

# ACTIVITY SEQUENCE LOGICS USING DAILY WORK REPORT DATA

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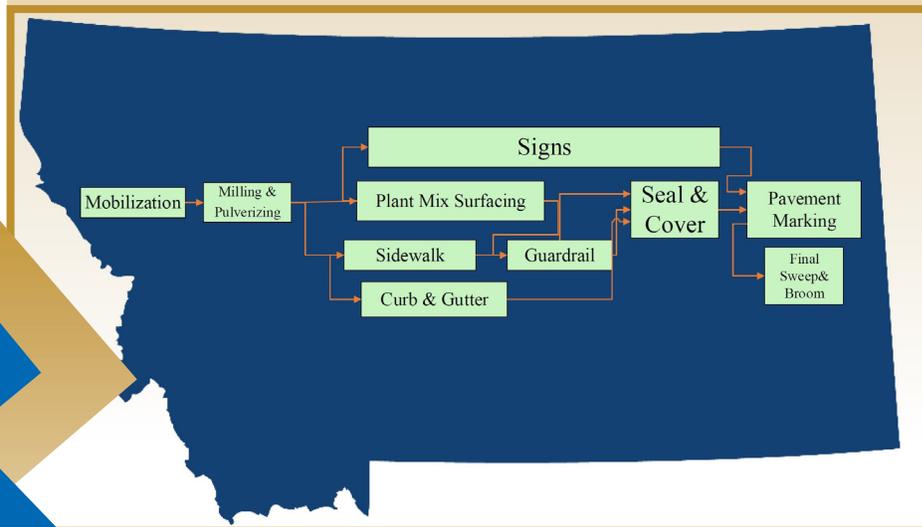
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*August 2020*

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## **Activity Sequencing Logics Using Daily Work Report Data**

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<b>16. Abstract</b> 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.			
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## 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 contract 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).

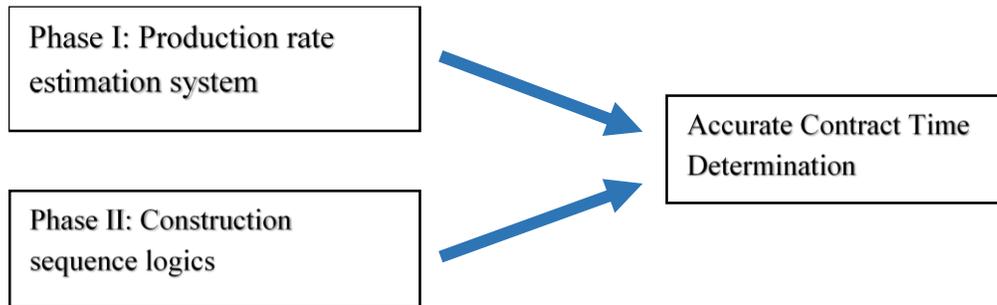


Figure 1.1 Phase II Research Goal

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	<b>Initial traffic control</b>	
2	<b>Detour</b>	1, 100%
3	<b>Milling/planning</b>	2, 100%
4	<b>Pavement repair</b>	
	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	<b>Initial traffic control</b>	
2	<b>Detour</b>	1, 100%
3	<b>ROW Preparations</b>	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	
4	<b>Excavation/ embankment</b>	
	A. Earth excavation	3, 25%
	B. Rock excavation	3, 25%
	C. Embankment	3, 25%
5	<b>Bridge structures</b>	
	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	<b>Retaining walls</b>	4A, 40%; 4C, 40%
7	<b>Base preparations</b>	
	A. Lime stabilizations	4, 100%
	B. Flexible base material	7A, 100%
	C. Cement treated base material	7A, 100%
8	<b>New curb and gutter</b>	7B, 100%; 7C, 100%
9	<b>Hot Mix asphalt base</b>	8, 75%
10	<b>Concrete paving</b>	7B, 100%; 7C, 100%
11	<b>Hot mix asphalt surface</b>	9, 100%
12	<b>Precast traffic barriers</b>	10, 100%; 11, 100%
13	<b>Permanent signing and traffic signals</b>	
	A. Small signs	10, 100%; 11, 100%
	B. Overhead signs	10, 100%; 11, 100%
	C. Major traffic signals	10, 100%; 11, 100%
14	<b>Seeding and landscape</b>	6, 100%; 10, 50%; 11, 50%
15	<b>Pavement markings</b>	10, 100%; 11, 100%; 12, 100%
16	<b>Final clean up</b>	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)

<b>S.No.</b>	<b>Project type</b>	<b>Project Description</b>
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.

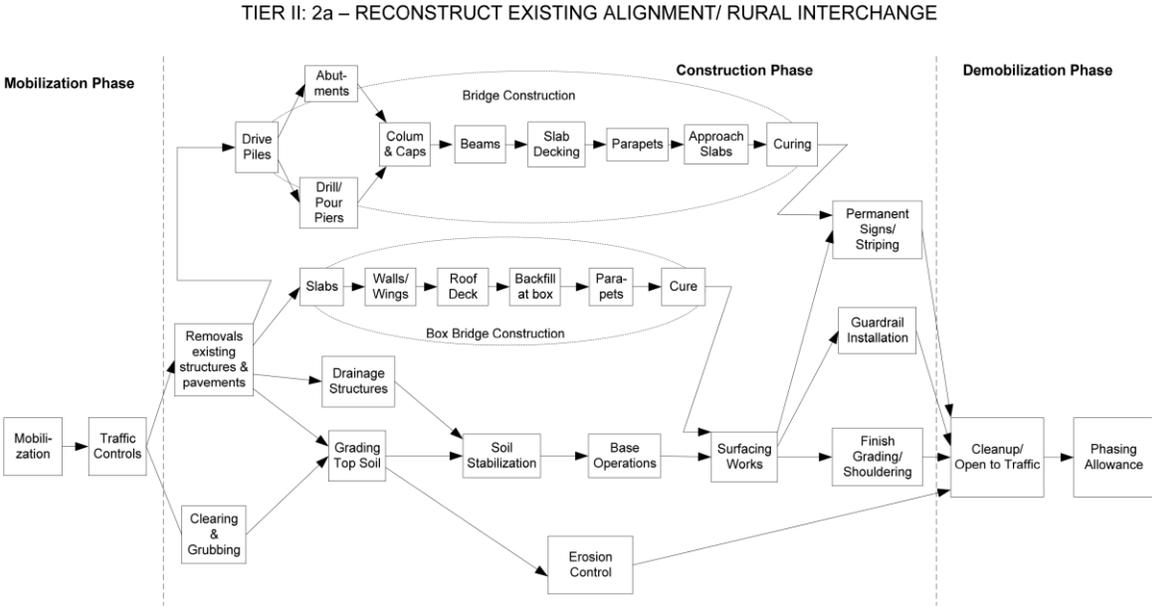


Figure 2.1 Sequence logic template for Reconstruct Existing Alignment/ Rural Interchange in OKDOT (Jeong et al., 2008)

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 REMOVAL	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
<b>Total</b>	<b>730</b>

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.

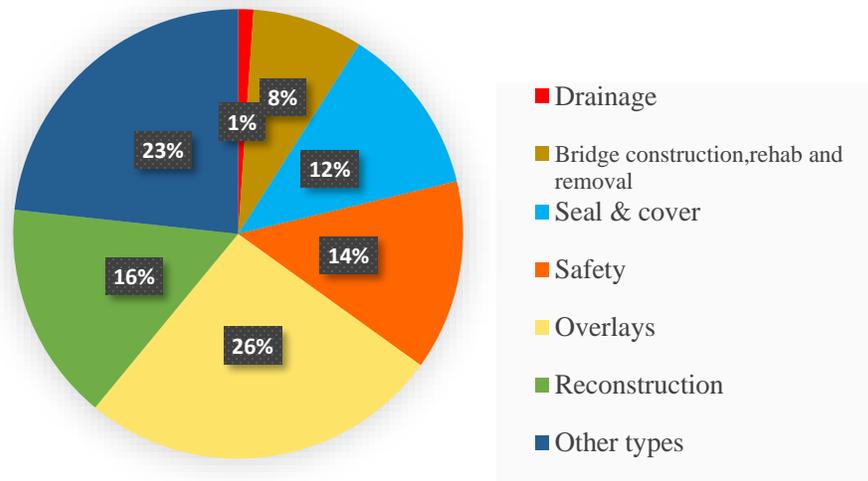


Figure 3.1 The most common project types in MDT

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%
<b>Total</b>		<b>437</b>	<b>60.0%</b>

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.

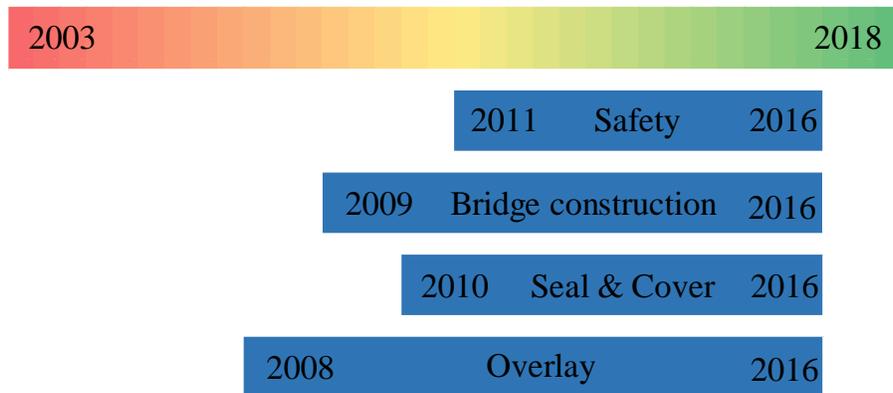


Figure 3.2 The timeline of the DWR dataset

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

\* 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.

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																		
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20151118																		
20151120																		
20151123																		
20151125																		
20151216																		
20151218																		
20160119																		
20160125																		
20160205																		

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.

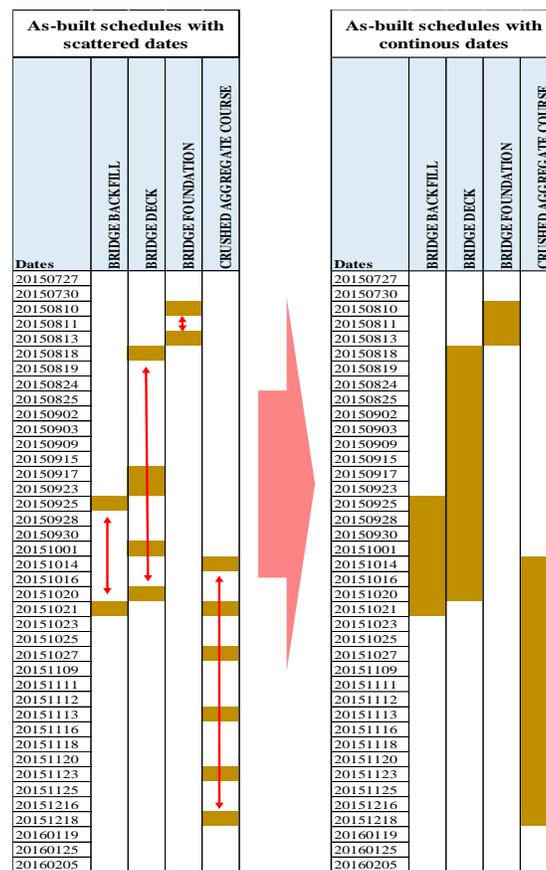


Figure 3.4 A sample of converting DWR data to a continuous and realistic as-built schedule

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

<b>Initial draft of controlling work items</b>			
<b>#</b>	<b>List of Controlling work items</b>	<b>#</b>	<b>List of Controlling work items</b>
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_DESCRPTION	Item-Code	Schedulers comments
BRIDGE DECK	BRIDGE DECK CRACK SEAL	552010160	<i>* Bridge Deck Hydrodemolition could be added to Bridge Deck Milling, since it is another form of Bridge Deck Milling</i>
	BRIDGE DECK HYDRODEMOLITION	552010199	
	BRIDGE DECK SCARIFICATION	552010150	
	BRIDGE DECK TREATMENT	552010430	
	CONCRETE-CLASS DD	551170000	
	CONCRETE-CLASS DD BRIDGE	551020035	
CLASS A BRIDGE DECK REPAIR	BRIDGE DECK REPAIR	552010250	<i>* The new Standard Specification (2014) defined new classes for bridge concrete that need to be included in bridge deck:</i>
	BRIDGE DECK REPAIR	552010300	
	BRIDGE DECK REPAIR	552010302	
BRIDGE DECK MILLING	BRIDGE DECK MILLING	552010155	<ul style="list-style-type: none"> <li>•Class Structure, 551020035</li> <li>•Class Deck, 551020107</li> <li>•Class Overlay, 563000000</li> <li>•Class Drilled Shaft, 551020166</li> </ul>
	BRIDGE DECK MILLING	561020110	

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

<b>Controlling work items</b>	<b>ITEM_DESCRIPTION</b>	<b>Item-Code</b>
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
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

<b>Final list of extended controlling work items</b>			
<b>#</b>	<b>Item description</b>	<b>#</b>	<b>Item description</b>
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)

<b>Overlay</b>				
<b>Controlling Work Items</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Expert's Opinion (Urban)</b>	<b>Expert's Opinion (Rural)</b>
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
<b>Total</b>	<b>191</b>	–	–	–

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

<b>Seal &amp; Cover</b>			
<b>Controlling Work Items</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Expert's Opinion</b>
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
<b>TOTAL</b>	<b>89</b>	–	–

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

<b>Safety</b>			
<b>Controlling Work Items</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Expert's Opinion</b>
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
<b>Total</b>	<b>100</b>	—	—

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

<b>Bridge Reconstruction and Rehabilitation</b>			
<b>Controlling Work Items</b>	<b>Frequency</b>	<b>Percentage</b>	<b>Expert's Opinion</b>
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
<b>Total</b>	<b>58</b>	<b>—</b>	<b>—</b>

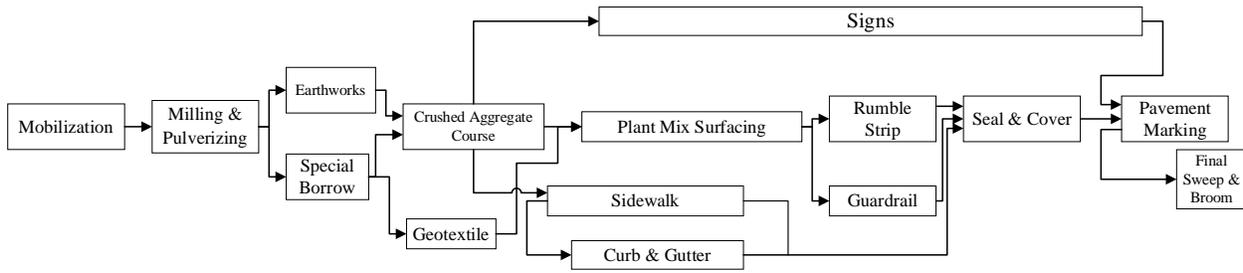
## 5. Construction Activity Sequence Logic Diagrams

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

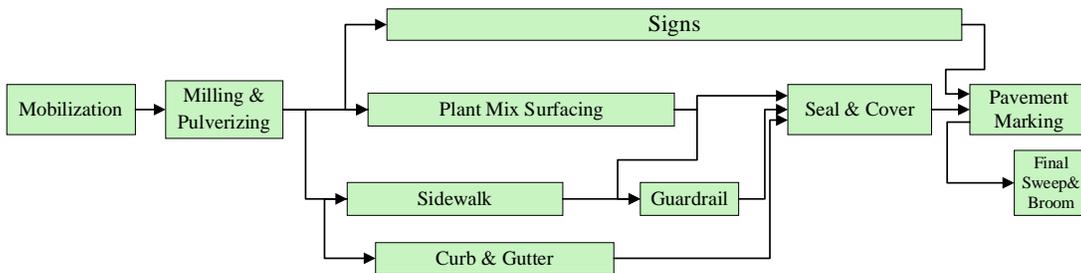
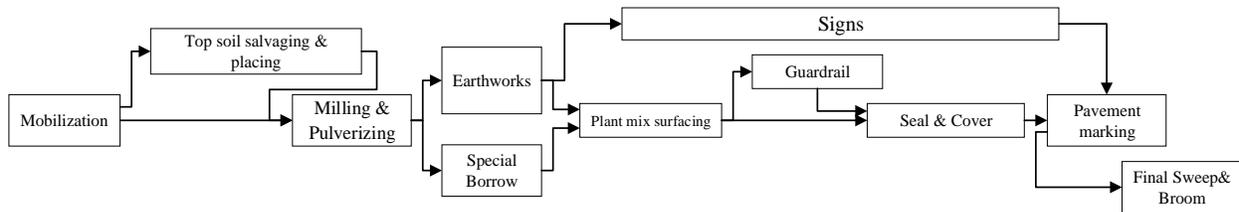


Figure 5.1 Sequence logic diagrams for overlay projects in urban areas

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

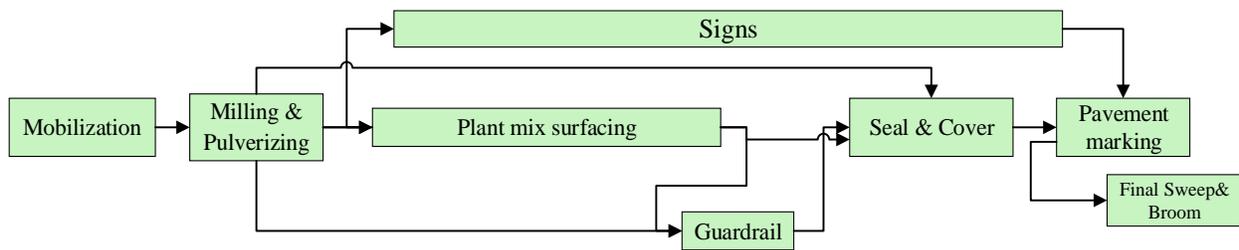
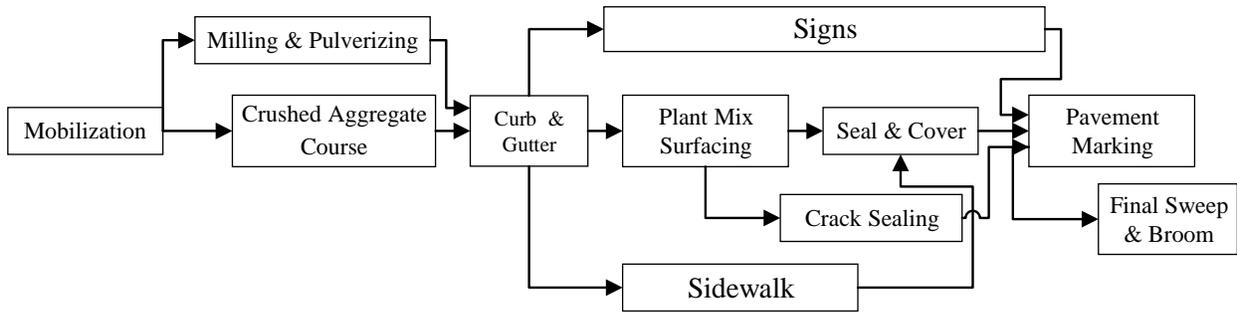


Figure 5.2 Sequence logic diagram for overlay projects in rural areas

### 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

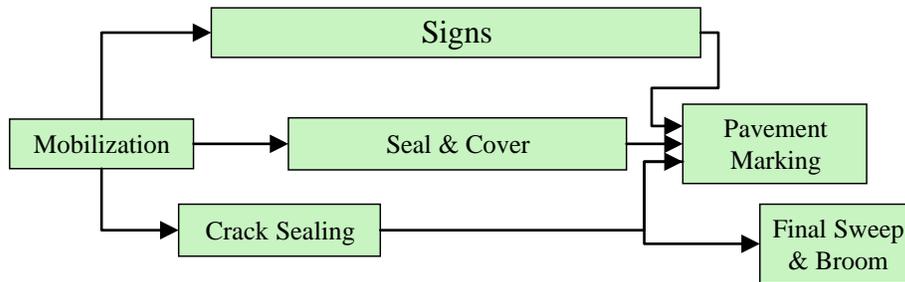
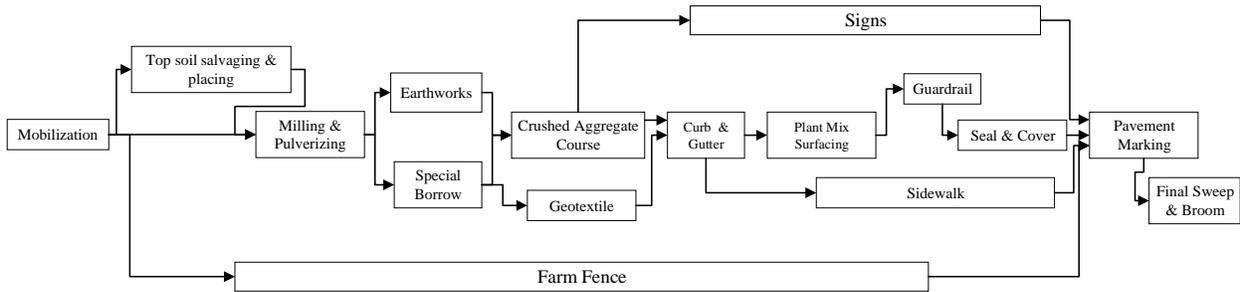


Figure 5.3 Sequence logic diagram for seal & cover projects

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

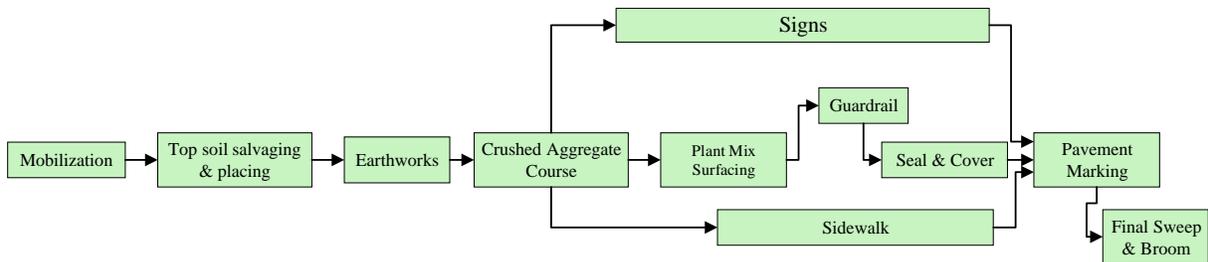


Figure 5.4 Sequence logic diagram for safety projects

## 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

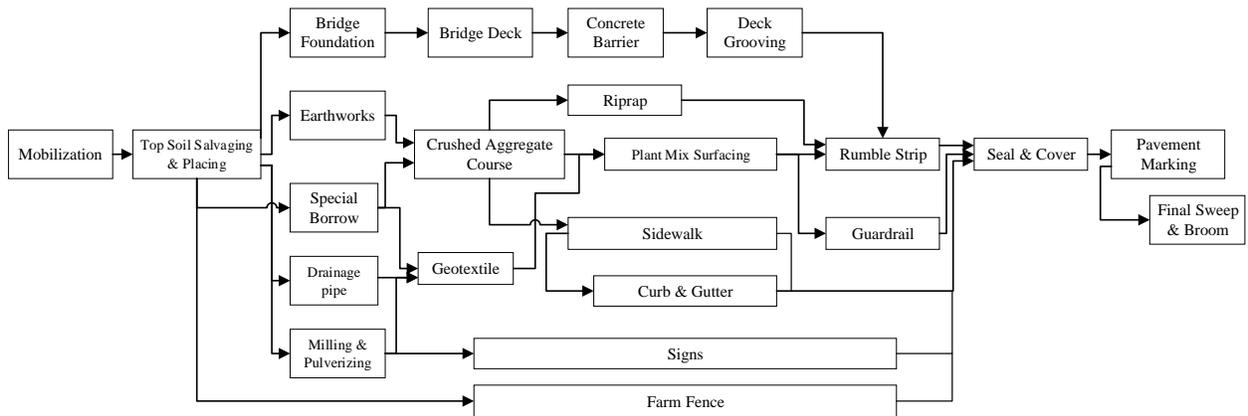


Figure 5.5 Sequence logic diagram for bridge reconstruction and rehabilitation projects

## 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

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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

<b>Detailed list of controlling work items</b>			
#	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
6	BRIDGE DECK REPAIR	CONCRETE-CLASS SD	551020107
		CLASS A BRIDGE DECK POLY REPAIR	552010250
		CLASS A BRIDGE DECK REPAIR	552010300
7	BRIDGE DECK MILLING	CLASS B BRIDGE DECK REPAIR	552010302
		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
		RPCA 1110 MM CL 3	603511030
		RPCA 1300 MM CL 3	603513030
		RPCA 1485 MM CL 3	603514830
		RPCA 1485 MM CL 4	603514831
		RPCA 1650 MM CL 3	603516530
		RPCA 36 IN CL 3	603013217
		RPCA 725 MM CL 2	603507110
		RPCA 725 MM CL 3	603507230
		RPCA 725 MM CL 4	603507232
		RPCA 920 MM CL 2	603508920
		RPCA 920 MM CL 3	603508930
		RPCA IRR 1110 MM CL 3	603561130
RPCA IRR 1300 MM CL 3	603513023		
RPCA IRR 1485 MM CL 2	603564820		
RPCA 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		

<b>Detailed list of controlling work items</b>			
<b>#</b>	<b>Controlling work items</b>	<b>Pat items</b>	<b>Item-Code</b>
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
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 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		

<b>Detailed list of controlling work items</b>			
<b>#</b>	<b>Controlling work items</b>	<b>Pat items</b>	<b>Item-Code</b>
37	RETAINING WALL	RETAINING WALL	614000000
38	REVISE BRIDGE CONCRETE BARRIER	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
42	SIDEWALK	SHOULDER GRAVEL	301020416
		SIDEWALK-CONCRETE 100 MM	608100000
		SIDEWALK-CONCRETE 150MM	608150000
		SIDEWALK-CONCRETE 4 IN	608010020
43	SIGNS	SIDEWALK-CONCRETE 6 IN	608010050
		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. #: 431268600	CRUSHED AGGREGATE COURSE	CURB AND GUTTER	EARTH WORKS	GEOTEXTILE	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	PLANT MIX SURFACING	SIDEWALK	SIGNS	SPECIAL BORROW
20140529											
20140530											
20140531											
20140601											
20140602											
20140603											
20140604											
20140605											
20140606											
20140607											
20140608											
20140609											
20140610											
20140611											
20140612											
20140613											
20140614											
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20140627											
20140628											
20140629											
20140630											
20140701											
20140702											
20140703											
20140704											
20140705											
20140706											
20140707											
20140708											
20140709											
20140710											
20140711											
20140712											
20140713											
20140714											
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20140716											
20140717											
20140718											
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20140721											
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20140723											
20140724											
20140725											
20140726											
20140727											
20140728											
20140729											
20140730											
20140731											
20140801											
20140802											
20140803											
20140804											
20140805											
20140806											
20140807											
20140808											
20140809											
20140810											
20140811											
20140812											
20140813											
20140814											
20140815											
20140816											
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20140818											
20140819											
20140820											
20140821											
20140822											
20140823											
20140824											
20140825											
20140826											
20140827											
20140828											
20140829											
20140900											
20140903											
20140904											
20140909											
20140918											
20140925											
20141002											
20141025											
20141229											

Proj. #: 7721004000	CRUSHED AGGREGATE COURSE	CURB AND GUTTER	FINAL SWEEP AND BROOM	GEOGRID	GEOTEXTILE	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIDEWALK	SIGNS	SPECIAL BORROW
20130909													
20130910													
20130911													
20130912													
20130913													
20130919													
20130923													
20130924													
20130925													
20130926													
20130927													
20130930													
20131001													
20131002													
20131003													
20131004													
20131007													
20131008													
20131009													
20131010													
20131011													
20131014													
20131015													
20131016													
20131017													
20131018													
20131021													
20131024													
20131025													
20131028													
20131101													
20131102													
20131104													
20131105													
20131106													
20131107													
20131108													
20131109													
20131110													
20131112													
20131113													
20131210													
20131211													
20131217													
20140110													
20140408													
20140425													
20140604													
20140625													
20140701													
20140702													
20140703													
20140725													
20140818													
20140825													
20140901													
20140925													
20141022													
20141027													

Proj. #: 7460081000	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	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	



Proj. #: 79411038000		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
Dates													
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		CURB AND GUTTER	MILLING AND PULVERIZING	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIDEWALK	SIGNS
Dates									
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	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	CRACK SEALING	FINAL SWEEP AND BROOM	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER
Dates						
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. #: 8162014000	CRACK SEALING	CRUSHED AGGREGATE COURSE	FINAL SWEEP AND BROOM	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SIGNS
Row Labels									
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		BRIDGE DECK	BRIDGE DECK REPAIR	CRACK SEALING	FINAL SWEEP AND BROOM	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER
Dates											
20160523											
20160524											
20160525											
20160601											
20160607											
20160608											
20160609											
20160610											
20160613											
20160614											
20160615											
20160616											
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20160622											
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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. #: 8793003000	BEAMS	BRIDGE BACKFILL	BRIDGE DECK	BRIDGE FOUNDATION	CONCRETE BARRIER RAIL-BRIDGE	CRUSHED AGGREGATE COURSE	EARTH WORKS	MOBILIZATION	PAVEMENT MARKING	REINFORCING STEEL	REMOVE EXISTING STRUCTURES	RIPRAP	SEEDING	SIGNS	TOP-SOIL-SALVAGING AND PLACING
20150113															
20150128															
20150316															
20150317															
20150318															
20150323															
20150325															
20150326															
20150330															
20150331															
20150406															
20150409															
20150410															
20150413															
20150415															
20150417															
20150422															
20150423															
20150424															
20150427															
20150428															
20150429															
20150504															
20150507															
20150511															
20150520															
20150521															
20150526															
20150601															
20150604															
20150610															
20150611															
20150615															
20150617															
20150622															
20150623															
20150630															
20150708															
20150709															
20150710															
20150713															
20150715															
20150716															
20150721															
20150722															
20150724															
20150730															
20150810															
20150825															
20150827															
20150915															

Proj. #: 8128215000	BRIDGE DECK	BRIDGE DECK MILLING	BRIDGE DECK REPAIR	CONCRETE-CLASS OVERLAY	DECK GROOVING (after curing)	EARTH WORKS	MILLING AND PULVERIZING	MOBILIZATION	PLANT MIX SURFACING	REMOVE EXISTING STRUCTURES	SEAL AND COVER	SHOULDER GRAVEL
20160225												
20160418												
20160419												
20160420												
20160421												
20160425												
20160426												
20160428												
20160429												
20160430												
20160502												
20160503												
20160504												
20160505												
20160506												
20160509												
20160510												
20160511												
20160512												
20160513												
20160516												
20160517												
20160518												
20160519												
20160523												
20160524												
20160525												
20160526												
20160531												
20160601												
20160602												
20160603												
20160606												
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20160701												
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20160726												
20160727												
20160801												
20160802												
20160803												
20160804												
20160815												
20160818												
20160825												
20160829												
20161101												
20161116												
20161125												
20161207												

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																
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20150812																
20150813																
20150825																
20150910																
20150914																
20150925																
20151006																
20151023																
20151025																
20151110																
20151203																

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																			
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20150824																			
20150825																			
20150902																			
20150903																			
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20150930																			
20151001																			
20151014																			
20151016																			
20151020																			
20151021																			
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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																				
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20141219																				
20141225																				
20150224																				
20150225																				
20150312																				
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20150724																				
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20151025																				
20160524																				
20160525																				
20160614																				

## 5- Safety

Proj. #: 7201015000		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
Dates													
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		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
Dates															
20160419															
20160420															
20160425															
20160426															
20160428															
20160429															
20160503															
20160504															
20160512															
20160513															
20160519															
20160520															
20160526															
20160607															
20160609															
20160610															
20160613															
20160614															
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20160624															
20160627															
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20160706															
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20160719															
20160721															
20160726															
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20160805															
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20160907															
20160929															
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20170103															

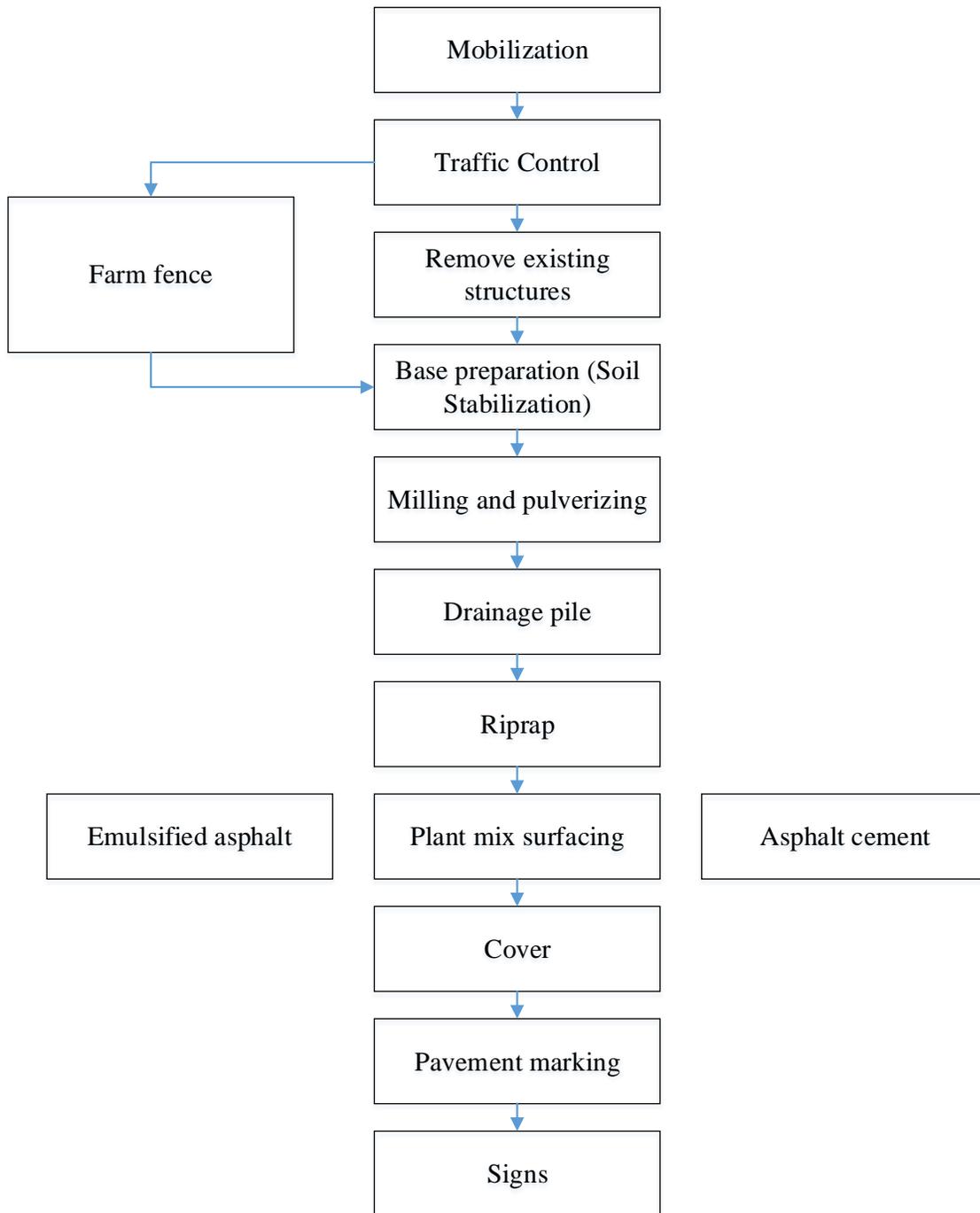
Proj. #: 7539041000	
Dates	
20150406	
20150408	
20150409	
20150410	
20150411	
20150413	CRUSHED AGGREGATE COURSE
20150414	EARTH WORKS
20150420	FINAL SWEEP AND BROOM
20150421	GUARD RAIL
20150422	MOBILIZATION
20150423	PAVEMENT MARKING
20150424	PLANT MIX SURFACING
20150427	REMOVE EXISTING STRUCTURES
20150430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

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

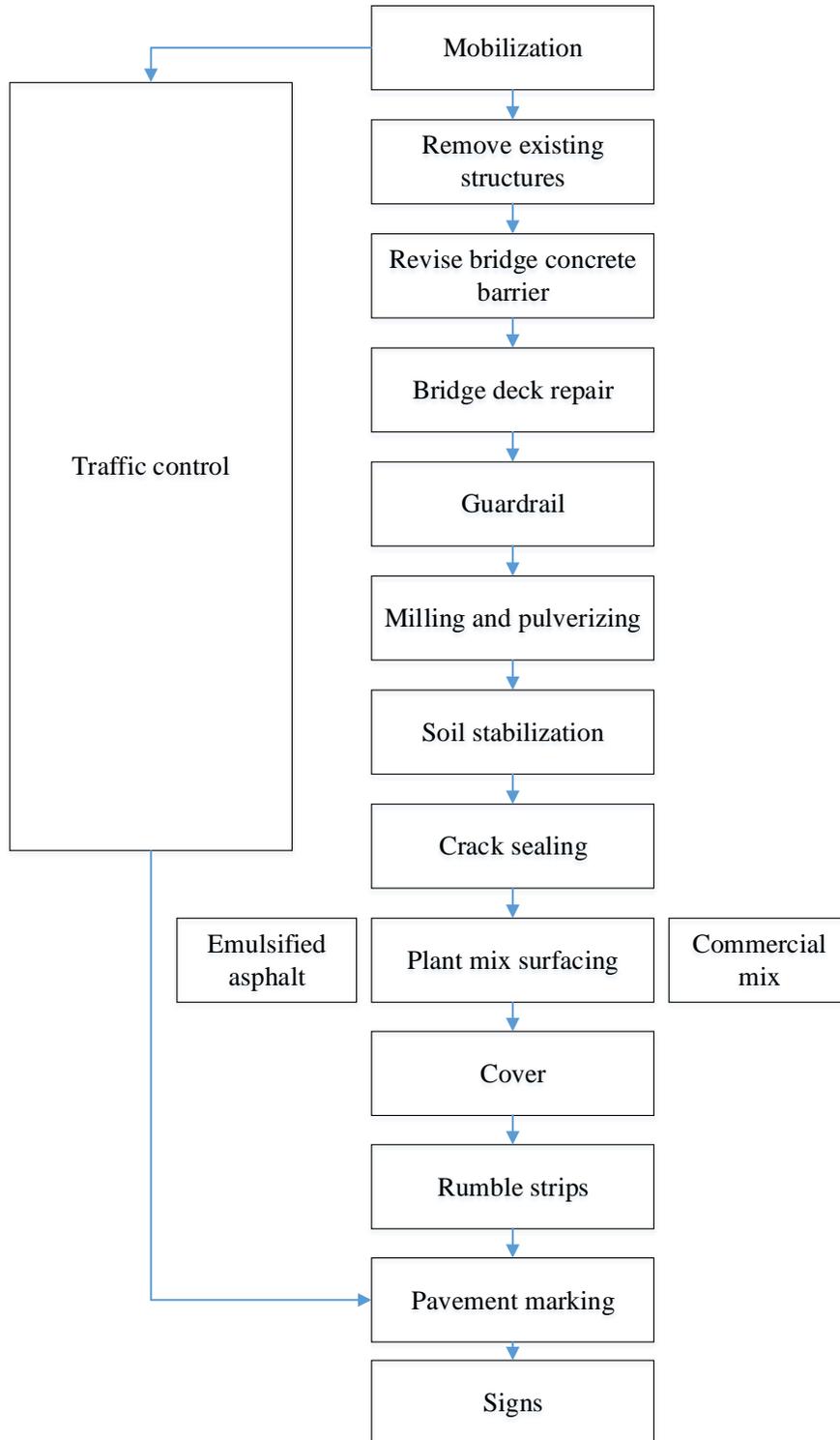
Proj. #: 8648074000		BRIDGE DECK	BRIDGE DECK REPAIR	CRACK SEALING	FINAL SWEEP AND BROOM	GUARD RAIL	MOBILIZATION	PAVEMENT MARKING	REMOVE EXISTING STRUCTURES	RUMBLE STRIPS	SEAL AND COVER
Dates											
20160523											
20160524											
20160525											
20160601											
20160607											
20160608											
20160609											
20160610											
20160613											
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## Appendix C: Initial sequence logics obtained from DWR data analysis

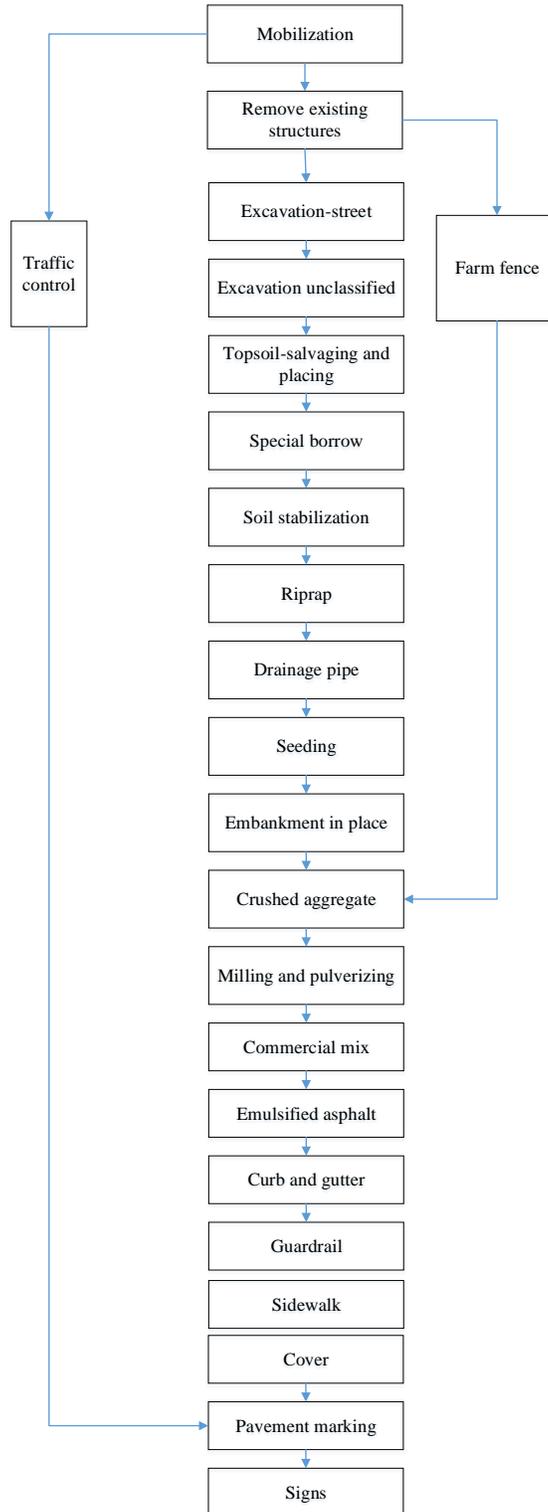
### 1. Overlay



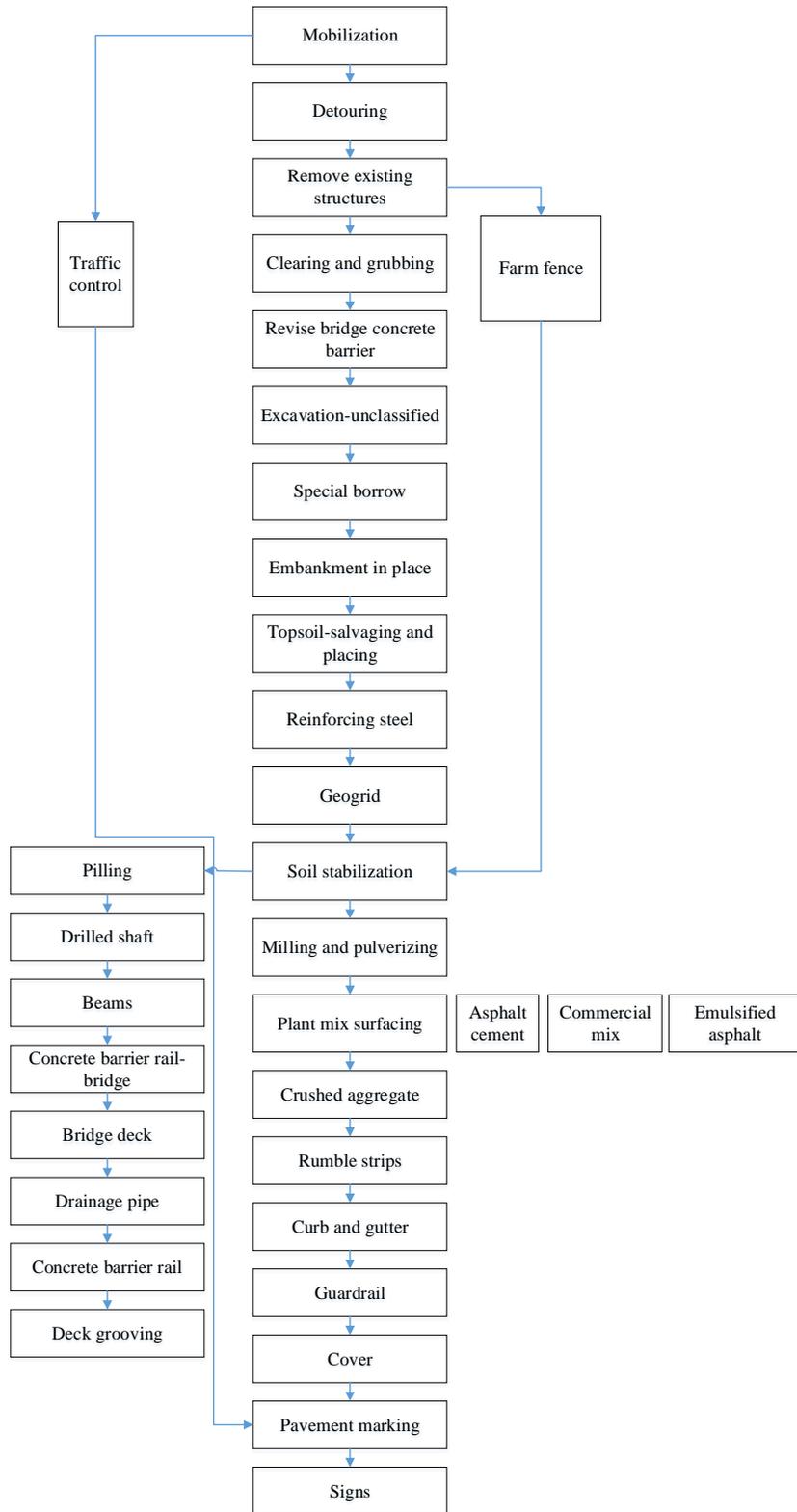
## 2. Seal & Cover projects



### 3. Safety



#### 4. Bridge reconstruction & rehabilitation



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