2017

STRIDE | Southeastern Transportation Research, Innovation, Development and Education Center

Final Report

Hands-on Workshop: Dynamic ATM Strategy Selection Tool FREEVAL-DSS (Workshop 3 & 4, Florida & California)

(Project # 2016-002)

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(North Carolina State University)

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Disclaimer

Acknowledgment of Sponsorship

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- Lily Elefteriadou, Professor at University of Florida and Director of STRIDE center
- Mohammed Hadi, Professor, Florida International University
- Bastian Schroeder, Principal Engineer, Kittelson and Associates Inc.
- Arron Elias, Senior Engineer, Kittelson and Associates Inc.
- Liz Foreman, Director of Operations, CMC & Associates
- Jay Calhoun, Principal, VIBE

EXECUTIVE SUMMARY

This technology transfer activity is a natural follow-up of the STRIDE project 2013-009S – "Dynamic Traffic Control Interventions for Enhanced Mobility and Economic Competitiveness". A deliverable of the project was the development of a dynamic version of FREEVAL, the computational engine of freeway facilities in the upcoming HCM update. The FREEVAL-DSS tool (for Dynamic Strategy Selection) enables the user to intervene within a FREEVAL run after each 15 minutes and implement one or more ATM strategies from a select menu.

This report covers two workshops that were held in West Palm Beach FL and Oakland CA on Nov 13 2016 and Feb 28 2017 respectively. The workshops were intended to be a mechanism to both receive feedback on the tool, as well as disseminate its capabilities. Five and twelve participants attended the workshops in West Palm Beach FL and Oakland CA respectively. The West Palm Beach FL workshop was conducted in conjunction with the Florida Transpo2016 conference. The Oakland CA workshop was conducted in Kittelson and Associates Inc. Oakland office next to Caltrans, which offered free space and meals for the participants. A modification to the Oakland workshop included additional background material on FREEVAL/ Freeway Facilities, which was needed to have the participants understand the contribution of the DSS version. The formal feedback received from the participants in both workshops was extremely positive.

1. BACKGROUND

According to the latest Urban Mobility Report, US urban motorists in 2011 traveled an additional 5.5 billion hours and purchased an extra 2.9 billion gallons of fuel as a result of congestion. The economic impact of degraded mobility has been estimated at $21 billion, which is quickly eroding the nation's economic competitiveness. The Federal Highway Administration estimates that about half of all congestion delays are caused by non-recurrent congestion events, including incidents, weather, work zones, demand surges and inadequate base capacity.

Yet methods for assessing the effectiveness of active traffic management (ATM) strategies aimed at improving mobility are still rooted at a planning level approach rather than the operational levels of implementation. This research has intended to develop efficient methods that dynamically evaluate the current traffic system performance, propose interventions that can ameliorate the performance as needed, and implement and re-evaluate the effectiveness of the intervention.

The research team has developed methods and a computerized Java tool (FREEVAL-DSS) that proposes and implements near real time active traffic management strategies on simulated freeway facilities. In a way, what the tool does is create a virtual (simulation) lab for assessing ATM methods in the same fashion they would be considered, evaluated and implemented in a freeway traffic management center (TMC), that is: observe conditions→diagnose problem→propose solution →implement solution→observe, and so on.

FREEVAL-DSS allows the assessment of alternative improvement strategies *before* actual implementation in the field. In addition, it adds to the knowledge base on the development of real-time decision support systems at traffic management centers. The utilization of a macroscopic rather than a microscopic simulation model as a basis for the development ensures an efficient use, calibration, and implementation of the developed environment.

The research team proposed conducting a hands-on workshops on findings of STRIDE 2013-009S project and primarily FREEVAL-DSS tool. These will be the third and fourth workshops on disseminating the outcomes and findings of STRIDE project 2013-009S.

2. OBJECTIVES

The objective of this project was to provide users with computerized and accessible tools to evaluate ATM strategies in a near real-time environment. This was achieved by offering two additional hands-on workshops on the FREEVAL-DSS tool which was developed under STRIDE Project 2013-009S - *Dynamic Traffic Control Interventions for Enhanced Mobility and Economic Competitiveness.* The workshops were offered with all the necessary requisite materials that users need to acquire in order to be able to effectively use the FREEVAL-DSS tool. In this report, we document the conduct of the third workshop at Tanspo2016 conference in West Palm Beach FL on Nov 13 2016, as well as the fourth workshop held in Oakland CA on Feb 28 2017. Two earlier workshops in Knoxville, Tennessee and Chicago Illinois have been documented in earlier reports.

3. WORKSHOPS DESCRIPTION

3.1. WEST PALM BEACH FL WORKSHOP

The third workshop was held on Nov 13 2016 at the Transpo2016 conference in West Palm Beach FL. It was a three hours workshop divided into two sessions. Dr. Nagui Rouphail and Dr. Behzad Aghdashi presented the material in this workshop. Appendix A contains the power point presentations that the presenters used in this workshop. Table 1 gives the outline of the workshop schedule.

Table 1 – FREEVAL-DSS workshop outline (West Palm Beach FL)

Time	Description
1:00PM to 1:15PM	Introductions and Sign Ups
1:15PM to 1:45PM	FREEVAL Core Methodology, Reliability & DSS
1:45PM to 2:15PM	FREEVAL-DSS Demo Examples (Modeler & Operator)
2:15PM to 2:30PM	Program Installation & BREAK
2:30PM to 3:15PM	Hands on Exercise (I-290 WB Chicago, IL)
3:15PM to 3:45PM	New & upcoming Features in FREEVAL-PRO (DEMO)
3:45PM to 4:00PM	Questions, Feedback, and Evaluation

The total number of attending participants was five, even though the number of original registrants was close to ten. One thing learned from this experience is that while offering free workshops is desirable, the downside is that last minute cancellations can occur without penalty to the no-show registrants. It is unclear how future workshops can be structured to make sure commitments are kept, while not incurring exorbitant charges to the registrants. The participants were required to bring their own laptops for the hands-on portion of the workshop, where they tried to select and implement Active Traffic Management (ATM) strategies on the example facilities. The project team provided each participant with the FREEVAL-DSS tool, a FREEVAL Users Guide, and a copy of the PowerPoint presentations.

3.2. OAKLAND CA WORKSHOP

The fourth and last workshop was held on Feb 28 2017 at the Kittelson and Associates Inc. office in Oakland CA next to Caltrans offices. It was a six and half hours workshop that was divided into four sessions and included background material on the HCM 6th Edition uninterrupted flow material, and on the core and reliability FREEVAL versions. Dr. Nagui Rouphail, Dr. Behzad Aghdashi, and Dr. Bastian Schroeder of KAI (chair of the uninterrupted flow group in AHB 40) presented in this workshop. KAI offered their facilities and amenities free to the instructors and

participants. Appendix B contains the power point presentations used in this workshop. Table 2 shows the outline of the workshop material.

Table 2 – FREEVAL and FREEVAL-DSS workshop outline (Oakland CA)

From	To	Description
9:30 am	9:45 am	- Sign in - Distribution of the course material - Introductions
9:45 am	10:30 am	- Overview of the new changes in the 6th edition of HCM
10:30 am	10:45 am	- Break
10:45am	12:00 pm	- Uninterrupted Flow Concepts, New material in Freeway Chapters (e.g. Managed Lanes, Reliability, ATDM, WZ)
12:00 pm	1:00 pm	- Lunch Break & Software Installation
1:00 pm	2:00 pm	- FREEVAL Demo with Hands-on Example, Segmentation, Calibration & Reliability Analysis
2:00 pm	2:30 pm	- FREEVAL-DSS Concepts and Demo
2:30 pm	2:45 pm	- Break
2:45 pm	3:45 pm	- FREEVAL-DSS Hands-on
3:45 pm	4:00 pm	- Questions, Feedback, and Evaluation

The total number of participants was twelve. Appendix C contains photos from these workshops. The participants were asked to bring their laptops for the hands-on portion of the workshop when selecting and implementing Active Traffic Management (ATM) strategies on the example facilities. The project team provided each participant with FREEVAL-PLUS tool, which is an enhanced version that included automated segmentation and planning level inputs, a FREEVAL Users Guide, and the PowerPoint presentations used at that workshop.

4. WORKSHOP OUTCOMES

The sections below describe results from our survey, comments from participants, and suggestions of our proof-of-concept study location.

4.1. WORKSHOP EVALUATION

At the conclusion of the workshop, the project team provided each participant with a feedback form. Out of the 17 participants in both workshops, we were able to retrieve 11 completed feedback forms. Table 3 gives a summary evaluation of the various components of the workshops.

Table 3 – Workshop Evaluation Results (1=poor; 5= excellent)

Feedback Item	Participant #1	Participant #2	Participant #3	Participant #4	Participant #5	Participant #6	Participant #7	Participant #8	Participant #9	Participant #10	Participant #11	Average
Overall Value of This Workshop	5	5	5	5	5	5	5	4	5	5	5	4.9
Quality of the Workshop Material and Presentation	5	5	5	5	5	5	5	4	5	5	5	4.9
Quality of the Instruction	5	5	5	5	5	5	5	4	5	5	5	4.9
Time Allocation and Duration	5	5	4	5	5	5	5	4	5	5	4	4.7

4.2. COMMENTS RECEIVED FROM PARTICIPANTS

Below are sample comments drawn from the participant feedback forms:

4.2.1. Suggestions for Workshop Presentation

- More discussion on calibration would have been useful
- Provide PPT files with screen shots of features of the program that will be discussed during the class
- Maybe having class material before the class be good (easier to follow)

4.2.2. Suggestions for Instructors

- Open screenshots with instructions to follow

4.2.3. Additional Comments

- Need a very good user's manual and help file.
- Great location.
- Share expectations from students after the class
- Thanks, good job

5. CONCLUSIONS

These two workshops disseminated the findings of STRIDE project 2013-009S Dynamic Control Interventions for Enhanced mobility and provided free computational tools to potential end users of this research. The primary focus of the workshop was on the FREEVAL-DSS tool that had been developed under the same project. We offer the following retrospective conclusions covering all four workshops.

1. As workshops progressed, the research team realized that additional background material preceding the introduction of FREEVAL-DSS was necessary to bring participants at the level needed to appreciate its utility.

2. Free registration while attractive to some comes with the challenge of ensuring no last minute drop-outs. This was unfortunately the case in West Palm Beach and to some extent in Knoxville. The Chicago workshop was well attended, and participants paid a fee of $50 mostly for space rental at the Midwest ITE summer meeting. The Oakland workshop was very well attended because (a) local support from KAI and (b) close proximity to CALTRANS, which contributed 11 of the 12 participants in that workshop.

3. It may be advisable to have a pre-workshop webinar with potential participants to provide some of the background material while focusing the actual face to face workshop on the hands-on portion of the material.

4. Every effort should be made in future workshops to use local datasets as the examples in the hands-on portion of the workshop. This will result in improving the engagement of the attendees who are familiar with the facility, and would also generate higher confidence in the results generated by the tool.

APPENDIX A: PRESENTATIONS SLIDES (WEST PALM BEACH FL 11/13/16)

Institute for Transportation Research and Education – N.C. State University

Active Traffic Management (ATM) at Your Fingertips

Workshop
Transpo2016
West Palm Beach, FL, Nov 13 2016

Behzad Aghdashi and Nagui Rouphail, NC State University

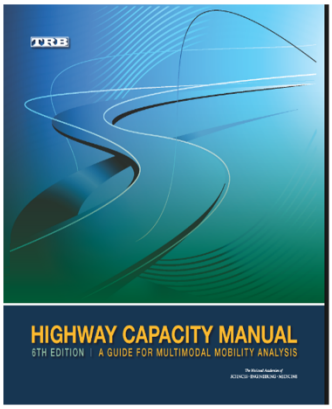
ITRE Institute for Transportation Research and Education http://www.itre.ncsu.edu

Workshop Agenda

Time	Description
1:00PM to 1:15PM	Introductions and Sign Ups
1:15PM to 1:45PM	FREEVAL Core Methodology, Reliability & DSS
1:45PM to 2:15PM	FREEVAL-DSS Demo Examples (Modeler & Operator)
2:15PM to 2:30PM	Program Installation & BREAK
2:30PM to 3:15PM	Hands on Exercise (I-290 WB Chicago, IL)
3:15PM to 3:45PM	New & upcoming Features in FREEVAL-PRO (DEMO)
3:45PM to 4:00PM	Questions, Feedback, and Evaluation

Workshop Outline

- Foundation: 6th Edition of HCM ---- Freeway Facilities Methodology
- FREEVAL 2015e Computational Engine in the HCM
- Capabilities and Limitations
- Dynamic Strategy Selection (DSS) Framework– FREEVAL-DSS



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Core HCM Freeway Facilities

- **Distinguishes between Different Segment Types**
  - Basic Freeway Segments
  - Weaving Segments
  - On-ramp and Off-Ramp Segments
- **Extended Time-Space Domain**
  - Queue propagation between segments and over multiple time periods
- **Flow Regimes**
  - Under-saturated (**all** d/c<1.0)
  - Oversaturated (**any** d/c>1.0)
- **Capacity and Free-Flow Speed Calibration**
  - Work Zone Effects
  - Incidents and Weather
  - Capacity Reduction Due to Congestion
- **Implemented in Macroscopic FREEVAL Tool**

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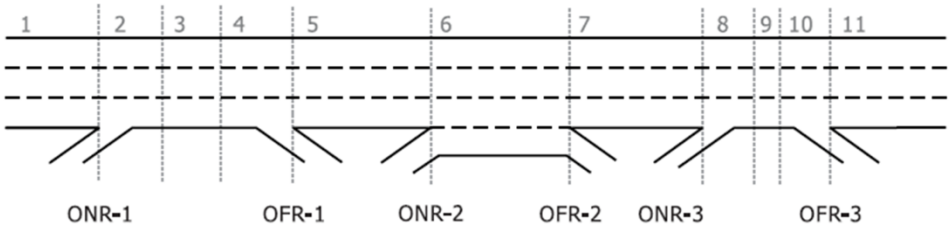
Why Analyze Freeways as Facilities?

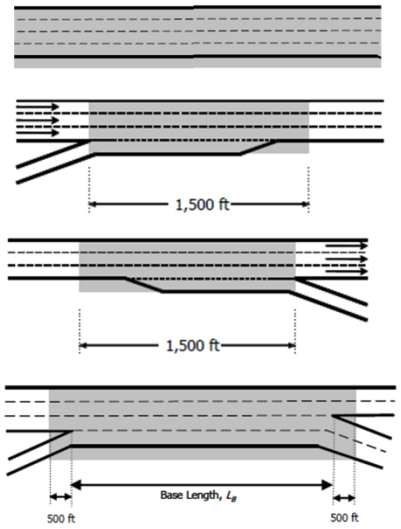
Core Freeway Facilities Method

- Method combines the analysis of multiple segments along an extended length of a freeway (up to 10-15mi)
- Considers oversaturated conditions with queue spillback
- Consider operations over multiple (15 min) analysis periods



Freeway Facility Comprised of Segment Types

- Basic **B** segment (Ch. 12)
- On-Ramp **ONR** segment (Ch. 13)
  (1,500 ft, ~ 455 meters)
- Off-Ramp **OFR** segment (Ch. 13)
  (1,500 ft, ~ 455 meters)
- Weaving **W** segment (Ch. 14)



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Capabilities of the Freeway Facility Methodology

- Enables the modeling of oversaturated & under-saturated conditions in an extended time-space domain (24 hrs. / 15 mi)
- Models all active and highlights hidden mainline bottlenecks
- Tracks queues as they form and dissipate across segments and time intervals
- Allows time-variant demands and capacities each 15 min
- Can model the effect of incidents, weather and work zones
- Validated against field data and compared to microsimulation very favorably

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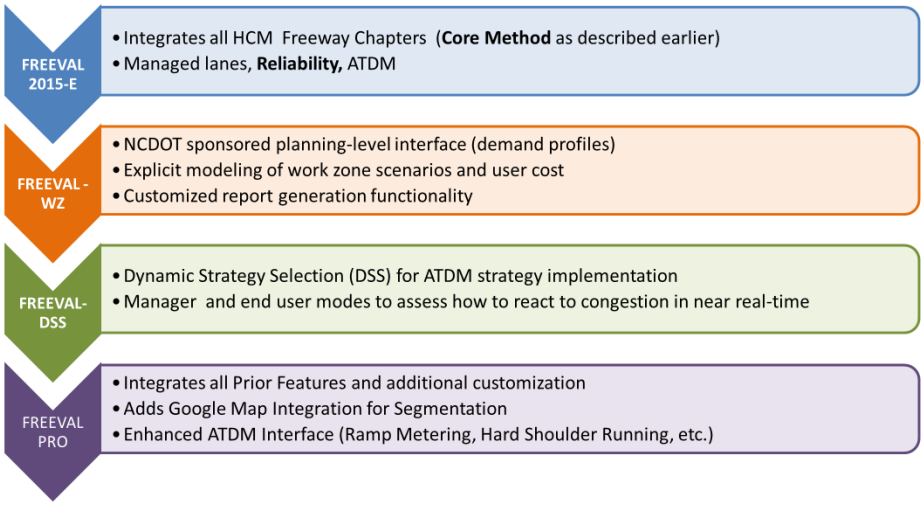
What the methodology 's limitations are…

- Does not account for off-ramp congestion due to surface street control and spillback onto mainline
- Not reliable in reporting the effect of multiple overlapping queues
- Requires input manipulation for the analysis of extended facilities (free-flow travel time greater than 15 minutes)
- Requires extensive demand inputs in each time period – cannot map sensor data to demand (FREEVAl-PRO/DSS)
- Time consuming in manually segmenting the facility into HCM analysis segments (FREEVAL-PRO)

FREEVAL Releases

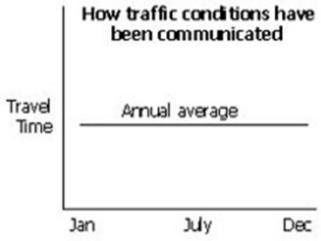


Freeway Travel Time Reliability

- Introduction:
  - Concepts and definitions
- Travel Time Reliability Analysis:
  - Recurring and Non-recurring Sources of Congestion
  - Reliability Scenarios Generation
  - Reliability Performance Measures

Introduction

- *HCM2010* methods focused on **average performance measures** such as average travel times, however, most travelers experience and remember something much different than a simple average throughout a year of commutes.



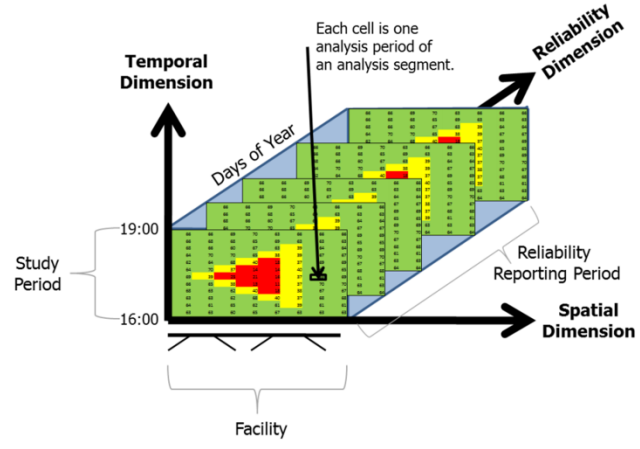
- The **Reliability** analysis in the *6th Edition of HCM*, accounts for these variations in the travel time and translates them into reliability performance measures.

Introduction

- What are the sources for variation in travel time?
  - Traffic Demand Surges
  - Incidents (Crashes, Stalls, Debris, etc.
  - Severe Weather Conditions
  - Work Zones
  - Special Events

- Reliability analysis accounts for these sources of variations.
- The congestion sources are modeled in **scenarios**, which represent a set of typical expected operational days for the facility.

Definitions



Source: Zegeer et al. (1)

Exhibit 11-1
Schematic Representation of Freeway Reliability Analysis Time–Space Domain

High Level View of HCM Reliability Methodology

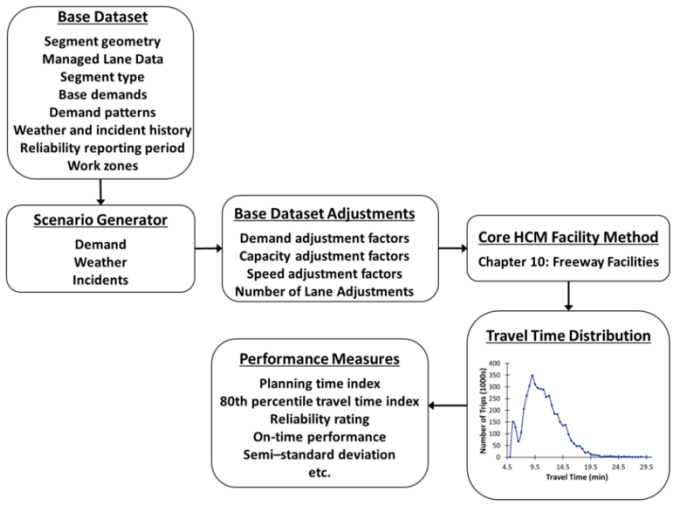
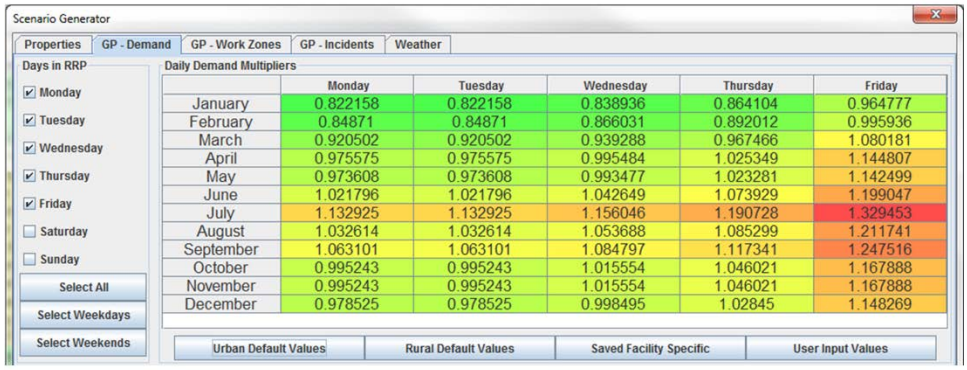


Exhibit 11-7
Freeway Reliability
Methodology Framework

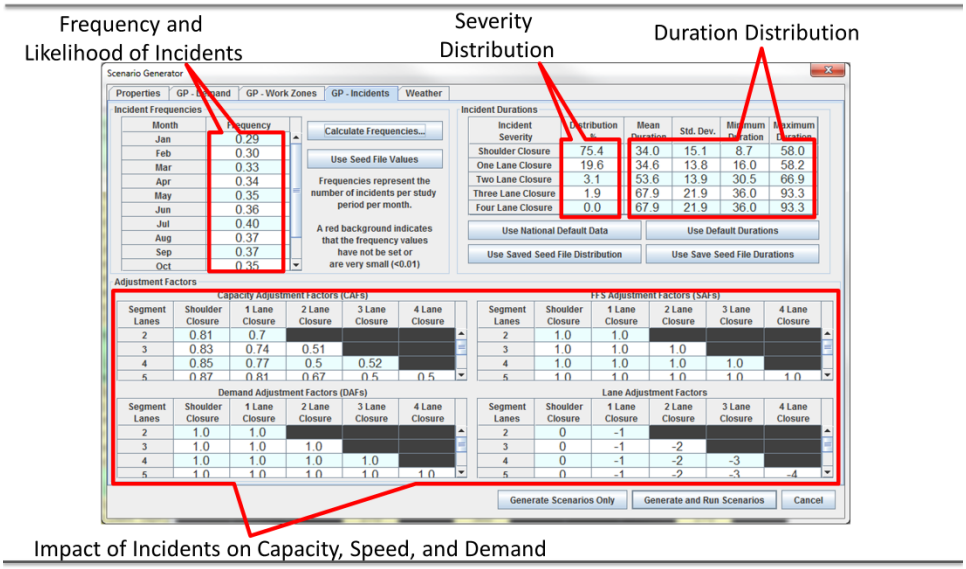
Traffic Demand Variation in FREEVAL

- Demand Multipliers in FREEVAL to characterize the demand variation across weekdays and months



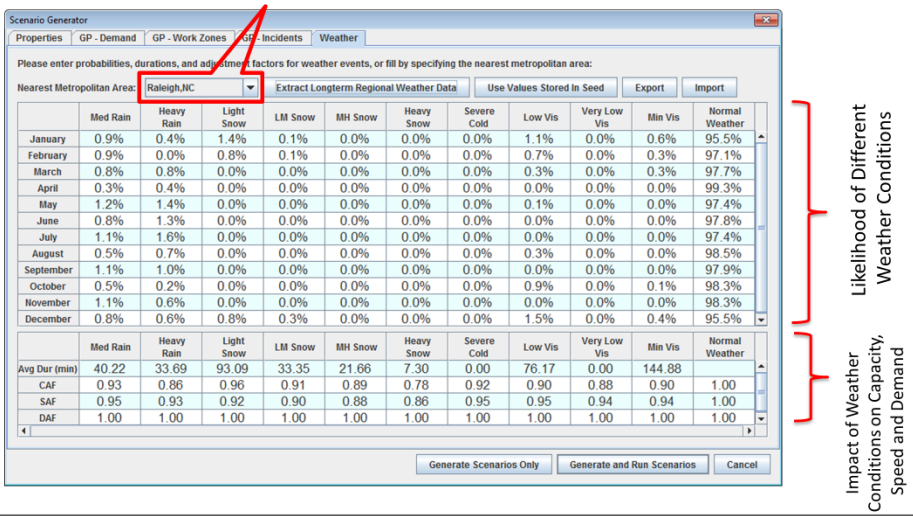
	Monday	Tuesday	Wednesday	Thursday	Friday
January	0.822158	0.822158	0.838936	0.864104	0.964777
February	0.84871	0.84871	0.866031	0.892012	0.995936
March	0.920502	0.920502	0.939288	0.967466	1.080181
April	0.975575	0.975575	0.995484	1.025349	1.144807
May	0.973608	0.973608	0.993477	1.023281	1.142499
June	1.021796	1.021796	1.042649	1.073929	1.199047
July	1.132925	1.132925	1.156046	1.190728	1.329453
August	1.032614	1.032614	1.053688	1.085299	1.211741
September	1.063101	1.063101	1.084797	1.117341	1.247516
October	0.995243	0.995243	1.015554	1.046021	1.167888
November	0.995243	0.995243	1.015554	1.046021	1.167888
December	0.978525	0.978525	0.998495	1.02845	1.148269

Incidents Parameters Configuration in FREEVAL



Weather Conditions Configuration in FREEVAL

List of 96 largest metropolitan area in US that weather information is available



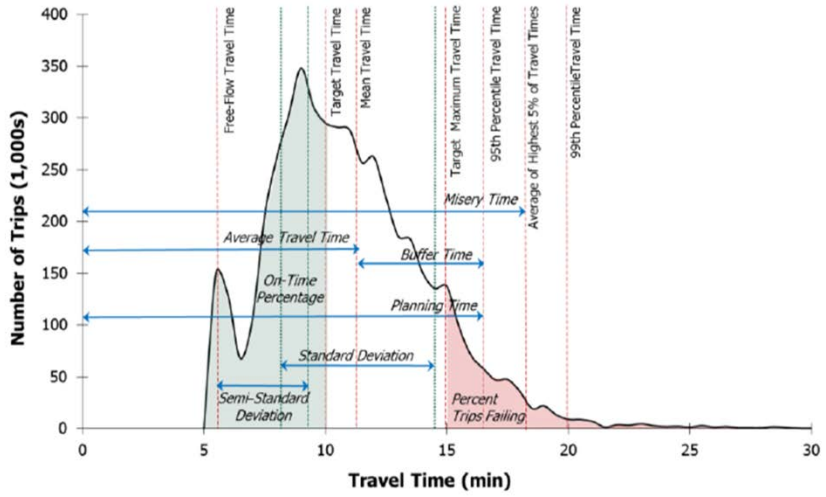
Scenario Generation

- Each Scenario can contain several non-recurring events.
- Overlap between different type of events are allowed in the methodology.
- Example shows effects of a rain event (R), a two-lane closure incident (I-2) and a shoulder-closure incident (I-S)

Analysis Period	Segment Number									
	1	2	3	4	5	6	7	8	9	10
1										
2										
3	R	R	R	R	R	R	R	R	R	R
4	R	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R and I-2	R	R
6								I-2		
7								I-2		
8								I-2		
9										
10										
11			I-S							
12										

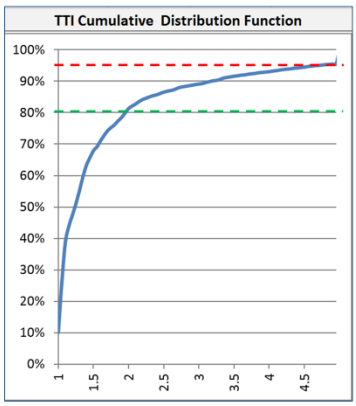
Exhibit 11-5
Scenario Illustrating Weather and Incident Events

The Travel Time Distribution



Reliability Performance Measures

- Reliability analysis will provide "**reliability performance measures**" that includes the impact of sources of recurring and non-recurring sources of congestion.
- All the performance measure are based on the estimated travel time reliability distribution.
- To bring estimated distributions to an equal scale, the travel times are divided by free flow travel time resulting in **Travel Time Index (TTI)** distribution.



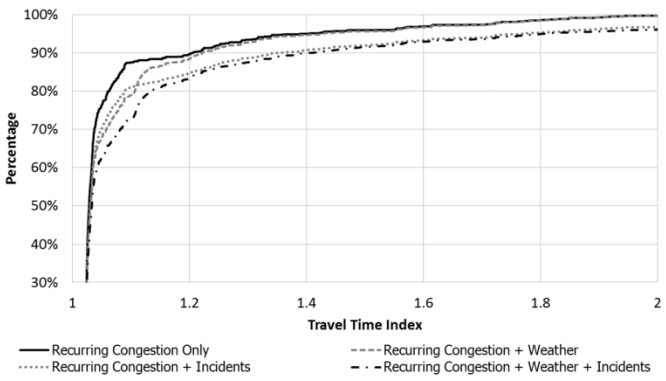
Reliability Performance Measures

- Key Reliability Performance Measures are:
  - 95th % TTI (PTI)
  - 50th % TTI
  - 80th % TTI
  - Reliability Rating (%)
  - Failure and on-time measures (%)
  - Misery Index
  - Semi-Standard Deviation
  - Standard Deviation
  - %VMT at TTI>2
    - percent vehicle-miles traveled at a TTI greater than 2

Effect of Different Congestion Sources on Reliability

- The reliability methodology can provide the effect of different congestion sources on the travel time reliability of the facility.

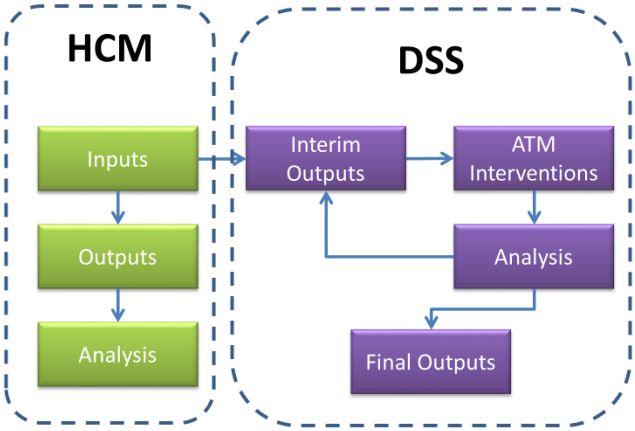
Exhibit 11-14
Illustrative Effects of Different Non-Recurring Sources of Congestion on the TTI Distribution



What is FREEVAL-DSS

- Based on the core Freeway Facilities method in the HCM 6th Edition, but runs it differently
- Creates a dynamic framework to test ATM strategies at different clock times, depending on traffic and external (incident, weather)conditions
- The operator can intervene midstream, & can alter ATM Strategies in the middle of the simulation run
- Can be viewed as a research and training tool for engineers and operators at freeway TMC's

DSS Concept Implementation



ATM strategies Covered in FREEVAL-DSS

- DSS→ **D**ynamic **S**trategy **S**election
- Ramp Metering
  - Adaptive (ALINEA and Fuzzy logic) and Fixed Rate
  - Local and System Wide
- Hard Shoulder Running on user selected segments
- Traffic Diversion
  - Upstream of the facility
  - Into Managed Lanes (HOV/HOT)
  - Via VMS into off-ramps
- Incident Management

Two Roles: Modeler vs. Operator

- The framework accommodates two types of users: **Modeler** (Professor; Supervisor ?) and **Operator** (Student ; TMC Technician?)
- The **Modeler** configures the facility, specifies various congestion sources including **weather events, incident events, work zones,** or **demand surges**.
- The **Modeler** also configures the **menu of available ATM strategies** and the **form of output options** to the operator(s)
- The **Operator** has access only to modeler-selected ATM **interventions** from a menu of options, after any 15 minute interval. Interventions can also be stopped or extended in time and space

FREEVAL- DSS Phases

- Consists of three phases:
  - **Phase 1: Scenario Configuration** by the **Modeler**
  - **Phase 2: Simulation and ATM Interventions** by **Operator**.
  - **Phase 3: Analysis Summary** and execution of multiple FREEVAL runs to compare Performance under various ATM strategies.

Modeler and Operator Demo Application

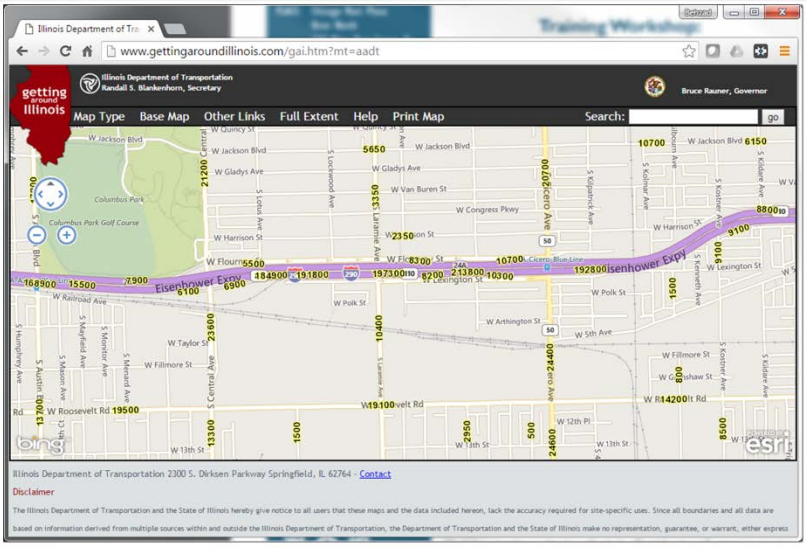
Break and Program Install

Hands-on Exercises
I-290 WB in Chicago
From Chicago River to S 1st Ave

Rules for Hands-on Exercise

- First exercise: meter all ramps, for the entire duration using Adaptive, ALINEA
- Second Exercise: Use HSR only at <=4 segments, =< 1 hour
- Beyond that:
  - No more than two concurrent strategies
  - No more than one hour for each strategy application (except for ramp metering)
  - At most four segments to apply strategies

AADT for I-290 Exercise: Populating the demand inputs



Demo of New and Upcoming FREEVAL-PRO Features

Discussion and Questions

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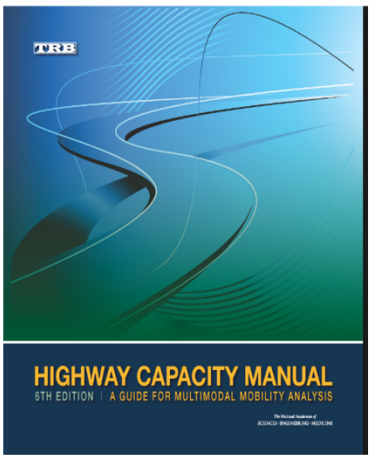

APPENDIX B: PRESENTATIONS SLIDES (OAKLAND CA 02/28/17)

FREEWAY ANALYSIS & SOFTWARE IN THE HCM 6TH EDITION: The Role Of Active Traffic Management Strategies

Nagui Rouphail, Ph.D.
Bastian Schroeder, Ph.D. P.E.
Behzad Aghdashi, Ph.D.

February 28, 2017

ITRE KITTELSON & ASSOCIATES, INC. TRANSPORTATION ENGINEERING/PLANNING

Instructors

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Workshop Schedule

9:30 am	9:45 am	- Signing in - Distribution of the course material - Introductions
9:45 am	10:30 am	- Method Overview and Applications
10:30 am	10:45 am	- Break
10:45am	12:00 pm	- Uninterrupted Flow Concepts, New material in Freeway Chapters (e.g. Managed Lanes, Reliability, ATDM, WZ)
12:00 pm	1:00 pm	- Lunch Break & Software Installation
1:00 pm	2:00 pm	- FREEVAL Demo with Hands-on Example, Segmentation, Calibration & Reliability Analysis
2:00 pm	2:30 pm	- FREEVAL-DSS Concepts and Demo
2:30 pm	2:45 pm	- Break
2:45 pm	3:45 pm	- FREEVAL-DSS Hands-on
3:45 pm	4:00 pm	- Questions, Feedback, and Evaluation

3

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Attendee Introduction

- Name
- Company
- Experience/Common Uses of HCM
- Key Questions for Today

4

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BACKGROUND AND INTRODUCTION

5

A Brief History of the HCM

- 1950: focus on capacity
- 1965: LOS concept, bus transit chapter
- 1985: new research, pedestrians, bicycles
  - 1994 & 1997 updates
- 2000: new research, multiple parts
- 2010: new research, multimodal focus, four volumes

First Freeway Facilities Method

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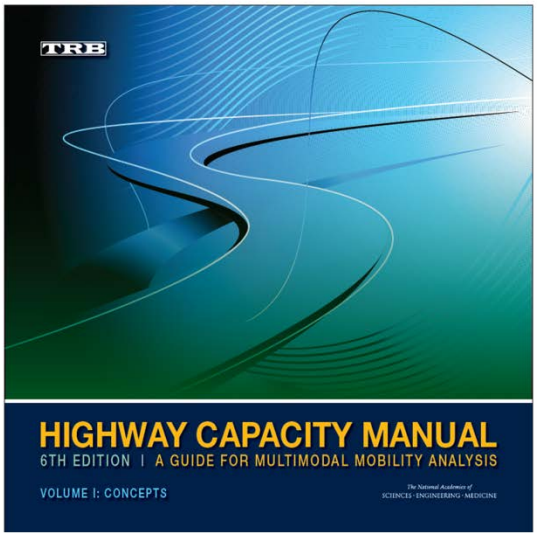
HCM 6th Edition: A Guide for Multimodal Mobility Analysis

- Published in October 2016



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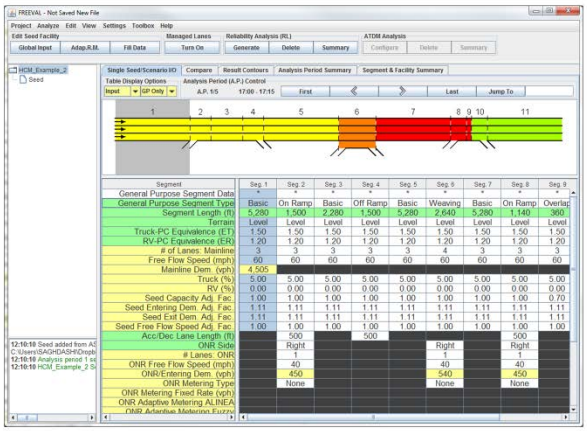
HCM 6th Edition: A Guide for Multimodal Mobility Analysis

- FREEVAL-JAVA
- Free download: hcmvolume4.org



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HCM 6th Edition: New Analysis Capabilities

Image Sources: Kittelson & Associates, ITRE

- Uninterrupted Flow
  - Reliability Analysis
  - Work Zone Analysis
  - New Truck Methodology
  - New Planning Methods
  - Managed Lanes
  - Active Traffic Management
  - Unified Speed-Flow Equation
  - Calibration Guidance
- All capabilities integrated in new Java-Based Software Engine (FREEVAL)

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FREEVAL Releases

FREEVAL 2015-E	• Integrates all HCM Freeway Chapters (Core Method) • Managed lanes, Reliability, ATDM	Available for Download
FREEVAL - WZ	• NCDOT sponsored planning-level interface (demand profiles) • Explicit modeling of work zone scenarios and user cost • Customized report generation functionality	Available for Download
FREEVAL-DSS	• Dynamic Strategy Selection (DSS) for ATDM strategy implementation • Modeler and operator modes to assess reaction to congestion in near real-time	Available for Download
FREEVAL-IAP	• Mapping tools for easy segmentation • AADT and hourly demand profile data entry • Segment based reliability MOEs	Available for Beta Testing
FREEVAL+	• Integrates all Prior Features and additional customization • Adds Google Map Integration for Segmentation • Enhanced ATDM Interface (Ramp Metering, Hard Shoulder Running, etc.)	Available for Beta Testing

http://freeval.org

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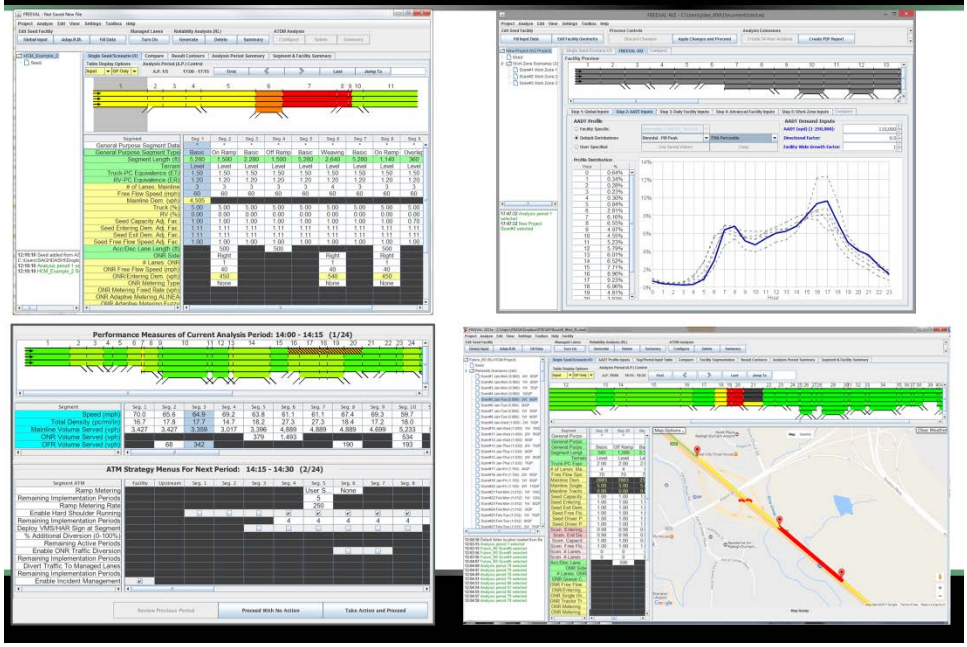
FREEVAL Custom Interfaces



FREEVAL Overview

- FREEVAL faithfully implements the HCM 6th Edition Freeway Facility Analysis
- FREEVAL is the official computational engine of the TRB Highway Capacity and Quality of Service Committee for freeways
- FREEVAL was developed in the late 1990s, and has been continuously improved since that time
- FREEVAL encompasses all freeway segment methods (basic, merge, diverge, and weave) for under-saturated computations
- FREEVAL is able to model oversaturated conditions and queue formation and dissipation over time and space
- FREEVAL integrates the latest HCM methods for managed lanes, freeway work zones, reliability analysis, and evaluation of active traffic and demand management (ATDM) strategies

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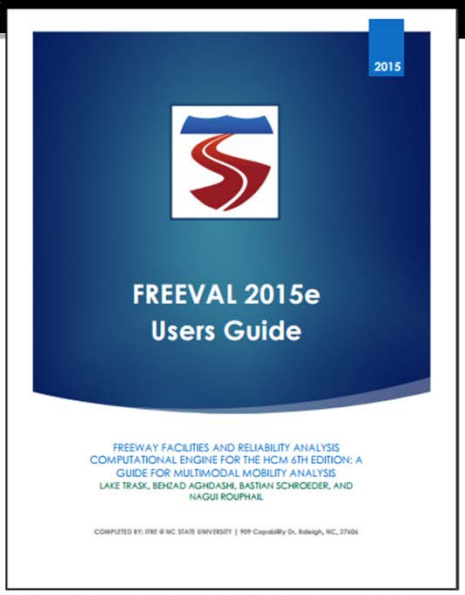
User Guide



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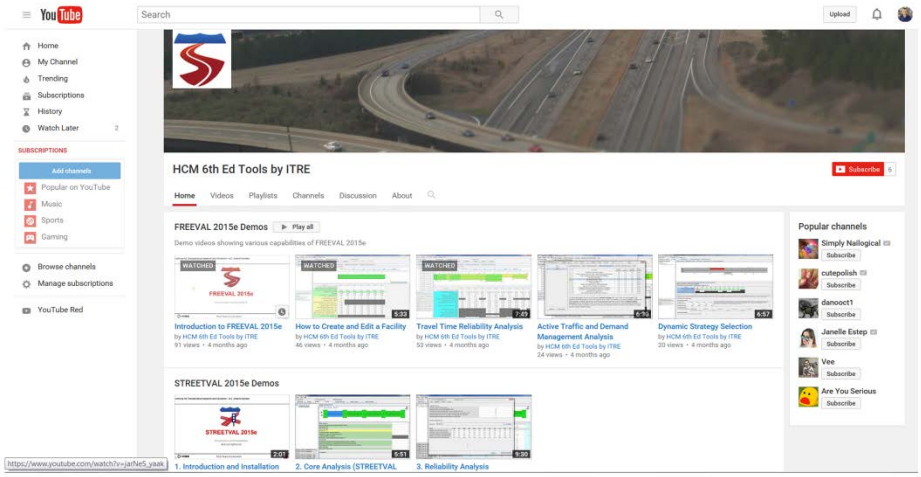
Website: http://go.ncsu.edu/FREEVAL



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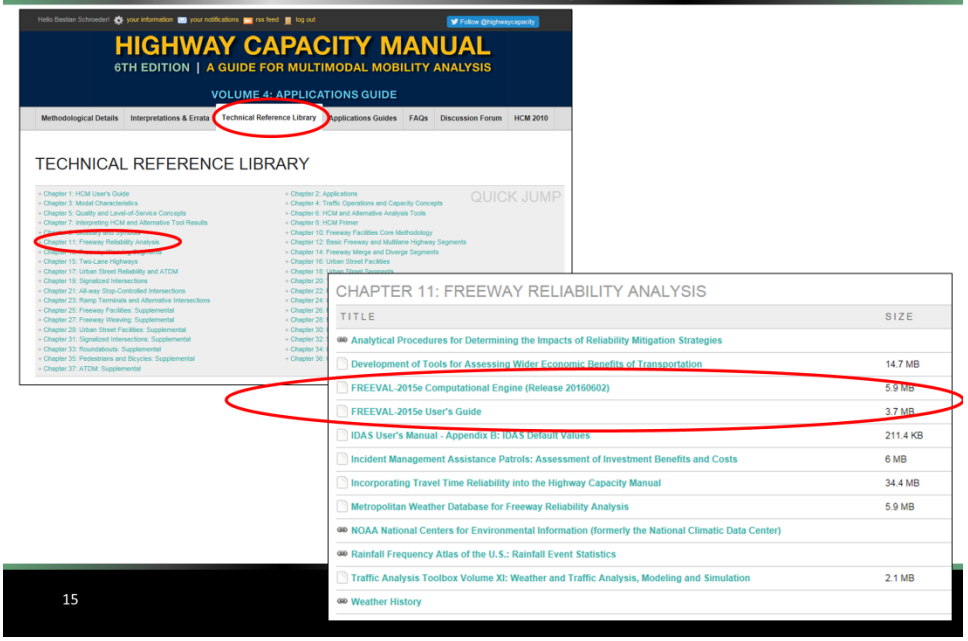
Available in HCM Volume 4 – Technical Reference Library → http://hcmvolume4.org



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APPLICATIONS

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Case Study Overview

1. Impacts from Major Freeway Work Zone
   - Estimating Queuing Impacts
   - Setting Lane Closure Requirements
   - Identifying Diversion Targets
2. Work Zone Lane Closure Sensitivity
   - Setting allowable work hours
   - Estimating Queuing Impacts
3. Interchange Evaluation
   - Comparing Scenario Performance
   - Identifying Interim Countermeasures
4. Ramp Metering Feasibility
   - Quantifying freeway congestion and whole-year reliability
   - Evaluating the temporal operation of ramp metering

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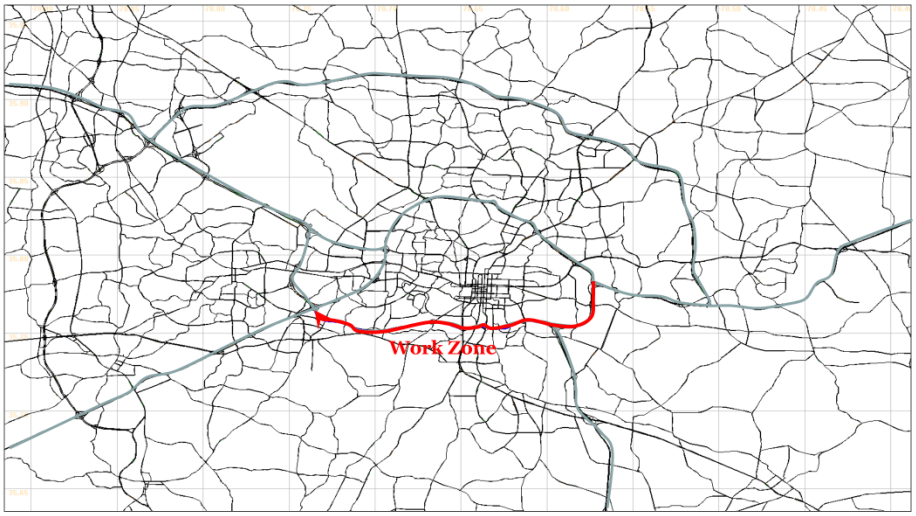
Case Study Application 1



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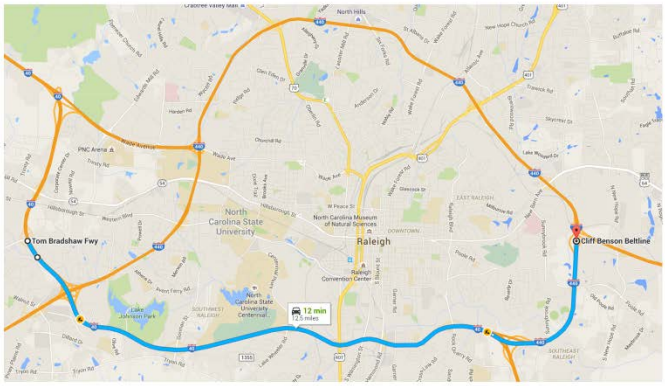
One of several facilities for the project analyzed with the HCM



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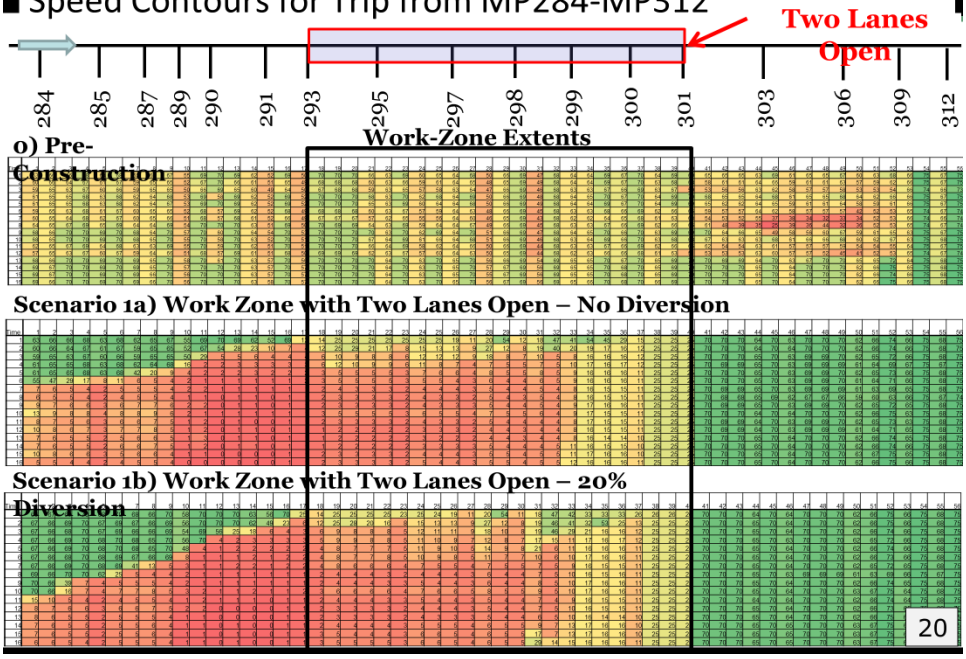
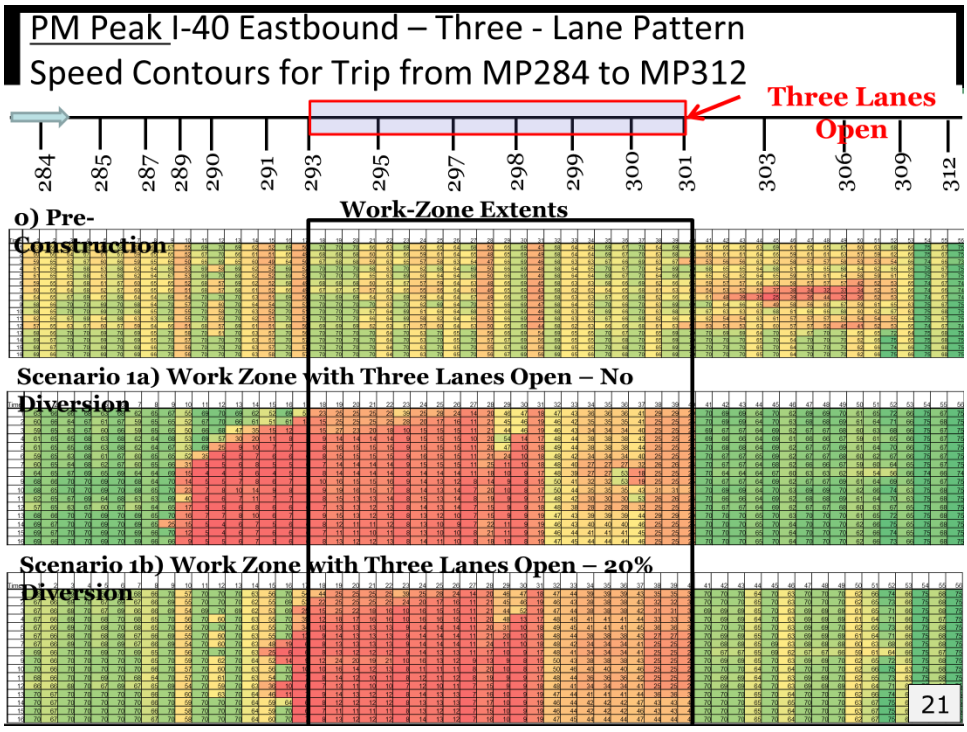
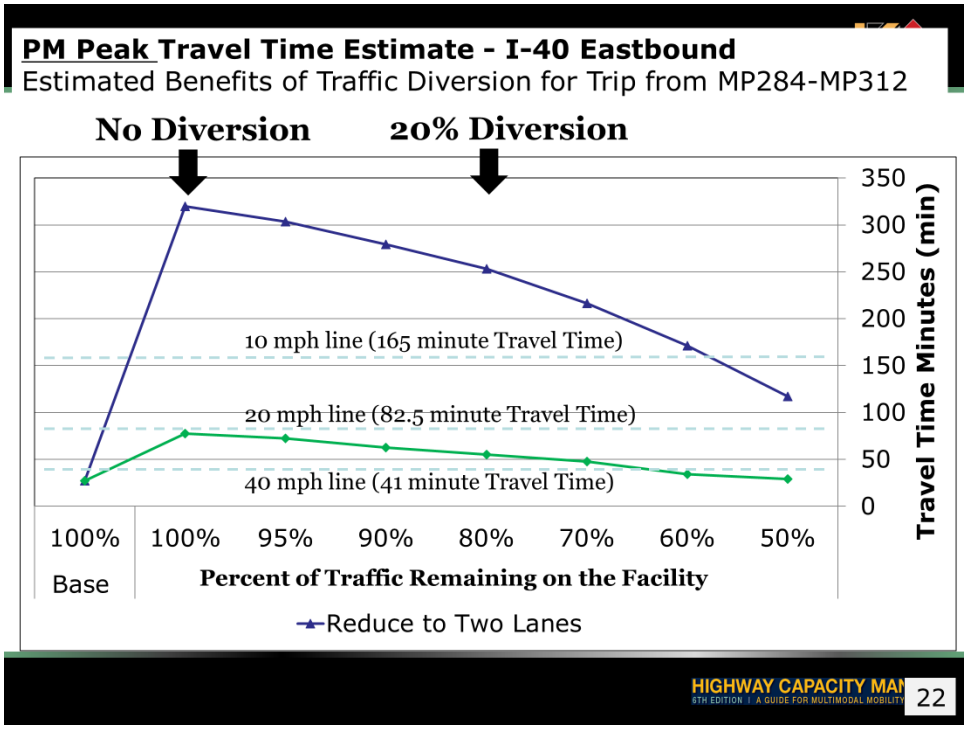
PM Peak I-40 Eastbound – Two - Lane Pattern
Speed Contours for Trip from MP284-MP312




PM Peak I-40 Eastbound – Three - Lane Pattern
Speed Contours for Trip from MP284 to MP312
Three Lanes Open
284
285
287
289
290
291
293
295
297
298
299
300
301
303
306
309
312
Work-Zone Extents
0) Pre-Construction
Scenario 1a) Work Zone with Three Lanes Open – No Diversion
Scenario 1b) Work Zone with Three Lanes Open – 20% Diversion
21


PM Peak Travel Time Estimate - I-40 Eastbound
Estimated Benefits of Traffic Diversion for Trip from MP284-MP312
No Diversion
20% Diversion
350
300
250
200
150
100
50
0
Travel Time Minutes (min)
10 mph line (165 minute Travel Time)
20 mph line (82.5 minute Travel Time)
40 mph line (41 minute Travel Time)
100% Base
100%
95%
90%
80%
70%
60%
50%
Percent of Traffic Remaining on the Facility
Reduce to Two Lanes
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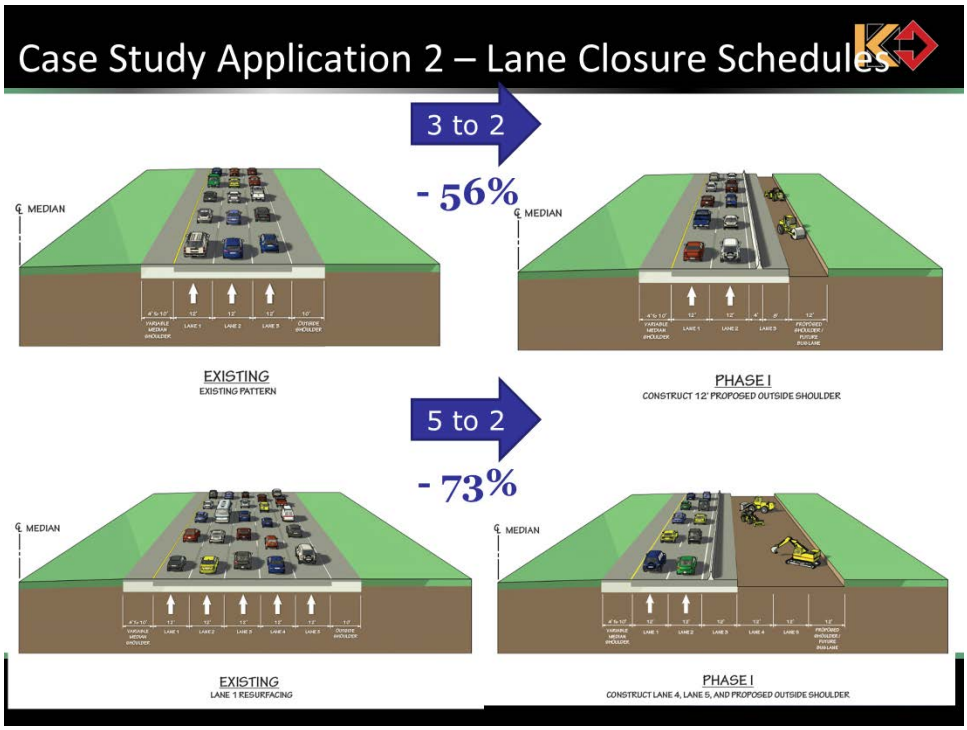
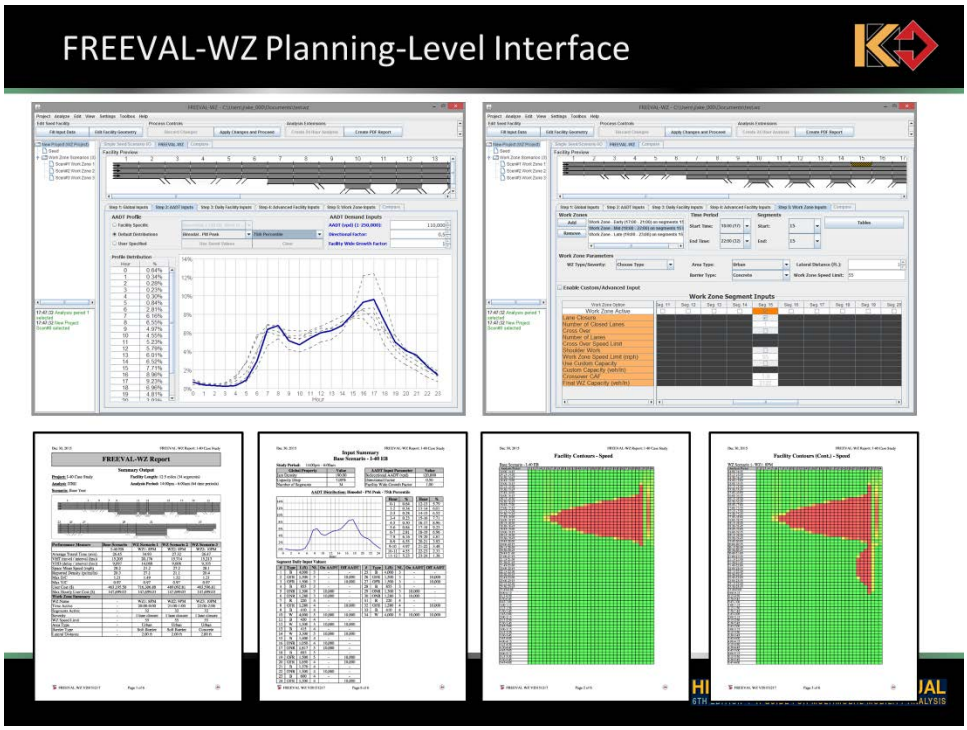
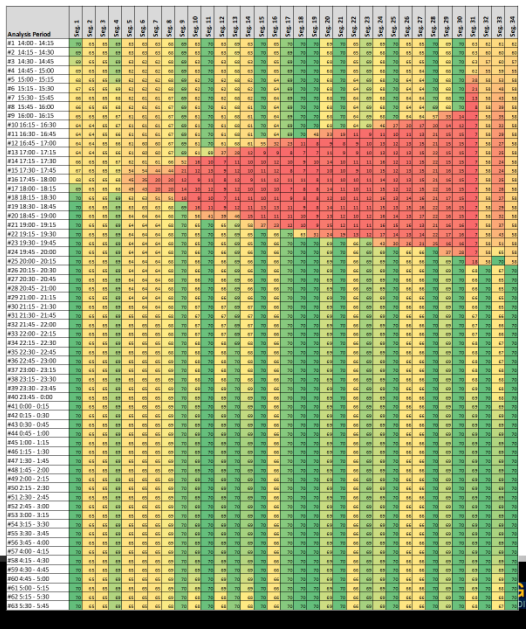

Case Study Application 2 – Lane Closure Schedules
3 to 2
- 56%
℄ MEDIAN
EXISTING
EXISTING PATTERN
PHASE I
CONSTRUCT 12' PROPOSED OUTSIDE SHOULDER
5 to 2
- 73%
℄ MEDIAN
EXISTING
LANE 1 RESURFACING
PHASE I
CONSTRUCT LANE 4, LANE 5, AND PROPOSED OUTSIDE SHOULDER


FREEVAL-WZ Planning-Level Interface
FREEVAL-WZ Report

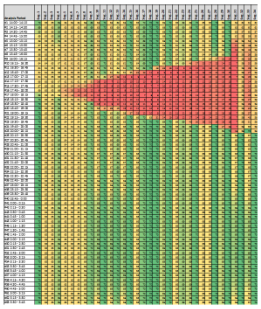
Night-Time Lane Closure Schedule



Analysis Segment
Seg 1 – Seg 34

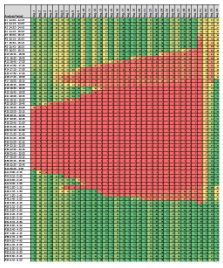
Time
2pm – 6am

Night-Time Lane Closure Schedule

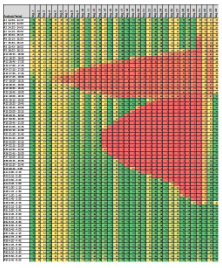


Base Case
– No Work Zone

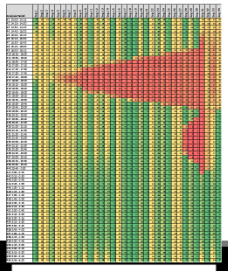
5PM Lane Closure



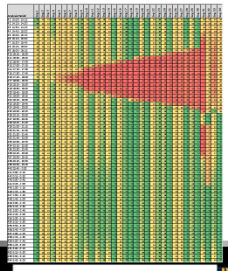
6PM Lane Closure



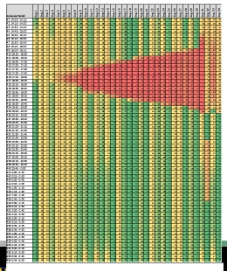
7PM Lane Closure



8PM Lane Closure



9PM Lane Closure



10PM Lane Closure

Case Study 3: Interchange Evaluation

- 4-mile freeway facility
- Evaluation done as part of an interchange evaluation
- FREEVAL Scenarios
  - 2011 No-Build
  - 2020 No-Build
  - 2020 Alternative 1
  - 2020 Alternative 2a
  - 2020 Alternative 2b (derived after initial FREEVAL run!)

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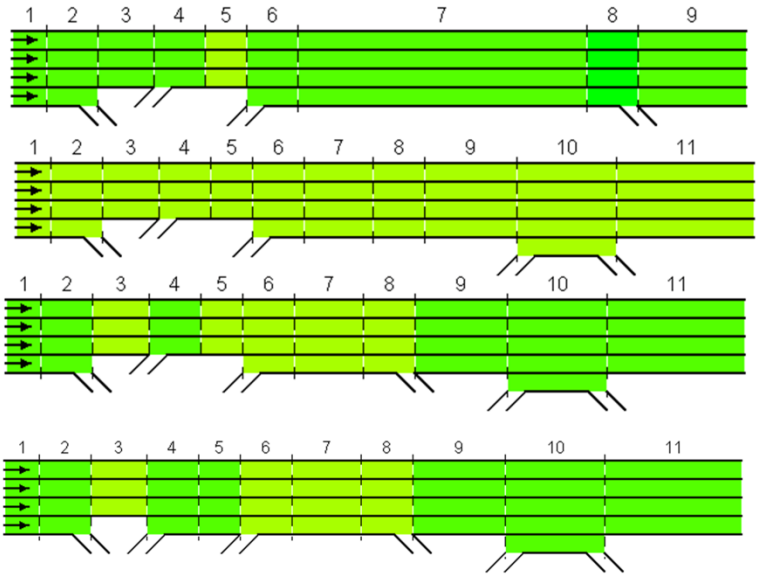
Facility Geometry and Scenarios



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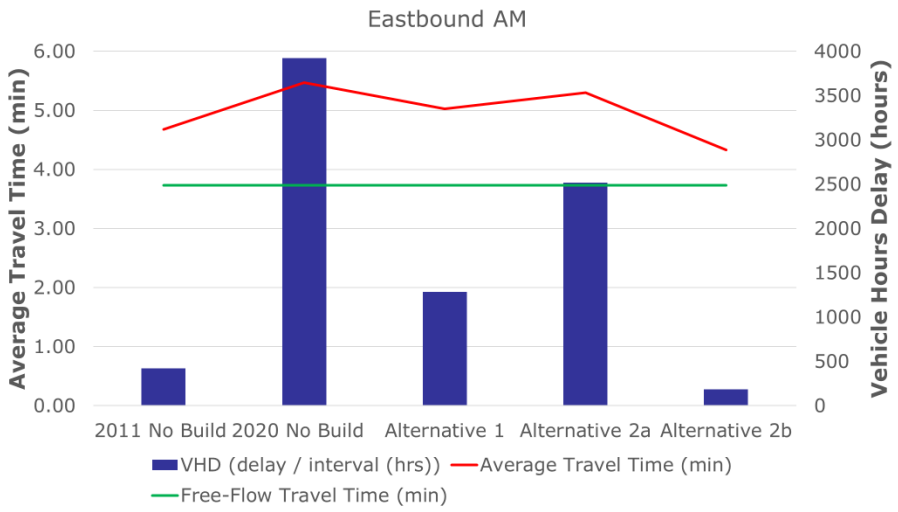
Analysis Results



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How FREEVAL helped arrive at Alternative 2b!

Alt. 2a

Demand to capacity ratio

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11
#1 6:00 - 6:15	0.49	0.49	0.57	0.64	0.64	0.54	0.54	0.54	0.54	0.56	0.51
#2 6:15 - 6:30	0.52	0.52	0.60	0.67	0.67	0.57	0.57	0.57	0.57	0.59	0.53
#3 6:30 - 6:45	0.52	0.52	0.60	0.67	0.67	0.57	0.57	0.57	0.57	0.59	0.53
#4 6:45 - 7:00	0.54	0.54	0.63	0.70	0.70	0.60	0.60	0.60	0.60	0.62	0.56
#5 7:00 - 7:15	0.72	0.72	0.84	0.93	0.93	0.80	0.80	0.80	0.80	0.82	0.74
#6 7:15 - 7:30	0.76	0.76	0.88	0.98	0.98	0.84	0.84	0.84	0.84	0.87	0.78
#7 7:30 - 7:45	0.76	0.76	0.88	0.98	0.98	0.84	0.84	0.84	0.84	0.87	0.78
#8 7:45 - 8:00	0.80	0.80	0.92	1.03	1.03	0.88	0.88	0.88	0.88	0.91	0.82
#9 8:00 - 8:15	0.82	0.82	0.96	1.06	1.06	0.91	0.91	0.91	0.91	0.94	0.85
#10 8:15 - 8:30	0.78	0.78	0.91	1.01	1.01	0.87	0.87	0.87	0.87	0.89	0.81
#11 8:30 - 8:45	0.78	0.78	0.91	1.01	1.01	0.87	0.87	0.87	0.87	0.89	0.81
#12 8:45 - 9:00	0.74	0.74	0.87	0.96	0.96	0.82	0.82	0.82	0.82	0.85	0.77

Alt. 2b

Demand to capacity ratio

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11
#1 6:00 - 6:15	0.49	0.49	0.60	0.49	0.49	0.56	0.56	0.56	0.49	0.50	0.51
#2 6:15 - 6:30	0.52	0.52	0.63	0.52	0.52	0.59	0.59	0.59	0.51	0.53	0.53
#3 6:30 - 6:45	0.52	0.52	0.63	0.52	0.52	0.59	0.59	0.59	0.51	0.53	0.53
#4 6:45 - 7:00	0.54	0.54	0.66	0.55	0.55	0.62	0.62	0.62	0.54	0.56	0.56
#5 7:00 - 7:15	0.72	0.72	0.87	0.72	0.72	0.82	0.82	0.82	0.71	0.73	0.74
#6 7:15 - 7:30	0.76	0.76	0.92	0.76	0.76	0.86	0.86	0.86	0.75	0.77	0.78
#7 7:30 - 7:45	0.76	0.76	0.92	0.76	0.76	0.86	0.86	0.86	0.75	0.77	0.78
#8 7:45 - 8:00	0.80	0.80	0.97	0.80	0.80	0.91	0.91	0.91	0.79	0.81	0.82
#9 8:00 - 8:15	0.82	0.82	1.00	0.83	0.83	0.94	0.94	0.94	0.82	0.84	0.85
#10 8:15 - 8:30	0.78	0.78	0.95	0.78	0.78	0.89	0.89	0.89	0.78	0.80	0.81
#11 8:30 - 8:45	0.78	0.78	0.95	0.78	0.78	0.89	0.89	0.89	0.78	0.80	0.81
#12 8:45 - 9:00	0.74	0.74	0.90	0.75	0.75	0.85	0.85	0.85	0.74	0.76	0.77

PACITY MANUAL
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Case Study 4: Ramp Metering Feasibility

- How does ramp metering affect the freeway congestion and whole-year reliability?
- How does the temporal operation of ramp metering impact congestion?

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Impact on representative Single Day operations (AM Peak)

- Before

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11	Seg. 12
#1 6:00 - 6:15	75.0	67.8	74.4	68.5	75.0	70.3	74.8	71.3	74.9	67.6	74.8	69.9
#2 6:15 - 6:30	71.9	68.7	73.2	66.1	70.1	69.0	72.3	67.7	68.9	68.3	71.5	66.7
#3 6:30 - 6:45	72.2	68.4	73.7	65.0	68.8	68.8	71.3	66.8	67.1	67.1	69.9	65.5
#4 6:45 - 7:00	69.2	68.5	71.5	63.8	65.3	65.3	68.7	64.3	64.3	64.3	68.1	63.3
#5 7:00 - 7:15	69.9	68.0	72.7	64.3	67.0	67.0	71.1	67.1	67.5	67.5	71.5	66.5
#6 7:15 - 7:30	68.9	68.2	71.6	63.8	65.5	65.5	69.6	64.9	64.9	64.9	69.7	65.1
#7 7:30 - 7:45	61.8	61.8	65.0	58.1	46.0	42.8	28.0	58.1	58.1	62.8	35.4	58.1
#8 7:45 - 8:00	62.7	66.3	30.4	36.7	33.6	32.7	26.0	58.2	51.3	40.7	27.6	58.2
#9 8:00 - 8:15	53.7	36.8	21.7	47.9	44.1	49.6	28.5	40.1	35.8	35.0	27.5	58.2
#10 8:15 - 8:30	47.4	31.0	21.5	37.3	36.6	47.9	30.8	37.3	53.0	61.8	30.0	58.2
#11 8:30 - 8:45	60.5	26.0	14.5	14.8	4.5	2.6	1.0	22.7	74.1	68.7	74.8	70.0
#12 8:45 - 9:00	1.2	1.0	1.0	1.2	1.1	1.1	1.0	35.3	74.3	68.7	74.8	69.9
#13 9:00 - 9:15	1.5	1.4	1.2	1.5	1.2	1.2	1.0	35.3	74.3	68.6	74.8	70.1
#14 9:15 - 9:30	1.6	2.3	3.2	5.6	34.1	32.3	36.1	58.3	58.3	58.3	64.3	61.6
#15 9:30 - 9:45	22.2	32.1	22.8	39.8	38.9	58.2	64.0	59.7	59.7	59.7	64.4	60.6
#16 9:45 - 10:00	31.8	30.8	23.1	40.6	39.0	58.2	63.3	58.9	58.9	58.9	63.5	60.2
#17 10:00 - 10:15	31.3	31.1	22.9	39.8	38.9	58.2	63.3	74.8	57.7	34.4	50.4	64.4
#18 10:15 - 10:30	27.9	25.7	18.0	29.0	23.8	50.5	70.1	74.9	69.5	46.4	54.5	65.9
#19 10:30 - 10:45	20.9	20.9	15.7	24.3	22.9	50.5	70.8	67.7	68.3	68.2	71.1	67.0
#20 10:45 - 11:00	26.3	20.7	17.5	48.2	40.8	58.2	64.1	60.2	60.2	60.2	65.0	62.3

- After

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11	Seg. 12
#1 6:00 - 6:15	75.0	67.8	74.4	69.1	75.0	70.6	74.8	71.5	74.9	67.6	74.8	70.0
#2 6:15 - 6:30	71.9	68.7	73.2	66.9	71.4	69.2	73.3	69.0	71.4	68.4	73.2	67.6
#3 6:30 - 6:45	72.2	68.4	73.7	67.2	72.1	69.4	73.5	69.2	71.8	68.6	73.2	67.6
#4 6:45 - 7:00	69.2	68.5	71.5	66.0	69.0	69.0	71.3	67.9	68.8	68.3	71.3	66.8
#5 7:00 - 7:15	69.9	68.0	72.7	66.6	70.6	68.8	73.2	69.0	71.3	68.0	73.5	67.7
#6 7:15 - 7:30	68.9	68.2	71.6	66.1	69.1	68.7	72.0	68.3	69.7	67.9	72.7	67.3
#7 7:30 - 7:45	61.8	55.5	30.6	38.1	58.4	58.4	63.6	62.2	59.4	59.4	63.8	62.4
#8 7:45 - 8:00	57.1	32.4	22.5	36.4	58.2	58.2	62.6	61.2	58.2	58.2	62.4	60.9
#9 8:00 - 8:15	64.6	59.6	30.5	36.4	58.2	58.2	62.8	61.3	58.4	58.4	62.7	61.3
#10 8:15 - 8:30	65.7	65.7	60.4	36.7	58.2	58.2	62.9	61.5	58.6	58.6	63.6	62.2
#11 8:30 - 8:45	68.2	59.2	30.8	23.2	6.8	3.9	1.5	35.9	74.3	68.7	74.8	70.0
#12 8:45 - 9:00	2.5	1.2	1.1	1.3	1.3	1.3	1.2	36.1	74.3	68.7	74.8	70.0
#13 9:00 - 9:15	1.5	1.5	1.4	1.7	1.4	1.3	1.2	36.1	74.3	68.6	74.8	70.0
#14 9:15 - 9:30	2.3	3.8	4.4	8.1	36.2	38.7	62.2	61.2	58.2	58.2	64.2	62.8
#15 9:30 - 9:45	28.2	32.1	23.1	37.5	38.9	58.2	64.0	62.5	59.8	59.8	64.5	63.0
#16 9:45 - 10:00	31.3	31.2	22.7	37.5	39.0	58.2	63.3	61.9	59.1	59.1	63.7	62.2
#17 10:00 - 10:15	31.0	31.8	22.7	36.9	38.9	58.2	63.3	61.9	61.5	34.7	50.4	64.3
#18 10:15 - 10:30	27.8	28.6	18.8	26.9	23.8	50.5	70.1	67.2	71.7	44.9	53.3	65.0
#19 10:30 - 10:45	32.8	34.5	23.0	23.3	22.9	50.5	70.8	67.6	68.1	68.1	71.0	66.4
#20 10:45 - 11:00	74.1	69.0	54.8	44.0	58.3	63.9	68.1	66.1	64.8	64.8	68.4	65.1

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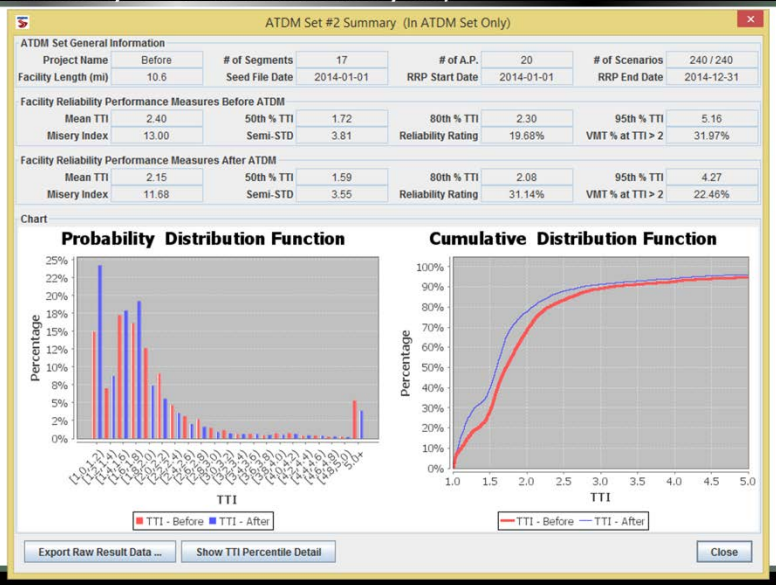
ATDM Analysis with ramp metering (Reliability Whole Year Analysis)



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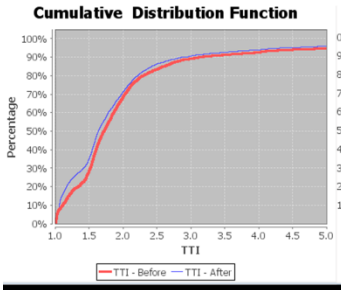
Impact of Temporal Operation of RMs on Reliability

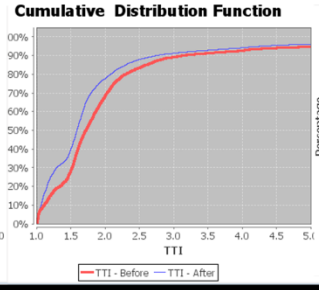
Numbers in the parenthesis show performance without any ramp metering

Temporal RM operation	8:30am to 9:30am	8am to 10am	7am to 10am
Mean TTI	2.23 (2.4)	2.16(2.4)	2.13(2.4)
80th TTI	2.22(2.3)	2.08(2.3)	1.99(2.3)
PTI (95th TTI)	4.38(5.16)	4.27(5.16)	4.42(5.16)

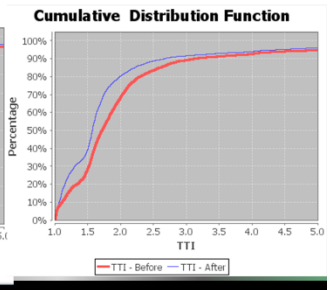
8:30 – 9:30AM



8:00 – 10:00AM



7:00 – 10:00AM



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FREEWAY ANALYSIS & SOFTWARE IN THE HCM 6TH EDITION: The Role Of Active Traffic Management Strategies

Nagui Rouphail, Ph.D.
Bastian Schroeder, Ph.D. P.E.
Behzad Aghdashi, Ph.D.

February 28, 2017

ITRE KITTELSON & ASSOCIATES, INC. TRANSPORTATION ENGINEERING/PLANNING

Workshop Schedule

9:30 am	9:45 am	- Signing in - Distribution of the course material - Introductions
9:45 am	10:30 am	- Overview of the new changes in the 6th edition of HCM
10:30 am	10:45 am	- Break
10:45am	12:00 pm	- Uninterrupted Flow Concepts, New material in Freeway Chapters (e.g. Managed Lanes, Reliability, ATDM, WZ)
12:00 pm	1:00 pm	- Lunch Break & Software Installation
1:00 pm	2:00 pm	- FREEVAL Demo with Hands-on Example, Segmentation, Calibration & Reliability Analysis
2:00 pm	2:30 pm	- FREEVAL-DSS Concepts and Demo
2:30 pm	2:45 pm	- Break
2:45 pm	3:45 pm	- FREEVAL-DSS Hands-on
3:45 pm	4:00 pm	- Questions, Feedback, and Evaluation

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S2: UNINTERRUPTED FLOW CONCEPTS & NEW MATERIAL IN FREEWAY CHAPTERS

3

HCM 6th Edition: New Analysis Capabilities

- Uninterrupted Flow
  - Reliability Analysis
  - Work Zone Analysis
  - New Truck Methodology
  - New Planning / Prelim. Engineering Methods
  - Managed Lanes
  - Active Traffic Management
  - Unified Speed-Flow Equation
  - Calibration Guidance
- Focus today on Freeway Facilities Methodology

Image Sources: Kittelson & Associates, ITRE

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HCM 6th Edition – Uninterrupted Flow Chapters

- Chapter 10: Freeway Facilities
- Chapter 11: Freeway Reliability Analysis
- Chapter 12: Basic Freeway and Multilane Highway Segments
- Chapter 13: Freeway Weaving Segments
- Chapter 14: Freeway Merge and Diverge Segments
- Chapter 25: Freeway Facilities Supplemental
- Chapter 26: Freeway and Highway Segments Supplemental
- Chapter 27: Freeway Weaving Supplemental
- Chapter 28: Freeway Merges and Diverges Supplemental

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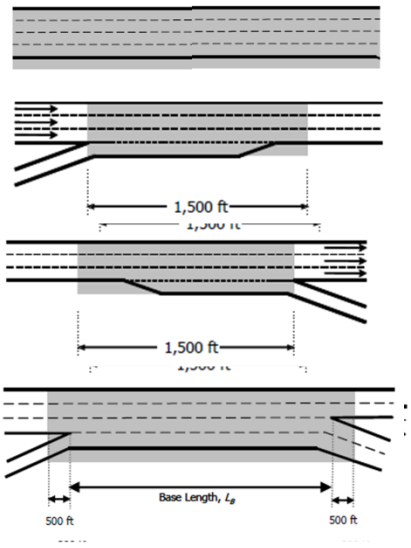
Why Analyze Freeways as Facilities?

Photo: Bastian Schroeder

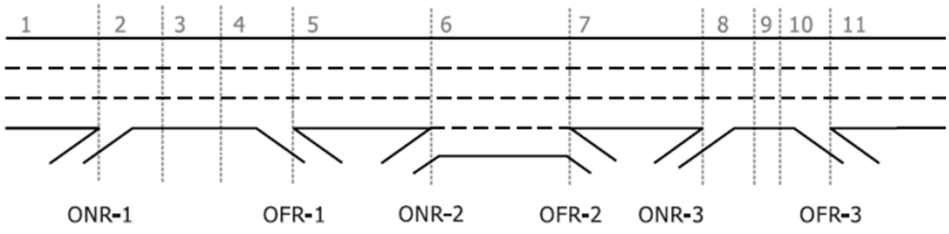
Existing: Core (single day) HCM Freeway Facilities

- **Distinguishes between Different Segment Types**
  - Basic Freeway Segments
  - Weaving Segments
  - On-ramp and Off-Ramp Segments
- **Extended Time-Space Domain**
  - Queue propagation between segments and over multiple time periods
- **Flow Regimes**
  - Under-saturated (**all** d/c<1.0)
  - Oversaturated (**any** d/c>1.0)
- **Capacity and Free-Flow Speed Calibration**
  - Work Zone Effects
  - Incidents and Weather
  - Capacity Reduction Due to Congestion
- **Implemented in Macroscopic FREEVAL Tool**



Existing: Core HCM Freeway Facilities

- Method combines the analysis of multiple segments along an extended length of a freeway (up to 10-15mi)
- Considers oversaturated conditions including queue spillback and effects on upstream and downstream flows
- Considers operations over multiple (15 min) contiguous analysis periods up to 24 hours



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Freeway Facility Methodology: Capabilities

- Enables the modeling of oversaturated & under-saturated conditions in an extended time-space domain (24 hrs. / 15 mi)
- Models the effect of all active and highlights hidden mainline bottlenecks
- Allows time-variant demands and capacities each 15 min
- Therefore, can model effect of incidents, weather and work zones
- Validated against field data and compared to microsimulation very favorably

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HCM 2010 Methodology Limitations

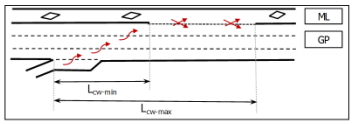
- Does not account for off-ramp congestion due to surface street control and spillback onto mainline
- Not reliable in reporting the effect of multiple overlapping queues
- Requires input manipulation for the analysis of extended facilities (free-flow travel time greater than 15 minutes)
- Requires extensive demand inputs in each time period – cannot map sensor data to demand
- Time consuming in manually segmenting the facility into HCM analysis segments

NEW CORE FREEWAY FACILITY MATERIAL
NEW CHAPTER 10

Updated Core Freeway Facilities (Chapter 10)

- New freeway work zone analysis method
- New managed lanes method
- New research on truck effects on freeway operations
- New guidance on evaluating ATDM strategies
- Improved guidance on segmenting freeway facilities
- New planning-level freeway analysis methodology
- New guidance on method calibration and validation

Image Source: Kittelson & Associates



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Integration of materials on work zones

Note: I-5, Los Angeles, California.

Exhibit 10-16
Example of Minimum Latera
Clearance in Work Zone

- Model for (indirectly) estimating work zone capacity:
  - Observed QDR→ Capacity Adjustment → Work Zone Capacity
- Model for estimating free flow speed in a work zones

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New Model for Work Zone Capacity

- Observed Queue Discharge Rate model depends on:
  - ***LCSI* = Lane closure severity index (next slide)**
  - f_{Br} = Indicator variable for **barrier type** (concrete vs. cone, drum)
  - f_{AT} = Indicator factor for **area type** (urban vs. rural)
  - f_{LAT} = **Lateral distance** from the edge of travel lane adjacent to the work zone to the barrier, barricades, or cones (0–12 ft);
  - f_{DN} = Indicator variable for **daylight or night** (0 for daylight)

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The Lane Closure Severity Index (LCSI)

- $LCSI = \frac{1}{OR \times N_o}$
  - *OR* = Open Ratio; ratio of the number of open lanes during work zone to the total (or normal) number of lanes.
  - N_o = Number of open lanes in the work zone.

Number of Total Lane(s)	Number of Open Lane(s)	Open Ratio	LCSI
3	3	1.00	0.33
2	2	1.00	0.50
4	3	0.75	0.44
3	2	0.67	0.75
4	2	0.50	1.00
2	1	0.50	2.00
3	1	0.33	3.00
4	1	0.25	4.00

Exhibit 10-15 Lane Closure Severity Index Values for Different Lane Closure Configurations

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Work Zone QDR and FFS Models

- **Queue Discharge Rate Model (pc/hr./lane):**
  - $QDR_{wz} = 2{,}093 - 154 \times LCSI - 194 \times f_{Br} - 179 \times f_{AT} + 9 \times f_{LAT} - 59 \times f_{DN}$
- Capacity is found by converting QDR to capacity (12%)
- **Free Flow Speed Model**
  - $FFS_{wz} = 9.95 + 33.49 \times f_{Sr} + 0.53 \times SL_{wz} - 5.60 \times LCSI - 3.84 \times f_{Br} - 1.71 \times f_{DN} - 8.7 \times TRD$

Ratio of non-WZ To WZ Speed Limit

WZ Speed limit

Total Ramp Density

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New Heavy Vehicle (HV) PCE, MFM estimation method

- Categorized into : Single-Unit Trucks (SUTs) Tractor-Trailers (TTs)
- Two methodologies to assess the effect of HV
  1. Traditional passenger-car-equivalent (PCE) factors to convert a mixed stream of cars and trucks to a single uniform PCE stream for purpose of analysis; when grades are light and truck % is low, and

Passenger Car Equivalent	Terrain Type	
	Level	Rolling
E_T	2.0	3.0

Exhibit 12-25 Passenger Car Equivalents for General Terrain Segments

  2. A new **M**ixed-**F**low **M**odel (MFM)that directly assesses the capacity, speed, and density of traffic streams that include a significant percentage of heavy vehicles operating on a single or composite grade.
     - MFM also must be used for mountainous terrain analysis

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Heavy Vehicle PCE's

- Specific Segment PCE values for a 30%/70% SUT/TT mix
- Tables are also available for a 50%/50% , 70%/30% mix
- Interpolate for other mixtures
- Extended tables to high % trucks
- Equation also available

% Grade	Length (mi)	Percentage of Trucks and Buses (%)								
		2%	4%	5%	6%	8%	10%	15%	20%	>25%
-2	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.625	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.875	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	1.25	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	1.5	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
0	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.625	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.875	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	1.25	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	1.5	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
2	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	3.76	2.96	2.78	2.65	2.48	2.38	2.22	2.14	2.09
	0.625	4.47	3.33	3.08	2.91	2.68	2.54	2.34	2.23	2.17
	0.875	4.80	3.50	3.22	3.03	2.77	2.61	2.39	2.28	2.21
	1.25	5.00	3.60	3.30	3.09	2.83	2.66	2.42	2.30	2.23
	1.5	5.04	3.62	3.32	3.11	2.84	2.67	2.43	2.31	2.23
2.5	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	4.11	3.14	2.93	2.78	2.58	2.46	2.28	2.19	2.13
	0.625	5.04	3.62	3.32	3.11	2.84	2.67	2.43	2.31	2.23
	0.875	5.48	3.85	3.51	3.27	2.96	2.77	2.50	2.36	2.28
	1.25	5.73	3.98	3.61	3.36	3.03	2.83	2.54	2.40	2.31
	1.5	5.80	4.02	3.64	3.38	3.05	2.84	2.55	2.41	2.32
3.5	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	4.88	3.54	3.25	3.05	2.80	2.63	2.41	2.29	2.22
	0.625	6.34	4.30	3.87	3.58	3.20	2.97	2.64	2.48	2.38
	0.875	7.03	4.66	4.16	3.83	3.39	3.12	2.76	2.57	2.46
	1.25	7.44	4.87	4.33	3.97	3.50	3.22	2.82	2.62	2.50
	1.5	7.53	4.92	4.38	4.01	3.53	3.24	2.84	2.63	2.51
4.5	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	5.80	4.02	3.64	3.38	3.05	2.84	2.55	2.41	2.32
	0.625	7.90	5.11	4.53	4.14	3.63	3.32	2.90	2.68	2.55
	0.875	8.91	5.64	4.96	4.50	3.92	3.56	3.07	2.82	2.67
	1	9.19	5.78	5.08	4.60	3.99	3.62	3.11	2.85	2.70
5.5	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	6.87	4.58	4.10	3.77	3.35	3.09	2.73	2.55	2.44
	0.625	9.78	6.09	5.33	4.82	4.16	3.76	3.21	2.93	2.77
	0.875	11.20	6.83	5.94	5.33	4.56	4.09	3.45	3.12	2.93
	1	11.60	7.04	6.11	5.47	4.67	4.18	3.51	3.17	2.97
6	0.125	2.62	2.37	2.30	2.24	2.17	2.12	2.04	1.99	1.97
	0.375	7.48	4.90	4.36	3.99	3.52	3.23	2.83	2.63	2.51
	0.625	10.87	6.66	5.79	5.21	4.46	4.01	3.39	3.08	2.89
	0.875	12.54	7.54	6.51	5.81	4.94	4.40	3.67	3.30	3.08
	1	13.02	7.78	6.71	5.99	5.07	4.51	3.75	3.37	3.14

Exhibit 12-26 PCEs for a Mix of 30% SUTs and 70% TTs

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Heavy Vehicle Treatment using MFM

- Treat the traffic stream as combined
- Under certain conditions, truck speeds affect auto speeds
- Can estimate auto, truck speeds and densities separately
- Uses a numerical simulation-based technique to estimate truck performance (speed, capacity, density) based on
  - Truck characteristics (Wt/HP ratio)
  - Grade %
  - Length of grade
- Computational engine available to carry out the process

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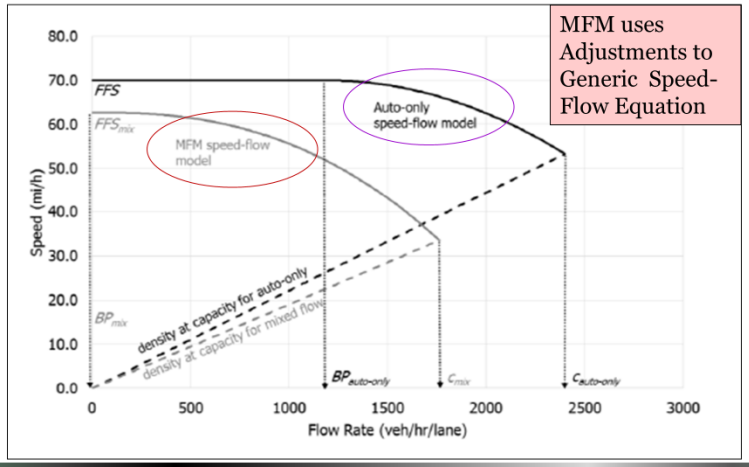
Heavy Vehicle Treatment in MFM

- For combinations that include steep grades and/or high truck percentages the mixed flow model (MFM) described in Volume 4 is recommended for computing mix flow speeds and densities and auto and truck speeds in a mixed traffic stream



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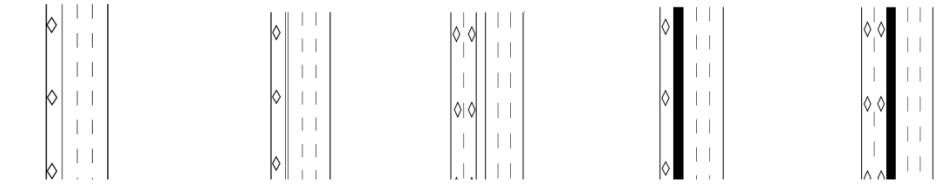
Integration of materials on managed lanes

- Incorporated five basic managed lane segment types:



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Managed Lane Capacities

- Managed lane capacities (actually maximum observed flows) for different separation types

FFS (mi/h)	Estimate Lane Capacities for Basic Managed Lane Segment Type (pc/h/ln)				
	Continuous Access	Buffer 1	Buffer 2	Barrier 1	Barrier 2
75	1,800	1,700	1,850	1,750	2,100
70	1,750	1,650	1,800	1,700	2,050
65	1,700	1,600	1,750	1,650	2,000
60	1,650	1,550	1,700	1,600	1,950
55	1,600	1,500	1,650	1,550	1,900

Exhibit 12-11 Estimated Lane Capacities for Basic Managed Lane Segments

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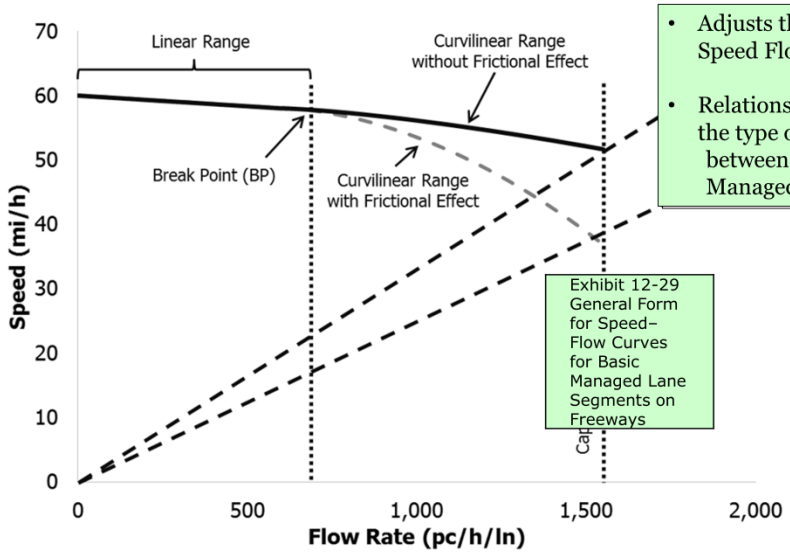
Managed Lanes – Speed Flow Curves Including the Effect of Adjacent GP Lanes Friction Effect



- Adjusts the Generic Speed Flow Equation
- Relationship depends of the type of separation between GP and Managed Lanes

Exhibit 12-29 General Form for Speed–Flow Curves for Basic Managed Lane Segments on Freeways

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New guidance on calibration and validation

- Why Calibrate ?
  1. To make sure that the method reflects real-world conditions
  2. As a prelude to any testing of proposed strategies
- Calibration is performed sequentially at three levels
  1. At the core freeway facility level (Chapter 10)
  2. At the reliability analysis level, (Chapter 11) and
  3. At the Active Traffic and Demand Management (ATDM) strategy assessment level (Chapter 11)

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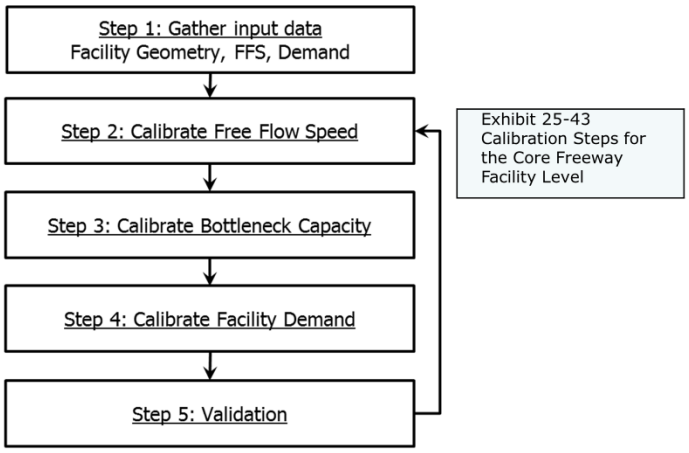
New Guidance on Calibration and Validation:

- Calibration at the core freeway facility level



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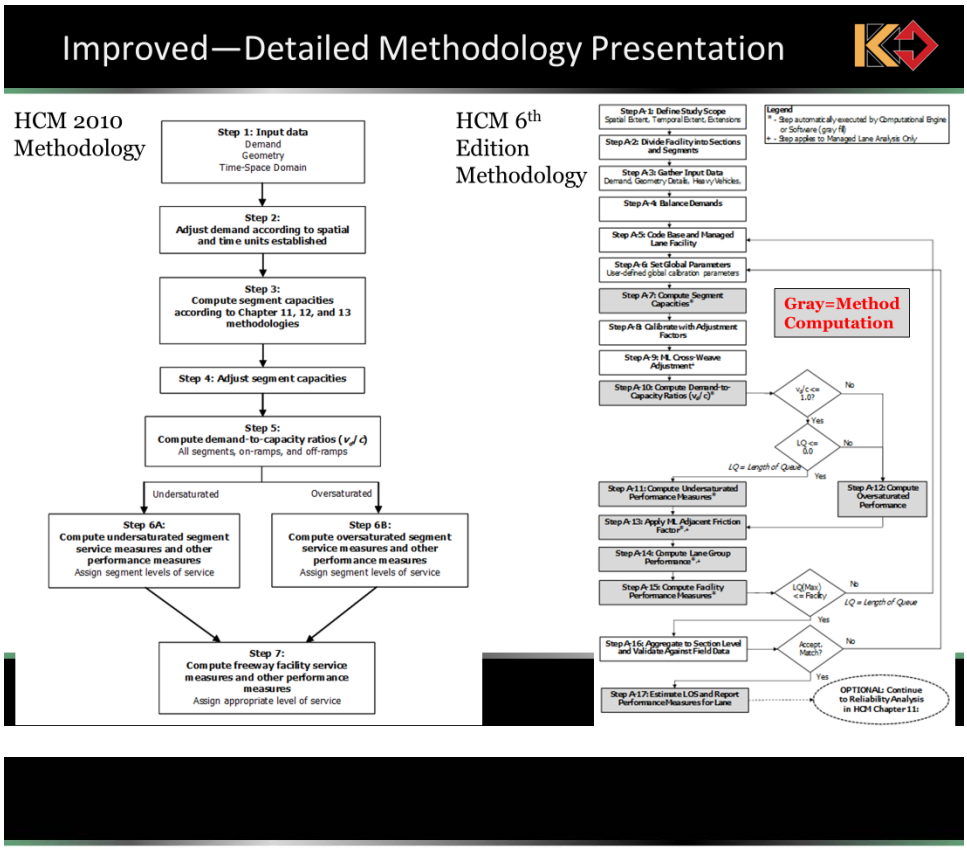
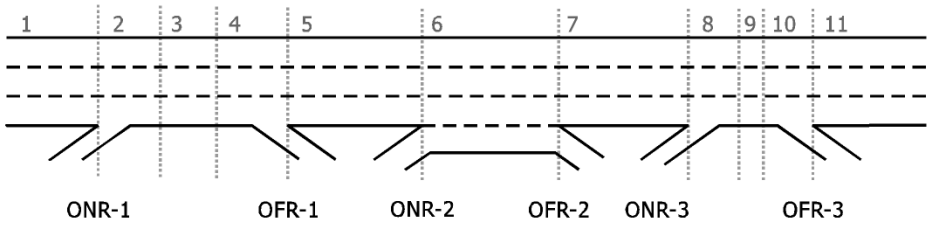


CORE FREEWAY FACILITIES EXAMPLE

Evaluation of an Oversaturated Facility



Segment No.	1	2	3	4	5	6	7	8	9	10	11
Segment type	B	ONR	B	OFR	B	B or W	B	ONR	R	OFR	B
Segment length (ft)	5,280	1,500	2,280	1,500	5,280	2,640	5,280	1,140	360	1,140	5,280
No. of lanes	3	3	3	3	3	4	3	3	3	3	3

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Evaluation of an Oversaturated Urban Freeway Facility

- The Facts:
  - Single Unit Trucks and Buses = 1.25% (all movements);
  - Mainline Tractor Trailers = 1.00% (all movements);
  - Driver population → regular commuters;
  - *FFS* = 60 mi/h (all mainline segments);
  - Ramp *FFS* = 40 mi/h (all ramps);
  - Acceleration lane length = 500 ft (all ramps);
  - Deceleration lane length = 500 ft (all ramps);
  - D_{jam} = 190 pc/mi/ln;
  - L_s = 1,640 ft (for Weaving Segment 6);
  - *TRD* = 1.0 ramp/mi;
  - Terrain = level;
  - Analysis duration = 75 min (divided into five 15-min time steps); and
  - Demand adjustment = +11% increase in demand volumes across all segments and time steps compared with Example Problem 1.
  - A queue discharge capacity drop of 7% is assumed.

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Evaluation of an Oversaturated Facility

- Step A3: Input Data
  - Traffic demand

Time Step (15 min)	Entering Flow Rate (veh/h)	Ramp Flow Rates by Time Period (veh/h)						Exiting Flow Rate (veh/h)
		ONR1	ONR2*	ONR3	OFR1	OFR2	OFR3	
1	5,001	500	599 (56)	500	600	400	300	5,600
2	5,500	599	799 (111)	599	400	400	300	6,399
3	5,800	699	899 (167)	699	300	400	500	6,899
4	5,200	400	400 (89)	500	300	400	300	5,500
5	4,201	200	300 (56)	300	300	200	200	4,301

- Step A7: Compute segment capacities

Time Step	Capacities (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1						8,273					
2						8,281					
3	6,748	6,748	6,748	6,748	6,748	8,323	6,748	6,748	6,748	6,748	6,748
4						8,403					
5						8,463					

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Evaluation of an Oversaturated Facility

- Step A10: Compute demand-to-capacity ratio

Time Step	Demand-to-Capacity Ratios by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	0.74	0.82	0.82	0.82	0.77	0.7	0.8	0.87	0.87	0.87	0.83
2	0.82	0.9	0.9	0.9	0.84	0.78	0.9	0.99	0.99	0.99	0.95
3	0.86	0.96	0.96	0.96	0.92	0.85	0.99	1.1	1.1	1.1	1.02
4	0.77	0.83	0.83	0.83	0.79	0.68	0.79	0.86	0.86	0.86	0.82
5	0.62	0.65	0.65	0.65	0.61	0.52	0.62	0.67	0.67	0.67	0.64

- Step A12: Compute Segment Volume served and Speeds

Time Step	Volumes Served (veh/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	5,001	5,500	5,500	5,500	5,200	5,800	5,400	5,900	5,900	5,900	5,600
2	5,500	6,099	6,099	6,099	5,700	6,499	6,099	6,699	6,699	6,699	6,399
3	5,800	6,499	6,499	6,499	5,831	6,281	5,584	6,284	6,284	6,284	5,859
4	5,200	5,600	5,600	5,600	5,668	6,311	5,776	6,276	6,276	6,276	5,934
5	4,201	4,401	4,401	4,401	4,102	4,608	4,840	5,140	5,140	5,140	4,912

Time Step	Speed (mi/h) by Segment										
	1	2	3	4	5	6	7	8	9	10	11
1	59.8	53.2	58.6	55.9	59.5	46.8	59	52.5	52.5	55.7	58.3
2	58.6	52.1	55.8	55.5	57.9	45.4	55.8	50.6	50.6	51.5	53.9
3	57.4	51.1	53.1	53.1	45.3	24.2	28.1	51.6	51.6	54.7	57.1
4	47.2	47.5	51.5	48.3	56.5	24.7	29.6	51.7	51.7	54.7	56.8
5	60	54.5	59.7	56.2	60	51.4	50.9	53.7	53.7	56.1	59.9

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Evaluation of an Oversaturated Facility

- Step A12: Compute Density and d/C Based Segment LOS

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11
#1 17:00 - 17:15	D	D	D	D	D	D	D	D	E	D	D
#2 17:15 - 17:30	D	D	E	D	D	E	E	E	E	D	E
#3 17:30 - 17:45	D	D	E	D	E	F	F	D	E	D	E
#4 17:45 - 18:00	D	E	E	E	D	F	F	D	E	D	E
#5 18:00 - 18:15	C	C	C	C	C	C	D	C	D	C	C

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11
#1 17:00 - 17:15											
#2 17:15 - 17:30											
#3 17:30 - 17:45								F	F	F	F
#4 17:45 - 18:00											
#5 18:00 - 18:15											

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FREEWAY RELIABILITY AND ATDM NEW CHAPTER 11

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Chapter 11 – Freeway Reliability Analysis

- Standalone, new chapter in HCM 6th Edition
- Description of the computational steps is very detailed and explains whether user or software needs to execute a given step
- A very efficient scenario generation process for freeway reliability analysis using few scenarios to account for a variety of operating and external conditions
- Implemented in software in FREEVAL-2015e

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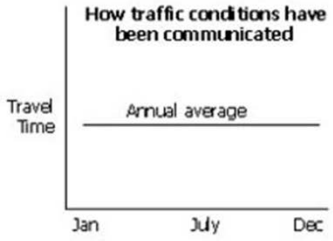
Introduction – Reliability and ATDM



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Sources of (Un)Reliability

- Traffic Demand Variations (TOD, DOW, etc.)
- Incidents (Crashes, Stalls, Debris, and etc.)
- Severe Weather Conditions
- Significant Work Zones
- Demand Surges (special events)

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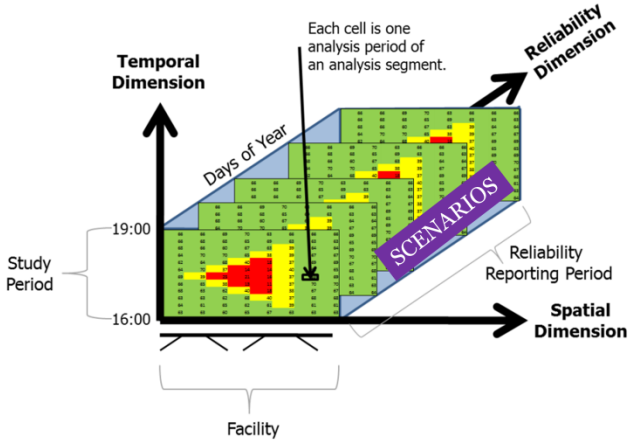
Reliability Analysis in the HCM



Source: Zegeer et al. (1)

Exhibit 11-1
Schematic Representation of Freeway Reliability Analysis Time–Space Domain

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Travel Time Distribution for Reliability Analysis

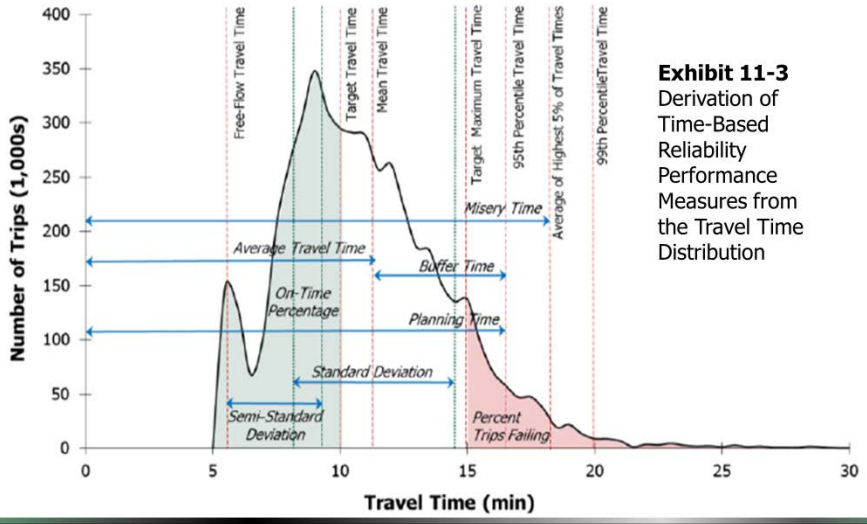

Exhibit 11-3
Derivation of Time-Based Reliability Performance Measures from the Travel Time Distribution

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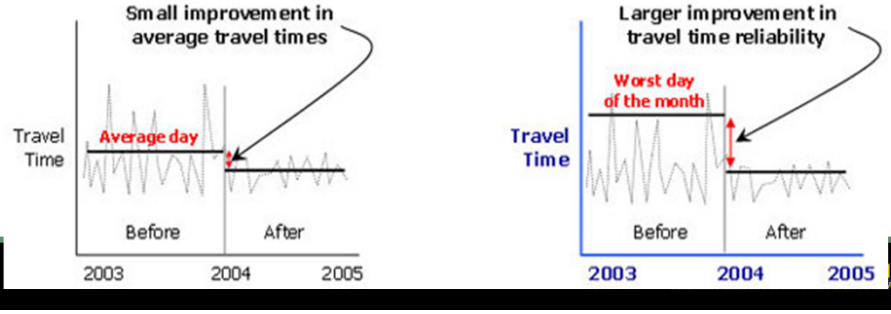
Active Traffic Management

- HCM 2010 can evaluate the effect of the Active Transportation and Demand Management (ATDM) strategies on *average travel times –**NOT** individual trips* (or any other *average* performance measure).
- ATDM analysis in the *6th edition of HCM*, provides a framework to evaluate reliability-level impacts of ATDM strategies.
- This is carried out as an extension to the travel time reliability methodology.



Recurring and Non-Recurring Sources of Congestion in HCM 6th Ed. Reliability Analysis

- What are the sources for variation in travel time?
  - Recurring Sources
    - Traffic Demand Cyclical Variations by TOD, DOW, MOY, etc.
  - Non-Recurring Sources
    - Incidents (Crashes, Stalls, and etc.)
    - Severe Weather Conditions
    - Work Zones
    - Demand Surges (special events)
- Demand is allowed to vary in each 15 min analysis period

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Scenario Generation

- *The 6th edition of HCM* uses an enhanced scenario generation approach compared to the SHRP2-L08 method.
- The revised method requires fewer number of scenarios but with higher quality.
- Method uses both deterministic and stochastic modeling in an optimization scheme to generate scenarios.

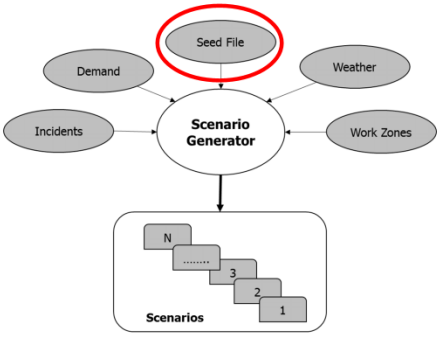

Exhibit 11-4
Schematic of the Freeway Scenario Generation Process and Impacting Factors

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Replication of Scenarios

- The current scenario generation approach sets a combination of a given weekday and a month (e.g. Tuesday in April) as its base element; it then replicates this combination several times.
- The recommended number of replications is a function of the duration of the reliability reporting period (RRP), typically one year

Exhibit 11-9
Recommended Number of Replications for Scenario Generation

RRP Duration (months)	Number of Days Considered	Recommended Number of Replications	Resulting Number of Scenarios
1	5 (all weekdays)	48	240
2	5	24	240
4	5	12	240
6	5	8	240
9	5	6	270
12*	5	4*	240*
12	2 (weekend only)	10	240
12	7 (all days)**	3	252

Notes: RRP = reliability reporting period.
*Default value.
**Not desirable; separating weekday and weekend reliability analysis is preferred.

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Representing Scenarios in Facility Time-Space Domain

- Each Scenario (which is a Day-Month replication) may contain several non-recurring events.
- Overlap between different types of events is allowed
- Example shows a single scenario with the effects of a rain event (R) lasting 45 min, a two-lane closure incident (I-2) lasting one hour

Analysis Period	Segment Number									
	1	2	3	4	5	6	7	8	9	10
1										
2										
3	R	R	R	R	R	R	R	R	R	R
4	R	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R and I-2	R	R
6								I-2		
7								I-2		
8								I-2		
9										
10										
11			I-S							
12										

Exhibit 11-5
Scenario Illustrating Weather and Incident Events

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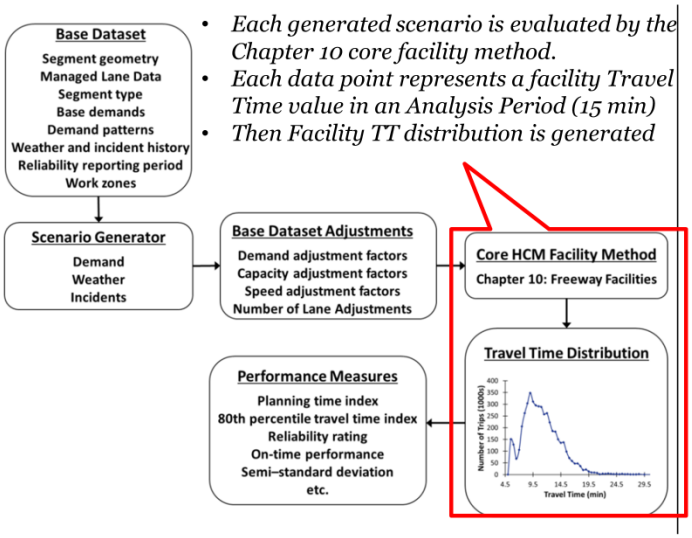
Evaluation of Scenarios and Methodology Outputs

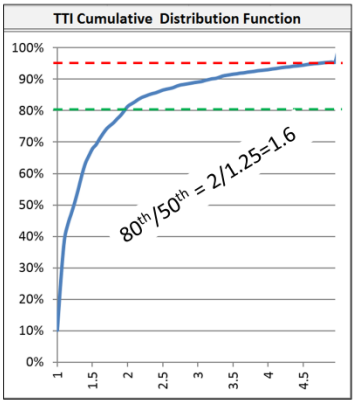


- *Each generated scenario is evaluated by the Chapter 10 core facility method.*
- *Each data point represents a facility Travel Time value in an Analysis Period (15 min)*
- *Then Facility TT distribution is generated*

Exhibit 11-7
Freeway Reliability
Methodology Framework

Reliability Performance Measures

- Reliability analysis produces " **reliability performance measures**" that include the impact of recurring and non-recurring sources of congestion.
- All performance measures are based on the estimated travel time distribution.
- To normalize and enable comparisons across facilities, travel times are divided by the free flow travel time resulting in **Travel Time Index (TTI)** distribution.



Reliability Performance Measures from the TTI Distribution

- Key Reliability Performance Measures from TT Distribution
  - **Mean TTI**
  - **95th % TTI (Planning Time Index)**
  - **80th % TTI**
  - **50th % TTI (Median)**
  - **Level of Travel Time Reliability (LOTTR)= 80th / 50th**
  - Reliability Rating – *how often the facility performs satisfactorily defined as the fraction of facility VMT operating below a TTI of 1.33*
  - Failure and on-time measures (%)
  - Misery Index - *average of the worse 5% TTI's*
  - Semi-Standard Deviation– *standard deviation from TTI=1*
  - Standard Deviation
  - %VMT at TTI>2
    - Percent vehicle-miles traveled at TTI greater than 2

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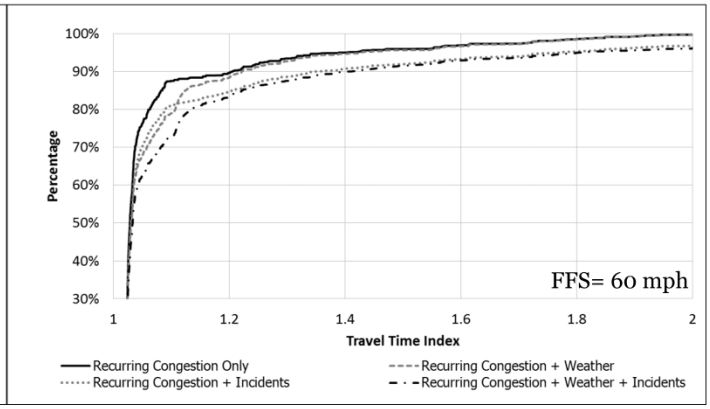
Illustrating the Effect of Different Sources on Reliability

Exhibit 11-14
Illustrative Effects of Different Non-Recurring Sources of Congestion on the TTI Distribution



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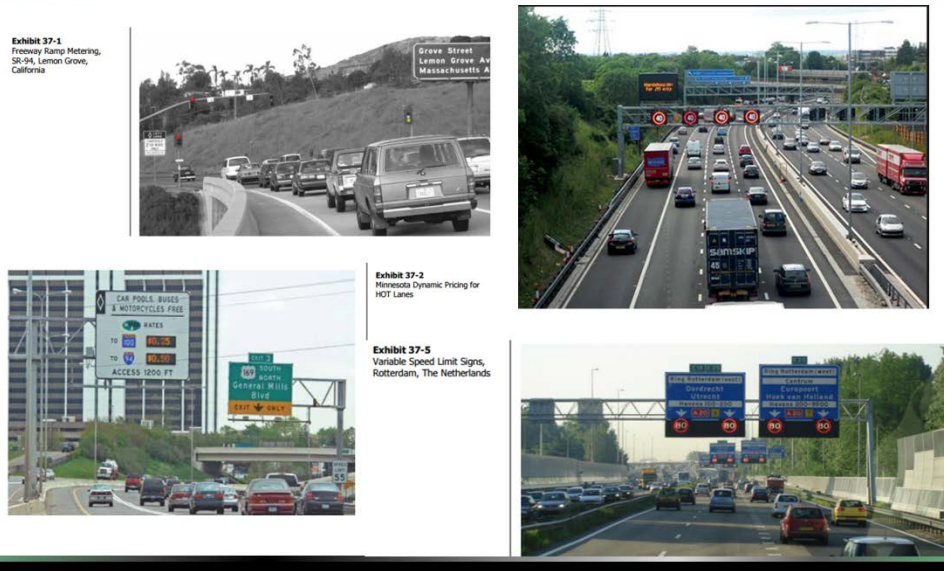
Evaluation of ATDM Strategies



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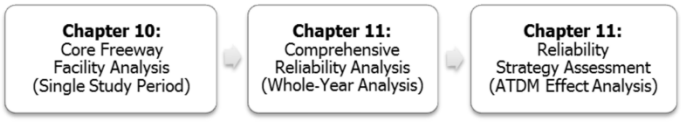
ATDM Analysis in the 6th edition of HCM

- The methodology allows the user to select a subset of reliability scenarios for ATDM analysis (since their implementation must be situation-specific)
- The user may select reliability scenarios that will most benefit from some type of ATDM treatment
- This enables the methodology to report improvements in traffic conditions using the reliability performance measures.

Exhibit 11-6
Process Flow for ATDM Implementation for Freeway Facilities



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ATDM Strategies and Plans

- Analysts may bundle one or many ATDM strategies into a ATDM plan
- ATDM plans can be assigned to specific ATDM scenarios.
- The HCM 6th Edition contains five different ATDM strategies categories:
  - *Demand Management*
  - *Weather Management*
  - *Incident Management*
  - *Work Zone Management*
  - *Special Segment-Specific Strategies*
- Different ATDM strategy categories are intended to target certain portions of the ATDM scenario (weather, incident, etc.)

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UPDATES TO FREEWAY SEGMENT CHAPTERS

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Chapter 12: Basic Freeway and Multilane Highway Segments

- Basic freeway segments and multilane highways merged into a single Chapter 12
- One unified speed–flow equation for all basic and multilane highway segments (same equation form used also for managed lanes and truck adjustments)
- Added emphasis on calibration through capacity and speed adjustment factors (CAFs and SAFs).
- New research is incorporated on truck effects on freeway operations, which has resulted in revised truck passenger car equivalent (PCE) tables and service volume tables.
- Methods for evaluating basic managed lane segments is integrated into the chapter.

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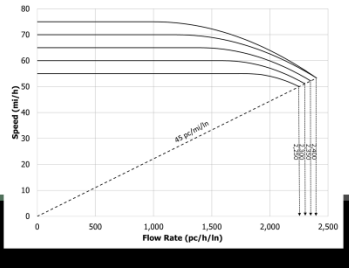
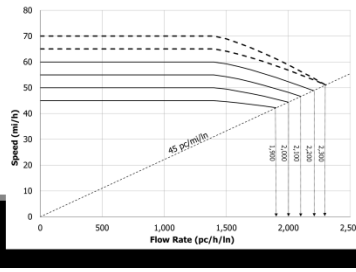
Basic Freeway and Multilane Highway Segments

- Basic freeway segments and multilane highways merged into a single Chapter 12
- One unified speed–flow equation for all basic and multilane highway segments (same equation form used also for managed lanes and truck adjustments)

- Freeways



Multilane Highways



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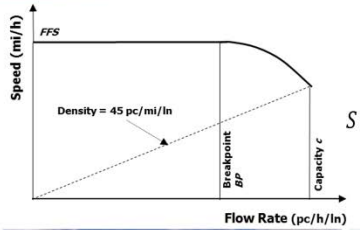
Unified Speed–Flow Equation & Calibration Guidance



$$S = FFS_{adj} \qquad v_p \leq BP$$

$$S = FFS_{adj} - \frac{\left(FFS_{adj} - \frac{c_{adj}}{D_c}\right)\left(v_p - BP\right)^a}{\left(c_{adj} - BP\right)^a} \qquad BP < v_p \leq c$$

Image Source: Kittelson & Associates

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Chapter 13 – Freeway Weaving Segments

- Incorporates the methods for evaluating managed lane weaving segments, managed lane access segments, and cross-weave effects

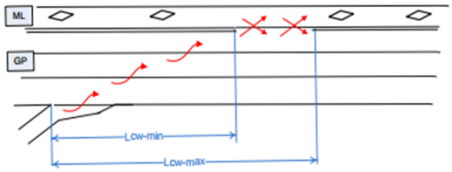

Exhibit 13-12
Weaving Movements Associated with Managed Lane Access and Egress

- Emphasis on calibration through the application of CAFs and SAFs
- Chapter 27, Freeway Weaving: Supplemental, includes new example problems that illustrate the new methods

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Chapter 14: Merge and Diverge Segments

- Integrates method for evaluating managed lane merge and diverge segments

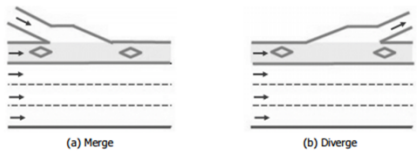
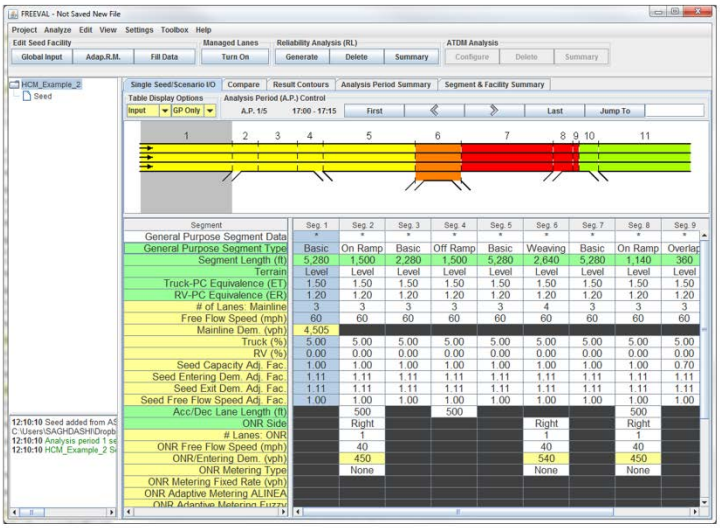


Exhibit 14-22
Direct Ramp Access to Managed Lanes

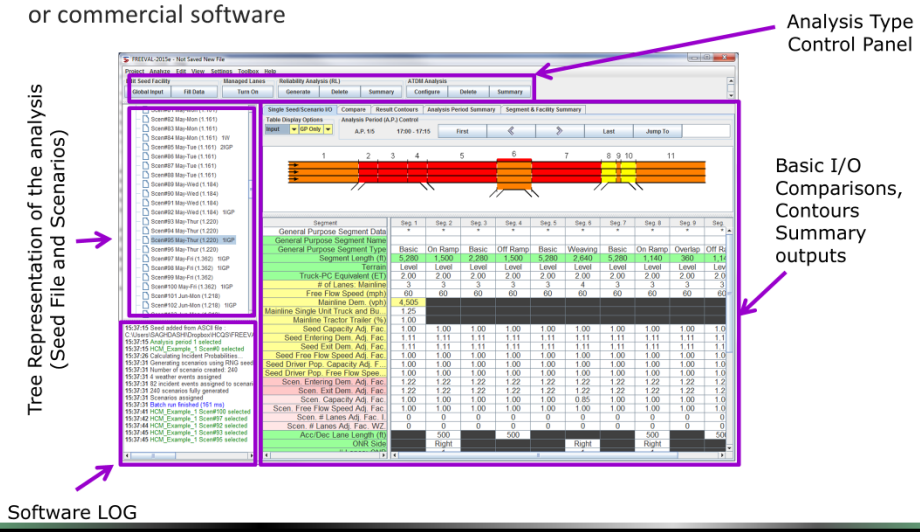
- Provides new formalized guidance for aggregating merge and diverge segment densities for segments with three or more lanes
- Chapter 28, Freeway Merges and Diverges: Supplemental, includes new example problems that illustrate the new methods

FREEVAL Computational Engine



Scenario Layout in FREEVAL Computational Engine

- Computations are automated in a computational engine (FREEVAL-2015E) or commercial software



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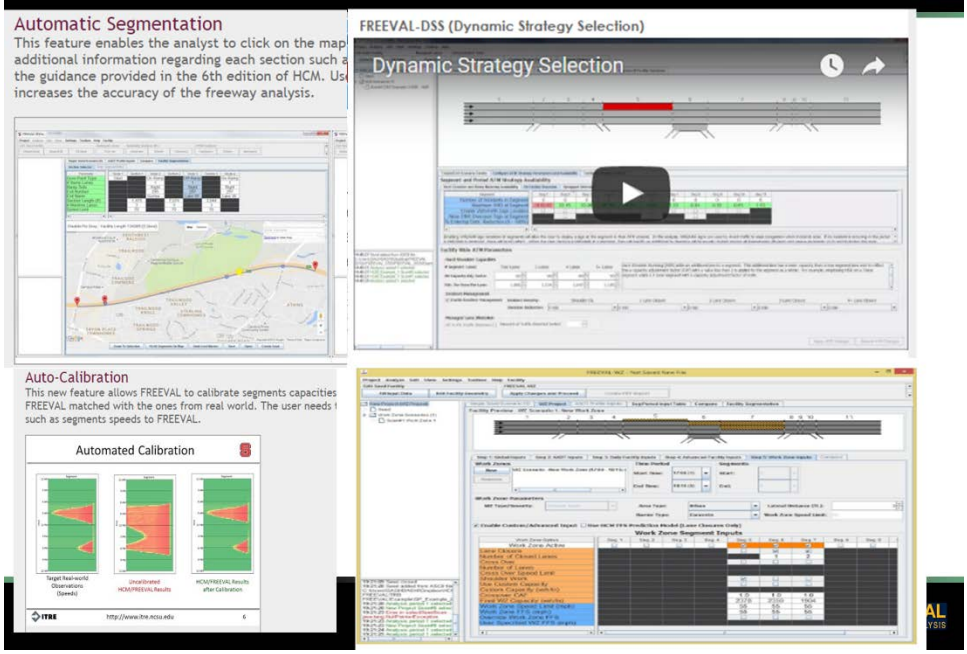
Website: http://FREEVAL.org



FREEWAY ANALYSIS & SOFTWARE IN THE HCM 6TH EDITION: The Role Of Active Traffic Management Strategies

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February 28, 2017

ITRE KITTELSON & ASSOCIATES, INC. TRANSPORTATION ENGINEERING/PLANNING

1 HIGHWAY CAPACITY MANUAL 6TH EDITION | A GUIDE FOR MULTIMODAL MOBILITY ANALYSIS

Workshop Overview

9:30 am	9:45 am	- Signing in - Distribution of the course material - Introductions
9:45 am	10:30 am	- Overview of the new changes in the 6th edition of HCM
10:30 am	10:45 am	- Break
10:45am	12:00 pm	- Uninterrupted Flow Concepts, New material in Freeway Chapters (e.g. Managed Lanes, Reliability, ATDM, WZ)
12:00 pm	1:00 pm	- Lunch Break & Software Installation
1:00 pm	2:00 pm	- FREEVAL Demo with Hands-on Example, Segmentation, Calibration & Reliability Analysis
2:00 pm	2:30 pm	- FREEVAL-DSS Concepts and Demo
2:30 pm	2:45 pm	- Break
2:45 pm	3:45 pm	- FREEVAL-DSS Hands-on
3:45 pm	4:00 pm	- Questions, Feedback, and Evaluation

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FREEVAL DEMO
CORE AND RELIABILITY METHOD

3

FREEVAL Releases

FREEVAL 2015-E	• Integrates all HCM Freeway Chapters (Core Method as described earlier) • Managed lanes, Reliability, ATDM	Available for Download
FREEVAL - WZ	• NCDOT sponsored planning-level interface (demand profiles) • Explicit modeling of work zone scenarios and user cost • Customized report generation functionality	Available for Download
FREEVAL-DSS	• Dynamic Strategy Selection (DSS) for ATDM strategy implementation • Modeler and operator modes to assess reaction to congestion in near real-time	Available for Download
FREEVAL-IAP	• Mapping tools for easy segmentation • AADT and hourly demand profile data entry • Segment based reliability MOEs	Available for Beta Testing
FREEVAL+	• Integrates all Prior Features and additional customization • Adds Google Map Integration for Segmentation • Enhanced ATDM Interface (Ramp Metering, Hard Shoulder Running, etc.)	Available for Beta Testing

http://freeval.org

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This Sessions Goals!

- To model a sample facility in FREEVAL+
  - Going over basic procedures
- To analyze it via HCM methods
  - Interpret operational conditions of the facility in FREEVAL+
- Prepare for next session
  - How to create example facility for DSS analysis

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Download and Install FREEVAL

- You can download FREEVAL from http://freeval.org
- FREEVAL+ version is under development and can be downloaded for beta testing. In this section we will use this version.
- FREEVAL's zip file needs to be **extracted** after downloading.
- Java Runtime Environment 8 and later is needed to execute FREEVAL.
- https://java.com/en/download/

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Hands-on Example (I-80 EB in CA)

- I-80 East Bound Direction in Solano County CA.
- Spatial scope is from Chad Bourne Rd toward Manuel Compos Rd.
  - From 38.235398, -122.102487
  - To 38.310433, -122.033184
- Temporal scope is PM peak from 3pm to 7pm.
- This facility has a recurring congestion near Manuel Campos Rd due to a lane drop.
- There is one HOV lane in this facility, however, for now we will ignore this lane and will treat that as a regular general purpose lane.

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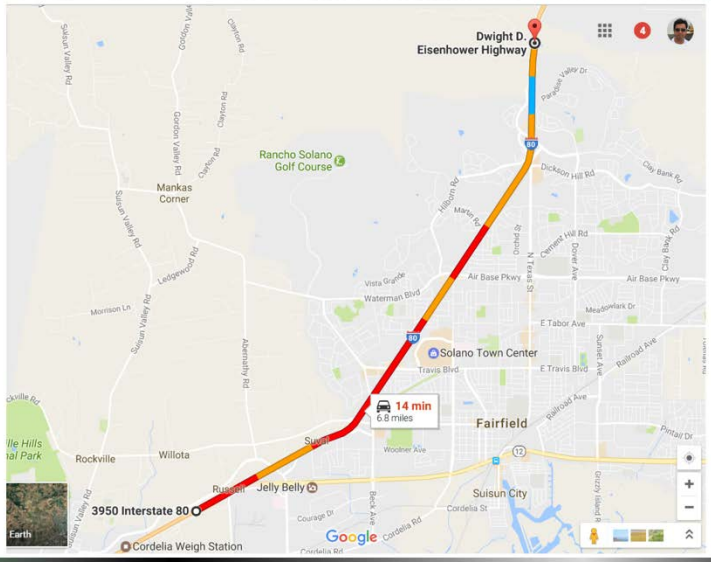
I-80 EB Facility in CA (Spatial Scope)



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Typical observed weekday speed contour

	Red Top Road On-ramp to SR12 Merge Interchange	SR12 Merge Interchange to Green Valley Road Off-ramp	Green Valley Road Off-ramp to I-680 Merge Interchange	I-680 Merge Interchange to Pitman Road Off-ramp	Pitman Road Off-ramp to Pitman Road On-ramp	Pitman Road On-ramp to Weigh Station Off-ramp	Weigh Station Off-ramp to Weigh Station On-ramp	Weigh Station On-ramp to SR12 EB Exit Off-ramp	SR12 EB Exit Off-ramp to Suisun Parkway Off-ramp	Suisun Parkway Off-ramp to Suisun Parkway On-ramp	Suisun Parkway On-ramp to W Texas Street Off-ramp	W Texas Street Off-ramp to Auto Mall Parkway On-ramp	Auto Mall Parkway On-ramp to Beck Avenue On-ramp	Beck Avenue On-ramp to Travis Boulevard Off-ramp	Travis Boulevard Off-ramp to Travis Boulevard On-ramp	Travis Boulevard On-ramp to Air Base Parkway Off-ramp	Air Base Parkway Off-ramp to Air Base Parkway On-ramp	Air Base Parkway On-ramp to Manuel Campos Road Off-ramp	Manuel Campos Road Off-ramp to Manuel Campos Road On-ramp	Manuel Campos Road On-ramp to Lagoon Valley Road Off-ramp	Lagoon Valley Road Off-ramp to Lagoon Valley Road On-ramp
Wednesday, May 14, 2014																					
15:00	61	64	67	71	69	68	67	67	67	69	70	70	64	62	63	64	66	65	65	64	72
15:15	63	66	66	57	54	60	62	63	64	63	63	63	57	59	59	59	64	60	64	65	74
15:30	66	67	68	67	63	64	63	65	63	69	69	65	64	59	62	59	57	55	63	63	71
15:45	58	62	62	60	54	61	65	65	66	66	68	67	65	66	66	65	48	36	54	56	70
16:00	70	71	70	72	69	71	71	69	71	71	71	71	67	61	63	63	64	30	58	64	70
16:15	64	62	64	65	59	60	62	64	63	62	62	61	59	61	62	59	35	26	57	60	71
16:30	59	62	64	64	64	66	66	67	67	69	69	67	65	62	60	34	20	22	55	58	72
16:45	64	68	64	61	62	66	71	72	72	72	70	73	70	46	21	36	34	23	61	61	66
17:00	65	67	66	66	65	66	65	66	69	68	67	65	57	34	20	31	37	34	56	59	73
17:15	59	60	62	65	64	64	64	66	61	20	34	24	24	47	37	35	42	33	56	60	71
17:30	66	74	71	70	69	66	67	70	46	58	65	69	34	51	47	34	41	28	55	49	73
17:45	67	71	71	71	71	71	70	69	66	66	65	66	66	53	35	31	38	29	49	58	70
18:00	62	64	62	64	66	68	69	70	71	71	72	69	67	68	67	62	43	22	55	60	72
18:15	68	71	71	74	69	67	68	71	72	70	71	72	70	69	67	71	73	68	65	64	69
18:30	69	73	70	68	68	66	67	69	71	71	68	69	68	68	66	67	72	72	70	66	72
18:45	60	63	63	65	65	68	72	72	69	69	70	68	69	68	69	69	67	65	66	60	70

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HCM Analysis Steps

- Step 1: Core (Single Day) Analysis
  - Determine Temporal and Spatial Scopes
  - Facility Segmentation
  - Demand Data Entry
  - Execution of Core Method and Interpret Results
- Step 2: Reliability (Whole Year) Analysis
  - Model Non-recurring Sources of Congestion (Incidents and Weather Conditions)
  - Generate and Evaluate Reliability Scenarios
  - Interpret Reliability Performance Measures

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Segmentation

- Segmentation guidance exists in HCM6 Chapter 10.
- In this workshop we will use FREEVAL auto-segmentation wizard.
- Select “Facility Creator” from “Facility” Menu.
- Drop pins on facilities start, end and gore points.
- Enter number of lanes for each section.
- Additional information such as mile posts and exit names are recommended to be filled.

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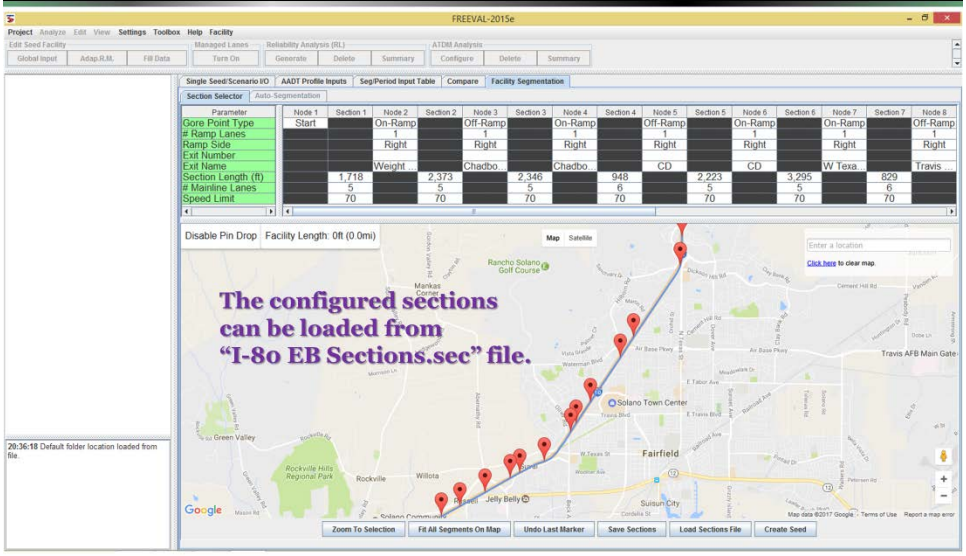
Identified 14 sections in Facility Creator



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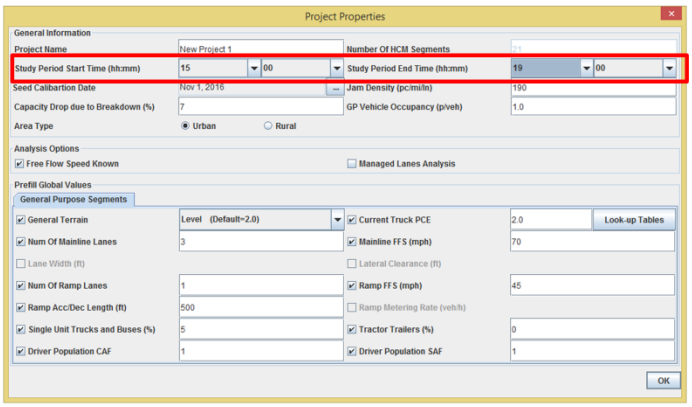
Create Seed

- After completion of sections identification, press "create seed" button to create facility geometry in the seed file.
- Select 3 pm to 7 pm as your temporal analysis period.



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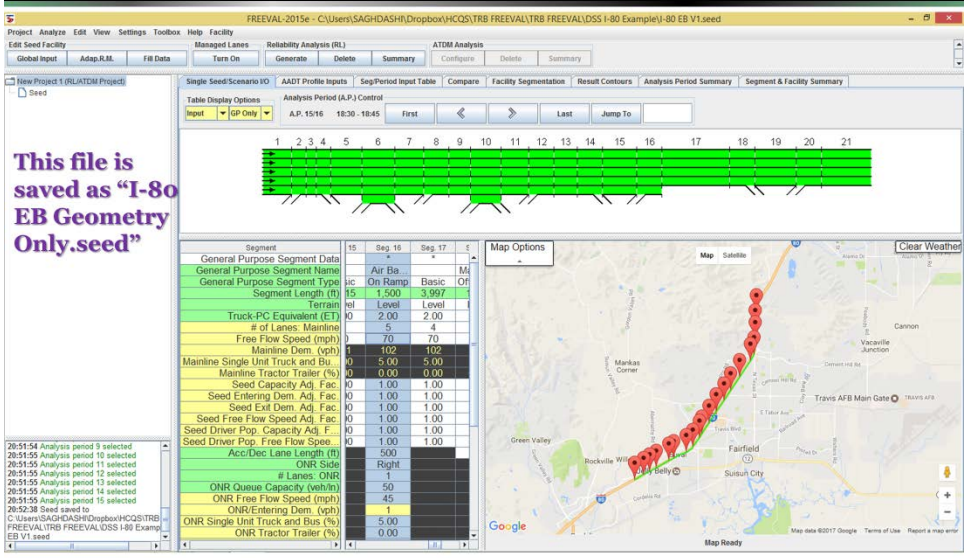
I-80 EB HCM Segmentation in FREEVAL



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Enter Demand Data

- In this example, we will use AADTs for freeway mainline entry, on-ramps and off-ramps (Next Slide).
- Also, hourly distributions will be used to breakdown AADT traffic into 15 minutes hourly flow rates. *(FREEVAL's bimodal-PM Peak average profile)*
- Resulting FREEVAL predicted speeds (Uncalibrated) should be comparable to the observed real-world.
- For further tune ups, "*Calibration Procedure*" should be used (Not for this workshop).

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AADTs for I-80 EB Facility

- These are the AADT values that needs to be entered in FREEVAL.
  - Right now mainline AADT 200,000 (50% directional split)
  - All ONRs 8400
  - All OFRs 10000

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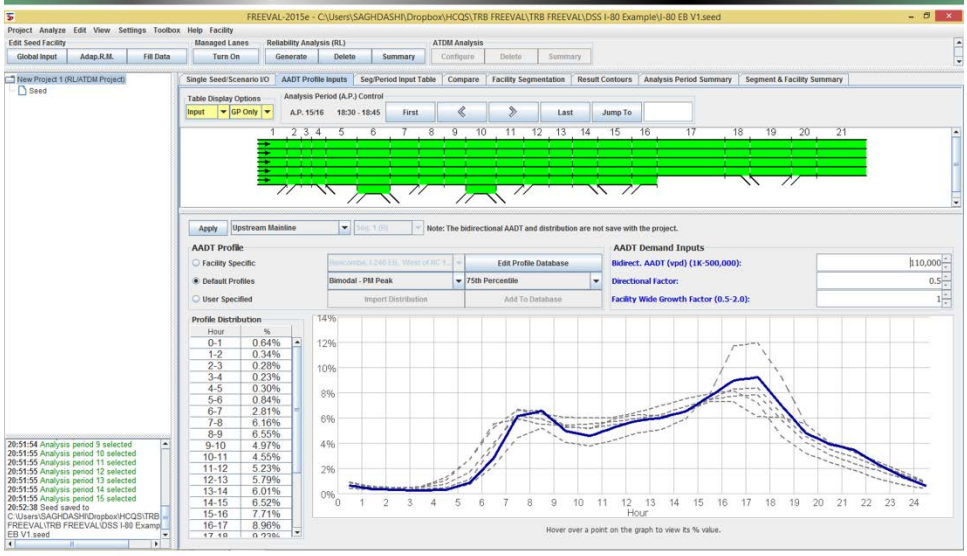
AADT Data Entry in FREEVAL



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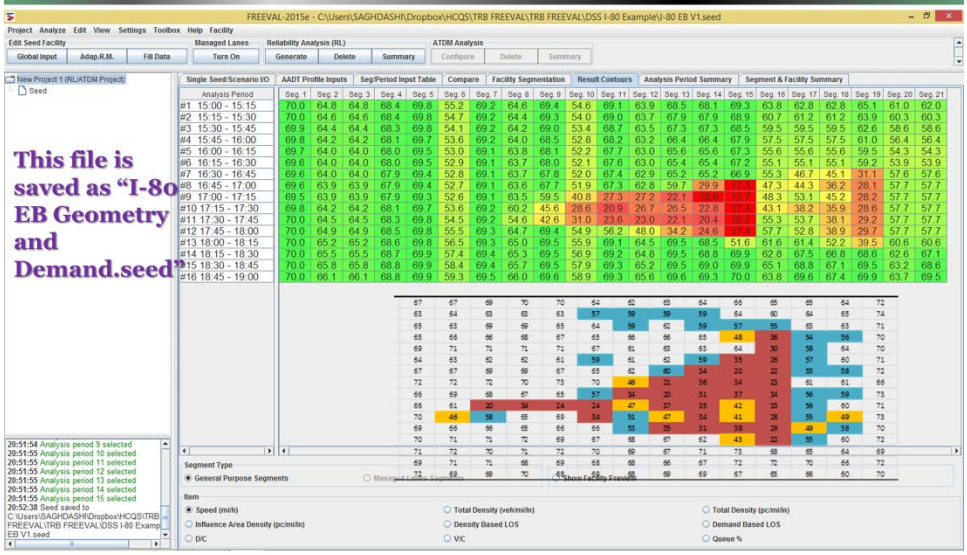
Resulted FREEVAL Speed Contour



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Further Calibration

- The user can vary Speed, Capacity and Demand Adjustment factors for further calibration and consistency with real world observations (Seg/Period Input Tables Tab in FREEVAL).
- Alternatively, the user can use auto-calibration procedure embedded in FREEVAL+. Empirical data for calibration can be downloaded from third party data providers (Here.com, NPMRDS, INRIX, and etc.)

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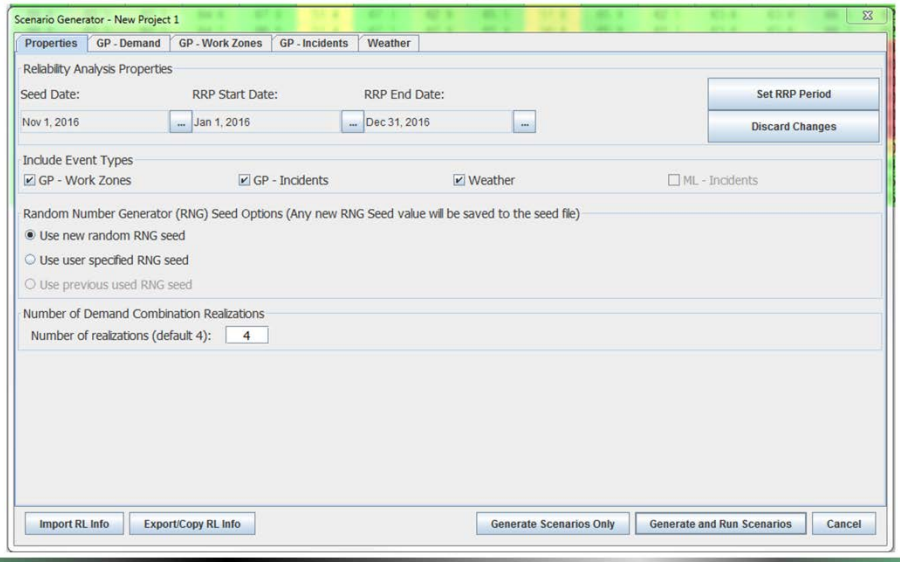
Reliability Analysis

- We would like to evaluate Reliability MOEs for this facility in a year worth of operation.
- Start and End of Analysis are 1/1/2016 and 12/31/2016 respectively.
- Seed date is Nov 1 2016.
- Use “Default Urban Values” for demand fluctuation between weekdays and months.
- Use 165 crashes per 100 million VMT and inflate to include non-crash incidents.
- Use San Francisco for default weather likelihoods.

vv

Scenario Generation – Global Inputs

This file is saved as “I-80 EB Rel.seed”



Scenario Generation – Demand Configuration

This file is saved as "I-80 EB Rel.seed"

Scenario Generator - New Project 1

Properties | GP - Demand | GP - Work Zones | GP - Incidents | Weather

Days in RRP

- ☑ Monday
- ☑ Tuesday
- ☑ Wednesday
- ☑ Thursday
- ☑ Friday
- ☐ Saturday
- ☐ Sunday

Select All | Select Weekdays | Select Weekends

Daily Demand Multipliers

	Monday	Tuesday	Wednesday	Thursday	Friday
January	0.822158	0.822158	0.838936	0.864104	0.964777
February	0.84871	0.84871	0.866031	0.892012	0.995936
March	0.920502	0.920502	0.939288	0.967466	1.080181
April	0.975575	0.975575	0.995484	1.025349	1.144807
May	0.973608	0.973608	0.993477	1.023281	1.142499
June	1.021796	1.021796	1.042649	1.073929	1.199047
July	1.132925	1.132925	1.156046	1.190728	1.329453
August	1.032614	1.032614	1.053688	1.085299	1.211741
September	1.063101	1.063101	1.084797	1.117341	1.247516
October	0.995243	0.995243	1.015554	1.046021	1.167888
November	0.995243	0.995243	1.015554	1.046021	1.167888
December	0.978525	0.978525	0.998495	1.02845	1.148269

Urban Default Values | Rural Default Values | Saved Facility Specific | User Input Values

Exclude Specific Calendar Dates From RRP

Specific Date | Jul 4, 2016 | Add | Remove | Remove All

Dates Excluded From RRP

Import RL Info | Export/Copy RL Info | Generate Scenarios Only | Generate and Run Scenarios | Cancel

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Scenario Configuration – Incident Events

This file is saved as "I-80 EB Rel.seed"

Scenario Generator - New Project 1

Properties | GP - Demand | GP - Work Zones | GP - Incidents | Weather

Incident Frequencies

Month	Frequency
Jan	1.50
Feb	1.53
Mar	1.66
Apr	1.78
May	1.76
Jun	1.85
Jul	2.06
Aug	1.86
Sep	1.94
Oct	1.80

Calculate Frequencies... | Use Seed File Values

Frequencies represent the number of incidents per study period per month.

A red background indicates that the frequency values have not be set or are very small (<0.01)

Incident Durations

Incident Severity	Distribution %	Mean Duration	Std. Dev.	Minimum Duration	Maximum Duration
Shoulder Closure	75.4	34.0	15.1	8.7	58.0
One Lane Closure	19.6	34.6	13.8	16.0	58.2
Two Lane Closure	3.1	53.6	13.9	30.5	66.9
Three Lane Closure	1.9	67.9	21.9	36.0	93.3
Four Lane Closure	0.0	67.9	21.9	36.0	93.3

Use National Default Data | Use Default Durations | Use Saved Seed File Distribution | Use Saved Seed File Durations

Adjustment Factors

Capacity Adjustment Factors (CAFs)

Segment Lanes	Shoulder Closure	1 Lane Closure	2 Lane Closure	3 Lane Closure	4 Lane Closure
2	0.81	0.7			
3	0.83	0.74	0.51		
4	0.85	0.77	0.5	0.52	
5	0.87	0.81	0.67	0.5	0.5

FFS Adjustment Factors (SAFs)

Segment Lanes	Shoulder Closure	1 Lane Closure	2 Lane Closure	3 Lane Closure	4 Lane Closure
2	1.0	1.0			
3	1.0	1.0	1.0		
4	1.0	1.0	1.0	1.0	
5	1.0	1.0	1.0	1.0	1.0

Demand Adjustment Factors (DAFs)

Segment Lanes	Shoulder Closure	1 Lane Closure	2 Lane Closure	3 Lane Closure	4 Lane Closure
2	1.0	1.0			
3	1.0	1.0	1.0		
4	1.0	1.0	1.0	1.0	
5	1.0	1.0	1.0	1.0	1.0

Lane Adjustment Factors

Segment Lanes	Shoulder Closure	1 Lane Closure	2 Lane Closure	3 Lane Closure	4 Lane Closure
2	0	-1			
3	0	-1	-2		
4	0	-1	-2	-3	
5	0	-1	-2	-3	-4

Import RL Info | Export/Copy RL Info | Generate Scenarios Only | Generate and Run Scenarios | Cancel

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Scenario Generation – Weather Events

This file is saved as "I-80 EB Rel.seed"

Scenario Generator - New Project 1

Properties | GP - Demand | GP - Work Zones | GP - Incidents | Weather

Please enter probabilities, durations, and adjustment factors for weather events, or fill by specifying the nearest metropolitan area:

Nearest Metropolitan Area: San Francisco,CA | Extract Longterm Regional Weather Data | Use Values Stored In Seed | Export | Import

	Med Rain	Heavy Rain	Light Snow	LM Snow	MH Snow	Heavy Snow	Severe Cold	Low Vis	Very Low Vis	Min Vis	Normal Weather
January	0.7%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	98.6%
February	1.6%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.4%
March	0.7%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.1%
April	0.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.1%
May	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.8%
June	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
July	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
August	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
September	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
October	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.9%
November	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	98.4%
December	2.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	96.3%

	Med Rain	Heavy Rain	Light Snow	LM Snow	MH Snow	Heavy Snow	Severe Cold	Low Vis	Very Low Vis	Min Vis	Normal Weather
Avg Dur (min)	46.23	30.36	33.33	19.00	17.00	0.00	0.00	36.42	0.00	76.11	
CAF	0.93	0.86	0.96	0.91	0.89	0.78	0.92	0.90	0.88	0.90	1.00
SAF	0.93	0.92	0.87	0.86	0.84	0.83	0.93	0.94	0.92	0.92	1.00
DAF	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Import RL Info | Export/Copy RL Info | Generate Scenarios Only | Generate and Run Scenarios | Cancel

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Reliability MOEs for I-80EB Example

Reliability Analysis Result Summary

General Information

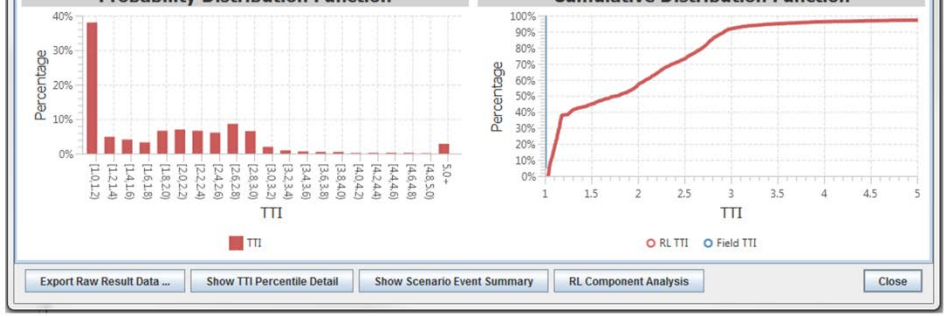
Project Name	New Project 1	# of Segments	21	# of A.P.	16	# of Scenarios	240
Facility Length (mi)	6.8	Seed File Date	2016-11-01	RRP Start Date	2016-01-01	RRP End Date	2016-12-31

Facility Reliability Performance Measures

Mean TTI	2.13	50th % TTI	1.78	80th % TTI	2.70	95th % TTI (PTI)	3.53
Misery Index	8.51	Semi-STD	2.72	Reliability Rating	41.87%	VMT % at TTI > 2	43.14%

Reliability Analysis Summary Charts | Scenario Summaries Table | Incident Charts | Weather Charts

Performance Measure Type: TTI | Chart Data Loaded: Done



Export Raw Result Data ... | Show TTI Percentile Detail | Show Scenario Event Summary | RL Component Analysis | Close

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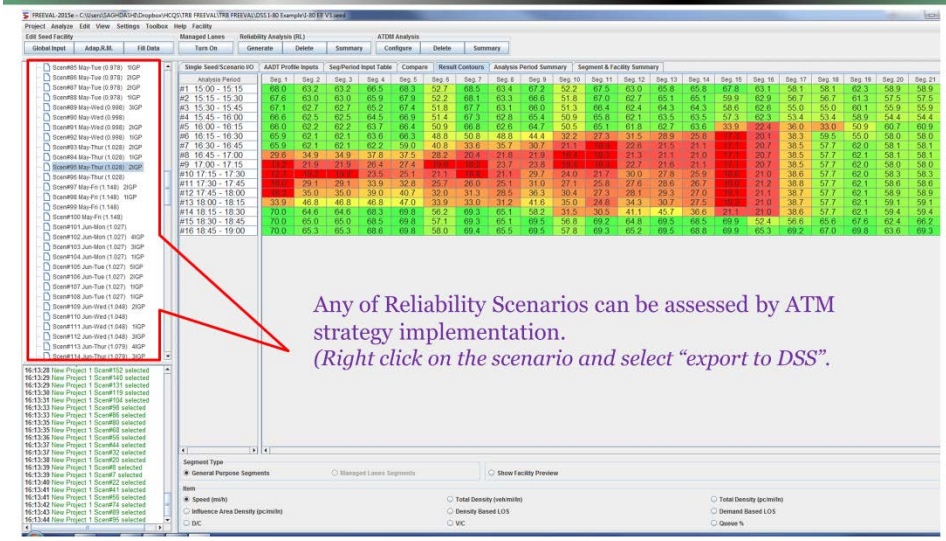
How to improve MOEs for this scenario with DSS?



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Interpreting Speed Contours

- Scenario #95 has two incidents:
- 1) Shoulder Closure at Segment 15 starting at AP2 for 45 mins
- 2) Shoulder Closure at Segment 19 starting at AP5 for 15 mins

Analysis Period	Seg. 1	Seg. 2	Seg. 3	Seg. 4	Seg. 5	Seg. 6	Seg. 7	Seg. 8	Seg. 9	Seg. 10	Seg. 11	Seg. 12	Seg. 13	Seg. 14	Seg. 15	Seg. 16	Seg. 17	Seg. 18	Seg. 19	Seg. 20	Seg. 21
#1 15:00 - 15:15	68.0	63.2	63.2	66.5	68.3	52.7	68.5	63.4	67.2	52.2	67.5	63.0	65.8	65.8	67.8	63.1	58.1	58.1	62.3	58.9	58.9
#2 15:15 - 15:30	67.6	63.0	63.0	65.9	67.9	52.2	68.1	63.3	66.6	51.8	67.0	62.7	65.1	65.1	59.9	62.9	56.7	56.7	61.3	57.5	57.5
#3 15:30 - 15:45	67.1	62.7	62.7	65.2	67.4	51.8	67.7	63.1	66.0	51.3	66.4	62.4	64.3	64.3	58.6	62.6	55.0	55.0	60.1	55.9	55.9
#4 15:45 - 16:00	66.6	62.5	62.5	64.5	66.9	51.4	67.3	62.8	65.4	50.9	65.8	62.1	63.5	63.5	57.3	62.3	53.4	53.4	58.9	54.4	54.4
#5 16:00 - 16:15	66.0	62.2	62.2	63.7	66.4	50.9	66.8	62.6	64.7	50.5	65.1	61.8	62.7	63.6	33.9	22.4	36.0	33.0	50.9	60.7	60.9
#6 16:15 - 16:30	65.9	62.1	62.1	63.6	66.3	48.8	50.8	48.8	44.4	32.2	27.3	31.5	28.9	25.8	17.3	20.1	38.3	59.5	55.0	58.0	58.0
#7 16:30 - 16:45	65.9	62.1	62.1	62.2	59.0	40.8	33.6	35.7	30.7	21.1	19.4	22.6	21.5	21.1	17.1	20.7	38.5	57.7	62.0	58.1	58.1
#8 16:45 - 17:00	29.6	34.9	34.9	37.8	37.5	28.2	20.4	21.8	21.9	18.4	18.3	21.3	21.1	21.0	17.1	20.7	38.5	57.7	62.1	58.1	58.1
#9 17:00 - 17:15	13.2	21.9	21.9	26.4	27.4	19.8	18.2	23.7	23.8	19.4	19.3	22.7	21.6	21.1	17.1	20.7	38.5	57.7	62.0	58.0	58.0
#10 17:15 - 17:30	12.3	19.2	19.2	23.5	25.1	21.1	18.8	21.1	29.7	24.0	21.7	30.0	27.8	25.9	18.6	21.0	38.6	57.7	62.0	58.3	58.3
#11 17:30 - 17:45	18.0	29.1	29.1	33.9	32.8	25.7	26.0	25.1	31.0	27.1	25.8	27.6	28.6	26.7	19.0	21.2	38.8	57.7	62.1	58.6	58.6
#12 17:45 - 18:00	18.3	35.0	35.0	39.0	40.7	32.0	31.3	28.5	36.3	30.4	27.3	28.1	29.3	27.0	19.1	21.1	38.7	57.7	62.1	58.9	58.9
#13 18:00 - 18:15	33.9	46.8	46.8	46.8	47.0	33.9	33.0	31.2	41.6	35.0	24.8	34.3	30.7	27.5	19.3	21.0	38.7	57.7	62.1	59.1	59.1
#14 18:15 - 18:30	70.0	64.6	64.6	68.3	69.8	56.2	69.3	65.1	58.2	31.5	30.5	41.1	45.7	36.6	21.1	21.0	38.6	57.7	62.1	59.4	59.4
#15 18:30 - 18:45	70.0	65.0	65.0	68.5	69.8	57.1	69.3	65.1	69.5	56.8	69.2	64.8	69.5	68.5	69.9	52.4	56.6	65.6	67.6	62.4	66.2
#16 18:45 - 19:00	70.0	65.3	65.3	68.6	69.8	58.0	69.4	65.5	69.5	57.8	69.3	65.2	69.5	68.8	69.9	65.3	69.2	67.0	69.8	63.6	69.3

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HIGHWAY CAPACITY MANUAL
6TH EDITION | A GUIDE FOR MULTIMODAL MOBILITY ANALYSIS

FREEWAY ANALYSIS & SOFTWARE IN THE HCM 6TH EDITION: Role Of Active Traffic Management Strategies

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Behzad Aghdashi, Ph.D.

February 28, 2017

ITRE KITTELSON & ASSOCIATES, INC. TRANSPORTATION ENGINEERING/PLANNING

1 HIGHWAY CAPACITY MANUAL 6TH EDITION ⫶ A GUIDE FOR MULTIMODAL MOBILITY ANALYSIS

Workshop Schedule

9:30 am	9:45 am	- Signing in - Distribution of the course material - Introductions
9:45 am	10:30 am	- Overview of the new changes in the 6th edition of HCM
10:30 am	10:45 am	- Break
10:45am	12:00 pm	- Uninterrupted Flow Concepts, New material in Freeway Chapters (e.g. Managed Lanes, Reliability, ATDM, WZ)
12:00 pm	1:00 pm	- Lunch Break & Software Installation
1:00 pm	2:00 pm	- FREEVAL Demo with Hands-on Example, Segmentation, Calibration & Reliability Analysis
2:00 pm	2:30 pm	- FREEVAL-DSS Concepts and Demo
2:30 pm	2:45 pm	- Break
2:45 pm	3:45 pm	- FREEVAL-DSS Hands-on
3:45 pm	4:00 pm	- Questions, Feedback, and Evaluation

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FREEVAL DSS
CONCEPTS AND DEMO

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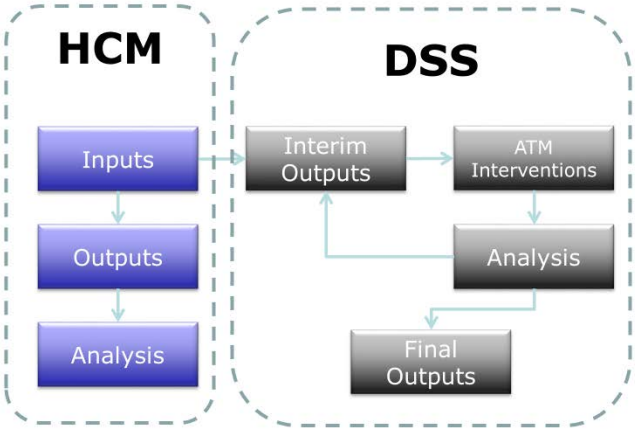
This Sessions Goals!

- To improve operational conditions on a freeway facility by implementing ATM strategies.
- Try to emulate the environment at TMCs including available operational information and strategies over time
- Introduce FREEVAL-DSS platform as a possible means to train TMC operators, junior engineers or students.

What is FREEVAL-DSS

- Based on the core Freeway Facilities method in the HCM 6th Edition, but runs differently
- Creates a dynamic framework to test ATM strategies at different clock times, depending on traffic and external (incident or weather) conditions
- The operator can intervene midstream, & can alter ATM Strategies in the middle of the simulation run

DSS Concept Implementation



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ATM strategies Covered in FREEVAL-DSS

- DSS→ **D**ynamic **S**trategy **S**election
- Ramp Metering
  - Adaptive (ALINEA and Fuzzy logic) and time-dependent Fixed Rate metering
  - Local and System Wide
- Hard Shoulder Running on user selected segments
- Traffic Diversion
  - Upstream of the facility
  - Into Managed Lanes (HOV/HOT)
  - Via VMS into off-ramps
- Improved Incident Response

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Two Roles: Modeler vs. Operator

- The framework accommodates two types of users: **Modeler** (Professor; Supervisor ?) and **Operator** (Student ; TMC Technician?)
- The **Modeler** configures the facility, specifies various congestion sources including **weather events, incident events, work zones,** or **demand surges**.
- The **Modeler** also configures the **menu of available ATM strategies** and the **form of output options** to the operator(s).
- The **Operator** has access only to modeler-selected ATM **interventions** from a menu of options, after any 15 minute interval. Interventions can also be stopped or extended in time and space

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FREEVAL- DSS Analysis Phases

- Consists of three phases:
  - **Phase 1: New Scenario Configuration or existing extraction** by the **Modeler**
  - **Phase 2: Simulation and ATM Interventions** by **Operator**.
  - **Phase 3: Analysis Summary** and execution of multiple FREEVAL runs to compare Performance under various ATM strategies.

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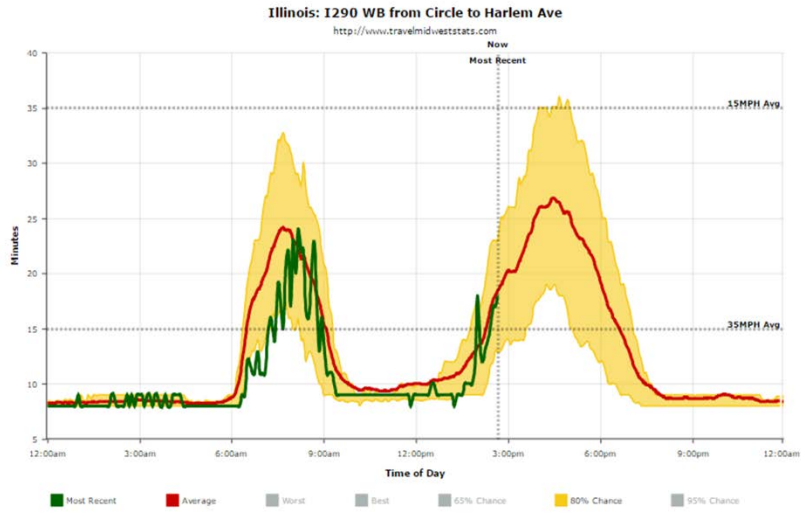
Modeler and Operator Demo Application

Hands-on Exercises I-290 WB in Chicago From Chicago River To South 1st Ave

Travel Time Profile for I-290 WB in Chicago



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Rules for Hands-on Exercise

- First exercise: meter all ramps, for the entire duration using Adaptive, ALINEA method
- Second Exercise: Use Hard Shoulder Running, but limited to <=4 segments, =< 1 hour each.
- Third Exercise: open competition subject to
  - No more than two concurrent strategies
  - No more than one hour for each strategy application (except for ramp metering)
  - At most four segments to apply strategies

FEEDBACK FORMS & CLOSING DISCUSSIONS

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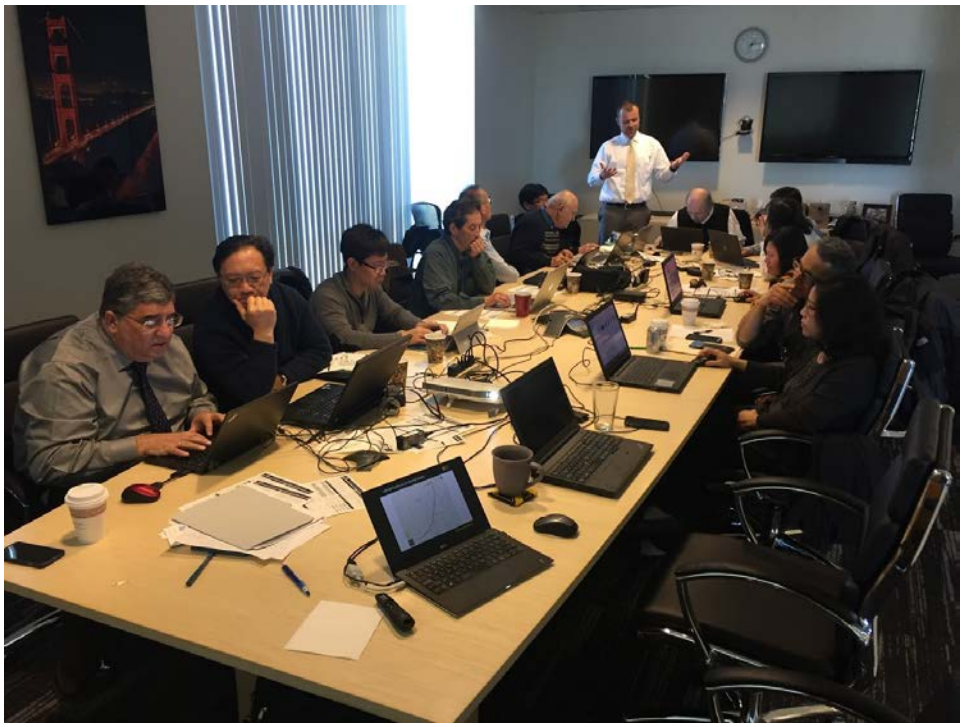
APPENDIX C: PICTURES FROM THE WORKSHOP

West Palm Beach FL Workshop (Nov 13 2016)

West Palm Beach FL Workshop (Nov 13 2016)

Oakland CA Workshop (Feb 28 2017)

Oakland CA Workshop (Feb 28 2017)



Oakland CA Workshop (Feb 28 2017)