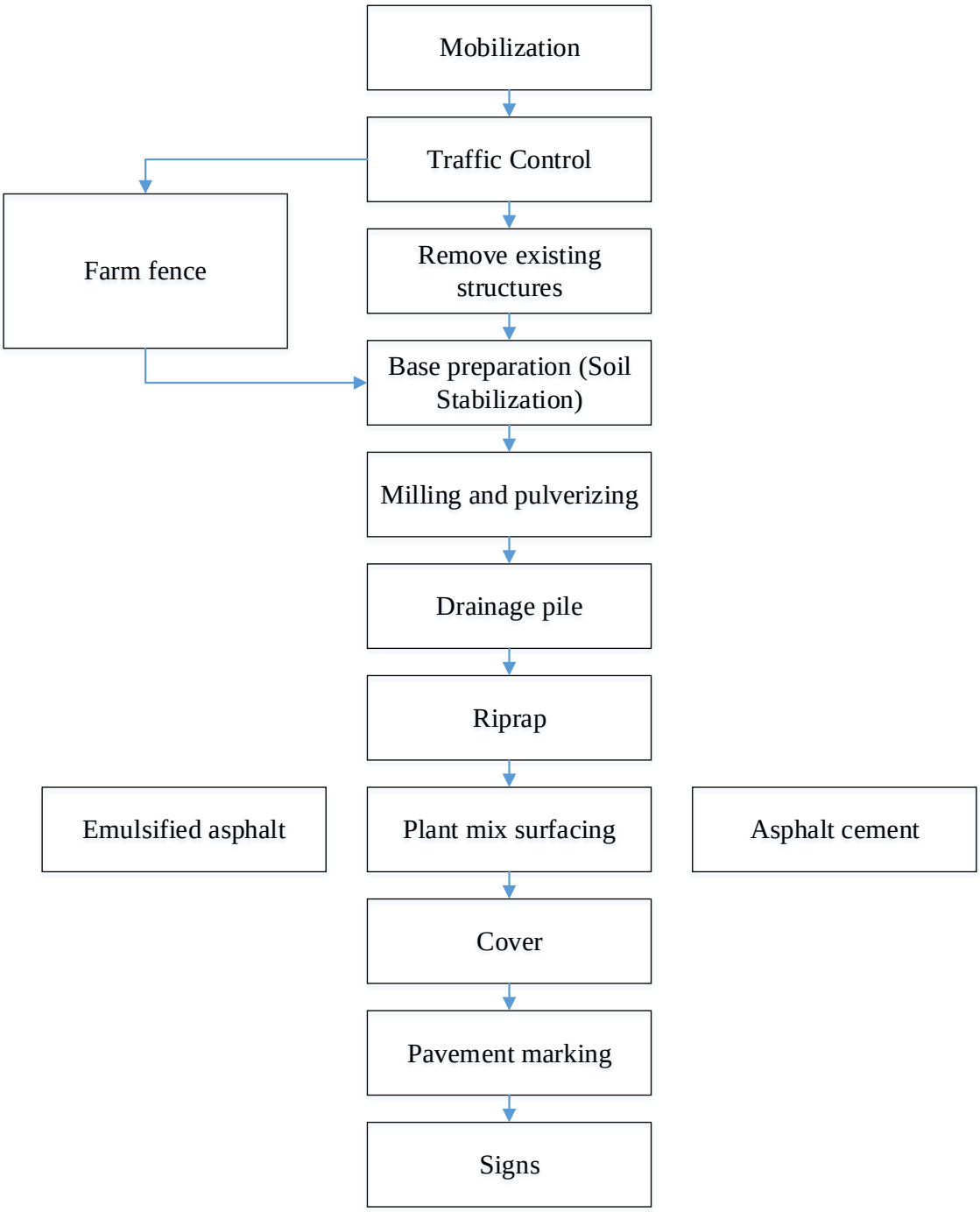
Proj. #: 7539041000 Dates	CRUSHED AGGREGATE COURSE	EARTH WORKS	FINAL SWEEP AND BROOM	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER	SEEDING	SHOULDER GRAVEL	SIGNS	TOPSOIL-SALVAGING AND PLACING
20150406														
20150408														
20150409														
20150410														
20150411														
20150413														
20150414														
20150420														
20150421														
20150422														
20150423														
20150424														
20150427														
20150430														
20150501														
20150504														
20150518														
20150526														
20150528														
20150529														
20150618														
20150707														
20150710														
20150722														
20150731														
20150810														
20151028														
20151123														

Proj. #: 7828039000 Dates	FINAL SWEEP AND BROOM	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIGNS
20140424						
20140425						
20140610						
20140611						
20140612						
20140613						
20140616						
20140617						
20140620						
20140623						
20140625						
20140710						
20140711						
20140716						
20140722						
20140725						
20141204						
20150422						

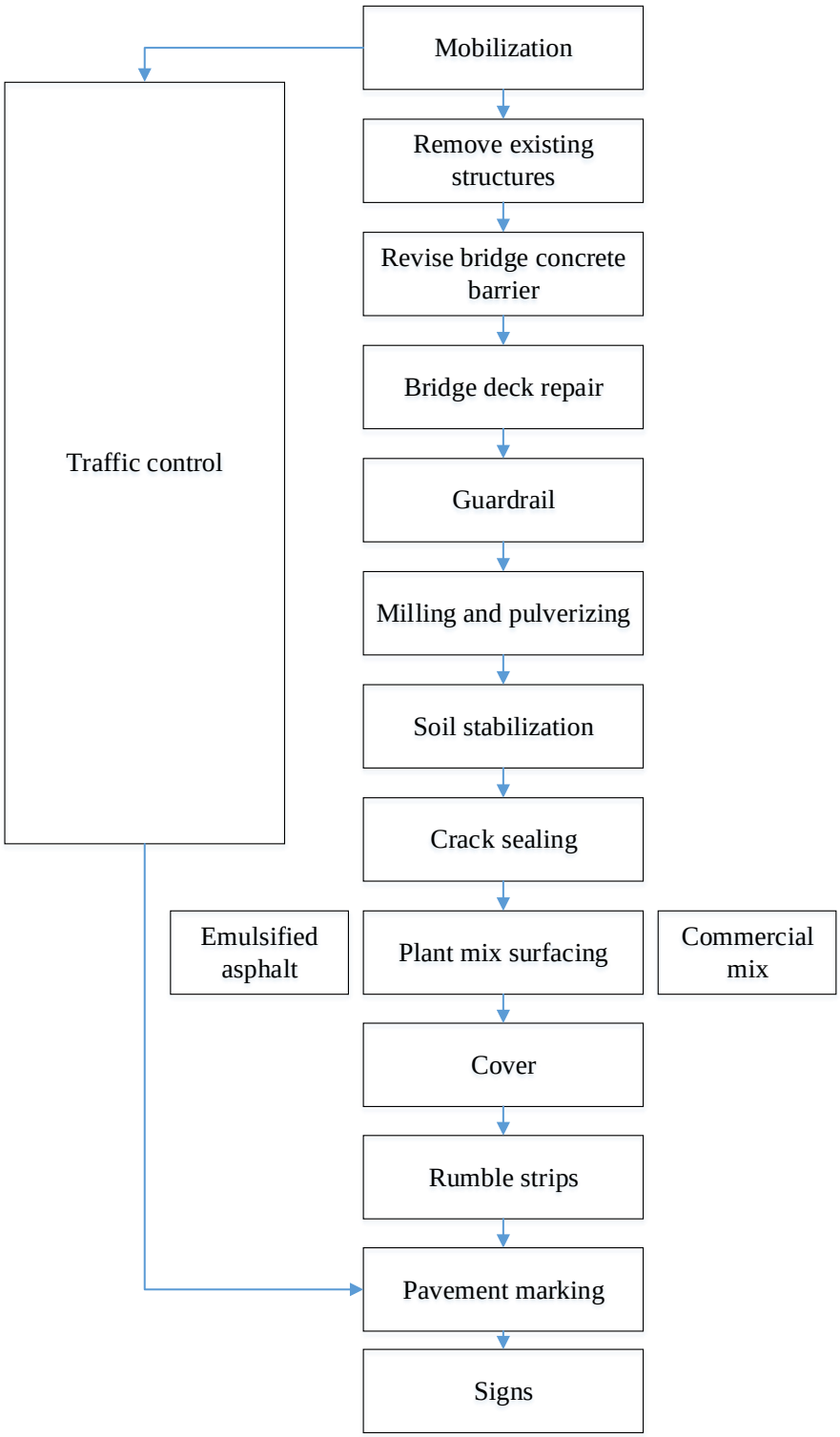

Proj. #:
8648074000
Dates
BRIDGE DECK
BRIDGE DECK REPAIR
CRACK SEALING
FINAL SWEEP AND BROOM
GUARD RAIL
MOBILIZATION
PAVEMENT MARKING
REMOVE EXISTING STRUCTURES
RUMBLE STRIPS
SEAL AND COVER
20160523
20160524
20160525
20160601
20160607
20160608
20160609
20160610
20160613
20160614
20160615
20160616
20160617
20160620
20160621
20160622
20160623
20160624
20160627
20160628
20160629
20160630
20160701
20160705
20160707
20160708
20160711
20160712
20160713
20160714
20160715
20160716
20160725
20160811
20160819
20160825
20160901
20160925

Appendix C: Initial sequence logics obtained from DWR data analysis

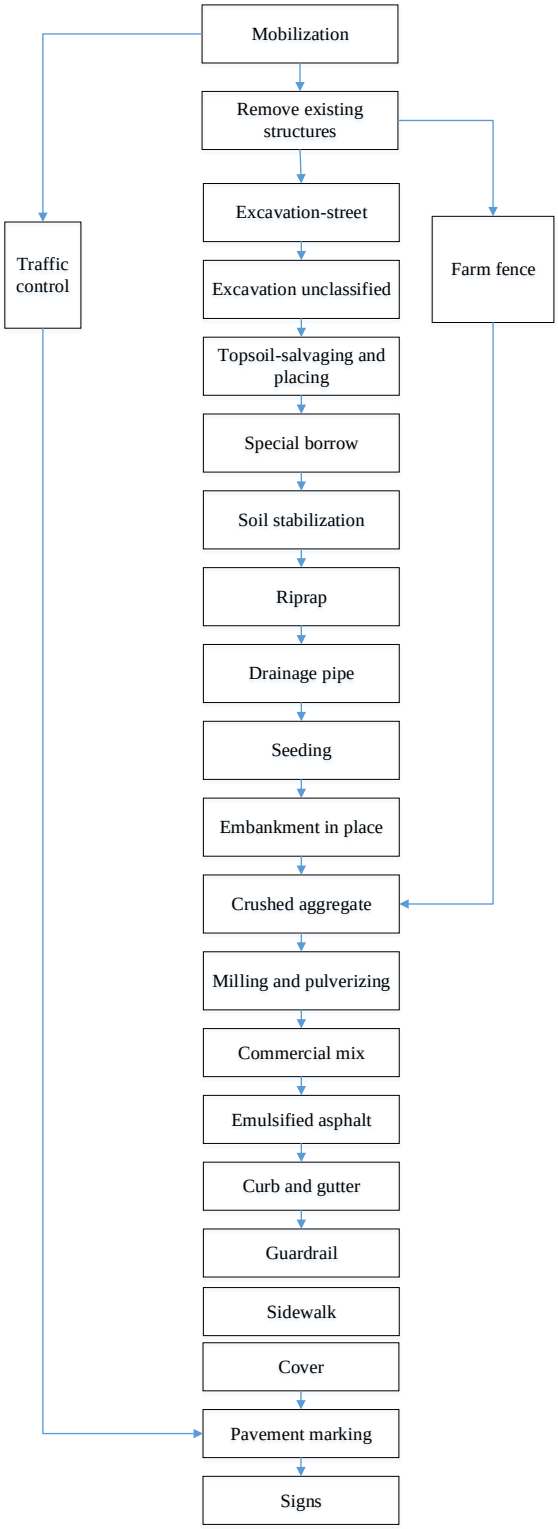
1. Overlay



2. Seal & Cover projects



3. Safety


Mobilization
Remove existing structures
Excavation-street
Excavation unclassified
Topsoil-salvaging and placing
Special borrow
Soil stabilization
Riprap
Drainage pipe
Seeding
Embankment in place
Crushed aggregate
Milling and pulverizing
Commercial mix
Emulsified asphalt
Curb and gutter
Guardrail
Sidewalk
Cover
Pavement marking
Signs
Traffic control
Farm fence

4. Bridge reconstruction & rehabilitation