SHRP 2 Project L38
Pilot Testing of Reliability Data and Analytical Products

Minnesota Reliability Workshop
February 20, 2014
WELCOME TO THE WORKSHOP
Welcome

SHRP 2 (TRB)

Minnesota Department of Transportation (Metro Planning)

SRF Consulting Group

Project Kickoff
- Apr 2013

Technical Analysis

Interim Update
- Oct 2013

Outreach

Minnesota Workshop
- Feb 2014

Reporting

Project Completion
- Jun 2014
Workshop Overview

• Morning Session
  – Introduction to technical tools and methods
  – Experience and lessons learned from working with tools

• Afternoon Session
  – Real-world examples of application of reliability analysis
  – Panel reaction to evaluation approach and value of information
CONTEXT FROM SHRP 2
What is SHRP 2?

Save lives. Save money. Save time.

- $218 million, federally funded research program to address critical transportation challenges:
  - Making highways safer
  - Fixing deteriorating infrastructure
  - Reducing congestion

- Collaborative effort of AASHTO, FHWA, and TRB

- Aims to advance innovative ways to plan, renew, operate, and improve safety on the Nation's highways
Safety: fielding the largest-ever naturalistic driving study to reduce crashes and save lives through understanding driver behavior

Renewal: making rapid, innovative construction possible for “ordinary” projects

Reliability: Providing management and technical tools to reduce congestion through operations

Capacity: Systematizing collaborative decision making to achieve better, faster project decisions
SHRP 2 Reliability Technical Tools

- L02 Reliability monitoring systems and data
- L05 Reliability in planning and programming
- L07 Impacts of geometric features and design on reliability
- L08 Reliability and the highway capacity manual
- C11 Economic benefits of improved reliability (from Capacity)

These tools are now being tested and developed more fully for implementation through the four L38 pilots
- Not all the tools are being tested by each pilot
- Next step: FHWA hosting an Implementation Planning Workshop this Spring to lay out a road map for rolling out this product bundle
- For more information about implementation opportunities, visit:
  http://www.fhwa.dot.gov/goshrp2/
INTRODUCTIONS

SHRP 2 Reliability Workshop
Morning Agenda

• Opening Survey
• Background and Concepts
• Technical Analysis
• Utility of SHRP 2 Tools
SHRP 2 Reliability

OPENING SURVEY
How do I use my “clicker”? 

• Press the number on your “clicker” that corresponds to an answer option for each question 
• To submit multiple answers for a single question, press “Enter” after each answer option 
• Allows for instant polling of the group 
• Let’s practice!
Practice Question # 1

Have you ever participated in a clicker survey before?

1. Many times
2. A few times
3. Once
4. Never
Practice Question # 2

What is your favorite summertime activity? (select all that apply)

1. Being on the lake
2. Golfing
3. Baseball games
4. Camping
Survey Question #1

What type of agency are you representing?

1. Federal
2. State DOT
3. MPO
4. County
5. City
6. Consultant/Other
Survey Question #2

How familiar are you with the concept of travel time reliability?

1) Very Familiar
2) Familiar
3) Unfamiliar
4) Very Unfamiliar
Survey Question #3

Describe the extent to which you believe travel time reliability can be quantified.

1) Highly
2) Moderately
3) Limited
4) Qualitatively only
Survey Question #4

How often have you seen travel time reliability used in project evaluations previously?

1. Frequently
2. Sometimes
3. Once
4. Never
Survey Question #5

How often as your agency used travel time reliability in a program or planning application?

1. Frequently
2. Sometimes
3. Once
4. Never
Survey Question #6

How likely are you to consider the evaluation of travel time reliability in the future?

1. Very Likely
2. Likely
3. Unlikely
4. Very Unlikely
Survey Question #7

What applications of travel time reliability do you find the most promising? (select all that apply)

1. Historical observations/delay categorization
2. Project evaluation
3. Benefit–cost analysis
4. Planning and programming
Survey Question #8

What types of reliability evaluation would your agency be most likely to implement? (select all that apply)

1. Annual or other regular reporting
2. Supporting information for project development
3. Feedback for highway operations and maintenance
4. Allocation of resources among or within funding programs
Survey Question #9

What barrier is most likely to impede your agency’s ability to evaluate travel time reliability?

1. Data availability
2. Staff expertise
3. Staff and time resources
4. Existing methods are adequate
5. Resistance to change
Reliability Background

Why Evaluate Travel Time Reliability?

• Quantify the frequency and effects of events that cause travel times to fluctuate in an unpredictable manner

• Attempt to help agencies reduce travel time variability and delay for travelers and shippers

• Address both recurring and non-recurring congestion

• Potential sources of unreliable travel times include:
  – Traffic incidents
  – Demand fluctuations
  – Traffic control devices
  – Inadequate base capacity
  – Work zones
  – Special events
  – Weather
• Numerous reliability studies completed to-date

• RFP issued for L38 – Pilot Testing of Reliability Data and Analytical Tools

• MnDOT submitted proposal in October 2012, in partnership with SRF

• Minnesota selected as 1 of 4 pilot sites – Others are Florida, California, Washington
Minnesota Pilot Site

• Focus on high availability of data
  – Freeway loop detectors
  – High-quality crash records
  – Active incident management approach

• Recent corridor enhancements
  – I–94 lane addition (I–35W traffic restoration)
  – TH 100 ramp metering
  – MnPASS managed lane corridors
  – Intelligent Lane Control Signals
Reliability tools under evaluation at SHRP 2 pilot test sites

- **Project L02**: Establishing Monitoring Systems for Travel Time Reliability
- **Project C11**: Improved Economic Analysis Tools
- **Project L08**: Non-Recurrent Congestion Factors in HCM Methods
- **Project L07**: Evaluation of Highway Design Features to Improve Reliability
- **Project L05**: Incorporating Reliability into Planning & Programming Process

**Identifying Issues** → **Prioritizing Solutions** → **Institutionalizing Reliability**
SHRP 2 Reliability Tools

Identifying Issues:
Data collection and analysis of reliability performance

- Project L02: Establishing Monitoring Systems for Travel Time Reliability
- Project C11: Improved Economic Analysis Tools
- Project L08: Non-Recurrent Congestion Factors in HCM Methods
- Project L07: Evaluation of Highway Design Features to Improve Reliability
- Project L05: Incorporating Reliability into Planning & Programming Process

Pie Chart:
- None: 49%
- Event: 24%
- Crash: 5%
- Weather: 4%
- Other: 49%

Date: 2/20/2014
Prioritizing Solutions: Economic benefits of transportation improvements
SHRP 2 Reliability Tools


Project L02
Establishing Monitoring Systems for Travel Time Reliability

Project C11
Improved Economic Analysis Tools

Project L08
Non-Recurrent Congestion Factors in HCM Methods

Project L07
Evaluation of Highway Design Features to Improve Reliability

Project L05
Incorporating Reliability into Planning & Programming Process

2/20/2014
Prioritizing Solutions: Cost-effectiveness of improving reliability

- Project L02: Establishing Monitoring Systems for Travel Time Reliability
- Project C11: Improved Economic Analysis Tools
- Project L08: Non-Recurrent Congestion Factors in HCM Methods
- Project L07: Evaluation of Highway Design Features to Improve Reliability
- Project L05: Incorporating Reliability into Planning & Programming Process
Institutionalizing Reliability: Incorporating consideration of reliability into standard practice
SHRP 2 Reliability Tools

Minnesota Pilot Site evaluating these reliability tools

- Project L02: Establishing Monitoring Systems for Travel Time Reliability
- Project C11: Improved Economic Analysis Tools
- Project L08: Non-Recurrent Congestion Factors in HCM Methods
- Project L07: Evaluation of Highway Design Features to Improve Reliability
- Project L05: Incorporating Reliability into Planning & Programming Process

2/20/2014
# Project Schedule

### Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
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<tbody>
<tr>
<td>Task 1</td>
<td>Attend kickoff meeting in Washington, D.C.</td>
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<tr>
<td>Task 2</td>
<td>Prepare a revised research plan</td>
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<tr>
<td>Task 3</td>
<td>Data compilation and integration</td>
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<tr>
<td>Task 4</td>
<td>Analyze the baseline reliability issues and alternative strategies to improve reliability</td>
</tr>
<tr>
<td>Task 5</td>
<td>Prepare an Interim Report on the data compilation and analysis tasks</td>
</tr>
<tr>
<td>Task 6</td>
<td>Use the results of the analyses to support funding for mitigating strategies in the decision-making process</td>
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<tr>
<td>Task 7</td>
<td>Evaluate the functionality of the products and outcomes that resulted</td>
</tr>
<tr>
<td>Task 8</td>
<td>Prepare a draft final report that documents all tasks; Submit to SHRP 2 for review</td>
</tr>
<tr>
<td>Task 9</td>
<td>Revise the draft final report in accordance with review comments</td>
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### Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection</td>
<td>Reliability Analysis</td>
<td>Planning and Programming Changes</td>
<td>Documentation</td>
</tr>
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2/20/2014
Twin Cities Highways
Instrumented System and Study Corridors

I–94: Minneapolis to St. Paul

TH 100: I–394 to I–94

I–94: I–494 to TH 101

TH 13: TH 169 to TH 77

MnPASS Corridor(s)
SHRP 2 Reliability Workshop

TECHNICAL ANALYSIS
L02 SYSTEM EVALUATION:
Establishing Monitoring Programs for Travel Time Reliability
L02 System Evaluation

• Reliability describes the variability of travel time over time

• Recognize that different conditions result in inconsistent driver experiences

• Understand the magnitude of variation in travel times

• Connect variable travel times to non-recurring congestion factors
TH 100 NB – Travel Time
Reliability – Travel Times

Minimum Travel Time = 13.0 min
Speed Limit Travel Time = 15.5 min
45 mph Travel Time = 19.5 min
Reliability – CDF Curves

Travel Time (minutes) vs. Reliability

- None
- Weather
- Event
- Crash
- Incident
- Roadwork
- Other*

*Other includes combinations of categories
Non-Recurring Conditions

(N) = # of time periods
X% = % of time periods

2/20/2014
Reliability – Delay by Condition

None: 52%

Events:
- Incident: 23%
- Crash: 5%
- Weather: 4%

X% = % of total delay

2/20/2014
Reliability Indices

Travel Time Index
Travel Time Index is the ratio of the average observed travel time divided by the average free-flow travel time.

Buffer Index
The buffer index is the proportion of extra time (or time cushion) that most travelers add to their average travel time when planning trips to ensure on-time arrival.

Planning Time Index
Planning Time Index is the factor applied to the free-flow time needed to ensure on-time arrival 95% of the time. It differs from the buffer index since it includes recurring delay as well as unexpected delay.

Planning Time Failure / On-Time Measures
Planning Time Failure / On-Time Measures describe the percentage of trips with travel times within a certain factor of the median travel time. Common thresholds include 1.1* Median Travel Time or 1.25* Median Travel Time. Other formulations of these measures denote the percentage of trips with average speeds below a specified threshold, for example 50 mph, 45 mph, or 30 mph.

80th Percentile Travel Time Index
80th Percentile Travel Time Index is the 80th percentile travel time divided by the free flow travel time. It represents another threshold of impacted traffic flow condition.

Misery Index
Misery Index is the average of the highest five percent of travel times divided by the free flow travel time. Often referred as the 97.5% travel time index.

\[
TTI = \frac{TT_{Observed}}{TT_{FreeFlow}}
\]

\[
BI = \frac{TT_{95\%} - TT_{Mean}}{TT_{Mean}}
\]

\[
PTI = \frac{TT_{95\%}}{TT_{FreeFlow}}
\]

\[
TTI_{80\%} = \frac{TT_{80\%}}{TT_{FreeFlow}}
\]

\[
MI = \frac{TT_{97.5\%}}{TT_{FreeFlow}}
\]
Travel Time Monitoring

• L02 Guidebook describes methods to develop a Travel Time Monitoring Database

• Store all data elements in related tables for easy data summary
  – Weather
  – Incident
  – Road Work
  – Crash
  – Event
TH 100 NB 2012—Crash
TH 100 NB 2012 - Incident
77th St to 57th Ave

- Road Closed
- Wrongway
- 2+ Lanes closed
- 1 Lane closed/Blocking
- Impacting
- Shoulder/Not Blocking
- Unknown
TH 100 NB 2012 - Event

77th St to 57th Ave

Events
TH 100 NB 2012–Road Work

TH 100 NB 2012 - Road Work
77th St to 57th Ave

- Road Closed
- 2 + Lanes Closed
- 1 Lane Closed

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

2/20/2014
TH 100 NB 2012 - VMT
77th St to 57th Ave

Vehicle Miles Traveled
- > 6000
- 5000-6000
- 4000-5000
- 3000-4000
- 2000-3000
- 1000-2000
- < 1000

2/20/2014
TH 100 NB 2012—Travel Time

TH 100 NB 2012 - Travel Time
77th St to 57th Ave

- > 4.0 TTI
- 3.5 TTI - 4.0 TTI
- 3.0 TTI - 3.5 TTI
- 2.5 TTI - 3.0 TTI
- 2.0 TTI - 2.5 TTI
- 1.5 TTI - 2.0 TTI
- 45 mph TT - 1.5 TTI
- Speed Limit TT - 45 mph TT
- < Speed Limit TT

Speed Limit TT = 14.8 min
45 mph TT = 19.5 min
TH 100 NB 2012 – Travel Time CDF Curve

TH 100 NB 2012 - Travel Time CDF Curve

77th st to 57th ave

![Graph showing Travel Time CDF Curve with various events and percentages.]

FFTT = 15.3 min
TH 100 NB 2012 – Observation Pie Chart
77th St to 57th Ave

None (Normal Conditions) 76%

Event 11%
Incident 4%
Crash 2%
Weather 4%
Road Work 1%
Combinations 2%

Legend:
- None (Normal Conditions)
- Weather
- Crash
- Incident
- Event
- Road Work
- Combinations
TH 100 NB – Delay

The diagram shows the delay for TH 100 NB from 2006 to 2012. The delays are categorized into different events:
- None
- Weather
- Event
- Crash
- Roadwork
- Incident
- Other
- Volume

The y-axis represents the delay in hours, ranging from 0 to 50,000, while the x-axis represents the years from 2006 to 2012.

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L02 System Monitoring

• Data is available to conduct reliability evaluation on instrumented system
  – Successful evaluation of travel time, delay, and non-recurring factors

• Non-instrumented system may require additional data sources

• Data storage and processing present new challenges

• Reliability evaluation may impact the types and methods of data collection
L07 ALTERNATIVE ANALYSIS:
Identification and Evaluation of the Cost-Effectiveness of Highway Design Features to Reduce Non-recurrent Congestion
History

- Traditionally address recurrent congestion with infrastructure treatments and non-recurrent congestion with ITS improvements
- Goal of using the L07 Tool to address geometric improvement impacts on non-recurrent congestion
History

• Previous SHRP 2 work included model development for predicting travel time index for:
  – Large metropolitan areas
  – Peak hours only
  – No snowfall

• Subsequent SHRP 2 research built on those models to include:
  – Lower D/C ratios
  – All hours of the day
  – Includes snowfall
  – Relationship between congestion and safety
Introduction

• Estimates benefit–cost ratio for geometric improvements mitigating non–recurrent congestion on freeway segments

• Elements of non–recurrent congestion include:
  – Crashes and non–crash incidents
  – Weather
  – Events
  – Work zones

• Compares untreated and treated conditions using cumulative travel time distribution

• Estimates operational and safety benefits

• Compares economic benefits for different design treatments
Introduction
**Input Data**
- Geometry
- Demand
- Weather
- Crashes
- Work Zones
- Events
- Treatment Characteristics

**Untreated Condition**
- D/C
- Lane Hours Lost
- Rain Impact
- Snow Impact

**Treated Condition**
- D/C
- Lane Hours Lost

**Prediction Model TTI Curves**

**Project Results Summary**
- Change in Reliability Indicators
- Operational Benefits
- Safety Benefits
- Net Present Value and B/C Ratio

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Calculating Delay

- TTI* (after improvement)
- Area between is proportional to delay reduction
- TTI (before improvement)
Required User Inputs

- Geometric Data
  - Length, Lanes, Width, Clearance, Interchanges per mile, Terrain

- Traffic Data
  - Free-flow speed, Demand Volume, PHF, Percent Truck/RV

- Crash Data
  - PDO, Minor Injury, and Major Injury Fatal Crash Types and Associated Crash Costs

- Benefit-Cost Data
  - Service Life, Construction Cost, Maintenance
Optional Detailed User Inputs

- Crash and Incident Data
  - Crash Duration, Incident Duration and Incident Frequency
- Weather Data
  - Weather Data by Hour
- Event Data
  - Frequency and Percent Increase of Traffic by Hour
- Work Zone Data
  - Frequency, Capacity, and Lanes Closed
- Benefit–Cost Data
  - Value of Time and Discount Rate

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## Design Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>B/C</th>
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<tbody>
<tr>
<td>Accessible Shoulder</td>
<td>0.21</td>
</tr>
<tr>
<td>Alternating Shoulder</td>
<td>0.29</td>
</tr>
<tr>
<td>Crash Investigation Site</td>
<td>0.55</td>
</tr>
<tr>
<td>Emergency Pull Off</td>
<td>2.74</td>
</tr>
<tr>
<td>Emergency Access</td>
<td>0.89</td>
</tr>
<tr>
<td>Emergency Cross Overs</td>
<td>2.61</td>
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<tr>
<td>Gated Turnarounds</td>
<td>0.57</td>
</tr>
<tr>
<td>Drivable Shoulders</td>
<td>0.12</td>
</tr>
<tr>
<td>Extra High Median Barrier</td>
<td>1.69</td>
</tr>
<tr>
<td>Runaway Truck Ramp</td>
<td>0.47</td>
</tr>
<tr>
<td>Incident Screen</td>
<td>0.32</td>
</tr>
<tr>
<td>Wildlife Crash Reduction</td>
<td>2.09</td>
</tr>
<tr>
<td>Anti-icing Systems</td>
<td>0.74</td>
</tr>
<tr>
<td>Snow Fence</td>
<td>0.61</td>
</tr>
<tr>
<td>Blowing Sand</td>
<td>0.20</td>
</tr>
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</table>
**Needed to Perform Analysis?**
- Length and other geometry
- Free Flow Speed
- Single Day Traffic Count
- Fatal and Major Injury, Minor Injury, and Property Damage Accidents
- Costs

**For a More Detailed Analysis?**
- Is there a stadium nearby?
- A better weather resource available?
- Detailed incident data?
- Construction and routine maintenance schedules available?
- Economic Inputs
SHRP 2 Reliability Workshop

L05 PLANNING AND PROGRAMMING:
Integrating Travel Time Reliability into Planning and Programming
Institutionalizing Reliability:
Incorporating consideration of reliability in standard practice
L05 Implementing Reliability

- “How-to” guide to incorporate reliability in the planning and programming process
- Help agencies make tradeoffs about funding and project priority
- Describes technical and institutional steps to incorporate reliability
  - Policy
  - Performance Measures
  - Needs/Deficiency Analysis
  - Project Prioritization
Policy & Programming Discussion

• Existing traffic evaluation considers only recurring delays

• 50% of delay caused by non-recurring congestion is not being evaluated
Performance Measures

Current performance measures
- Congestion
- Safety
- Bridge Condition
- Pavement Condition
- Reliability (future performance measure?)
Future Applications

• Reliability anticipated to be a performance measure required under MAP–21
• Pilot testing an opportunity to shape evaluation tools and use of results
• Evaluation of delay due to non-recurrent conditions in benefit/cost analysis
Future Applications

• Performance Based Planning
• Highway Systems Operations Plan
• Congestion Management Process
• Programming Implications
  – Identification of operations level investments to address non-recurrent congestion
Communicating Reliability

• Who is the audience for evaluations of travel time reliability?
  – Designers
  – Planners
  – Legislators
  – Engineers
  – Operators
  – Road users

• How can reliability be communicated most effectively?
  – Graphs and charts
  – Travel Time Indices
  – Congestion and Delay
UTILITY OF SHRP 2 TOOLS
System Evaluation

• Magnitude of Issues
  – Size of the pie charts AND allocation of slices within the pies
  – Causes of congestion on different metro corridors (event, recurring, weather)
  – Geographic specificity within corridor – isolated segments vs. overall corridor (compare to other elements within system)
System Evaluation

• Defining the Problem
  – Is it telling us anything we don’t already know?
  – Metro area – causes of congestion
  – Plan differently depending on corridor
  – Rural? Snow = slower traffic...not new info
  – More appropriate for urban compared to rural, especially given effort to prepare
System Evaluation

• Data Needs
  – How much effort needed?
  – Where does data come from?
  – Weather data a challenge
    • Plan for collecting it differently in the future
    • Additional/more reliable R/WIS data
  – Does this replace something vs. add to it?
  – Potential for GIS probe data
  – Additional ATR stations in outstate MN
Topic Brainstorming

Project Evaluation

• Reliability Solutions
  – Identify causes
  – Weather/crashes
  – Incident response
  – Snow removal
  – Special event management
    • Signing
    • Ramp meters
    • Managed lane scheduling
    • Additional discussion/event planning
  – Maintenance scheduling
SHRP 2 Reliability Workshop

L02 SYSTEM EVALUATION:
Establishing Monitoring Programs for Travel Time Reliability
System Evaluation Findings

Travel Time (minutes)

I-94 EB 2012 - Observation Pie Chart
TH 61 St. Paul to TH 55 Minneapolis

I-94 EB 2012 - Delay Pie Chart
TH 61 St. Paul to TH 55 Minneapolis
Input Data Preparation

Data Sources
- DMS Logs
  - Message
  - Time Deployed
  - Time Cleared
- MnCMAT Records
  - Time
  - Location
  - Severity
- RTMC Incidents
  - Time
  - Type Code
  - Response Code

Pre-Processing
- Road Work¹
  - Time/duration
  - Location
  - Impacts
- Crashes
  - Time/duration
  - Location
  - Severity
- Incidents
  - Time/duration
  - Impact
  - Type/cause

Database Inputs
- Road Work DB
  - Time Start/End
  - Impact
  - Details
- Crash Database
  - Time Start/End
  - Impact
  - Details
- Incident Database
  - Time Start/End
  - Impact
  - Details

¹ Construction and maintenance activities also being identified through MnDOT news releases.

² Crash records also contain weather and road conditions data will be referenced to weather data.
Regime Comparison

![Graph showing travel time distribution for different regimes.](image)

- **None_Weekdays_Apr to Sep time: 9 to 19 (12849)**
- **Twins_A_Weekdays_Apr to Sep time: 9 to 19 (1813)**
- **VMT & None_Weekdays_Apr to Sep time: 9 to 19 (12849)**
- **VMT & Twins_A_Weekdays_Apr to Sep time: 9 to 19 (1813)**

2/20/2014
Project Data Demands
Useful Graphical Outputs

I-94 EB 2012 - Crash
TH 61 St.Paul to TH 55 Minneapolis

[Graph showing crash data with time and date axes, colors for different categories]
Real World Connections
2012 Metro Freeway Congestion

2:00 pm - 7:00 pm

Congestion:

ESTIMATED SPEEDS
< 45 MPH

PM Congestion
No Recurring Congestion
<1 Hour of Congestion
1-2 Hours of Congestion
2-3 Hours of Congestion
3+ Hours of Congestion

Date collected during October 2012.
DATA COLLECTION
Data Collection

Need traffic volumes and travel times to conduct reliability evaluation

• Traffic volumes can be collected by loop detectors, microwave, other continuous count devices

• Travel time can be collected by a number of sources
  – Loop detectors
  – Bluetooth
  – GPS probe data
  – Interconnected signal controllers (Smart Signals)
Loop Detectors

- Twin Cities highly instrumented on freeway system
- Continuous collection of speed and volume data for (15+ years)
- Programs available to provide corridor VMT and travel time
Bluetooth

- Set up for specific short-term evaluations
- Need separate source of volume data
- Can provide sample OD travel patterns for small area studies
GPS Probe Data

• Available from commercial vendors including TomTom, INRIX, ATRI, cell phone carriers
• Available from FHWA for State DOTs and MPOs through NPMRDS
• Requires significant data storage and processing capabilities
• Need independent source of volume data
• Provide speed and travel time off of instrumented or Interstate system
Smart Signals

• Signal controllers are interconnected with count loop detectors and tied back to RTMC
• Proprietary program estimates speed profile, flow rate, queue movements
• Allows user to simulate “virtual probe” to get specific travel times
Crash and Incident Data Sources

- **MnCMAT** – Minnesota Crash Mapping Analysis Tool
  - Published crash records
  - No duration

- **CAD** – Computed Added Dispatch Records
  - Provided by State Highway Patrol
  - Crash and incident data
  - Includes duration and impact

- **DMS** – Dynamic Message Sign Logs
  - Records for all messages posted
  - Filter out crash and incident data
  - Includes duration and impact
Event Data Sources

• Minneapolis Event Catalog
  – Large stadium events
  – Conventions
  – Concerts
  – Starting time and duration

• Reversible HOV Schedule
  – Monthly timing plan for reversible lane switches
  – Includes larger scale events
Weather Data Sources

- Road and Weather Information System
  - Small time intervals
  - Statewide coverage
  - Precipitation intensity and roadway surface condition
- Other non-MnDOT data sources available
  - National Oceanic and Atmospheric Administration
  - Weather Underground
  - National Climactic Data Center (L07 Default)
Work Zone Data Sources

• DMS – Dynamic Message Sign Logs
  – Location
  – Deployment time
  – Duration
  – Impact
L07 PROJECT EVALUATION:
Identification and Evaluation of the Cost-Effectiveness of Highway Design Features to Reduce non-recurrent Congestion
L07 Project Evaluation

I-94 Westbound

Lowry Hill Tunnel
I-35W SB On Ramp to 11th Street
TH 280 On Ramp to Huron Blvd

2/20/2014
Lessons Learned

• Calibrates well for bottleneck segments
  – Upstream segments impacted by queues
  – Downstream segments choked by bottleneck

• Modest sensitivity to weather inputs
  – 2x difference in rain and snow in observations in TTRMS gives <15% difference

• High sensitivity to crash and incident duration
  – Use duration data available from L02 database for more accurate local conditions
Lessons Learned

• Segment tool that requires uniform geometry and traffic volumes. Does not account for node issues

• Level of effort compounds with:
  – Access points – require further segmentation
  – Evaluation years – no traffic growth function provided
  – Alternative geometric layouts – need to adjust geometry inputs

• Analysis performance time for single segment analysis ranges from two hours to multiple days – what data is available?

• Challenge to perform system wide analysis
Product Refinements

- Adjust tool to allow for corridor analysis opposed to segment analysis
- Provide additional treatment options
  - Auxiliary lanes
  - Dynamic shoulder lanes
  - Managed lanes
  - Highway helper
  - Dynamic message signs
  - Intelligent lane control systems
  - Ramp meters
- Adjust for occupancy
- Allow for traffic growth within the tool
- More detailed instructions regarding demand inputs in the L07 user guide
- Compute delay using volume, not PCE
Demonstrated delay associated with other factors than simply demand

Traffic management techniques can address nonrecurring factors without the significant capital investment needed to provide additional capacity

Consider increased support for operations, maintenance, and advanced warning programs
  - Real time data collection
  - ITS solutions
Topic Brainstorming

Project Evaluation

• Reliability Solutions
  – Identify causes
  – Weather/crashes
  – Incident response
  – Snow removal
  – Special event management
    • Signing
    • Ramp meters
    • Managed lane scheduling
    • Additional discussion/event planning
  – Maintenance scheduling
• Other reliability treatments
  – Rural applications
  – Recreational travel
  – Data availability
  – Geometric treatments
    • Pull-offs
    • Shoulders
    • Glare screen
    • Snow fence
SHRP 2 Reliability Workshop

LO5 PLANNING & PROGRAMMING:
Integrating Travel Time Reliability into Planning and Programming
Objectives

- Capital investment versus operations and maintenance expenditures
- Quantify costs of road work and other causes of delay
Planning & Programming

Implementation Issues

• Will additional congestion information influence planning process?
• What is done with the information once it has been collected/prepared?
• Do the tools help move towards analysis and performance-based planning?
Planning & Programming

Applications

- Historical vs. predictive/speculative
- Compare to level of effort required for travel demand modeling
- Use in benefit–cost analysis
- Project comparison in system–level analysis (resource allocation)
Wide Range of Tools

Project L02: Establishing Monitoring Systems for Travel Time Reliability
Project C11: Improved Economic Analysis Tools
Project L08: Non-Recurrent Congestion Factors in HCM Methods
Project L07: Evaluation of Highway Design Features to Improve Reliability
Project L05: Incorporating Reliability into Planning & Programming Process

Identifying Issues → Prioritizing Solutions → Institutionalizing Reliability
Planning & Programming

- Questions/Challenges
  - Rural different than Metro
  - Commitment to legacy systems/tools
    - Congestion Report
    - Crash Report(s)
    - State Transportation Scorecard
    - CORSIM, other modeling
UTILITY OF TOOLS SUMMARY
Other Considerations

• Will FHWA become the owners of the tools?
  – If so, will it influence how dollars are distributed?
  – Will implementation be a ‘requirement’ or a ‘suggestion’
  – What opportunities exist for us to continue to shape the implementation process?
Implementation Considerations

• FHWA, AASHTO and TRB implementation workshop
  – Communicate and discuss research outcomes
  – Identify potential users of Reliability Data and Analysis tools
  – Identify specific, prioritized actions for the next five years
    • Federal Government, State DOT’s, MPO’s, Consultants, Universities
  – Build awareness of tools/implementation strategies, tactics & performance measures
Other Considerations

• Who will own and maintain tools within implementing agency/region?
  – Traffic/other technical
  – Planning
  – Program Management
  – Operations
  – Program Delivery
  – MPO/FHWA/outside agency
Final Thoughts

• Initially set out to test technical tools
• Non-technical questions about their use and policy considerations arose
  – How should information be presented to different audiences

<table>
<thead>
<tr>
<th>Reliability Index</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( TT_1 = \frac{TT_{\text{Mean}}}{TT_{\text{FreeFlow}}} )</td>
<td>1.08</td>
</tr>
<tr>
<td>( BI = \frac{TT_{95%} - TT_{\text{Mean}}}{TT_{\text{Mean}}} )</td>
<td>0.26</td>
</tr>
<tr>
<td>On-Time Performance (1.25*FFTT)</td>
<td>92.4%</td>
</tr>
<tr>
<td>( PTI = \frac{TT_{95%}}{TT_{\text{FreeFlow}}} )</td>
<td>1.36</td>
</tr>
<tr>
<td>( TT_{80%} = \frac{TT_{80%}}{TT_{\text{FreeFlow}}} )</td>
<td>1.07</td>
</tr>
<tr>
<td>( MI = \frac{TT_{97.5%}}{TT_{\text{FreeFlow}}} )</td>
<td>1.66</td>
</tr>
</tbody>
</table>

VS.
Final Thoughts

- How should information be presented to different audiences

- Appropriate level of effort and resources required to operate and/or maintain?
Wrap-Up

• Minnesota is pilot testing reliability tools and will report findings back to SHRP 2

• Technical tools must be continuously maintained and improved as they move towards implementation

• We will (with your help) continue to pose questions about tool ownership, maintenance, and use
Afternoon Agenda

• Review SHRP 2 Background and Concepts
• Example Applications for Travel Time Reliability
• Travel Time Reliability Survey
• Next Steps
SHRP 2 Reliability Workshop

REVIEW SHRP 2 BACKGROUND AND CONCEPTS
Reliability tools under evaluation at SHRP 2 pilot test sites

Project L02: Establishing Monitoring Systems for Travel Time Reliability
Project C11: Improved Economic Analysis Tools
Project L08: Non-Recurrent Congestion Factors in HCM Methods
Project L07: Evaluation of Highway Design Features to Improve Reliability
Project L05: Incorporating Reliability into Planning & Programming Process

Identifying Issues → Prioritizing Solutions → Institutionalizing Reliability
Identifying Issues:
Data collection and analysis of reliability performance

- Project L02: Establishing Monitoring Systems for Travel Time Reliability
- Project C11: Improved Economic Analysis Tools
- Project L08: Non-Recurrent Congestion Factors in HCM Methods
- Project L07: Evaluation of Highway Design Features to Improve Reliability
- Project L05: Incorporating Reliability into Planning & Programming Process
Prioritizing Solutions: Economic benefits of transportation improvements
SHRP 2 Reliability Tools

Prioritizing Solutions: Cost-effectiveness of improving reliability

Project L02
Establishing Monitoring Systems for Travel Time Reliability

Project C11
Improved Economic Analysis Tools

Project L08
Non-Recurrent Congestion Factors in HCM Methods

Project L07
Evaluation of Highway Design Features to Improve Reliability

Project L05
Incorporating Reliability into Planning & Programming Process

Cost-Benefit Defaults

- Value of Time (VOT), $/hr: 15.68
- Reliability Ratio: 0.793
- Value of Reliability (VOR), $/hr: 12.43
- Discount Rate: 7.00%

Done

2/20/2014
Institutionalizing Reliability: Incorporating consideration of reliability into standard practice
SHRP 2 Reliability Tools

Minnesota Pilot Site evaluating these reliability tools

Project L02
Establishing Monitoring Systems for Travel Time Reliability

Project C11
Improved Economic Analysis Tools

Project L08
Non-Recurrent Congestion Factors in HCM Methods

Project L07
Evaluation of Highway Design Features to Improve Reliability

Project L05
Incorporating Reliability into Planning & Programming Process

2/20/2014
REAL–WORLD EXAMPLES FOR TRAVEL TIME RELIABILITY
Panelist Introductions

- Deanna Belden
- Mark Filipi
- Jim McCarthy
SHRP 2 Reliability Workshop

I–94 MAPLE GROVE TO ROGERS
I–94 Maple Grove to Rogers
Travel Time Reliability Evaluation

• Measures/Data Sources
  – Corridor Traffic Volumes (VMT)
  – Average Travel Times

• Analysis Timeframe/Location
  – Every 5-minute period during 2012
  – I–94 westbound from I–494 to TH 101
Existing Conditions

I-94 WB 2012 - Travel Time CDF Curve
I-494 to TH 101

- 3.5 TTI
- 3.0 TTI
- 2.5 TTI
- 2.0 TTI
- 1.5 TTI
- 1.25 TTI
- FFIT

Weekdays (2 PM to 7 PM)
All days

Percentage
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
6 8 10 12 14 16 18 20 22 24 26 28 30 32
min
Traffic Forecasts Update

• Additional Travel Time Reliability Analysis
  – TH 101 NB Flyover: Before and After
Travel Time – 2008

I-94 WB 2008 - Travel Time
I-494 to TH 101

- > 4.0 TTI
- 3.5 TTI - 4.0 TTI
- 3.0 TTI - 3.5 TTI
- 2.5 TTI - 3.0 TTI
- 2.0 TTI - 2.5 TTI
- 1.5 TTI - 2.0 TTI
- 1.25 TTI - 1.5 TTI
- Speed Limit TT - 1.25 TTI
- < Speed Limit TT

Speed Limit TT = 7.9 min
55 mph TT = 9.8 min
45 mph TT = 12.0 min
Travel Time – 2009

I-94 WB 2009 - Travel Time
I-494 to TH 101

- > 4.0 TTI
- 3.5 TTI - 4.0 TTI
- 3.0 TTI - 3.5 TTI
- 2.5 TTI - 3.0 TTI
- 2.0 TTI - 2.5 TTI
- 1.5 TTI - 2.0 TTI
- 1.25 TTI - 1.5 TTI
- Speed Limit TT - 1.25 TTI
- < Speed Limit TT

Speed Limit TT = 7.9 min
55 mph TT = 9.8 min
45 mph TT = 12.0 min

2/20/2014
Travel Time – 2011

I-94 WB 2011 - Travel Time
I-494 to TH 101

Speed Limit TT = 7.9 min
55 mph TT = 9.8 min
45 mph TT = 12.0 min
Travel Time – 2012

I-94 WB 2012 - Travel Time
I-494 to TH 101

Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
9:00
8:00
7:00
6:00

> 4.0 TTI
3.5 TTI - 4.0 TTI
3.0 TTI - 3.5 TTI
2.5 TTI - 3.0 TTI
2.0 TTI - 2.5 TTI
1.5 TTI - 2.0 TTI
1.25 TTI - 1.5 TTI
Speed Limit TT - 1.25 TTI
< Speed Limit TT

Speed Limit TT = 7.9 min
55 mph TT = 9.8 min
45 mph TT = 12.0 min

2/20/2014
Annual Traffic and Delay

I-94 WB (I-494 to TH 101)

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Delay (hr)</th>
<th>AADT</th>
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</thead>
<tbody>
<tr>
<td>2008</td>
<td>300,000</td>
<td>50,000</td>
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<td>50,000</td>
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<tr>
<td>2010</td>
<td>300,000</td>
<td>50,000</td>
</tr>
<tr>
<td>2011</td>
<td>300,000</td>
<td>50,000</td>
</tr>
<tr>
<td>2012</td>
<td>300,000</td>
<td>50,000</td>
</tr>
</tbody>
</table>

2/20/2014
SHRP 2 Reliability Workshop

I–35 LAKEVILLE
I–35 in Lakeville

- 5–minute volumes and travel times for 2012
- Data downloaded using TICAS software
- Processed in travel time database
- Evaluation did not include non–recurring factors (weather/crash/incident/event/road work)
Example Applications

I–35 Lakeville

- 6-mile segment of northbound I–35W from CSAH 70 to I–35E/35W split
- Reliability evaluation to determine frequency and magnitude of congestion and delay
I-35 in Lakeville

I-35 NB 2012 - VMT (5:00 AM to 10:00PM)
210th St (S1585) to Crystal Lake Rd (S910)

Vehicle Miles Traveled
- >2000
- 1700-2000
- 1400-1700
- 1100-1400
- 800-1100
- 500-800
- < 500
I–35 in Lakeville

I-35 NB 2012 - Travel Time CDF Curve
210th St (S1585) to Crystal Lake Rd (S910)

- Travel Time % _ All days
- Travel time % _ Weekday 6:00 AM to 9:00 AM

Percentage

4 6 8 10 12 14 16 18 20 22 24

min

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

1.25 TTI

1.5 TTI

2.0 TTI

2.5 TTI

3.0 TTI

3.5 TTI

2/20/2014
I-35 in Lakeville

- Could be performed as part of any metro freeway corridor evaluation
- Additional information, or substitute for, traditional evaluations
  - Safety
  - Congestion
  - Simulation modeling
- These results took ~8 staff hours to produce
Level of Effort

Value of Information

Level of Effort

AADT

Annual Delay (hr)

Delay (hr)

2/20/2014
Value of a Shoulder

• Proposed major highway reconstruction on congested segment with extreme right-of-way restrictions

• Two viable alternatives
  – Eight-lane, at-grade facility with eleven-foot lanes and two-foot shoulders
  – 10 lane alternative with standard width shoulders

• Evaluated with nonrecurring delay elements including crash, incident, event and weather data with the L07 Tool
Value of a Shoulder

Accessible Shoulder

**Operational Inputs**
- Note: Defaults assume only one shoulder is to be made accessible (either left or right)

- Percent of each incident type expected to be relocated to the accessible shoulder:
  - Crashes
    - PDO: 50%
    - Minor Injury: 30%
    - Major Injury & Fatal: 10%

**Benefits**
- Annual Delay Reduction, veh-hr: 19,360
- Standard Dev. Change Indicator: 1.0
- Annual Operational Benefit (AOB), $:
  - Delay Component: $390,025
  - Reliability Component: $2,937
  - Total AOB: $392,962

- Annual Safety Benefit (ASB), $:
  - Benefits due to Congestion Reduction
    - Fatal/Maj Inj: $1,015
    - Minor Injury: $581
    - PDO: $103
  - Benefits due to Treatment Effects
    - Fatal/Maj Inj: $0
    - Minor Injury: $0
    - PDO: $0
  - Total ASB: $1,700

- Other Annual Benefits, $ (User-Specified): 0
- Total Annual Benefits, $: $304,262

**Net Present Value of Benefits**: $4,880,421

**Cost Effectiveness**
- Net Present Benefit: $3,752,100
- B/C Ratio: 4.33
Value of a Shoulder

Project Set Up

• Project segmentation
  – Different cross sections between alternatives at different locations along the study corridor
  – Identify common boundary (different number of total segments between alternatives, same total length)

• Analysis Horizon
  – Year of opening, end of design life, and two intermediate years

• Traffic Forecasts
  – ATR data used to develop 24-hour profiles
  – Adjusted and applied to future peak hour forecasts
# Value of a Shoulder

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>2,640</th>
<th>1,590</th>
<th>3,310</th>
<th>Total</th>
<th>7,540</th>
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<tbody>
<tr>
<td>Design</td>
<td>Standard</td>
<td>Standard</td>
<td>Narrow Lanes/Shoulders</td>
<td></td>
<td></td>
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</tbody>
</table>

- 11-ft Lane
- 11-ft Lane
- 11-ft Lane
- 11-ft Lane

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>1,010</th>
<th>3,220</th>
<th>860</th>
<th>2,450</th>
<th>Total</th>
<th>7,540</th>
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<tr>
<td>Design</td>
<td>Standard</td>
<td>Standard</td>
<td>Standard</td>
<td>Standard</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 11-ft Lane
- 11-ft Lane
- 11-ft Lane
- 11-ft Lane

2/20/2014
Project Assumptions

• Crash Data
  – Used crash rates were developed using the Enhanced Interchange Safety Analysis Tool (previous analysis)
  – Used L07 Tool default for crash duration

• Incident Data
  – Used L07 Tool defaults for incident occurrence and duration

• Weather Data
  – Used L07 Tool defaults

• Event Data
  – Percent volume increases and event occurrence rate data was obtained from a previous study

• Work Zone Data
  – Use of this feature was not included in the analysis
Value of a Shoulder

- Results show less non-recurring delay with full shoulders.
- Increasing non-recurring delay over time under both alternatives.
Year 2040 Hourly Non-Recurring Delay Comparison

Daily Non-Recurring Delay (vehicle-hours)

Hour of Day

8-Lane
10-Lane
Difference
### Value of a Shoulder

<table>
<thead>
<tr>
<th>Design</th>
<th>Standard</th>
<th>Standard</th>
<th>Narrow Lanes/Shoulders</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Non-Recurring Delay (hr/day)</td>
<td>34.3</td>
<td>20.1</td>
<td>60.5</td>
<td>114.9</td>
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### Design

<table>
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<th>Standard</th>
<th>Standard</th>
<th>Standard</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Recurring Delay (hr/day)</td>
<td>10.9</td>
<td>38.1</td>
<td>7.7</td>
<td>28.7</td>
</tr>
</tbody>
</table>

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2/20/2014
Conclusions and Considerations

• The tool produced intuitive results based on geometry and traffic growth conditions

• Limitations regarding the entire project study area – the L07 analysis only considered mainline conditions

• The analysis was not exhaustive
  – Incident and crash durations
  – Work zone and lane closure information
Example Applications for Travel Time Reliability

FLORIDA RELIABILITY REPORTS
Florida DOT/University of Florida

- Established methods to estimate reliability performance
- Developed estimates of reliability on all freeway segments of their Strategic Intermodal System
- Produced “Reliability Report” with MOEs including:
  - Average speed
  - 95th percentile speed
  - On-time arrival percentage
  - Travel Time Index
  - Planning Time Index
## Florida Reliability

<table>
<thead>
<tr>
<th>Facility</th>
<th>From</th>
<th>To</th>
<th>Average Weighted Speed</th>
<th>95th% Speed</th>
<th>Daily Measures</th>
<th>Buffer Index</th>
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</thead>
<tbody>
<tr>
<td>I-10/SR 8</td>
<td>State Line</td>
<td>I-110/SR 8A</td>
<td>58.90</td>
<td>57.20</td>
<td>97.4%</td>
<td>97.3%</td>
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<tr>
<td>I-10/SR 8</td>
<td>I-110/SR 8A</td>
<td>SR 87</td>
<td>60.70</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
</tr>
<tr>
<td>I-10/SR 8</td>
<td>SR 87</td>
<td>SR 85/S Ferdon Blvd</td>
<td>60.73</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.9%</td>
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<tr>
<td>I-10/SR 8</td>
<td>SR 85/S Ferdon Blvd</td>
<td>US 331/SR 83</td>
<td>60.74</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.9%</td>
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<tr>
<td>I-10/SR 8</td>
<td>US 331/SR 83</td>
<td>US 231/SR 75</td>
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<td>97.6%</td>
<td>97.9%</td>
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<td>I-10/SR 8</td>
<td>US 231/SR 75</td>
<td>SR 263/Capital Circle NW</td>
<td>60.74</td>
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<td>I-10/SR 8</td>
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<td>US 90/SR 10</td>
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<td>97.8%</td>
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<td>I-10/SR 8</td>
<td>US 90/SR 10</td>
<td>US 19/Florida Georgia Pkwy/SR 57</td>
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<td>57.20</td>
<td>97.6%</td>
<td>97.9%</td>
</tr>
<tr>
<td>I-10/SR 8</td>
<td>US 19/Florida Georgia Pkwy/SR 57</td>
<td>I-75/SR 93</td>
<td>60.74</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.9%</td>
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<td>I-10/SR 8</td>
<td>I-75/SR 93</td>
<td>US 301/SR 200</td>
<td>60.74</td>
<td>57.20</td>
<td>97.6%</td>
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<tr>
<td>I-10/SR 8</td>
<td>US 301/SR 200</td>
<td>I-295/SR 9A</td>
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<td>97.8%</td>
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<td>I-10/SR 8</td>
<td>I-295/SR 9A</td>
<td>I-95/SR 9</td>
<td>63.38</td>
<td>60.92</td>
<td>98.5%</td>
<td>98.2%</td>
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<td>I-110 Spur/SR 8A</td>
<td>SR 30/E Chase St</td>
<td>I-10/SR 8</td>
<td>60.70</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
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<tr>
<td>I-275/SR 93</td>
<td>I-75/SR 93</td>
<td>SR 682/54th Ave S</td>
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<tr>
<td>I-275/SR 93</td>
<td>SR 682/54 Ave S</td>
<td>I-175/SR 594</td>
<td>64.54</td>
<td>60.92</td>
<td>97.7%</td>
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<tr>
<td>I-275/SR 93</td>
<td>I-175/SR 594</td>
<td>SR 694/Gandy Blvd</td>
<td>61.53</td>
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<td>I-275/SR 93</td>
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<td>100.0%</td>
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<td>SR 60/Memorial Hwy</td>
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<td>60.50</td>
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<tr>
<td>I-275/SR 93</td>
<td>SR 60/Memorial Hwy</td>
<td>I-4/SR 400</td>
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<td>I-275/SR 93</td>
<td>I-4/SR 400</td>
<td>I-75/SR 93</td>
<td>48.96</td>
<td>54.58</td>
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<td>I-175/SR 594</td>
<td>I-275/SR 93</td>
<td>SR 687/4th St S</td>
<td>60.73</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
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<tr>
<td>I-375/SR 592</td>
<td>I-275/SR 93</td>
<td>SR 595/4th Ave N</td>
<td>60.73</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
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<td>Veterans Exp/SR 589</td>
<td>SR 60/Courtney Campbell Cwy</td>
<td>Veterans Spur Exwy/SR 568</td>
<td>60.72</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
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<td>Suncoast Pkwy/SR 589</td>
<td>Veterans Spur Exwy/SR 568</td>
<td>SR 54</td>
<td>60.73</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
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<tr>
<td>Suncoast Pkwy/SR 589</td>
<td>SR 54</td>
<td>SR 50/Cortez Blvd</td>
<td>60.74</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.9%</td>
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<td>Suncoast Pkwy/SR 589</td>
<td>SR 50/Cortez Blvd</td>
<td>US 98/SR 700/Ponce de leon Blvd</td>
<td>60.75</td>
<td>57.20</td>
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<tr>
<td>Veterans Spur Exp/SR 589</td>
<td>Veterans Expy/SR 589</td>
<td>SR 597/Dale Mabry Hwy N</td>
<td>60.73</td>
<td>57.20</td>
<td>97.6%</td>
<td>97.8%</td>
</tr>
</tbody>
</table>
Reliability Indices

Travel Time Index
Travel Time Index is the ratio of the average observed travel time divided by the average free-flow travel time.

Buffer Index
The buffer index is the proportion of extra time (or time cushion) that most travelers add to their average travel time when planning trips to ensure on-time arrival.

Planning Time Index
Planning Time Index is the factor applied to the free-flow time needed to ensure on-time arrival 95% of the time. It differs from the buffer index since it includes recurring delay as well as unexpected delay.

Planning Time Failure / On-Time Measures
Planning Time Failure / On-Time Measures describe the percentage of trips with travel times within a certain factor of the median travel time. Common thresholds include 1.1* Median Travel Time or 1.25* Median Travel Time. Other formulations of these measures denote the percentage of trips with average speeds below a specified threshold, for example 50 mph, 45 mph, or 30 mph.

80th Percentile Travel Time Index
80th Percentile Travel Time Index is the 80th percentile travel time divided by the free flow travel time. It represents another threshold of impacted traffic flow condition.

Misery Index
Misery Index is the average of the highest five percent of travel times divided by the free flow travel time. Often referred as the 97.5% travel time index.

\[ TTI = \frac{TT_{Observed}}{TT_{FreeFlow}} \]

\[ BI = \frac{TT_{95\%} - TT_{Mean}}{TT_{Mean}} \]

\[ PTI = \frac{TT_{95\%}}{TT_{FreeFlow}} \]

\[ TTI_{80\%} = \frac{TT_{80\%}}{TT_{FreeFlow}} \]

\[ MI = \frac{TT_{97.5\%}}{TT_{FreeFlow}} \]
<table>
<thead>
<tr>
<th>Reliability Index</th>
<th>Measured Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( TTI = \frac{TT_{Mean}}{TT_{FreeFlow}} )</td>
<td>1.08</td>
</tr>
<tr>
<td>( BI = \frac{TT_{95%} - TT_{Mean}}{TT_{Mean}} )</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>On-Time Performance (1.25*FFTT)</strong></td>
<td>92.4%</td>
</tr>
<tr>
<td>( PTI = \frac{TT_{95%}}{TT_{FreeFlow}} )</td>
<td>1.36</td>
</tr>
<tr>
<td>( TTI_{80%} = \frac{TT_{80%}}{TT_{FreeFlow}} )</td>
<td>1.07</td>
</tr>
<tr>
<td>( MI = \frac{TT_{97.5%}}{TT_{FreeFlow}} )</td>
<td>1.66</td>
</tr>
</tbody>
</table>

**Reliability Indices**
WisDOT currently uses a traditional benefit–cost analysis procedure to assist with evaluation of Major Highway Projects, which includes:

- **Transportation Efficiency Benefits** – Reductions in:
  - Travel delay cost – *recurring congestion* for 52–year facility service life
  - Crash costs based on fatal/injury/property damage crash rates
  - Vehicle operating costs
- **Capital/Maintenance costs**
- **Measures of Economic Efficiency** – B/C ratio and Net Present Value

Include costs associated with *non–recurring congestion* factors in benefit–cost analysis:

- Crash/Incident Delay
- Weather Delay
- Road Work Delay
- Event Delay
Reliability Project Goals

• Understand the impacts of non-recurring congestion factors on highway travel times at varying demand levels
• Develop a model to capture delays caused by non-recurring congestion factors
• Update WisDOT’s benefit–cost tool with the new travel time estimation model
• Evaluate candidate Major Highway Projects with new tool to capture expanded benefits
• Refine benefit–cost tool by reviewing assumptions/ methods and adding a streamlined user interface
Project Evaluation Process

**No Build Condition**
- Roadway Design
- Maintenance Schedule
- Construction Schedule

**Build Condition**
- Facility Type
- Recurring and non-recurring congestion
- Volume and travel time data
- Weather data
- Crash Data
- Incident Data
- Work Zone Data

**Travel Time Tool**

**Benefit-Cost Tool**
- Project Costs
- Travel Time Benefits
- Vehicle Operating Cost Benefits
- Safety Benefits
- Economic Computations

**Project Results Summary**
- Net Present Value
- Benefit-Cost Ratio
- Internal Rate of Return
Project Evaluation Process

BCA Ratio

Build Condition

No Build Condition

Travel Time Tool

Benefit-Cost Tool

Project Results Summary

Project Prioritization

BCA Ratio

1.2

1.8

Benefit-Cost Tool

Travel Time Tool

Project Results Summary

Build Condition

No Build Condition

Travel Time Tool

Benefit-Cost Tool

Project Results Summary
Travel Time Model Process

Determine Hourly Volumes

- Base Condition
- Rain
- Snow
- Incident
- Rain & Incident
- Snow & Incident

Estimate Hourly Travel Time for each Scenario

- Look Up Free Flow Speed and Capacity Parameters

Estimate Probability of Occurrence for each Scenario

- Probability of occurrence

Calculate Weighted Travel Time for each Hour

- Weighted average of TT & delay

Sum Travel Time for each Year

- $\sum$ all hours of year

Average annual travel time and total delay

More categories may be identified based on review of weather, incident, and travel time data.
Section Categorization

Roadway Type
- 2–Lane Arterial
- 4–Lane Freeway
- 4–Lane Arterial
- 6–Lane Freeway

Facility Function
- Urban/Commuter
- Rural
- Recreational
- Interregional/Freight
- Regional Center Connector
Highway Sample Sections

- 51 sections selected
- 15 roadway classifications
- Prioritize high-volume/high-crash corridors
- Mix of freeways and arterials
WisDOT provided 3 years of hourly count data from 124 ATR sites

Count data reviewed for completeness

Hourly counts used to develop annual traffic profiles and confirm facility function

Traffic volumes profiled by:
  - Month of Year
  - Day of Week
  - Hour of Day

Holidays and other unique travel days evaluated separately
  - Some holidays fall on different weekdays each year
Holiday Traffic

Sunday

Monday

Tuesday

Wednesday

Thursday

Friday

Saturday
Annual Traffic Profiles

• Total Day Definitions = 109
  – 12 months x 7 days = 84
  – 25 holidays and unique travel days

• ATR count data averaged by day for each year (2010–2012) using hourly percent of AADT

• Yearly averages from individual ATR sites were averaged to create annual profile
INRIX Speed Data

- Data obtained for 800 directional highway miles
- 5-minute data for 2011
- 1-minute data for 2011–12
- 1 year of data:
  - >17 GB
  - >400,000,000 rows!
- Compare speeds to NPMRDS and ATR speed data
INRIX Speed Data

The chart shows the number of records over time, with different colors representing different categories:
- **Real Time**
- **Historical**
- **Reference**

The y-axis represents the number of records, ranging from 0 to 18,000. The x-axis represents time, from 0:00 to 23:00.

The data is presented on February 20, 2014.
Weather/Crash/Incident Data

- Obtained from NOAA, RWIS, and Maintenance Records
  - Provides precipitation type and intensity
  - Indicates roadway condition (snow/ice)
- MV4000 Crash Data
  - Crashes recorded in police accident reports
- EventManager Incident Data
  - Collected by STOC for observed incidents
  - Subset triggers 511, DMS, media alerts
Model Estimation Process

- Weather
- Incidents
- Crashes

Categorize weather & incident conditions

Estimate demand-speed equations for travel time model

Travel Time

Volume

Graph: Travel Time Factor vs Volume (vph)
Travel Time Model Process

Determine Hourly Volumes

- Base Condition
- Rain
- Snow
- Incident
- Rain & Incident
- Snow & Incident

Estimate Hourly Travel Time for each Scenario

- Look Up Free Flow Speed and Capacity Parameters

Estimate Probability of Occurrence for each Scenario

- Probability of occurrence

Calculate Weighted Travel Time for each Hour

- Average hourly travel time and delay

Sum Travel Time for each Year

- Σ all hours of year

Average annual travel time and total delay

More categories may be identified based on review of weather, incident, and travel time data.
Example Applications

Benefit–Cost Enhancement

• Refine existing processes to include influence of non-recurring congestion

• Evaluation of projects will include recurring and non-recurring delay (incidents, weather, road work)

• Application to statewide system
SHRP 2 Reliability

EXAMPLE APPLICATION
SUMMARY
Example Applications

CMSP – Primary Screening

Existing process based on:

- MnDOT 2010 AADT
- Top 200 Interchange List
- Top 200 Intersections
- RTMC Freeway and Expressway Crash Report

Next time include RELIABILITY?
### Example Applications

#### CMSP – Secondary Screening

<table>
<thead>
<tr>
<th>Quantified Attributes</th>
<th>Project Cost</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Magnitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of Existing Delay and Crash Costs</td>
<td>Planning-Level Construction Cost Estimate</td>
<td>Percent of Existing Delay and Crash Costs Solved by Proposed Solution</td>
</tr>
</tbody>
</table>

Scoring performed by computing the Return Period: the Length of Time for Delay and Crash Savings to Equal Project Cost

\[
\text{Return Period} = \frac{\text{Project Cost}}{\text{Problem Magnitude} \times \text{Effectiveness}}
\]
Example Applications

- MnSHIP Process
- CMSP
- MnPASS
- Benefit–Cost
- Corridors of Commerce
SHRP 2 Reliability Survey

TRAVEL TIME RELIABILITY SURVEY
Survey Question #1

How familiar are you with the concept of travel time reliability?

1) Very Familiar
2) Familiar
3) Unfamiliar
4) Very Unfamiliar
Survey Question #2

Describe the extent to which you believe travel time reliability can be quantified.

1) Highly
2) Moderately
3) Limited
4) Qualitatively only
Survey Question #3

How often have you seen travel time reliability used in project evaluations previously?

1. Frequently
2. Sometimes
3. Once
4. Never
Survey Question #4

How often has your agency used travel time reliability in a program or planning application?

1. Frequently
2. Sometimes
3. Once
4. Never
Survey Question #5

How likely are you to consider the evaluation of travel time reliability in the future?

1. Very Likely
2. Likely
3. Unlikely
4. Very Unlikely
Survey Question #6

What applications of travel time reliability do you find most promising? (select all that apply)

1. Historical observations/delay categorization
2. Project evaluation
3. Benefit–cost analysis
4. Planning and programming
Survey Question #7

What types of reliability evaluation would your agency be most likely to implement? (select all that apply)

1. Annual or other regular reporting
2. Supporting information for project development
3. Feedback for highway operations and maintenance
4. Allocation of resources among or within funding programs
Survey Question #8

What barrier is most likely to impede your agency’s ability to evaluate travel time reliability?

1. Data availability
2. Staff expertise
3. Staff and time resources
4. Existing methods are adequate
5. Resistance to change
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NEXT STEPS
Ongoing SHRP 2 Projects

• Project L35 – Estimating the Value of Travel Time Reliability
  – Defined by reliability ratio

\[ RR = \frac{VOR}{VOT} \]

• L35A – U of Arizona, Portland Metro
  – Estimate RR using stated preference surveys

• L35B – U of Maryland, Maryland St Hwy Admin
  – Estimate RR using analytical methods
Ongoing SHRP 2 Projects

• Project L36 – Regional Operations Forum
  – SHRP 2 sponsors group of young professionals to attend multi-state retreats for training in operations and management
  – Midwest retreat scheduled for June 2014 in Milwaukee
Future Outreach

• Minnesota Pilot Team available to share findings and provide progress updates

• Presentation of final report via webinar (anticipated May 2014)

• Final Report will be available via FTP
More Information

• SHRP 2 Website:
  http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Pages/Reliability_159.aspx

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THANK YOU!

SHRP 2 Reliability Workshop