STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR-0003 (REV 04/2024)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA24-3847	N/A	N/A

4. TITLE AND SUBTITLE	5. REPORT DATE
Development of a Maintenance Prioritization Assessment and Safety Tool	December 14, 2023
	6. PERFORMING ORGANIZATION CODE AHMCT Research Center, UC Davis
7. AUTHOR	8. PERFORMING ORGANIZATION REPORT NO.
Travis Swanston, Iman Soltani, and Ty Lasky	UCD-ARR-23-12-31-03
9. PERFORMING ORGANIZATION NAME AND ADDRESS AHMCT Research Center UCD Dept. of Mechanical & Aerospace Engineering Davis, California 95616-5294	10. WORK UNIT NUMBER N/A
	11. CONTRACT OR GRANT NUMBER 65A0749 Task 3847
12. SPONSORING AGENCY AND ADDRESS California Department of Transportation P.O. Box 942873, MS #83, Sacramento, CA 94273-0001	13. TYPE OF REPORT AND PERIOD COVERED Final Report January 2022 – December 2023
	14. SPONSORING AGENCY CODE Caltrans

15. SUPPLEMENTARY NOTES

N/A

16. ABSTRACT

Highway construction and maintenance work is one of the most hazardous occupations in the United States. In 2018, more than 7,000 work-zone collisions occurred on California roadways, about 2,300 resulting in injuries, and 46 involving fatalities. This research helped move toward reducing those numbers. The California Department of Transportation (Caltrans) needs operational performance metrics that can be used to evaluate the safety risks to highway workers in planning and scheduling of maintenance operations. This research project developed a maintenance task analysis and safety index tool that can be used by the Division of Maintenance for planning of their maintenance work activities. The tool is based on index of difficulty and collision risks to the maintenance workers. The goal of this research was to develop a tool that will help Caltrans achieve its Priorities and Department Goals by improving the safety and efficiency of its highway maintenance activities by providing detailed data that can be used to plan lane closures, time duration of operation, and consider other factors. The tool allows for planning that would improve the safety of highway workers and traveling public. The tool facilitates calculation of maintenance task difficulty and collision risk indices, supporting maintenance planning and scheduling. The tool supports easier identification and input of the most pertinent parameters to determine difficulty and collision risk index. Caltrans can then use objective data and measures for decision-making in planning and scheduling a maintenance operation. The tool is particularly useful in prioritizing multiple operations and selecting operations based on lower difficulty and/or collision risk. The results can also be used in allocating resources in terms of personnel and equipment, considering additional safety measures, and deciding if and what type of lane closure is necessary to reduce the risk of collision and injury potential to personnel and roadside workers. This report documents the tool development and the related research.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Highway maintenance, highway construction, Performance metrics, Planning software, Decision Support Tool	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	45	N/A

DISCLAIMER

The research reported herein was performed by the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, within the Department of Mechanical and Aerospace Engineering at the University of California – Davis, for the Division of Research, Innovation and System Information (DRISI) at the California Department of Transportation. AHMCT and DRISI work collaboratively to complete valuable research for the California Department of Transportation.

This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification or regulation. This report does not constitute an endorsement by the Department of any product described herein.

The contents of this report do not necessarily reflect the official views or policies of the University of California. This report does not constitute an endorsement by the University of California of any product described herein.

For individuals with sensory disabilities, this document is available in alternate formats. For information, call (916) 654-8899, TTY 711, or write to California Department of Transportation, Division of Research, Innovation and System Information, MS-83, P.O. Box 942873, Sacramento, CA 94273-0001.

Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis

Development of a Maintenance Prioritization Assessment and Safety Tool

Travis Swanston, Iman Soltani &
Ty Lasky: Principal Investigator

Report Number: CA24-3847
AHMCT Research Report: UCD-ARR-23-12-31-03
Final Report of Contract: 65A0749 Task 3847

December 14, 2023

California Department of Transportation

Division of Research, Innovation and System Information

Executive Summary

Highway construction and maintenance work is one of the most hazardous occupations in the United States. In 2018, over 7,000 work-zone collisions occurred in California. About 2,300 of these resulted in injuries, and 46 involved a fatality. This research was meant to help move toward reducing these numbers.

The California Department of Transportation (Caltrans) needs metrics to evaluate safety risks to highway workers in planning and scheduling maintenance operations. This research project developed a Maintenance Planning Dashboard (MPD) that can be used by the Division of Maintenance for prioritizing and planning maintenance activities. The tool is based on index of difficulty and collision risks to maintenance workers.

The goal of this research project was to develop a tool to help Caltrans improve the safety and efficiency of highway maintenance by providing detailed data that can be used to plan lane closures, time duration of operation, and other factors. The tool was meant to improve the safety of highway workers and traveling public.

The Advanced Highway Maintenance and Construction Technology Research Center work [1] previously developed maintenance task difficulty and collision risk indices. The MPD developed in this research facilitates index calculations, allowing science-based maintenance planning and scheduling. The MPD supports easier identification and input of the pertinent parameters. With difficulty and collision risk indices available, Caltrans can use objective data and metrics for decision-making in maintenance operation planning and scheduling. The primary use for the tool is prioritizing multiple operations based on difficulty and collision risk. The results can also be used in allocating resources in terms of personnel and equipment, considering additional safety measures, and deciding whether and what type of lane closure is necessary to reduce risk of collision and injury to maintenance personnel.

The research included project management and reporting, development of the MPD backend and frontend, implementation of the MPD, testing, and reporting. The key MPD design and implementation issues are discussed below.

Major Results and Recommendations

The key deliverables of this project include:

- The design and implementation of the MPD backend
- MPD user interface design and implementation documented herein
- Thefinal version of the MPD tool and installer

The MPD backend performs the needed background calculations, thus enabling MPD decision support. The MPD backend is discussed in Chapter 2. The tool calculates:

- Postmile resolution and route odometer estimation
- Work length estimation
- Traffic estimation
- Collision density estimation
- Difficulty index calculation

The MPD UI supports calculation of difficulty indices and collision risks for multiple user-proposed maintenance activities. Its primary purpose is to allow a maintenance activity planner to classify and sort a group of specified maintenance activities by their difficulty index and collision risk estimates to assist in prioritizing the safest and simplest activities. The MPD UI is discussed in Chapter 3.

The MPD tool development used only Caltrans IT-approved components. The key elements include Spring Boot, Java 11, Gradle, HyperText Markup Language 5 (HTML5), Cascading Style Sheets Level 3 (CSS3), and JavaScript ES2015. All internal data dependencies are packed as part of the installer.

Table of Contents

Executive Summary ii
Major Results and Recommendations iii
Table of Contents iv
Figures vi
Tables vii
Acronyms and Abbreviations viii
Acknowledgments ix
Chapter 1: Introduction 1
Problem 1
Objectives and Scope 1
Research Methodology 2
Overview of Research Results and Benefits 2
Chapter 2: MPD Application Design and Implementation 4
Design Goals and Architecture 4
Packaging 5
Backend Implementation 5
Postmile Resolution and Route Odometer Estimation 7
Work Length Estimation 7
Traffic Estimation 7
Collision Density Estimation 7
Difficulty Index Calculation 8
Collision Risk Calculation 8
Frontend Implementation 9
Chapter 3: MPD Application Usage 11
User Interface Overview 11
Activity Specification 13
Activity Workspace 14
MPD Test Results and Summary of User Feedback 17
Chapter 4: Conclusions and Future Research 19
References 21
Appendix A: Activities, Difficulty and Risk Categories and Thresholds, and Considerations Messages 22
Activity Codes, Descriptions, and Difficulty Indices 22
Difficulty Categories and Thresholds 27

Risk Categories and Thresholds 28
Considerations 29

Figures

Figure 2.1: MPD application architecture 5
Figure 3.1: MPD user interface at application start 11
Figure 3.2: MPD user interface in use 12
Figure 3.3: Populated Activity details 14
Figure 3.4: Populated Activity workspace 14
Figure 3.5: Enabling ascending sort by activity code 16
Figure 3.6: Activity Workspace sorted by Collision Risk (ascending) 16

Tables

Table 2.1: MPD backend data assets 6
Table 2.2: MPD frontend data assets 6
Table 2.3: $\boldsymbol{\beta i}$ coefficients of the collision risk equation 9
Table 2.4: $\boldsymbol{xi}$ coefficients of the collision risk equation 9
Table A.1: Activity codes, descriptions, and difficulty indices 22
Table A.2: Difficulty index categories and thresholds 28
Table A.3: Collision risk categories and thresholds 29

Acronyms and Abbreviations

Acronym	Definition
AADT	Average Annual Daily Traffic
AADTT	Average Annual Daily Truck Traffic
AHMCT	Advanced Highway Maintenance and Construction Technology
API	Application Programming Interface
Caltrans	California Department of Transportation
CSS3	Cascading Style Sheets Level 3
DOT	Department of Transportation
DRISI	Division of Research, Innovation and System Information
DST	Decision Support Tool
HMTL5	HyperText Markup Language 5
JSON	JavaScript Object Notation
MPD	Maintenance Planning Dashboard
SHN	State Highway Network
SWITRS	Statewide Integrated Traffic Records System
TSN	Transportation System Network
UI	User Interface
URL	Uniform Resource Locator

Acknowledgments

The authors thank the California Department of Transportation (Caltrans) for their support, particularly Kenneth Murray - Supervising Landscape Architect, Gregory Balzer - Senior Landscape Architect, Scott Blair – Senior Landscape Architect, and Jack Broadbent - Supervising Landscape Architect, Landscape Architecture Program, Division of Design. We also thank Theresa Drum - Deputy Division Chief for Maintenance Safety, Equipment, and Training; Larry Schwartz - Deputy Division Chief for Maintenance Safety, Equipment, and Training; Paul Featherstone, Safety and Training Liaison, Division of Maintenance; Chuy Gonzalez – Supervising Transportation Engineer, Division of Maintenance; and Hamid Ikram and Juan Araya with the Division of Research, Innovation and System Information. The authors acknowledge the dedicated efforts of the AHMCT team who have made this work possible.

Chapter 1: Introduction

Problem

According to the U.S. Bureau of Labor Statistics, highway construction and maintenance work is one of the most hazardous occupations in the United States. In 2018, more than 7,000 work-zone collisions occurred on California roadways. About 2,300 of these resulted in injuries, and 46 involved a fatality. This research project helped move toward reducing those numbers.

The California Department of Transportation (DOT) (Caltrans) needs operational performance metrics that can be used to evaluate the safety risks to highway workers in planning and scheduling of maintenance operations. The research project developed a Maintenance Planning Dashboard (MPD) that can be used by the Division of Maintenance for planning of their maintenance work activities. The tool is based on index of difficulty and collision risks to maintenance workers.

Objectives and Scope

The goal of this research project was to develop the MPD tool to help Caltrans improve the safety and efficiency of its highway maintenance activities by providing detailed data that can be used to plan lane closures, time duration of operation, and consider other factors. The tool allows for planning that would improve the safety of highway workers and the traveling public.

A previous Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) research project [1] developed difficulty and collision risk indices for maintenance tasks. The calculation of these indices is based on many factors, including lane closure presence and type, crew size, work duration, and work zone length. The tool developed in this research facilitates calculation of maintenance task difficulty and collision risk indices, thus supporting maintenance planning and scheduling based upon difficulty and collision risk. The MPD supports easier identification and input of the parameters to determine difficulty and collision risk index. With difficulty and collision risk indices more easily calculated, Caltrans can then use objective data and measures for data-driven decision-making in planning and scheduling maintenance operations. The primary use of the MPD is prioritizing a group of operations based on difficulty and collision risk. The results can also be used in allocating resources in terms of personnel and equipment, considering additional safety measures, and deciding if and what type of lane closure is

necessary to reduce the risk of collision and injury potential to maintenance workers and the traveling public.

Research Methodology

The research included the following tasks:

Task 1: Manage project

Task 2: Design maintenance planning dashboard backend

Task 3: Implement maintenance planning dashboard backend

Task 4: Design maintenance planning dashboard user interface

Task 5: Implement maintenance planning dashboard user interface

Task 6: Support Caltrans testing of maintenance dashboard and summarize user feedback

Task 7: Develop final report

The primary research efforts included the design and development of the MPD backend and frontend (discussed in detail in Chapter 2), implementation of the MPD (also Chapter 2), testing, and reporting. MPD implementation used only Caltrans IT-approved components, including Spring Boot, Java 11, Gradle, HyperText Markup Language 5 (HTML5), Cascading Style Sheets Level 3 (CSS3), and JavaScript ES2015. All internal data dependencies are packed as part of the installer.

More than the technical aspects of the research and development, the most important part of this research was direct interaction with and advice from the project panel. We were fortunate to have a strong PM and a highly skilled, active, and experienced project panel. We met with the panel regularly (approximately 9 times through the project, or about every 2.5 months) to discuss status, design, user interface, issues, and related topics. Most importantly, the panel helped us understand the specific needs of Caltrans Maintenance for a tool like the MPD. This regular interaction supported a successful research effort.

Overview of Research Results and Benefits

The key deliverables of this project include:

- The design of the maintenance planning dashboard backend documented herein. The MPD backend performs the needed background calculations, thus enabling MPD decision support. The MPD backend design is discussed in Chapter 2. The tool calculates postmile resolution and route odometer estimation, work length estimation, traffic estimation, collision density estimation, and difficulty index calculation.

- Implementation of the maintenance planning dashboard backend. The MPD backend implementation, performed in Java 11, is discussed in Chapter 2.
- Maintenance planning dashboard user interface (UI) design. The UI design is discussed in Chapter 3. The MPD UI supports calculation of difficulty indices and collision risks for multiple user-proposed maintenance activities. Its primary purpose is to allow a maintenance activity planner to classify and sort a group of specified maintenance activities by their difficulty index and collision risk estimates to assist in prioritizing the safest and simplest activities.
- Description of the implementation and usage of the maintenance planning dashboard UI. MPD UI implementation leverages HTML5 and CSS3 and is discussed in Chapter 2. Chapter 3 discusses the usage of the frontend (UI), including activity specification and prioritization.
- Maintenance dashboard test results and summary of user feedback. The primary feedback, as discussed in Chapter 3, related to postmile input challenges and timing of display of work activity information. The display timing was deliberate and prevents display of incorrect work activity information based on partial input. The postmile issue can be addressed by leveraging existing Caltrans postmile tools.
- Final report.

Chapter 2:
MPD Application Design and Implementation

Design Goals and Architecture

The purpose of the MPD application is to leverage the results of previous AHMCT research project [1] into an easy-to-use tool to assist in maintenance activity planning. If successful, the intention is for the tool to be deployed for use by Caltrans Maintenance. This objective was paramount in the establishment of the application's design goals.

The primary design goals were:

- **Compliance with Caltrans standards**: Avoid dependencies upon languages, runtimes, frameworks, application servers, or operating systems that are not recommended in the Caltrans IT software standards [2].
- **Ease of deployment and management**: Keep the architecture as simple as feasible and avoid the use of niche technologies.
- **Ease of use**: Avoid the need for end-user software installation (e.g., standalone application or client).

Given these design goals, and after discussions with the project panel about the application's functionality, it was decided that:

- The MPD should be a pure, client-server web application.
- The backend should be stateless.
- The backend should be compilable into a single distributable file.
- The backend should be a Spring Boot 2 application written in Java 11.
- The backend should be compatible with at least one Caltrans-approved application server (e.g., JBoss).
- The frontend should be written in HyperText Markup Language 5 (HTML5), Cascading Style Sheets Level 3 (CSS3), and JavaScript ES2015.
- The frontend should be compatible with Google Chrome, Mozilla Firefox, and Microsoft Edge.

The resulting application architecture is illustrated in Figure 2.1.

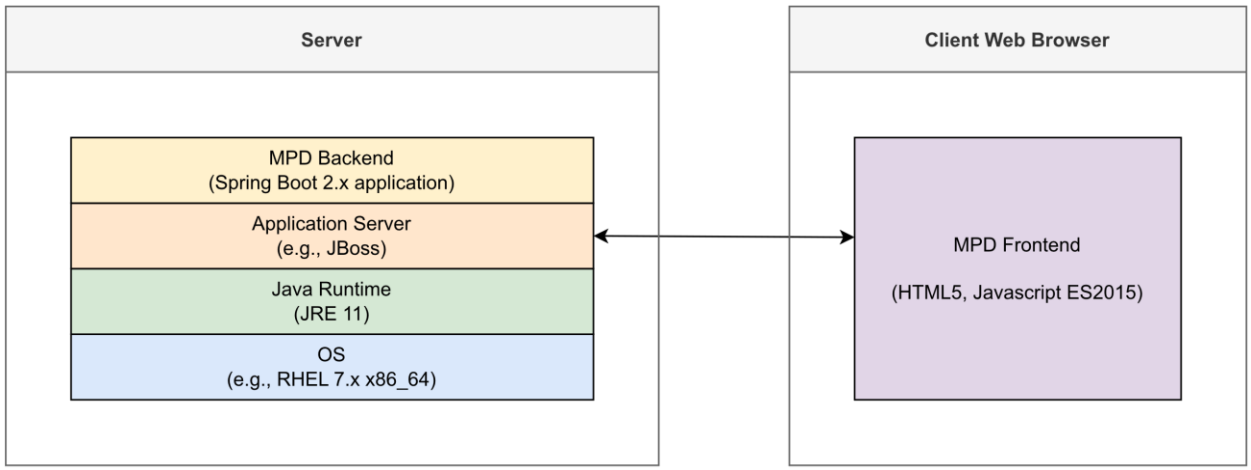


Figure 2.1: MPD application architecture

Designs proposed earlier in the project also employed a MySQL database, but as the application's requirements evolved over the course of the project, the retention of application state on the backend became unnecessary and the database was dropped from the design.

Packaging

The MPD application is packaged into a single-file distributable (.war or .jar) containing the following components:

- Backend service bytecode
- Backend libraries
- Frontend HTML, CSS, JavaScript, and media assets
- Frontend and backend data assets

The included backend data assets are identified in Table 2.1, while the included frontend data assets are identified in Table 2.2.

Backend Implementation

The MPD backend is a Spring Boot 2 web service written in Java 11. Its Application Programming Interface (API) consists of a single GET endpoint (`/query`), which returns several pieces of data that represent the results of processing the maintenance activity specified in the API call.

Primary data processing components of the backend include:

- Postmile resolution and route odometer estimation
- Work length estimation
- Traffic estimation

- Collision density estimation
- Difficulty index calculation
- Collision risk calculation

Table 2.1: MPD backend data assets

File	Description
data/aadt.json	Traffic census data, preprocessed from
data/collision_density.csv	Collision density data from previous project phase [1]
data/collrisk_categories.json	Collision risk categories and category thresholds
data/considerations_rules.json	Text and display rules for "considerations" notices
data/diffidx_categories.json	Difficulty index categories and category thresholds
data/diffindices.json	Precomputed with-crew and without-crew difficulty index mappings for maintenance activities
data/SHN_Postmiles_Tenth.csv	Original "tenth" postmile data from Caltrans

Table 2.2: MPD frontend data assets

File	Description
static/activities.json	Maintenance activity definitions
static/county_select.json	County definitions
static/pmpfx_select.json	Postmile prefix definitions
static/pmsfx_select.json	Postmile suffix definitions
static/rtnum_select.json	Route number definitions
static/rtsfx_select.json	Route suffix definitions

Postmile Resolution and Route Odometer Estimation

Many of the algorithms used in the MPD application require the specification of a valid county, route, postmile, and/or route odometer value. The purpose of this component is to validate a specified postmile and to estimate its corresponding route odometer value.

At the heart of this process is the 0.1-mile-interval postmile dataset generated from the Caltrans Transportation System Network (TSN) database [3]. The MPD application imports this State Highway Network (SHN) database (`data/SHN_Postmiles_Tenth.csv`) upon startup and builds various data structures, which it then uses during query processing to locate and validate postmiles and to estimate their corresponding route odometer values.

Work Length Estimation

Calculation of the collision risk value requires the specification of the activity work length in miles. This value is determined by estimating route odometer values for the activity's starting and ending postmiles and calculating the absolute value of the difference between them.

Traffic Estimation

An estimate of Average Annual Daily Traffic (AADT) volume for the work area is computed for the purposes of display to MPD users as a data point to aid in their planning decisions. In addition, an estimate of Average Annual Daily Truck Traffic (AADTT) volume for the work area is computed, as it is needed, for the calculation of collision risk values. To make these estimates, traffic census datasets were obtained for the years 2013-2018 [4]. These datasets were in Microsoft Excel format, so they were preprocessed into a JavaScript Object Notation (JSON) file. This file (`data/aadt.json`) is distributed as part of the MPD application and is imported upon startup and processed into various data structures.

AADT and AADTT estimates are determined by using these data structures, along with the MPD postmile data structures, to calculate weighted averages of the all-vehicle and truck-only traffic volumes across the span of a work area.

Collision Density Estimation

Calculation of the collision risk value requires an estimate of the collision density across the span of the work area. For this purpose, collision density is defined as the number of historical collisions per two-mile segment and is calculated from a dataset originally generated during the previous phase of this

research using SWITRS (Statewide Integrated Traffic Records System) data for collisions from 2011 through 2018. This dataset is distributed as part of the MPD application in the following file:

`data/collision_density.csv`

Using this dataset, work area collision risk estimates were processed, along with the MPD postmile data structures, to compute a weighted average of the collision density across the span of the work area.

Difficulty Index Calculation

Difficulty indices per maintenance activity type were computed in the previous phase of this project using historical maintenance activity data from 2013-2018 [1]. These data were preprocessed into a file containing mappings between each maintenance activity type and its corresponding difficulty index and non-crew difficulty index. This file (`data/diffindices.json`) is distributed as part of the MPD application. The index of difficulty is calculated as shown in Equation (1).

$$\begin{aligned}\text{Index of Difficulty} = {} & 4.66 \times \text{Lane closure score} + \\ & 4.47 \times \text{Number of crew score} + \\ & 4.41 \times \text{Access score} + \\ & 4.25 \times \text{Duration score} + \\ & 4.01 \times \text{Mile-length score} + \\ & 3.92 \times \text{LEMO costs score}\end{aligned} \tag{1}$$

Collision Risk Calculation

The formula for collision risk along with its $\boldsymbol{\beta_i}$ coefficients were developed in the previous phase of this project using historical maintenance activity data from 2013-2018 [1]. The formula is shown in Equation (2).

$$p = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4)}} \tag{2}$$

The β_i coefficients and x_i variables are defined in Tables 2.3 and 2.4. In Equation (2), p represents the probability of a collision that can lead to an injury. Its values range between 0 (low probability) and 1 (high probability).

Table 2.3: β_i coefficients of the collision risk equation

Coefficient	Feature	Value
$\boldsymbol{\beta_0}$		−5.262
$\boldsymbol{\beta_1}$	Lane closure	1.731
$\boldsymbol{\beta_2}$	Work length	0.03
$\boldsymbol{\beta_3}$	Collision density	0.002
$\boldsymbol{\beta_4}$	AADTT	-3.77×10^{-7}

Table 2.4: x_i coefficients of the collision risk equation

Variable	Definition
$\boldsymbol{x_1}$	1 if a work order requires lane closure, otherwise 0
$\boldsymbol{x_2}$	Length (miles) of the work area
$\boldsymbol{x_3}$	Collision density of the work area
$\boldsymbol{x_4}$	AADTT of the work area

Frontend Implementation

The MPD frontend is a single-page HTML/CSS/JavaScript client that takes input from the user, interacts with the MPD backend via the MPD API, and updates the display accordingly. All application state (e.g., current activity parameters, the activity group, and activity sorting) is maintained as JavaScript execution state in the client. No state is retained between page visits.

The entry point to the frontend (`/static/index.html`) is reachable at the root (`/`) path Uniform Resource Locator (URL) of the application's virtual host. This entry point, along with all frontend dependencies (CSS files, JavaScript files, media assets, and JSON datasets) are distributed as part of the MPD application in the `static/` directory and are accessible by the client via URLs under the `/static/` path.

The frontend internally manages all MPD functionality other than postmile validation and the calculation of activity values (work length, collision density, AADT, AADTT, difficult index and category, collision risk and category, and considerations notices). When the user changes any activity parameters on

which this functionality depends, the frontend makes an API call to the backend for recalculation and updates the display accordingly.

Chapter 3:
MPD Application Usage

The MPD application estimates difficulty indices and collision risks for proposed maintenance activities specified by the user. Its primary purpose is to allow a maintenance activity planner to classify and sort a group of specified maintenance activities by their difficulty index and collision risk estimates to assist in prioritizing the safest and simplest activities.

User Interface Overview

The MPD user interface at the time of application start is shown in Figure 3.1. An example of the interface in use is shown in Figure 3.2.

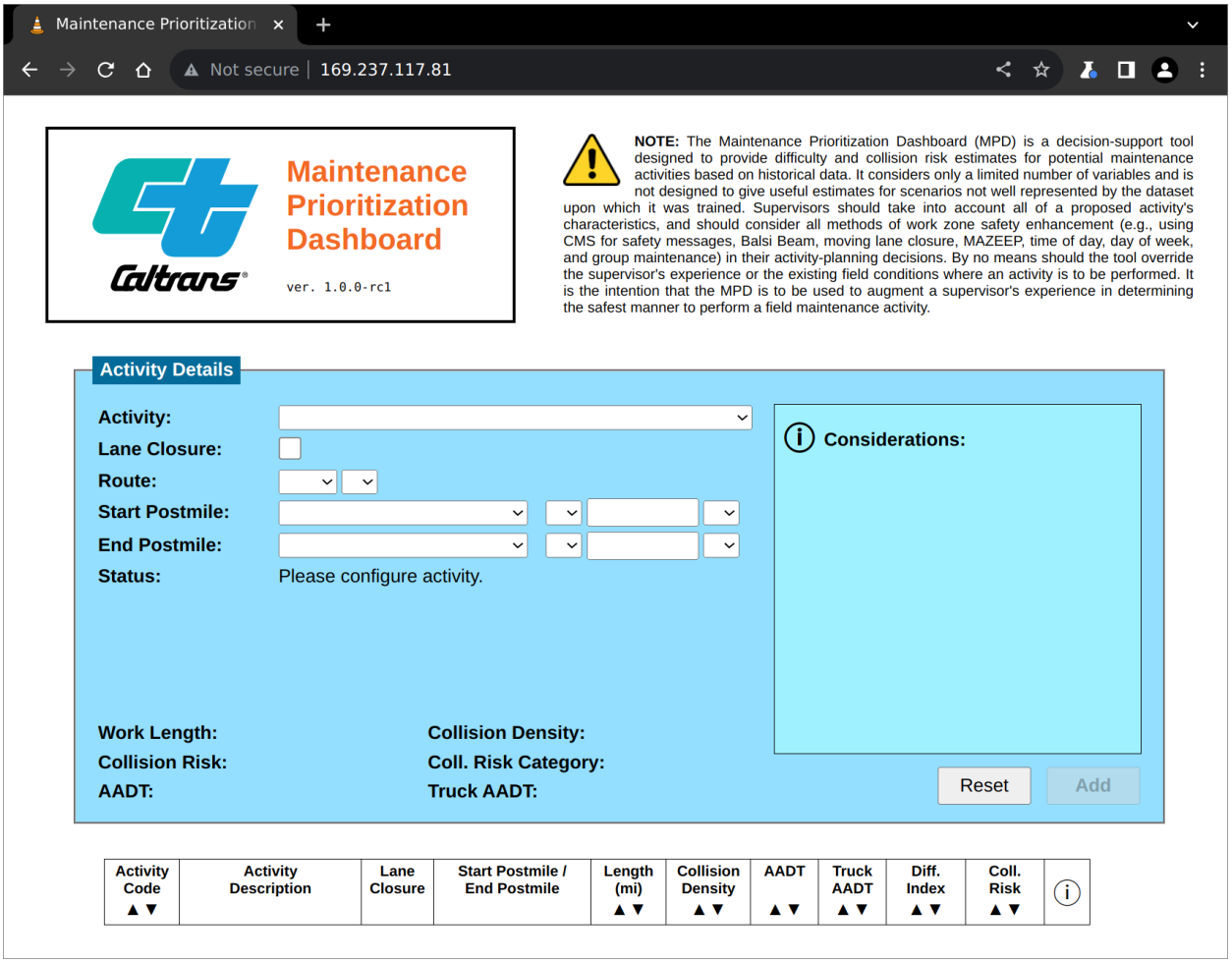
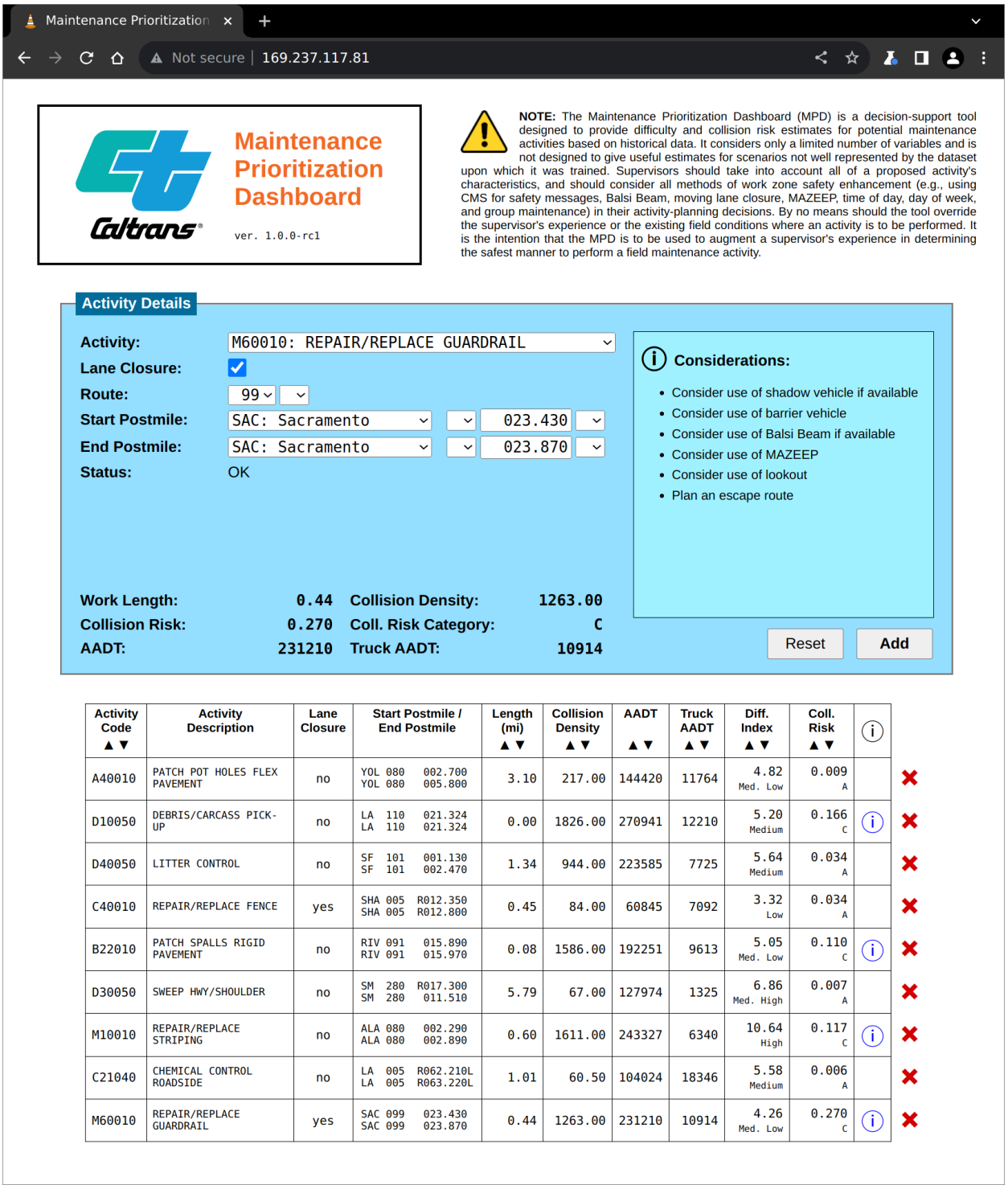


Figure 3.1: MPD user interface at application start



Activity Code	Activity Description	Lane Closure	Start Postmile / End Postmile	Length (mi)	Collision Density	AADT	Truck AADT	Diff. Index	Coll. Risk	
A40010	PATCH POT HOLES FLEX PAVEMENT	no	YOL 080 002.700 YOL 080 005.800	3.10	217.00	144420	11764	4.82 Med. Low	0.009 A	
D10050	DEBRIS/CARCASS PICK-UP	no	LA 110 021.324 LA 110 021.324	0.00	1826.00	270941	12210	5.20 Medium	0.166 C	ⓘ
D40050	LITTER CONTROL	no	SF 101 001.130 SF 101 002.470	1.34	944.00	223585	7725	5.64 Medium	0.034 A	
C40010	REPAIR/REPLACE FENCE	yes	SHA 005 R012.350 SHA 005 R012.800	0.45	84.00	60845	7092	3.32 Low	0.034 A	
B22010	PATCH SPALLS RIGID PAVEMENT	no	RIV 091 015.890 RIV 091 015.970	0.08	1586.00	192251	9613	5.05 Med. Low	0.110 C	ⓘ
D30050	SWEEP HWY/SHOULDER	no	SM 280 R017.300 SM 280 011.510	5.79	67.00	127974	1325	6.86 Med. High	0.007 A	
M10010	REPAIR/REPLACE STRIPING	no	ALA 080 002.290 ALA 080 002.890	0.60	1611.00	243327	6340	10.64 High	0.117 C	ⓘ
C21040	CHEMICAL CONTROL ROADSIDE	no	LA 005 R062.210L LA 005 R063.220L	1.01	60.50	104024	18346	5.58 Medium	0.006 A	
M60010	REPAIR/REPLACE GUARDRAIL	yes	SAC 099 023.430 SAC 099 023.870	0.44	1263.00	231210	10914	4.26 Med. Low	0.270 C	ⓘ

Figure 3.2: MPD user interface in use

The Activity Details section (in blue) is where proposed maintenance activities are specified, one at a time. The area below the Activity Details section is the Activity Workspace. The Activity Workspace is used to examine and compare the set of proposed activities and to sort them by various statistics.

Activity Specification

The Activity Details section contains a number of fields that allow the user to specify a proposed maintenance activity:

- **Activity**: A drop-down for specifying the proposed activity (Integrated Maintenance Management System [IMMS] activity code and description). The range of activities that can be selected was determined by the project panel.
- **Lane Closure**: A checkbox for specifying whether a lane closure is proposed.
- **Route**: Drop-downs for specifying the route number and the route suffix (if present) of the proposed activity.
- **Start Postmile**: Drop-downs and a text field for specifying the county, postmile prefix, postmile, and postmile suffix of the start point of the work area of the proposed activity.
- **End Postmile**: Drop-downs and a text field for specifying the county, postmile prefix, postmile, and postmile suffix of the end point of the work area of the proposed activity.

Once the activity is complete and valid, MPD will compute various activity-related values (work length, collision density, AADT, AADTT, collision risk and category) and display them at the bottom of the Activity Details section. If the proposed activity triggers any consideration notice rules, one or more consideration notices will also be displayed in the Considerations box at the right of the Activity Details section.

An example of the Activity Details section populated with the details of a proposed activity is shown in Figure 3.3.

Once the user is satisfied with the specification, the "Add" button at the lower right of the Activity Details section may be clicked to add the activity to the Activity Workspace.

Next to the "Add" button, there is a "Reset" button which may be clicked at any time to reset the Activity Details section (without affecting the Activity Workspace).

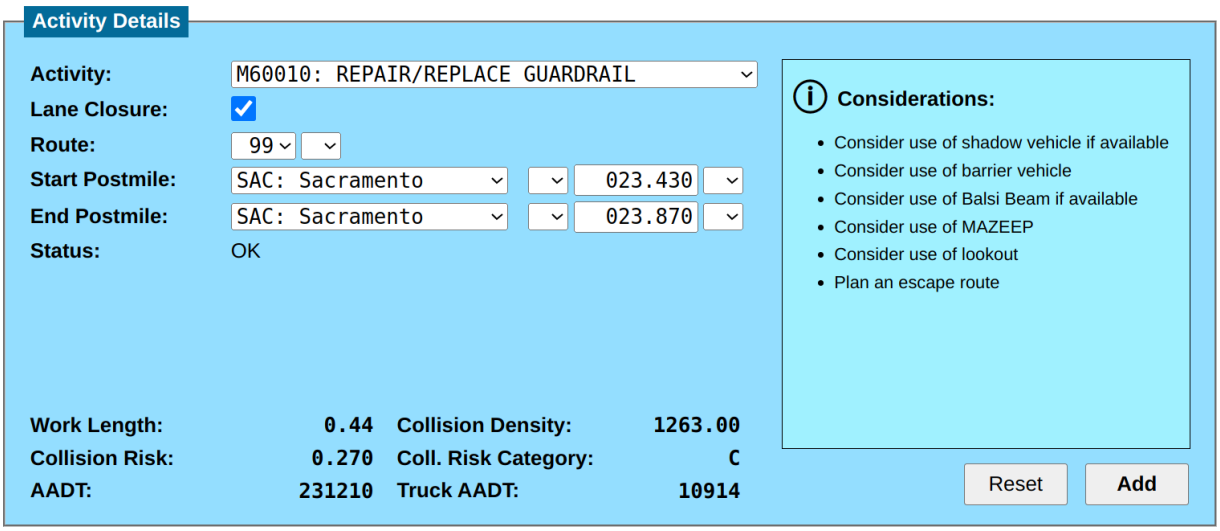


Figure 3.3: Populated Activity details

Activity Workspace

Once the user has completed adding a set of proposed activities to the Activity Workspace, they may be compared and sorted by various statistics. An example of a populated Activity Workspace is shown in Figure 3.4.

Activity Code ▲▼	Activity Description	Lane Closure	Start Postmile / End Postmile	Length (mi) ▲▼	Collision Density ▲▼	AADT ▲▼	Truck AADT ▲▼	Diff. Index ▲▼	Coll. Risk ▲▼	ⓘ	
A40010	PATCH POT HOLES FLEX PAVEMENT	no	YOL 080 002.700 YOL 080 005.800	3.10	217.00	144420	11764	4.82 Med. Low	0.009 A		✖
D10050	DEBRIS/CARCASS PICK-UP	no	LA 110 021.324 LA 110 021.324	0.00	1826.00	270941	12210	5.20 Medium	0.166 C	ⓘ	✖
D40050	LITTER CONTROL	no	SF 101 001.130 SF 101 002.470	1.34	944.00	223585	7725	5.64 Medium	0.034 A		✖
C40010	REPAIR/REPLACE FENCE	yes	SHA 005 R012.350 SHA 005 R012.800	0.45	84.00	60845	7092	3.32 Low	0.034 A		✖
B22010	PATCH SPALLS RIGID PAVEMENT	no	RIV 091 015.890 RIV 091 015.970	0.08	1586.00	192251	9613	5.05 Med. Low	0.110 C	ⓘ	✖
D30050	SWEEP HWY/SHOULDER	no	SM 280 R017.300 SM 280 011.510	5.79	67.00	127974	1325	6.86 Med. High	0.007 A		✖
M10010	REPAIR/REPLACE STRIPING	no	ALA 080 002.290 ALA 080 002.890	0.60	1611.00	243327	6340	10.64 High	0.117 C	ⓘ	✖
C21040	CHEMICAL CONTROL ROADSIDE	no	LA 005 R062.210L LA 005 R063.220L	1.01	60.50	104024	18346	5.58 Medium	0.006 A		✖
M60010	REPAIR/REPLACE GUARDRAIL	yes	SAC 099 023.430 SAC 099 023.870	0.44	1263.00	231210	10914	4.26 Med. Low	0.270 C	ⓘ	✖

Figure 3.4: Populated Activity workspace

The activities are displayed in a tabular format, consisting of the following columns:

- **Activity Code**: IMMS activity code
- **Activity Description**: Activity description
- **Lane Closure**: Whether a lane closure is proposed (yes/no)
- **Start Postmile / End Postmile**: Starting and ending postmiles
- **Length (mi)**: Work area length in miles
- **Collision Density**: Estimated collision density for the work area
- **AADT**: Estimated AADT for the work area
- **Truck AADT**: Estimated Truck AADT (aka AADTT) for the work area
- **Diff. Index**: Difficulty index for the activity (technically unbounded due to the nature of the equation and inputs, but for practical purposes in the range 0.5 – 12)
- **Coll. Risk**: Collision risk for the activity (range 0 – 1, low to high probability)
- ⓘ: Whether considerations are present. If consideration notices were triggered for the activity, a ⓘ icon will appear here. Hovering over this icon with the mouse cursor will display a pop-up overlay containing the considerations notices for the activity.

To assist in the activity comparison and prioritization process, the activities in the Activities Workspace may be sorted by the contents of certain columns. These columns are indicated by the presence of arrows (▲: ascending, ▼: descending) in the column headers. To select a column-sort mode, click on the header of the desired column. Each click on the column header will cycle between sort modes for that column (none, ascending, descending).

For example, to do an ascending sort of the activities by activity code, click on the "Activity Code" column header. The ascending arrow will turn green as illustrated in Figure 3.5. In this state, an additional click will switch to a descending sort, and another after that will disable sorting altogether (all header arrows black).

When no sorting is selected, the activities will be presented in the order in which they were added to the Activity Workspace. To reduce UI complexity, no more than one sort mode may be active at a time (no hierarchical sort). Selecting a column sort mode while another column sort mode is active simply changes the sort mode to the newly-selected one.

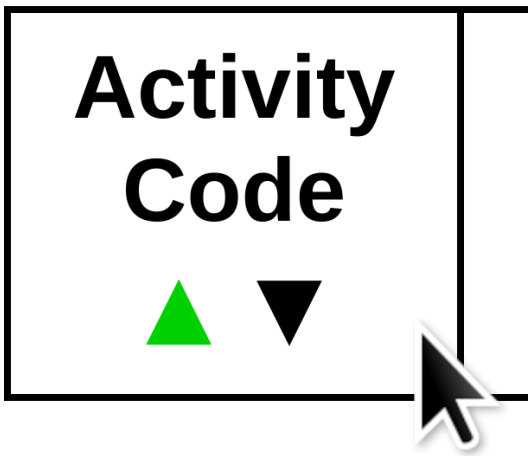


Figure 3.5: Enabling ascending sort by activity code

An example of sorting the Activity Workspace from Figure 3.4 by Collision Risk (ascending) is shown in Figure 3.6.

Activity Code ▲▼	Activity Description	Lane Closure	Start Postmile / End Postmile	Length (mi) ▲▼	Collision Density ▲▼	AADT ▲▼	Truck AADT ▲▼	Diff. Index ▲▼	Coll. Risk ▲▼	ⓘ	
C21040	CHEMICAL CONTROL ROADSIDE	no	LA 005 R062.210L LA 005 R063.220L	1.01	60.50	104024	18346	5.58 Medium	0.006 A		✖
D30050	SWEEP HWY/SHOULDER	no	SM 280 R017.300 SM 280 011.510	5.79	67.00	127974	1325	6.86 Med. High	0.007 A		✖
A40010	PATCH POT HOLES FLEX PAVEMENT	no	YOL 080 002.700 YOL 080 005.800	3.10	217.00	144420	11764	4.82 Med. Low	0.009 A		✖
C40010	REPAIR/REPLACE FENCE	yes	SHA 005 R012.350 SHA 005 R012.800	0.45	84.00	60845	7092	3.32 Low	0.034 A		✖
D40050	LITTER CONTROL	no	SF 101 001.130 SF 101 002.470	1.34	944.00	223585	7725	5.64 Medium	0.034 A		✖
B22010	PATCH SPALLS RIGID PAVEMENT	no	RIV 091 015.890 RIV 091 015.970	0.08	1586.00	192251	9613	5.05 Med. Low	0.110 C	ⓘ	✖
M10010	REPAIR/REPLACE STRIPING	no	ALA 080 002.290 ALA 080 002.890	0.60	1611.00	243327	6340	10.64 High	0.117 C	ⓘ	✖
D10050	DEBRIS/CARCASS PICK-UP	no	LA 110 021.324 LA 110 021.324	0.00	1826.00	270941	12210	5.20 Medium	0.166 C	ⓘ	✖
M60010	REPAIR/REPLACE GUARDRAIL	yes	SAC 099 023.430 SAC 099 023.870	0.44	1263.00	231210	10914	4.26 Med. Low	0.270 C	ⓘ	✖

Figure 3.6: Activity Workspace sorted by Collision Risk (ascending)

To delete an activity from the Activity Workspace, click on the ✖ at the far right of its table row.

MPD Test Results and Summary of User Feedback

With implementation of the MPD complete, the project supported testing by Caltrans personnel. The MPD (backend and frontend) was hosted at AHMCT, with the UI accessed using a web page. This section provides an overview of the deployment for Caltrans testing, and the feedback received during and following the testing. Early feedback was encouraged so that the MPD tool could be improved based upon participants' responses.

The MPD tool was available for testing for two months. The primary feedback indicated some issues with entering postmile information into the tool. It is quite easy to specify a postmile which is technically incorrect and will be rejected. For normal use by Caltrans Maintenance and other divisions, a "close enough" postmile will get a worker close to the site, and they can often navigate to the specific work location even if the postmile is not exactly right. This is not true for an automated system. The MPD will reject any incorrect postmile, no matter how small the issue. Future work may investigate a means to suggest postmile corrections to the user; any approach will ultimately rely on the user, as automatic correction is not feasible.

Additional feedback also focused on the postmile entry. The specific feedback was "It would also be a little easier to navigate the start and end postmile tab after the selection of county if it could pre-populate instead of the 11 selections in the small box." The interpretation is to have the unselected dropdowns self-limit to only the potential choices applicable for the selected dropdowns, which is quite reasonable. The challenge with this approach is that it can sometimes become confusing to the user when trying to modify selections. For example, if a user currently had TEH-172 (Tehama County Route 172) in the tool but wanted to switch to SHA-44 (Shasta County Route 44), they would first have to clear both the county and the route dropdowns before being able to change either to the desired selection. This is because, if they tried to switch TEH to SHA first, the tool would not let them because Route 172 does not pass through Shasta County. If they tried to switch Route 172 to 44 first, the tool would not let them because 44 does not run through Tehama County. So, they'd have to set TEH to "", then set 172 to "". Only then would the tool let them choose SHA-44. This is essentially the behavior of the public Caltrans postmile tool. One approach to resolve this difficulty would be to provide a conspicuous "Start Over" button.

To obtain postmiles which are acceptable to the MPD, we recommend users leverage existing Caltrans postmile tools, specifically:

- Caltrans external postmile service (https://postmile.dot.ca.gov/PMQT/PostmileQueryTool.html?)

- Caltrans internal postmile service (http://postmile-internal.dot.ca.gov/PMQT/PMQT_Internal.html?)

Note that the terminating "?" is required in each link. Such tools should provide complete and accurate postmiles, including county, route, mileage number, alignment, and direction. With such accurate postmiles, interaction with the MPD will be greatly facilitated. As such tools exist within Caltrans and are readily available to Maintenance, there is no need for incorporation of such capability in the MPD.

Additional feedback was provided related to the timing of display updates for work activity information during user input. The design decision was to deliberately delay updates until all needed info was entered, rather than updating part way through the entry. This prevented situations where incorrect work activity information might be displayed. The approach of waiting until full data entry is complete is a best practice.

Additional feedback indicated that removing some of the activity-related detail from the activity panel may improve useability. This would include calculated values for difficulty index and corresponding category. This information has been eliminated but remains in the prioritization table to support related sorting and decision-making.

Based upon the feedback received, there were no further issues or problems identified with the MPD UI and its use.

Chapter 4:
Conclusions and Future Research

Caltrans needs a Maintenance decision support tool (DST) designed and implemented for its specific needs. The DST must be based on operational performance metrics allowing evaluation of safety risks to highway workers in planning and scheduling of maintenance operations. This research project developed the MPD that can be used by the Division of Maintenance for planning of their maintenance work activities, i.e. such a DST. The tool is based on the operational metrics of difficulty index and collision risks to maintenance workers, as developed in a previous AHMCT research project [1]. In addition, the DST must comply with Caltrans IT software standards [2].

Key contributions of this research project included:

- MPD tool design and development, compliant with Caltrans IT standards [2]
- Support for MPD tool testing and user feedback
- The final MPD decision-support tool installer including related data

With the developed MPD tool, Caltrans now has the ability to incorporate statistical inputs/data into their work activities prioritization decision process based on difficulty index and collision risk. This should improve worker safety.

Future work could include:

- Enhanced method for inputting postmile information. This could be based on guidance for use of existing Caltrans postmile services, or more direct integration into such a tool, if it has a documented API. One possibility is developing a means to suggest postmile corrections to the user. Any approach will ultimately rely on the user, as automatic correction is not feasible.
- Testing feedback indicated it would be easier to navigate the start and end postmile tab after the selection of county if the input form could pre-populate. This revision is left for future work, including a means to resolve the inherent difficulty noted in Chapter 3.
- Additional validation of backend calculations to assure fidelity with Caltrans safety and traffic data.
- Enhancing difficulty index calculations to be specific to the activity as configured in the MPD tool (rather than simply based on historical averages).

- Update of the data used in [1] to develop difficulty and collision metrics. Traffic data was from approximately 2013 – 2018. Collision density data was from approximately 2011 – 2018. A refresh is in order.
- Further testing of the tool by Caltrans subject matter experts to confirm it is meeting their needs, followed by additional development and revision as needed.
- As noted in Appendix A, threshold values to display conditions were set by the researchers. If there is a follow-up task, we recommend careful review including coordination between the follow-up researchers, the project panel, and subject experts. In addition, this group should review whether the current considerations text is sufficient, and whether considerations are indicated for other activities and conditions.

References

[1] A. Nasrollahzadeh, and B. Ravani, "Research to Develop Performance Measures for Maintenance of Roadside Features," AHMCT Research Center, UCD-ARR-20-06-30-04, Jun. 2020. [Online]. Available: https://ahmct.ucdavis.edu/sites/g/files/dgvnsk8581/files/inline-files/UCD-ARR-20-06-30-04.pdf

[2] California Department of Transportation. Information Technology, "Information Technology Hardware & Software Standards Catalog 2022.3." 2022. [Online]. Available: https://it.onramp.dot.ca.gov/downloads/it/files/standards/2022_3%20IT%20Standards%20Update.pdf

[3] California Department of Transportation, "SHN Postmiles Tenth." Accessed: Aug. 19, 2023. [Online]. Available: https://gis.data.ca.gov/datasets/c22341fec9c74c6b9488ee4da23dd967_0/about

[4] California Department of Transportation, "Traffic Count Data." Accessed: Aug. 19, 2023. [Online]. Available: https://dot.ca.gov/programs/traffic-operations/census

Appendix A:
Activities, Difficulty and Risk Categories and Thresholds, and Considerations Messages

Activity Codes, Descriptions, and Difficulty Indices

The activities that can be configured in the MPD tool were selected by the project panel. The difficulty index for each activity was calculated statistically in the previous phase of this project.

The activities and their corresponding difficulty indices are summarized in Table A.1 and are specified in the following files, respectively:

`src/main/resources/static/activities.json`

`src/main/resources/data/diffindices.json`

Table A.1: Activity codes, descriptions, and difficulty indices

Activity Code	Activity Description	Difficulty Index
A10110	CRACK SEAL FLEX PAVEMENT	8.311323882
A20010	OVERLAY/LEVELING FLEX PAVEMENT	9.757010148
A21010	PROFILE GRINDING FLEX PAVEMENT	8.425535308
A30010	DIG OUT FLEX PAVEMENT	11.76758291
A40010	PATCH POT HOLES FLEX PAVEMENT	4.822260852
A50010	SEAL (ALL OTHER) FLEX PAVEMENT	10.70184479
B10110	CRACK SEAL RIGID PAVEMENT	8.407376691
B20010	PROFILE GRINDING RIGID PAVEMNT	6.919778508
B21010	OVERLAY/LEVELING RIGID PAVEMNT	7.030361417
B22010	PATCH SPALLS RIGID PAVEMENT	5.045107637

Activity Code	Activity Description	Difficulty Index
B30010	SUB SEAL/JACK SLAB RIGID PVMNT	6.675758621
B31010	SLAB REPLACEMENT RIGID PAVEMNT	7.543851988
C10010	LATERAL SUPPORT - NATIVE MATL	7.348039089
C11010	LATERAL SUPPORT - IMPORT MATL	7.776721221
C20040	MECHANICAL CONTROL ROADSIDE	6.564563038
C21040	CHEMICAL CONTROL ROADSIDE	5.578387874
C22040	MANUAL CONTROL ROADSIDE	5.82208803
C23040	RODENT CONTROL ROADSIDE	4.824334958
C24040	ALL OTHER WEED CONTROL RDSD	6.161006195
C30040	TREE TRIMMING	6.569375273
C31040	REMOVE TREE	6.32286525
C32040	BRUSH CONTROL	6.885951367
C40010	REPAIR/REPLACE FENCE	3.324225277
C50010	REPAIR/REPLACE DITCH/CHANNEL	6.893153392
C50150	CLEAN DITCH/CHANNEL	7.321065313
C51010	REPAIR/REPLACE CURB/DIKE	6.161408408
C51050	CLEAN CURB/DIKE	6.835637244
C60010	REPAIR/REPLACE DRAINAGE	5.66192328
C60050	CLEAN DRAINAGE	6.50780991
C90010	REPAIR/REPLACE WALL	4.271678946
C91010	REPAIR/REPLACE BIKE PATH	4.608229347
C91050	CLEAN BIKE PATH	4.447391632
C92010	REPAIR/REPLACE SIDEWALK	5.360541675

Activity Code	Activity Description	Difficulty Index
C92050	CLEAN SIDEWALK	5.299482533
C93010	REPAIR/REPLACE CATTLEGUARD	5.037769177
C93050	CLEAN CATTLEGUARD	7.057258374
C94010	REPAIR/REPLACE DRYWELL	3.875747058
C95010	REPAIR/REPLACE MANHOLE	3.331771127
C95050	CLEAN MANHOLE	3.346531342
C96010	REPAIR/REPLACE WATER SITE	4.580615269
C96050	CLEAN RADIATOR WATER SITE	3.100753067
D10050	DEBRIS/CARCASS PICK-UP	5.202136264
D10150	CARCASS PICKUP	3.662416438
D30050	SWEEP HWY/SHOULDER	6.864360264
D40050	LITTER CONTROL	5.638208048
D40150	ROAD PATROL / DEBRIS PICKUP	5.276143633
D42050	ILLEGAL ENCAMPMENT DEBRIS RMVL	3.590749946
D50050	SPILLS RWY, LANE, SHLDR & APPURT	3.302843334
D60050	GRAFFITI REMOVAL ALL ASSETS	4.247123943
D90000	ILLEGAL SIGN REMOVAL	4.993968571
E10040	MECHANICAL CONTROL LANDSCAPE	4.9888824
E11040	MANUAL CONTROL LANDSCAPE	5.409089382
E12040	CHEMICAL CONTROL LANDSCAPE	3.545874282
E13040	RODENT CONTROL LANDSCAPE	4.288003246
E21040	PRUNING GROUNDCOVER	5.324430674
E22040	PRUNING - LINEAR MECHANICAL	6.177305698

Activity Code	Activity Description	Difficulty Index
E23040	REPLANT GROUNDCOVER LANDSCAPE	4.332039809
E24040	MAINTAIN PLANTINGS	4.658731716
E25040	FERTILIZING LANDSCAPE	4.408011516
E30010	IRRIGATION SYSTEM REPAIR LNDSC	4.105106793
E31010	IRRIG ELECTRICAL REPAIR LNDSCP	3.425134804
E32020	BACKFLOW PREVENTER CERT LNDSCP	3.769641517
E33040	IRRIGATING LANDSCAPE	4.532917018
E34040	TRUCK WATERING LANDSCAPE	3.922228798
F20005	DRAIN STENCILING	6.071562164
F20050	DRAIN CLEANING	10.2101947
F20051	SWEEP HWY/SHOULDER	6.908449385
F30301	EQUIPMENT WASH SYSTEMS	7.006618797
F40010	REPAIR/REPLACE SOIL/SEDMNT/RSP	6.376832891
F40020	INSTALL SOIL STAB/SEDIMENT/RSP	6.996066002
F40110	PERIMETER CONTROL STOCKPILES	4.499678157
F40130	DISPOSAL OF SURPLUS STOCKPILES	5.569673999
F40210	SNOW HAULING (STORMWATER)	7.855981839
F40310	REPAIR/REPLACE EXISTING CNTRLS	6.752258363
F60050	CLEANUP OF ILLEGAL DISCHARGE	4.386286612
F60150	REMOVE ILLEGAL CONNECTION	3.330969041
F70010	REPAIR/REPLACE STRUCTURAL BMP	5.740729935
F70050	CLEAN/MOW STRUCTURAL BMP	5.249243427
F70110	REPAIR OF TREATMENT BMP	3.9469277

Activity Code	Activity Description	Difficulty Index
F90050	TRANSFER OF SITE MATERIAL	5.715772577
F90101	NEW WASTE &/OR WORK STOCK SITE	4.985393058
F90150	DISPOSAL OF SITE MATERIAL	5.187761309
J10140	MAINTENANCE PUMPING PLANT	4.801990243
J50060	TOW TRUCK OPERATIONS	3.145200087
J60010	REPAIR/REPLACE CHANNELIZERS	3.674033538
J60040	MAINTENANCE CHANNELIZERS	2.481601416
J60060	SCHEDULED LANE CHANGE CHNLZERS	5.185671042
K10010	REPAIR/REPLACE HIGHWAY LIGHTNG	3.47974238
K10140	GROUP RELAMP HWY LIGHTING	4.480378006
K20010	REPAIR/REPLACE SIGN LIGHTING	3.45931067
K20140	GROUP RELAMP SIGN LIGHTING	4.367093465
K70010	REPAIR/REPLACE TOS EQUIPMENT	4.889813187
M10010	REPAIR/REPLACE STRIPING	10.63860454
M20010	REPAIR/REPLACE MARKINGS	7.579542783
M30010	REPAIR/REPLACE PVMT MARKERS	9.153518021
M40010	REPAIR/REPLACE SIGNS	3.725586166
M41000	INSTL/RMV GRFTI DTRNT SGN STRC	4.891426008
M41010	REPAIR/REPLACE SIGN STRUCTURES	4.828168318
M50010	REPAIR/REPLACE DELINEATORS	6.644299364
M60010	REPAIR/REPLACE GUARDRAIL	4.257331695
M61010	REPAIR/REPLACE END TREATMNT GR	3.948283199
M70010	REPAIR/REPLACE BARRIER	3.23747509

Activity Code	Activity Description	Difficulty Index
M80010	REPAIR/REPLACE ATTENUATOR	4.005943347
M90000	EMERGENCY TRAFFIC CONTROL	4.098729896
R10000	SNOW REMOVAL	8.727143721
R11000	SNOW HAULING	6.045163321
R20000	COVER SNOW & ICE ON PAVEMENT	6.423944534
R21000	SAND/SALT MATERIAL HANDLING	5.689800893
R22000	APPLY ANTI-ICER	5.53341738
R30110	REPAIR/REPLACE FIXED HARDWARE	6.715003604
R40000	CHAIN CONTROL	7.689041702
R91000	AVALANCHE CONTROL	5.893515434
S10000	SAND/ROCK PATROL	6.29368326
S20000	STORM PATROL	6.311023214
S21000	FLOOD CONTROL	3.962865659
S30110	MINOR SLIDE/SLIP REMOVE/REPAIR	7.006775089
S31010	REPR/REPLCE ROCK FALL PROTECTN	7.027239637
S31040	ROCK SCALING	9.591033229
S32050	BENCH CLEANING	7.310796443
S33000	BLASTING	7.45980243
S40010	MAJOR SLIDE/SLIP REMOVE/REPAIR	8.187688761
Y91000	ILLEGAL SIGN REMOVE OUTDOOR AD	4.81191037

Difficulty Categories and Thresholds

To categorize activity difficulty indices, a set of categories and thresholds were defined by the project panel. These are specified in the following file:

`src/main/resources/data/diffidx_categories.json`

The currently defined values (as of the time of this writing) are summarized in Table A.2.

Table A.2: Difficulty index categories and thresholds

Name	Difficulty Index Range
Low	[0, 4.18)
Medium Low	[4.18, 5.12)
Medium	[5.12, 6.24)
Medium High	[6.24, 8.02)
High	[8.02, …)

Risk Categories and Thresholds

To categorize activity collision risk values, a set of categories and thresholds were established. Currently, the sole purpose of these categories (which are defined by their respective threshold values) is to serve as a criterion to determine which, if any, "considerations" messages are to be displayed for a configured activity (the panel recommended activity type and risk category to be the determining factors for these messages). Considerations messages are discussed in further detail in the below Considerations section.

While the collision risk categories were implicitly chosen by the panel by means of their considerations messages recommendations, the current threshold values for these categories were chosen somewhat arbitrarily by the researchers in this task. Although no feedback was received from the project panel regarding adjusting the conditions under which considerations messages are displayed, further scrutiny of these values is merited. If there is a follow-up task, we recommend careful review including coordination between the follow-up researchers, the project panel, and subject experts. In addition to whether the considerations are triggered (or absent) in the appropriate circumstances, this group should also review whether the current considerations text is sufficient, and whether considerations are indicated for other activities and conditions.

The collision risk categories and thresholds are specified in the following file:

`src/main/resources/data/collrisk_categories.json`

The currently defined values (as of the time of this writing) are summarized in Table A.3.

Table A.3: Collision risk categories and thresholds

Name	Collision Risk Range
A	[0.00, 0.05)
B	[0.05, 0.10)
C	[0.10, 1.00]

Considerations

The MPD tool will display a set of "considerations" to the user under specific, predefined circumstances. These considerations and their corresponding activation rules are called "considerations cases" and are specified in the following file:

`src/main/resources/data/considerations_rules.json`

A considerations case is activated if and only if the following conditions are both true:

- The activity currently configured in the MPD tool has an activity ID that matches at least one of the considerations case's activity IDs.
- The activity currently configured in the MPD tool falls into a risk category that matches at least one of the considerations case's risk categories.

The currently defined considerations cases (as of the time of this writing) are summarized below.

Case #1

Activities:

- A10110: CRACK SEAL FLEX PAVEMENT
- B10110: CRACK SEAL RIGID PAVEMENT

Risk Categories: B, C

Considerations:

- Shadow vehicle required if working in live lane

- Consider use of barrier vehicles
- Consider use of Balsi Beam if available
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #2

Activities:

- A40010: PATCH POT HOLES FLEX PAVEMENT

Risk Categories: B, C

Considerations:

- Shadow vehicle required if working in live lane
- Use barrier vehicle behind truck with apron on shoulder
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP/CHP traffic breaks
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #3

Activities:

- B22010: PATCH SPALLS RIGID PAVEMENT

Risk Categories: B, C

Considerations:

- Shadow vehicle required if working in live lane
- Consider use of barrier vehicle
- Consider use of Balsi Beam if available
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP

- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #4

Activities:

- C21040: CHEMICAL CONTROL ROADSIDE

Risk Categories: B, C

Considerations:

- Consult SHSP Crash Data Dashboard for alternative work time indications
- Consider using arrow board or attenuator truck while performing spray operations
- Make sure all placards are on display for the products being used during the application and that there is water available for emergency purposes in case of an exposure to the spray mixture

Source: Ken Murray

Case #5

Activities:

- C40010: REPAIR/REPLACE FENCE

Risk Categories: B, C

Considerations:

- Consider use of shadow vehicle if available
- Consider use of barrier vehicle
- Consider use of Balsi Beam if available
- Consider use of MAZEEP
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #6

Activities:

- E11040: MANUAL CONTROL LANDSCAPE

Risk Categories: A, B, C

Considerations:

- Consult SHSP Crash Data Dashboard for alternative work time indications
- Look at using attenuator truck or shadow vehicle for more protection while performing work
- Consider MAZEEP
- Make sure to take extra precautions especially with work on roadside on foot

Source: Ken Murray

Case #7

Activities:

- E30010: IRRIGATION SYSTEM REPAIR LNDSC

Risk Categories: A, B, C

Considerations:

- Consult SHSP Crash Data Dashboard for alternative work time indications
- Look at using attenuator truck or shadow vehicle for more protection while performing work

Source: Ken Murray

Case #8

Activities:

- D10050: DEBRIS/CARCASS PICK-UP
- D10150: CARCASS PICKUP
- D40150: ROAD PATROL / DEBRIS PICKUP

Risk Categories: C

Considerations:

- Consider use of shadow vehicle if available
- Consider use of barrier vehicle
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP
- Use CHP traffic breaks to remove items from lanes
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #9

Activities:

- D40050: LITTER CONTROL

Risk Categories: C

Considerations:

- Consider use of shadow vehicle if available
- Consider use of barrier vehicle
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP
- Use CHP traffic breaks to remove items from lanes
- Work facing traffic
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum

Case #10

Activities:

- D30050: SWEEP HWY/SHOULDER
- F20051: SWEEP HWY/SHOULDER

Risk Categories: B, C

Considerations:

- Shadow vehicle required if working in live lane

- Consider use of fusee ejector if available
- Consider use of shadow vehicle on shoulder if available
- Consider use of barrier vehicle on shoulder if shadow unavailable
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP

Source: Theresa Drum

Case #11

Activities:

- M10010: REPAIR/REPLACE STRIPING

Risk Categories: C

Considerations:

- Shadow vehicle required
- Consider use of fusee ejector if available
- Consider a worker safety message on a PCMS/CMS
- Consider use of MAZEEP

Source: Theresa Drum

Case #12

Activities:

- M60010: REPAIR/REPLACE GUARDRAIL

Risk Categories: B, C

Considerations:

- Consider use of shadow vehicle if available
- Consider use of barrier vehicle
- Consider use of Balsi Beam if available
- Consider use of MAZEEP
- Consider use of lookout
- Plan an escape route

Source: Theresa Drum