RESEARCH & DEVELOPMENT

Final Pilot Study Report

SHRP2 L38 Reliability Data and Analysis Tools Implementation Assistance: Program Proof of Concept Pilot Study

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16. Abstract

Under the SHRP2 program, certain projects resulted in the development of various methods and tools. The SHRP2 tools were developed in various forms ranging from guidebooks, frameworks, and modeling and analysis software programs. The SHRP2 tools that were evaluated in this pilot study are from the SHRP2 Reliability Program. The reliability program tools were developed for travel time reliability analysis.

The intent of this pilot study was to evaluate how effective those developed tools would be for transportation agencies desiring to implement travel time reliability monitoring, modeling, and analysis. The pilot study team organized the evaluated tools into three logical categories that reflect three distinct elements of NCDOT's overall mission of "Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina."

The categories and associated SHRP2 projects are:

- **Tools for Monitoring Travel Time Reliability** (SHRP2 L02 "Establishing Monitoring Programs for Mobility and Travel Time Reliability")
- **Tools for Modeling Travel Time Reliability** (SHRP2 C11 "Development of Improved Economic Analysis Tools Based on Recommendations from Project C03," SHRP2 L07 "Evaluation of Cost-Effectiveness of Highway Design Features," SHRP2 L08 "Incorporation of Travel Time Reliability into the Highway Capacity Manual")
- **Tools for Incorporating Reliability into Transportation Planning and Programming (**SHRP2 L05 "Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes")

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Pilot Study Executive Summary

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1. INTRODUCTION

The pilot study documented in this report was conducted under Round 4 of the second Strategic Highway Research Program (SHRP2) Implementation Assistance Program (IAP). Specifically, this pilot study was conducted by the Institute of Transportation Research and Education at North Carolina State University under the direction of an NCDOT Steering and Implementation Committee chaired by Jennifer Portanova, North Carolina's State Traffic Systems Operations Engineer. NCDOT was the Round 4 applicant for this IAP pilot study.

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- Tools for Monitoring Travel Time Reliability
  - SHRP2 L02 "Establishing Monitoring Programs for Mobility and Travel Time Reliability" – The pilot study evaluated all tool components, namely the project Final Report, Guidebook, and Handbook.
- Tools for Modeling Travel Time Reliability
  - SHRP2 C11 "Development of Improved Economic Analysis Tools Based on Recommendations from Project C03" – The pilot study only evaluated one component of the C11 products, namely the "Reliability Tool," which is a macro-enabled spreadsheet implementation of the SHRP2 L03 reliability regression equations.
  - SHRP2 L07 "Evaluation of Cost-Effectiveness of Highway Design Features" – The pilot study evaluated all tool components, namely the Report, Guide, and Software tool.
  - SHRP2 L08 "Incorporation of Travel Time Reliability into the Highway Capacity Manual" – The pilot study evaluated the key modeling tool from this project, namely the FREEVAL-RL freeway facility software tool.

- Tools for Incorporating Reliability into Transportation Planning and Programming
  - SHRP2 L05 “Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes” – The pilot study assessed the status of incorporating reliability into planning by holding a round table discussion of the L05 products (Guide, Technical Reference, and Final Report) and the role of the L08 FREEVAL tool in freeway project level reliability modeling.

For the travel time monitoring and modeling categories, the evaluation methodologies were principally based on the use of real corridors and actual data.

This pilot study report is organized in a manner consistent with the tool categorization. This report section provides a brief overview of the pilot study including a summary of key findings and recommendations for each of the tool categories and documentation of the efforts to disseminate the pilot study results. The report section labeled Volume I provides a detailed documentation of the pilot testing of the travel time monitoring tools. The report section labeled Volume II provides a detailed documentation of the pilot testing of the travel time modeling tools. The report section labeled Volume III provides a detailed documentation of the assessment of tools for incorporating reliability into transportation planning and programming. Each section, including this summary section, includes appendices as appropriate for additional detail that is important for archival documentation and may be of interest to some readers.

The remainder of this pilot study executive summary is organized as follows. The next section provides a summary of the pilot study team’s review of the findings from previous tool validation efforts. This review of prior findings is followed by a high level summary of the key findings and results from each of the tool categories. The executive summary then concludes with a summary of the pilot study results dissemination efforts.

2. REVIEW OF PRIOR VALIDATION EFFORTS

As a starting point for this pilot study, the team carefully reviewed the findings from the first round of Implementation Assistance Program pilot testing. This section summarizes tool specific comments provided by the first round contractors. These were gathered from the final reports submitted under SHRP2 L38. In general, our related findings in the current pilot study were consistent with the findings summarized below.

2.1. SHRP2 C11 Tool

Although the SHRP2 C11 project was part of the SHRP2 Capacity Program, one of the tools developed was a spreadsheet implementation of the travel time reliability regression equations developed under the earlier SHRP2 L03 project entitled *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies*. The intended functionality of this macro-based spreadsheet tool was to provide sketch planning estimates of travel time reliability for freeways, rural highways, and signized intersections.

It is important to note that the tool is not designed to analyze a facility or system. In other words, the freeway and rural highway modules look only at a single segment with uniform traffic and geometric conditions, and the signalized intersection model only considers signalization in terms of how traffic signals impact delay in a very general sense. As with the freeway and rural highway analysis, the signalized analysis assumes uniform traffic demand along the corridor and consistent geometry (not even considering the number of signalized intersections or any signal timing details). The tool is available for download at - http://www.tpics.us/tools/documents/SHRP2-C11-Reliability-Tool.xlsm.

At the time of the pilot study team's assessment in 2016 and 2017, the tool had fallen behind in terms of compatability with the versions of Excel in use at the time. Although the pilot study team possessed the expertise necessary to overcome the compatability issues, this level of macro programming and debugging knowledge is not likely to be readility available in transportation agencies, and therefore, the inoperability of the available version of the tool renders it of no practical usefulness.

Summary of Prior Validation Results

- Difficult to calibrate with real world conditions: The study team eventually discovered that the tool can be calibrated to the observed conditions on the facility by adjusting the peak capacity and the hourly distribution of demand.

- Issues with adjusting peak capacity: to calibrate the tool, capacities as low as 1,300 vehicles per hour per lane were used, which is well below the known flow rate at capacity for the two facilities used for validation (but probably indicative of throughput during congestion).

- Issues with adjusting hourly distribution of demand: The tool's interface does not allow the user to input the hourly distribution of demand. Only after going into a hidden password-protected tab was the study team able to discover the default distribution assumed in the tool and adjust the distribution to match the actual volume found on the facilities.

- All the input fields were not clearly documented. Some include the "current AADT" field in the traffic data tab.

- The tool's user interface includes preset analysis periods from which to choose, but users may need to analyze a different time period based on facility characteristics, organizational standards, or other factors.

- The C11 tool refers to the value of time associated with trucks as "commercial value of time." This nomenclature could be confused with on-the-clock travel, which includes automobiles used for business purposes.

- The travel time unit costs appear to be on a per vehicle basis. Neither the C11 user's guide nor the technical documentation refers to average vehicle occupancy (i.e., the average number of people per vehicle). In addition, the C11 tool does not provide an input for entering the average number of occupants in personal vehicles on the facility.

- Difficult to correlate benefit results to TTI. Although the results are generally easy to understand, the tool does not specify which set of reliability data are used to calculate the benefits. The study team eventually discovered that the benefits are based on 50th and 80th percentile (TTIs) after review of the C11 technical documentation.

- Team found inconsistency in the definitions of recurring delay.

- Difficult to use reliability ratios from other sources.

- Use the C11 tool. Agencies model facility performance using traditional tools, such as travel demand or microsimulation models. The C11 tool can be used to estimate reliability changes by logical segments (e.g., defined by bottlenecks or highway geometry). The mobility benefits are adjusted to match the traditional tools and the resulting reliability improvement is reported as part of the benefit-cost analysis.

2.2. SHRP2 L02 Tool/Guidance

The "tool" provided by the SHRP2 L02 project consisted of the project report, a guidebook titled *Guide to Establishing Monitoring Programs for Travel Time Reliability*, and a handbook titled *Handbook for Communicating Travel Time Reliability Through Graphics and Tables*. Taken together, these documents provide the theorectical framework, technical guidance, and practical communication strategies to support transportation agency efforts to establish robust enterprise systems for continuously monitoring travel time reliability.

Summary of Prior Validation Results

- Analysts using the tool need to be cognizant of their audience and generate reports from the tool that will connect with them. Outputs range from single values to detailed graphs, and audiences range from decision makers to the general public.

- Level of effort is directly related to the detail of results. For example, 1 year of historical travel time information for a single segment can be processed in a day, while system level analysis broken down by delay regime could potentially take months.

- The tool could be used to determine what the specific sources of delay were, so that specific treatments could be focused to address these conditions.

- For larger-scale analysis, data storage can become an issue.

- Documentation and guidance regarding the collection of data for use in this tool should be provided, so that agencies with different sources of data can adapt data to meet the needs of the tool.

- Stakeholders were supportive of the potential of this tool to be used to categorize historical data by delay type, to provide information for a project-level evaluation, and to be used in the planning and programming process.

- The distribution of travel times and how it is affected by recurrent congestion and nonrecurring events is clearly and efficiently shown by creating the cumulative distribution function (CDF) charts using the L02 methodology. Comparing performance targets to actual freeway performance is then easily accomplished, as long as targets are expressed in a way that is compatible with the L02 output. For example, agencies should express desired performance in terms of performance at various percentiles, or as the standard deviation of travel time.

- The need for capacity investments and other improvements is not perfectly addressed by the L02 tools. The research team felt it was necessary to analyze the relative contribution of each regime to the overall reliability and delay. This could not be directly taken from the L02 methods; however, it did provide a strong foundation for such analysis.

- Finally, the L02 methodology and CDFs were helpful in determining the effectiveness of improvements and investment. However, it is important to note that L02 specifies route-level analysis, which is a much larger scale than most improvements. The research team chose to examine improvements near the segment level and found that plotting standard deviations of travel times could be more helpful for detailed analysis.

2.3. SHRP2 L05 Tool/Guide

Similar to the SHRP2 L02 products, SHRP2 L05 delivered three documents: a final project report, a technical reference, and a guide. The aim of these documents is to demonstrate the incorporation of "reliability performance measures into the transportation planning and programming processes" through a series of case studies, document lessons learned, and provide recommendations and strategies for bringing travel time reliability into planning and programming processes. For a period of time, the spreadsheets used in the case studies were available for download. However, these were provided for illustration and were not designed to be easily used for travel time analysis in different contexts. Likely for this reason, the spreadsheets are no longer available for download.

Summary of Prior Validation Results

- The L05 tool is less of a technical tool compared with L02 and L07 and more of a guidance strategy for implementing reliability.

- A survey conducted during the validation workshop demonstrated a need for reliability education, as the definition of reliability currently varies between transportation professionals and agencies.

- There were concerns among the survey respondents with how to institutionalize reliability between urban and rural areas.

- The survey also revealed barriers that exist to institutionalize reliability, such as level of effort and staff capabilities.

2.4. SHRP2 L07 tool

The SHRP2 L07 project delivered a standalone Java-based analysis tool. At the tool's core are the same SHRP2 L03 regression equations that were the basis of the C11 tool. The intent of the L07 tool was to extend the L03 regression-based analysis for rural areas and to add a range of local site conditions as additional factors for which to estimate their impact on travel time reliability. As with the C11 tool, the L07 tool only analyzes segments of uniform demand and geometry. Also, as in the case of the C11 tool, the pilot study team had to find workarounds to Java runtime compatability issues in order to evaluate the tool. However, unlike the C11 Excel tool, the L07 tool is no longer available for download.

Summary of Prior Validation Results

- Due to the complexity of this tool relative to the C11 tool, the study team found gathering several pieces of data required by the L07 Analysis Tool to be time-consuming and, at times, difficult. This mainly includes demand and incident data using the Freeway Performance Measurement System (PeMS).

- Difficult to understand Events input. The study team had difficulty understanding what type of events should be included in the Event input screen.

- Limited geometry input options. The L07 Analysis Tool provides a limited number of choices for Lane Width and Lateral Clearance via dropdown boxes. For greater accuracy, the tool should provide more options for these fields.

- Difficult to calibrate. As with the C11 Reliability Analysis Tool, the L07 tool and its associated user's guide (MRIGlobal 2013a) provide little instruction on how to calibrate the tool to real-world conditions.

- Demand Growth. The L07 Analysis Tool does not provide an input box for demand growth. As a result, all analyses assume that demand remains constant over time.

- Risk of Inaccuracies in the *Utilizing Custom Treatment Incidents Module*.

- Limited Urban Area Operational Strategies. While the L07 Analysis Tool provides a broad array of treatment options, the tool does not include several of the common operational strategies that can benefit urban facilities. The study team wanted to test several strategies not found in the tool: advanced ramp metering, auxiliary lanes, and ramp modifications.

- Audience members at the validation presentation and discussion expressed concern about the level of effort required to perform a fully detailed analysis, and they expressed concern that in some cases detailed data would not be available at all.

- There was also concern expressed about the level of effort required to perform a system level analysis using this tool. It was suggested that the L02 tool be used as an initial screening to identify potential high-reward corridors before performing a detailed analysis.

- It was expressed that if a fully detailed analysis did not substantially increase the accuracy of the tool output, certain categories should be targeted first to help increase the accuracy of the analysis. It was suggested that crash and incident data be looked at before weather data.

- One audience member mentioned that there was skepticism on how the tool was computing benefits for each treatment, since they are often based on case studies, and that more analysis would be required for the audience members to become comfortable with the results.

- Neither the output comparison between L07 and DRIVE Net (*Washington State's Digital Roadway Interactive Visualization and Evaluation Network*) nor the software accuracy comparison between L07 before-treatment curve and L07 after-treatment curve yields a positive conclusion. At the same time, the research team suggests that the L07 project team help revise the tool and allow the user to obtain more detailed output information from it.

- In the L07 tool, the treatment "Extra High Med Barrier" only deals with gawk-inducing incidents. However, such treatment in reality can also help prevent other types of incidents. For example, some high concrete median barriers can also prevent vehicles from crossing over into the opposite direction, so that some severe accidents can be prevented. Therefore, more potential effects of the proposed design treatments in L07 are recommended for consideration.

- In the case study, the test project did not provide meaningful results in the cost–benefit analysis. It may be because of an underestimation of the project effect on preventing major injury and fatal incidents. It can be concluded that the net present benefit is sensitive to the number of fatal and major injury incidents. This is consistent with the fact that fatal and major injuries contribute the most to total cost. For most fatal injuries, the cost mostly depends on the number of deaths during the crash; however, the L07 tool suggests using uniform cost values for incidents with the same severity level. Thus, the research team recommends that the L07 tool should allow users to modify the cost of incidents and provide a modification factor for the users to input location-specific cost values for different severity levels of incidents.

2.5. SHRP2-L08 Tools (FREEVAL-RL and STREETVAL):

The SHRP2 L02 delivered two analytical tools that provide detailed travel time reliability estimatesL FREEVAL-RL for freeways and STREETVAL for arterial streets. Unlike the C11 and L07 tools, FREEVAL-RL and STREETVAL analyze a facility or system corridor with turning movements at intersections and ramp junctions and considering changes to number of lanes and other key geometric features along the route. It is important to note that at the time of the initial validation efforts summarized below, the analysis methodologies were implemented in Excel spreadsheets. Since that time, both tools have been implemented in standalone programs with improvements that substantially addressed the limitations mentioned below.

Summary of Prior Validation Results

FREEVAL-RL

- The FREEVAL-RL tool requires the user to enter various input data (including geometry data, segment type data, and demand flow data) cell-by-cell. This data entry method is slow and time consuming.

- Limitation on maximum number of lanes. FREEVAL-RL allows the user to define a mainline segment with one to six lanes in one direction. In addition, the maximum number of on-ramp and off-ramp lanes is limited to two lanes.

- Model Freeway Connectors. FREEVAL-RL is not able to serve the demands from a three-lane freeway-to-freeway connector with high flow. The study team found that a workaround is to model a short two-lane on-ramp segment followed by another one-lane on-ramp segment.

- No Network Geometry Viewer and Audit Tool. It is easy to make mistakes when entering network geometries, particularly for large networks. FREEVAL-RL does not provide a graphical tool that can assist users in visualizing the results of segment coding.

- FREEVAL-RL must be able to handle the weaving and merging associated with limited-access high-occupancy vehicle lanes or managed lanes.

- High default capacity. Through extensive calibration testing, the study team found that the default capacity value in FREEVAL-RL was too high for the tested facility. This capacity can be modified through adjustments to the capacity adjustment factor (CAF) until the capacities calibrate to real-world traffic flows.

- Speed Contour Maps. The study team found the three-dimensional speed contour maps produced automatically in FREEVAL-RL hard to read.

- Ramp Merging Model. The on-ramp flow for mainline segments in congestion may not be fully served because HCM 2010 gives the mainline flow a higher priority than the on-ramp flow. The study team found through its testing that the FREEVAL-RL model does not allow the vehicles on the ramp to merge to the freeway mainline if the mainline is congested and the on-ramp flow is high.

- In summary, although it is impossible to evaluate the accuracy of FREEVAL-RL based on the results of two tests, it is fair to say that the reliability estimates of the software seem reasonable compared to the ground truth reliability determined from the dual-loop detector data. Overall, FREEVAL-RL tends to be overoptimistic in its estimates and produced consistently smaller TTI values and smaller semi-standard deviations.

- A redeeming quality of the software is that it was able to provide a reasonable prediction for the mean and median travel times, differing by less than 10%.

STREETVAL

- Based on test results, it was shown that STREETVAL was unable to provide a reasonable travel time reliability prediction for the urban arterial test site. The difference in variance and widths of the ground truth travel time distribution, and the predicted travel time distribution from STREETVAL is significant. Although the assessment of the software is biased because of a 0.03-mile difference in the lengths of travel time links between the ground truth data and STREETVAL results, an only 3% margin of error is not sufficient to explain this large of a discrepancy. This error is likely a result of both inaccurate demand prediction and not accounting for some principal factor influencing travel times.

3. KEY FINDINGS AND RECOMMENDATIONS BY TOOL CATEGORY

3.1. Reliability Monitoring Tools

The L02 reliability monitoring tools were evaluated on a series of freeway routes in the Triangle region of North Carolina. Extensive data was assembled as recommended in the L02 Guidebook and Handbook. Data included incident and weather data in addition to archived traffic condition data from both probe vehicles and fixed point sensors. The pilot study details are documented in pilot study report Volume I.

3.1.1. Findings

The top level finding is that travel time reliability monitoring as recommended in the L02 guidebook is possible. The pilot study also indicates that a worthwhile monitoring program can be developed in the absence of vehicle flow rate data even though the availability of flow rate data does have significant value. Although the overall experience in piloting an L02-based monitoring program was positive, data assembly and pre-processing is significantly challenging. Areas of complexity and difficulty include:

- Mapping incident and weather data to Traffic Message Channel (TMC) freeway segments
- Temporal stitching based on time interval speeds to produce reasonable travel time estimates
- Dealing with missing data
- Infering causal factors for archived events
- Classification of normal versus abnormal prevailing conditions

Challenges also arise due to “thinness” of data, and there is still work to be done to develop better ways to account for the interaction of various factors in producing “abnormal” traffic conditions. An interesting finding that should be a subject of further research is that archived weather warning data may have more explanatory value than weather station data.

3.1.2. Recommendations

The pilot study team developed the following primary recommendations:

- There is great value in automatic data collection protocols for capturing and archiving the types of data assembled in the case study, and establishing such protocols should be seriously considered.
- Temporal stitching is very important – if not essential – if constistently reasonable travel times are desired when travel time estimates are to be based on time interval, segment-based speed measurements.
- In a further validation of one of the key findings from the L02 project, there is much information that will be lost in working directly with travel time cumulative distribution functions in any attempt to make assessments and decisions based on a few select percentile values.

3.2. Reliability Modeling Tools

The modeling tool pilot study began with some simple segment based analysis of the three modeling tools that were evaluated: C11 Reliability Tool, L07 Software Tool, and L08 FREEVAL-RL. After a significant and careful evaluation, the pilot study team concluded that travel time realibility is a facility/route phenomenon and therefore cannot be accurately modeled with static section features as is used in the methods implemented in the C11 Reliability Tool and the L07 Software Tool. Therefore, the pilot study team concluded that there are no viable use cases for the C11 and L07 tools. After this assessment, the pilot study moved forward with an evaluation of the L08 FREEVAL tool on several freeway routes in the region of North Carolina. The pilot study details are documented in pilot study report Volume II.

3.2.1. Findings

The high level pilot study findings fall into four categories: data collection, incident modeling, model calibration, and long versus short routes. The routes were along I-40 in North Carolina. See Volume II of the pilot study report for more detail.

- Data Collection
    - Estimating demand from AADT works well for facilities with single peak bottlenecks and with homogeneous trends throughout the day. Otherwise, independently estimated 15-min demands are needed.
    - Demand multiplier estimation is challenging in the absence of point-based sensors that provide continuous flow rate observations. Inferior demand multiplier estimates will degrade the fidelity of the reliability results.
    - Weather data probabilities based on an average of 10 years of data is quite adequate.
    - Incident data from NCDOT's Traveler Information Management Systems (TIMS) is appropriate and has all the attributes required in the L08 tool (frequency, severity, duration, etc.).
- Incident Modeling
    - Incident patterns from FREEVAL's VMT-weighted method do not match the spatial and temporal distributions from TIMS.
    - Cascading effect of incidents (secondary incidents) are not captured.
    - FREEVAL generates higher average incident durations due to the model's 15-min resolution.
    - Capabilities to enable spatial or temporal allocation of incidents to segments and time periods are being added in the ongoing FREEVAL development.
- Model Calibration
    - Successfully managed to close the gap between observed probe speeds and estimated FREEVAL speeds on all routes.

- Automated calibration works best for short to medium routes (10-25 miles) but may be problematic for longer routes due to limitations on Google Maps API. This study performed a manual calibration for Route 4 (~ 49miles).
- Manual calibration is limited to varying the capacity adjustment factor (CAF) for a single floating segment or to three known segments.

- Long versus Short Routes (All routes were along I-40 in North Carolina)
  - The effect of using the simultaneous (travel time estimated by segment speeds along the entire route at a single point in time) vs. "walking the travel time" (speeds updated as the cumulative travel time progresses through time) approach is much more critical on longer routes (i.e., the simultaneous method can be grossly inaccurate).
  - Also longer routes necessitate the "dilution" of demand flow rates to be fixed for periods longer than 15 minutes. The longest route (~49 miles) had to use fixed demand volumes for about one hour.
  - Using AADT daily profiles on a long route cannot capture the wide variation in demand. In the approximately 49-mile route for example, AADT varied from 40,000-190,000 vpd.

3.2.2. Recommendations

The pilot study resulted in the following recommendations for future enhancement to the L08 FREEVAL tool.

- Enable the user to enter incident data by time of day or by Highway Capacity Manual segment-type. Allocation by VMT can be used otherwise.
- Automatically generate FHWA rulemaking metrics on travel time reliability, such as Level of Travel Time Reliability (LOTTR) for the specific recommended time periods.
- Always, within the context of facility-wide performance, extract the individual segment-based reliability from FREEVAL in order to calculate network wide reliability measures.
- Enable both temporal and spatial stitching or "walking the travel time" capability in FREEVAL for improved realism.
- To better model the congested flow regime and queues, move from a quasi (segment-based) approach to a true cell transmission model-based approach to enable the modeling of interacting bottlenecks (Possibly through NCHRP 03-96a).

- Users should try to avoid modeling very long routes in the L08 tool unless they have access to high resolution demand data from road sensors on both mainline and ramp segments across at least the peak periods.

- Implement some of the above enhancements in conjunction with the ongoing FREEVAL-NC project (Project to create FREEVAL facility files for the entire NC Freeway network).

3.3. Tools for Incorporating Reliability into Planning

The project team held a roundtable workshop with a select gathering of NCDOT and MPO professionals on the topic of incorporating travel time reliability into the transportation planning and programming function. The workshop was held October 18, 2020. The meeting included two presentations by the pilot study team. The first presentation was a summary of key findings and recommendations from the published documentation for the SHRP2 L05 "Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes" project. The second presentation provided an overview of the functionality of the special version of the FREEVAL L08 tool that was created for NCDOT under the research project RP 2017-46 "FREEVAL-NC Development, Training and Support." These presentations were followed by an open discussion among the meeting participants. The workshop is discussed in greater detail in Volume III of this pilot study report.

3.3.1. Findings

The workshop discussions confirmed that NCDOT professionals and leaders engaged in providing safe, accessible, and reliable mobility to the citizens and businesses of North Carolina are keenly focused on travel time reliability. Nonetheless is it still the case that travel time reliability is a difficult concept to understand, define, and communicate. NCDOT mobility managers understand the uses and limitations of the MAP-21 LOTTR performance measure and are actively working to develop and continually enhance NCDOT's reliability monitoring practices. Based on the meeting discussions, the pilot study team is hopeful that the FREEVAL-NC tool will soon be embedded in freeway route analyses for both the identification and comparative evaluation of project alternatives.

3.3.2. Recommendations

NCDOT and metropolitan planning organization partners should continue a broad-based dialogue to develop a consensus working definition of travel time reliability and continue to discuss, first conceptually and then practically, how travel time reliability can and should be incorporated into transportation planning and programming processes. Relevant NCDOT units should begin to incorporate FREEVAL-NC into standard freeway route assessment and project alternative evaluations. The FREEVAL-NC tool's rigorous modeling of freeway travel time reliability can provide a first test of the value of robust travel time reliability analysis in the context of an important functional class.

4. SUMMARY OF DISSEMINATION EFFORTS

In consultation with the pilot study project steering and implementation committee, a consensus was reached that the most effective strategy for dissemination of the travel time reliability monitoring and modeling tool evaluations would be the development and recording of webinars, one for each of the two tool categories. Draft versions of the presentation slides and preliminary webinar recordings were provided to Dr. Scott Washburn for his review. The presentation materials were revised based in his comments, and the webinars re-recorded.

Copies of the webinar presentation slides are included in the appendix to this Executive Summary. The roundtable workshop held on the topic of incorporating travel time reliability into transportation planning and programming processes was also a dissemination effort. As mentioned above, the workshop included presentations of the key findings and recommendations from the SHRP2 L05 project and an overview and demonstration of the new FREEVAL-NC analysis tool. The workshop is covered in Volume III of this report, and Appendix B of Volume III include copies of the workshop presentation files.

The webinar recordings will be provided to NCDOT and FHWA and the pilot study team will work with both agencies to ensure that the webinars are published in appropriate venues to ensure access to all interested parties.

APPENDIX A –WEBINAR PRESENTATION SLIDES

Webinar on Travel Time Reliability Monitoring Tools – Presentation Slides

NC STATE UNIVERSITY

Demonstration of the L-02 Tools

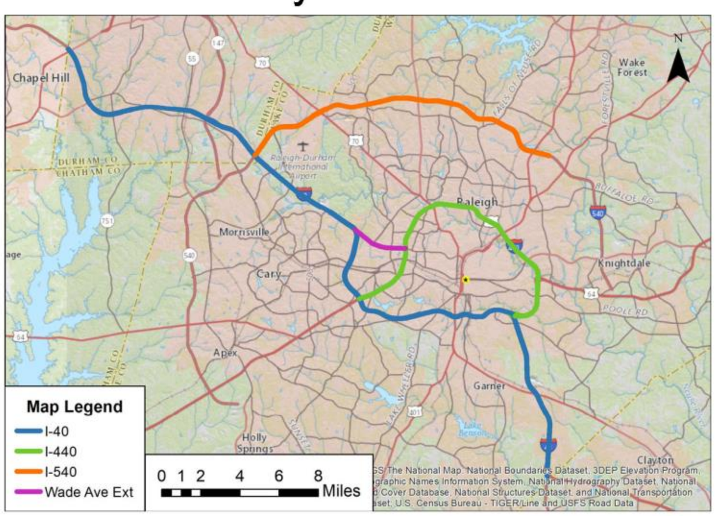
SHRP2 Reliability Data and Analysis Tools:
Implementation Assistance Program Pilot Study

George List
NC State University
February 26, 2020

Thanks to: Nagui Rouphail, Billy Williams, Russell Smith,
Alan Karr, and Alain Kornhauser

NC STATE UNIVERSITY

Study Network



SHRP2 Reliability Pilot Study 2

ITRE Institute for Transportation Research and Education

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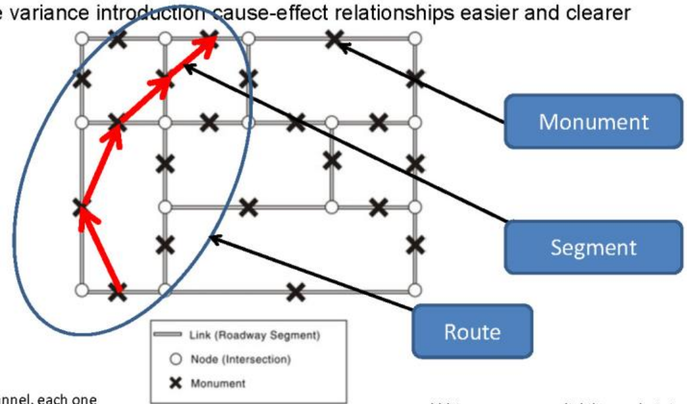
Monitoring Points

- Spots *in-between* the junctions (we call them monuments*)
- Good choices are TMC** boundaries mid-block locations
- They create virtual segments
- The "vehicle treatments" on these segments is very similar***
- They make the variance introduction cause-effect relationships easier and clearer

* A "monument location" is a spot where vehicle time stamps , spot speeds, flow rates and other data are collected.



** Traffic Message Channel, each one of which corresponds to a short stretch of highway

*** In many ways, reliability analysis is about the sources of variance

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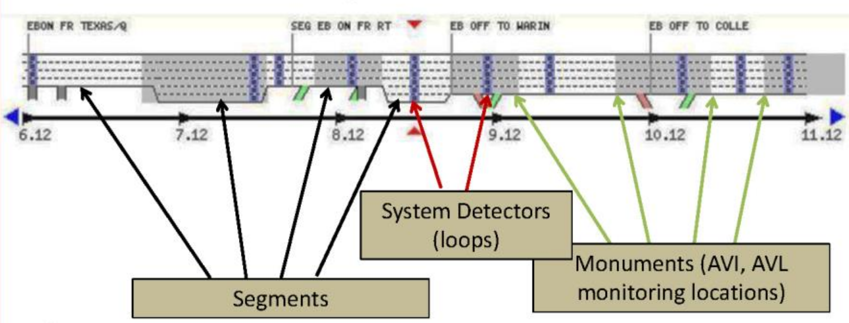
Freeway Illustration

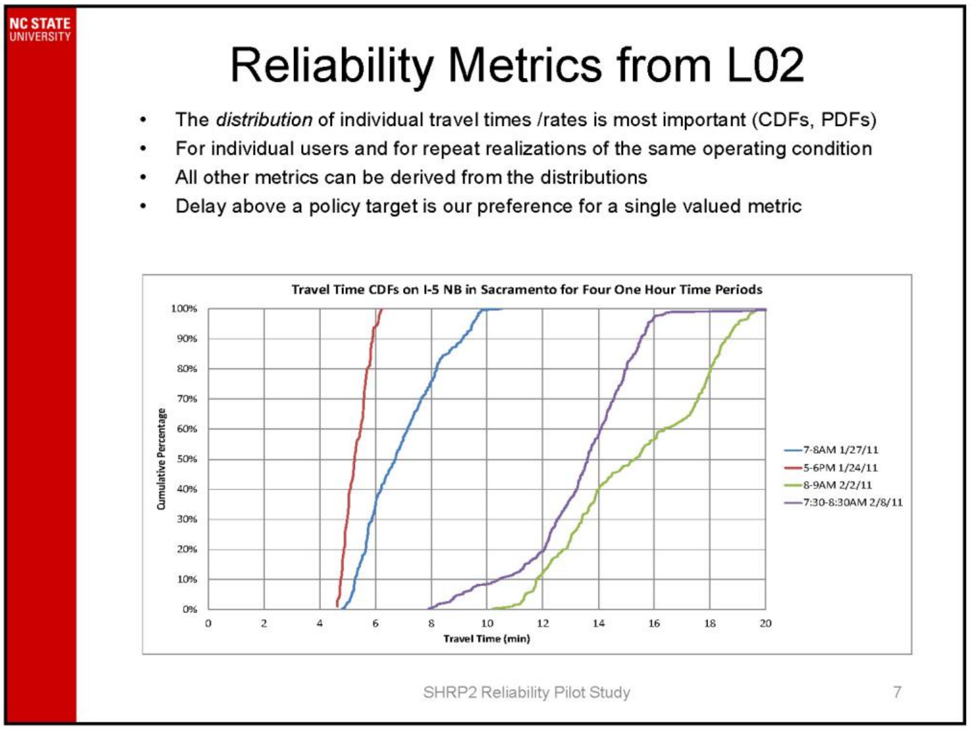
Segment Definitions



Notes

- Segments are between the monuments
- AVI, AVL monitoring should occur at the monuments (travel times)
- For system detectors (e.g., loops) there should be at least one sensor for each segment (assume spot speed pertains to segment)

SHRP2 Reliability Pilot Study 6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Reliability Metrics from L02
• The *distribution* of individual travel times /rates is most important (CDFs, PDFs)
• For individual users and for repeat realizations of the same operating condition
• All other metrics can be derived from the distributions
• Delay above a policy target is our preference for a single valued metric
Travel Time CDFs on I-5 NB in Sacramento for Four One Hour Time Periods
Cumulative Percentage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 2 4 6 8 10 12 14 16 18 20
Travel Time (min)
7-8AM 1/27/11
5-6PM 1/24/11
8-9AM 2/2/11
7:30-8:30AM 2/8/11
SHRP2 Reliability Pilot Study
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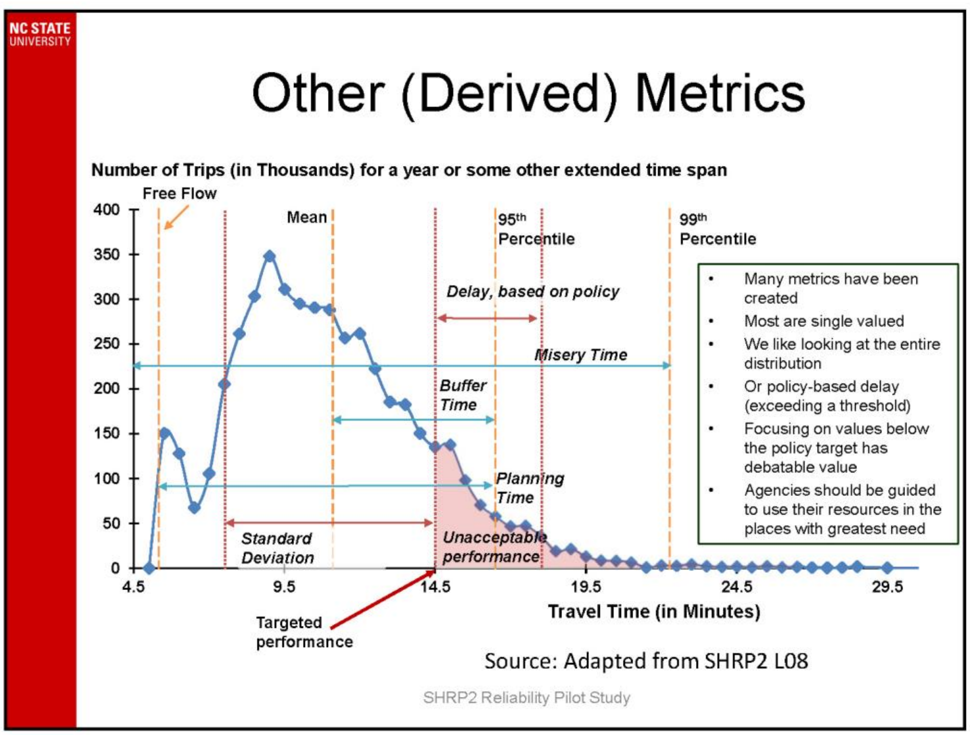
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Other (Derived) Metrics
Number of Trips (in Thousands) for a year or some other extended time span
Free Flow
Mean
95th Percentile
99th Percentile
Delay, based on policy
Misery Time
Buffer Time
Planning Time
Standard Deviation
Unacceptable performance
Targeted performance
400
350
300
250
200
150
100
50
0
4.5 9.5 14.5 19.5 24.5 29.5
Travel Time (in Minutes)
• Many metrics have been created
• Most are single valued
• We like looking at the entire distribution
• Or policy-based delay (exceeding a threshold)
• Focusing on values below the policy target has debatable value
• Agencies should be guided to use their resources in the places with greatest need
Source: Adapted from SHRP2 L08
SHRP2 Reliability Pilot Study

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Operating Environment Events

DataTime	Visib	Wind	Wind Spd	Gust Spd	Precip	Events	Cond
1/28/2011 0:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 1:53	10	South	3.5	-	N/A		Clear
1/28/2011 2:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 3:53	10	South	5.8	-	N/A		Clear
1/28/2011 4:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 5:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 6:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 7:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 8:53	10	Calm	Calm	-	N/A		Clear
1/28/2011 9:53	10	Calm					
1/28/2011 10:53	10	NNE					
1/28/2011 11:53	10	NE					
1/28/2011 12:53	10	NNE					
1/28/2011 13:53	10	NNE					
1/28/2011 14:53	10	Variabl					
1/28/2011 15:53	10	SSW					
1/28/2011 16:53	10	SSW					
1/28/2011 17:53	10	Calm					
1/28/2011 18:53	10	South					
1/28/2011 19:53	10	Calm					
1/28/2011 20:53	10	South					
1/28/2011 21:53	10	SSW					
1/28/2011 22:53	10	Calm					
1/28/2011 23:53	10	Calm					
1/29/2011 0:53	10	Calm					

Incident Id	Start Time	Dur (min)	Freeway	Abs PM	Location	Description
11724869	1/28/2011 3:50	41	US50-E		EB US50 ON 15TH ST OFR	1182 - Collision - Non Injury
11724935	1/28/2011 5:45	7	US50-E		EB US50 ON POWER INN RD OFR	
11724958	1/28/2011 6:02	27	US50-E	5.89	EB US50 ON 34TH ST OFR	
11725029	1/28/2011 6:55	0	US50-E		EB US50 JEO EL DORADO HILLS BLVD	
11725175	1/28/2011 7:57	2	US50-E	31.755	EB US50 JWO BASS LAKE RD	
11725425	1/28/2011 9:33	22	US50-E	17.601	EB US50 JWO SUNRISE BLVD	
11725782	1/28/2011 12:24	22	US50-E	298.514	EB US50 JWO SB SR99	
11725927	1/28/2011 13:17	0	US50-E	64.033	EB US50 AT HAZEL VALLEY RD	
11726010	1/28/2011 13:49	10	US50-E		EB US50 AT FRONT ST	
11726196	1/28/2011 14:51	59	US50-E	10.488	EB US50 JWO NB WATT AV	
11726269	1/28/2011 15:11	23	US50-E		EB US50 JWO POWER INN RD	
11726302	1/28/2011 15:23	0	US50-E		EB US50 JWO 48TH ST	
11726453	1/28/2011 16:03	19	US50-E		EB US50 JWO POWER INN RD	1179H - Collision - Ambulance - Blocking Lane
11726532	1/28/2011 16:29	0	US50-E	10.688	EB US50 AT NB WATT AV	1126 - Disabled Vehicle
11726568	1/28/2011 16:39	0	US50-E	26.68	EB US50 JWO E BIDWELL ST	1125 - Traffic Hazard
11726655	1/28/2011 17:04	2	US50-E	8.83	EB US50 JWO HOWE AV	FIRE - Fire
11726737	1/28/2011 17:29	14	US50-E	5.89	EB US50 ON 34TH ST OFR	1125V - Traffic Hazard - Vehicle
11727378	1/28/2011 22:21	60	US50-E	26.88	EB US50 AT E BIDWELL ST	1126 - Disabled Vehicle
11727377	1/28/2011 22:25	0	US50-E	29.838	EB US50 JEO LATROBE RD	1126 - Disabled Vehicle
11727559	1/29/2011 1:25	20	US50-E	298.384	EB US50 JWO NB SR99	1126 - Disabled Vehicle
11727710	1/29/2011 6:12	1	US50-E	298.514	EB US50 JWO SB SR99	1125 - Traffic Hazard

Weather

Challenging to find this perishable data and make it align temporally with travel rate data

Incidents and Other Events

- Location
- Start time
- End time
- Lanes blocked
- Max queue length
- Description

Note: Be sure to capture incident events that happen nearby as well as on the subject facility. Explanatory events may not be on the facility of interest.

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Event Labels / Flags

- Flags for: weather, incidents, roadwork, special events
- Recorded labels: direct records of events
- Induced labels: imputed labels based on logic
- Primary label coding scheme
  - 000: Normal rate / no incident or weather
  - 008: Normal rate / weather
  - 080: Normal rate / incident
  - 088: Normal rate / incident and weather
  - 200: Abnormal rate / no incident or weather
  - 208: Abnormal rate / weather
  - 280: Abnormal rate / incident
  - 288: Abnormal rate / incident and weather
- Careful choice of numerical values helps with analysis
  - Conditional formatting in Excel, for example

"Abnormal" means a travel rate different than expected or different from earlier and later time intervals

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Induced Labels / Flags

- Inference based on the primary labels
  - Add to time periods following an "8" where the travel rate is still high
  - We used "7"s (e.g., 207 instead of 208, 270 instead of 280)
- Criteria for adding
  - Adverse weather (208) within the last hour (207)
  - Incident (280) within the past hour (270)
  - Incident and weather (288) within the last hour (277)
  - Helps with conditional formatting

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Operating Conditions*

- Definition: a traffic level and an environmental situation
- Environment can be single or compound events
- Objective: clarify the effects of a given condition
- Minimize / eliminate confusion from mixing conditions

Analysis Regimes								
Illustrative Regimes	Expected Congestion Level			Normal	Abnormal Condition			
	Low	Moderate	High		Incident	Weather	Roadwork	Demand
High/Normal			X	X				
Low/Incident	X				X			
Moderate/Weather		X				X		
High/Demand			X					X
High/Weather/Incident			X		X	X		
Moderate/Roadwork							X	
Moderate/Roadwork/Incident		X				X		
None/Moderate		X		X				

Note: Time of day, season, region, facility types, etc. are related, but separate thoughts.

*Also called "regimes"

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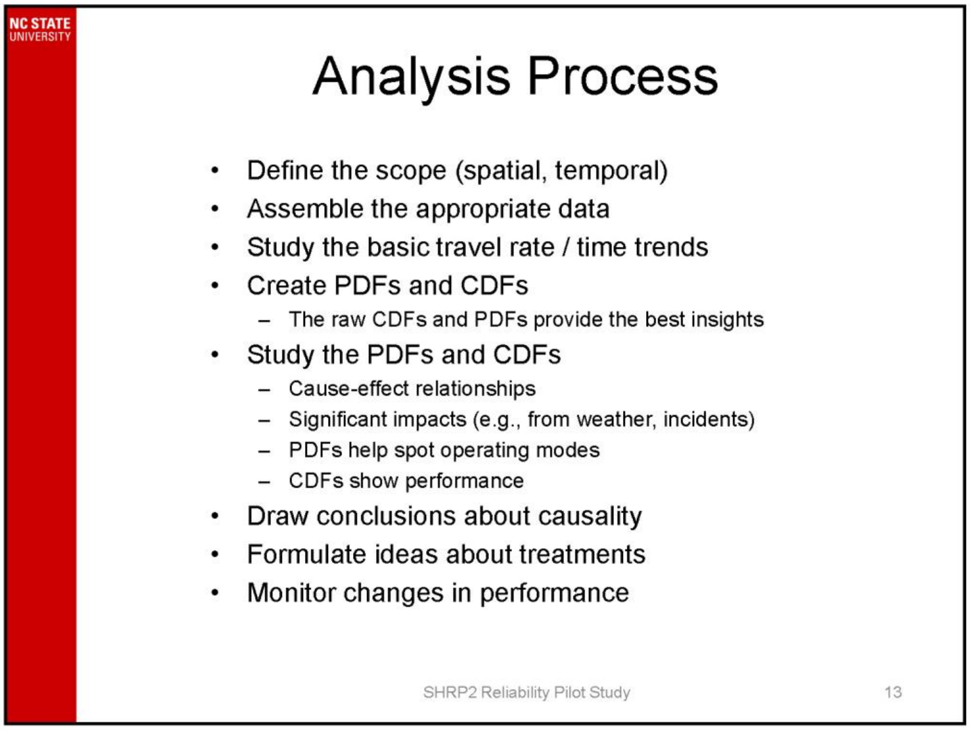
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Analysis Process
• Define the scope (spatial, temporal)
• Assemble the appropriate data
• Study the basic travel rate / time trends
• Create PDFs and CDFs
– The raw CDFs and PDFs provide the best insights
• Study the PDFs and CDFs
– Cause-effect relationships
– Significant impacts (e.g., from weather, incidents)
– PDFs help spot operating modes
– CDFs show performance
• Draw conclusions about causality
• Formulate ideas about treatments
• Monitor changes in performance
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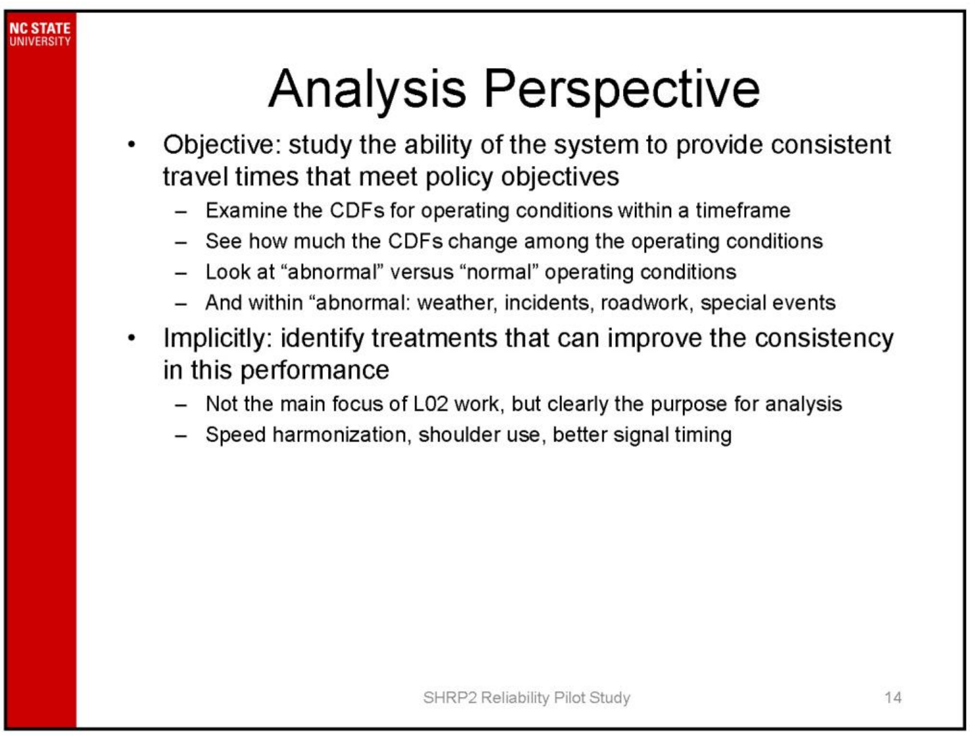
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Analysis Perspective
• Objective: study the ability of the system to provide consistent travel times that meet policy objectives
– Examine the CDFs for operating conditions within a timeframe
– See how much the CDFs change among the operating conditions
– Look at "abnormal" versus "normal" operating conditions
– And within "abnormal: weather, incidents, roadwork, special events
• Implicitly: identify treatments that can improve the consistency in this performance
– Not the main focus of L02 work, but clearly the purpose for analysis
– Speed harmonization, shoulder use, better signal timing
SHRP2 Reliability Pilot Study
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Graphical Depiction

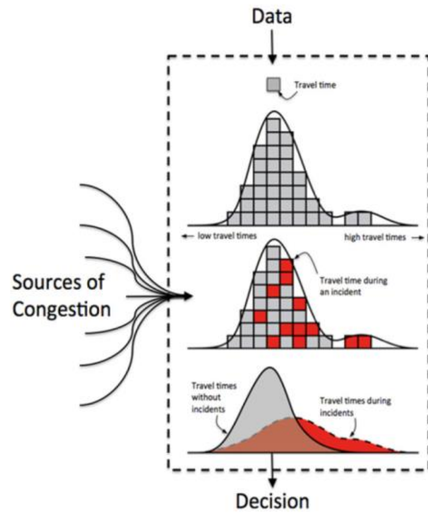
Define the analysis setting
- o Temporal and spatial scope
- o Time interval granularity

Assemble the data
- o Spot speeds (e.g., loops)
- o Vehicle trajectories
- o Non-recurring event data

Prepare for the analysis
- o Add non-recurring event labels
- o Add congestion level labels
- o Group data by operating condition

Analyze
- o Identify operating conditions
- o Frequency of occurrence
- o Travel time / rate impacts

Identify treatment ideas / options



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Scope Definition
Three Illustrations

- Single operating condition (specific operating condition):
  - Simplest, provides greatest insight, motivates treatment thoughts
- Single period of time during a type of day:
  - AM peak, PM peak, midday during weekdays; holiday peaks
  - Inherently has multiple operating conditions
  - Complex to analyze
- Whole year (complete duty cycle):
  - Creates a comprehensive picture of performance
  - Highlights relative frequency with which operating conditions arise
  - Inherently complex – multitude of operating conditions

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Raleigh Area Analyses

- Freeway facilities
- 2010 - entire year
- Travel rates, as affected by congestion, incidents, weather, and special events
- Only some of the analyses are presented here*

	I-40 EB	I-40 WB	I-440 EB	I-440 WB	I-540 EB	I-540 WB	Wade EB	Wade WB	All
# of TMC Segments	51	51	30	30	16	16	6	6	206
Total Length (mi)	40.56	40.86	15.06	15.71	16.08	15.98	2.33	2.28	148.86

*See: Smith, R. (2018) Development and Evaluation of a Prototype Travel Time Reliability Monitoring System for Freeway Facilities in North Carolina, Master's Thesis, North Carolina State University, Raleigh, North Carolina.

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Data Assembly

- Travel times/rates
  - Segments and routes, temporal resolution (e.g., 5 minutes)
  - INRIX, probe data, TMCs, 5-minute resolution
- Flow rates
  - Vehicles per hour, broken down by classes
  - HERE side-fire radar stations, 5-minute resolution
- Incidents
  - When they occurred, where, lanes blocked
  - NCDOT Traveler Information Management System (TIMS)
- Weather
  - Conditions (e.g., rain, snow, hail, temperature)
  - NWS warnings, by geographic polygons
  - Five weather stations, air temperature and precipitation
- Special events
  - Sporting events at stadiums, concerts, state fairs, etc.
  - Surges in demand
  - Local media sources, football games, other sporting events, concerts, state fair, etc.

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Dataset Preparation

- Create travel time/rate datasets (by facility and direction)
  - Temporally / spatially stitched to create more defensible values
  - Gaps filled if data missing for 2 or fewer 5-minute intervals
  - Stitched travel times / rates where applicable
- Create flow rate datasets (by facility and direction)
  - Counts converted to flow rates per hour per lane
  - Transformed into pc/hr/ln for HCM compatibility
  - Observations assigned to all TMCs, flow rate flags
- Create incident dataset
  - Spatially referenced to TMCs
  - Vehicle collisions, disabled vehicles, emergency road work, flags
- Create “other events” dataset
  - Spatially referenced to TMCs where applicable
  - Work zones, planned maintenance, special events
- Create weather dataset
  - Weather flag (temp ≤ 32 deg; precipitation ≥ 0.1”/hr, warning in effect)
  - Data from nearest of 5 weather stations, plus NWS
- Fuse datasets using labels / flags (by facility and direction)
- Augment with inferred labels / flags

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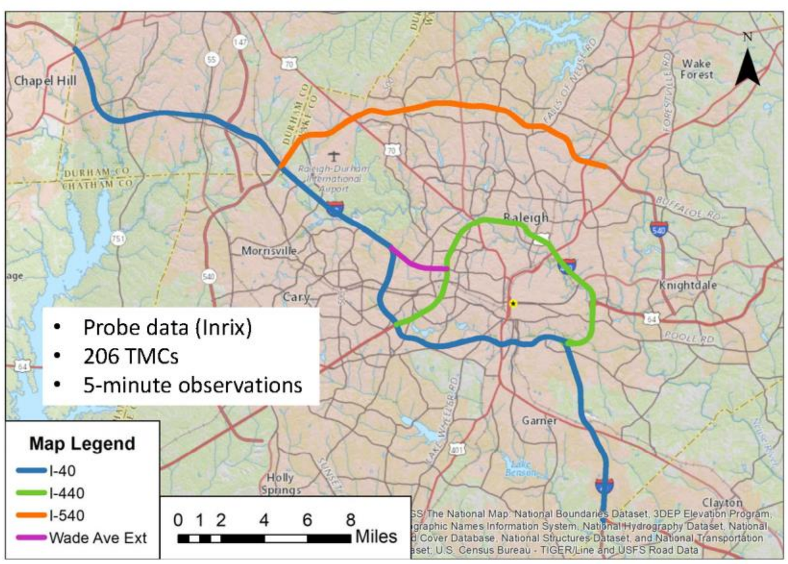
Travel Time / Rate Data



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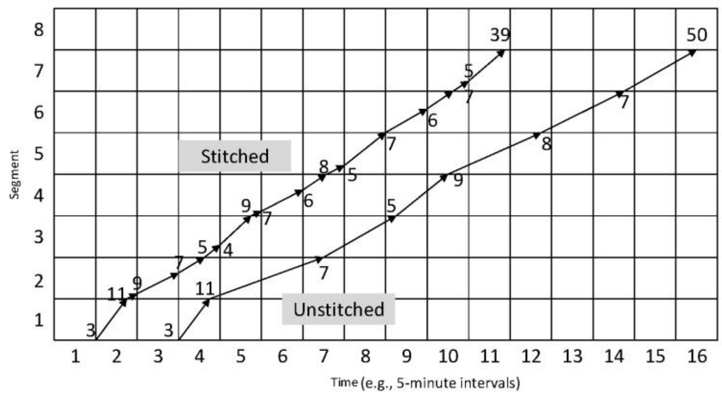
Travel Times ← TMC Data

- Do *not* use travel rates extant at the start of trip (not shown)!!
- Use the spatial-temporal variations in TMC travel rates
- Update the rate at every spatial-temporal boundary crossing!
- Stitch times based on the rates to create travel times / overall rates



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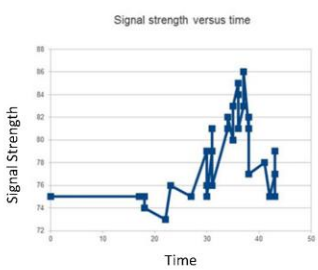
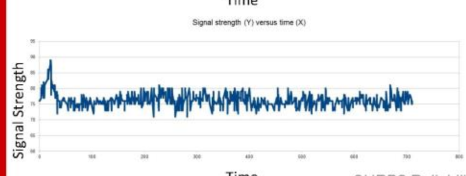
Travel Times: Probes

AVI Timestamps
- Wayside sensors
- Pairing timestamps





AVL Timestamps / Locations
- Frequent pings
- Monitoring locations
- Recorded pings

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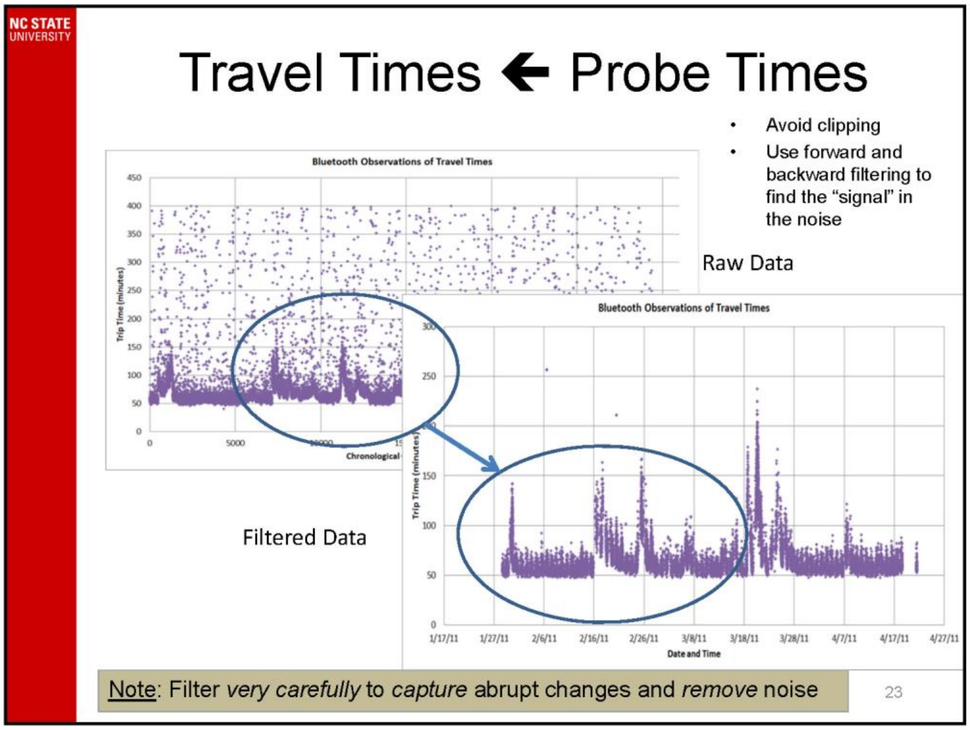
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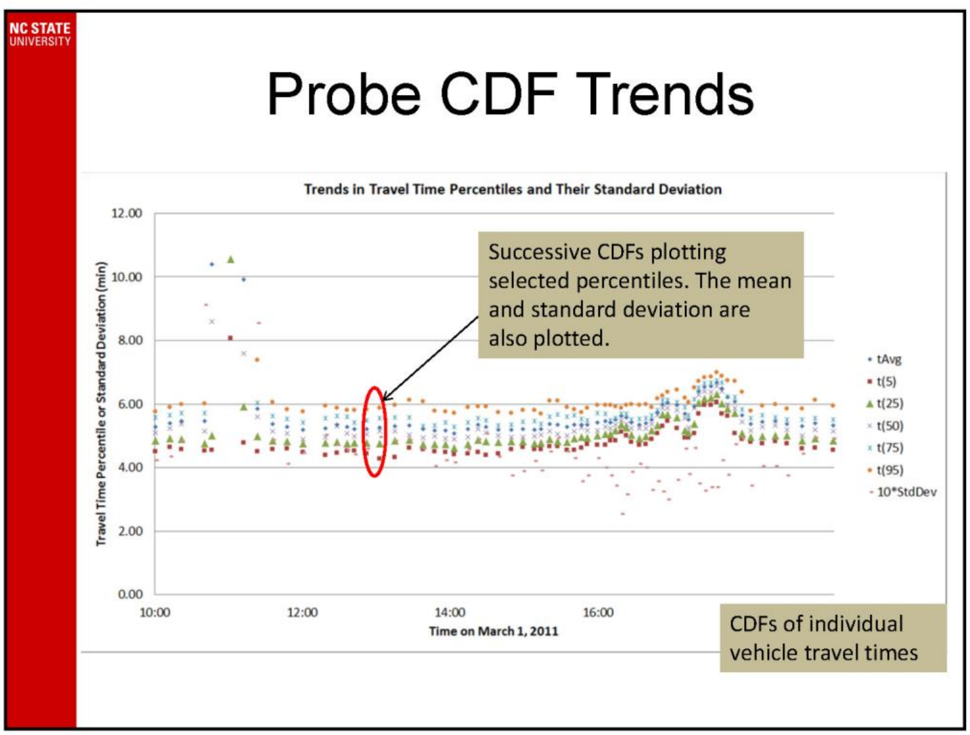
Travel Times ← Probe Times
Avoid clipping
Use forward and backward filtering to find the "signal" in the noise
Bluetooth Observations of Travel Times
Raw Data
Filtered Data
Trip Time (minutes)
Date and Time
Note: Filter very carefully to capture abrupt changes and remove noise
23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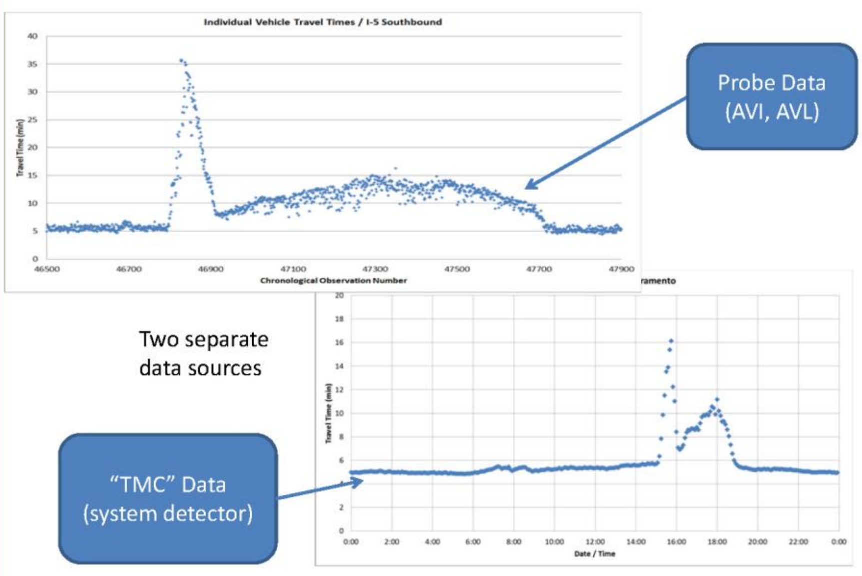
Probe CDF Trends
Trends in Travel Time Percentiles and Their Standard Deviation
Travel Time Percentile or Standard Deviation (min)
Time on March 1, 2011
Successive CDFs plotting selected percentiles. The mean and standard deviation are also plotted.
tAvg
t(5)
t(25)
t(50)
t(75)
t(95)
10*StdDev
CDFs of individual vehicle travel times

Operating Environment

- “Non-recurring” events
  - Weather
  - Incidents
  - Roadwork
  - Special events
  - Other
  - Combinations
- “Recurring” events
  - Traffic flows
  - HOV lane use
  - Signal timing plans
  - Shoulder use
  - Other

May 29, 2018 SHRP2 Reliability Pilot Study 25

Abnormal Condition Identification



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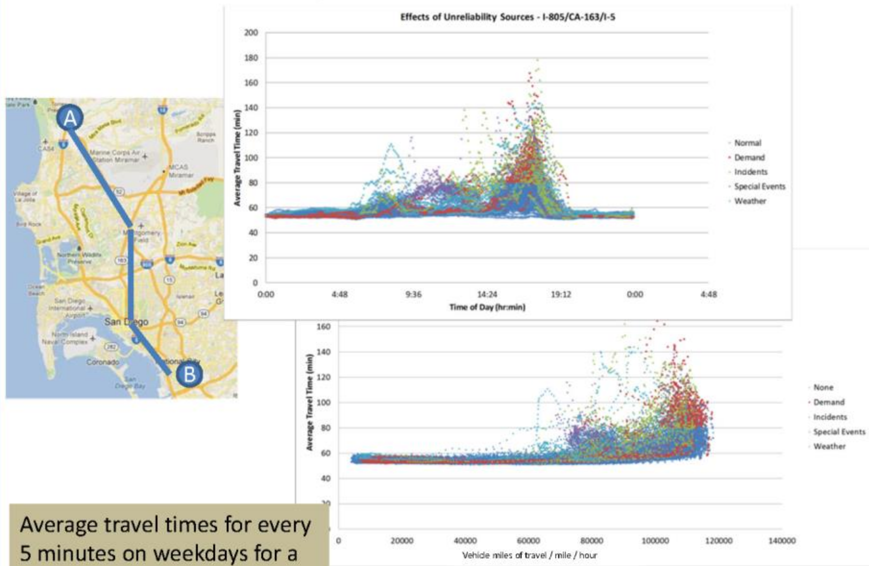
Time of Day and Load Condition



Average travel times for every 5 minutes on weekdays for a year

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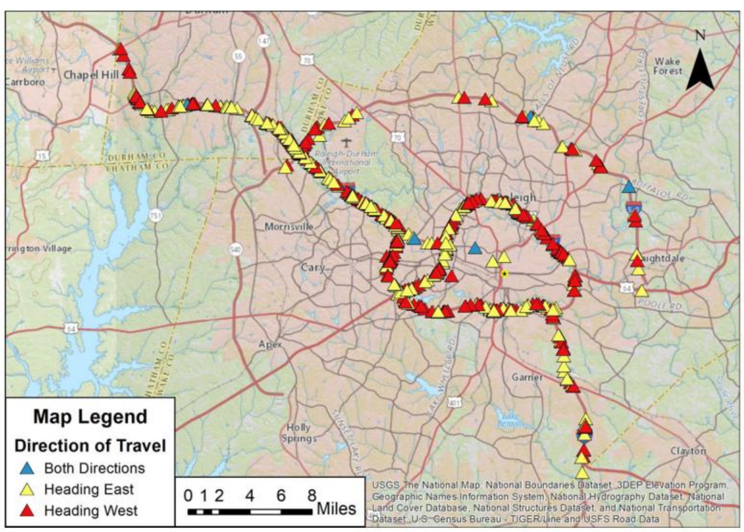
Incidents



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Incident Types and Locations*

Incident Type	I-40 EB	I-40 WB	I-440 EB	I-440 WB	I-540 EB	I-540 WB	Wade EB	Wade WB	Total
Congestion	14	13	4	1	0	1	0	0	33
Construction	2	9	0	0	0	0	0	0	11
Disabled Vehicle	20	22	6	12	3	1	1	1	66
Fire	3	8	1	1	2	0	0	0	15
Maintenance	8	11	9	8	0	0	1	0	37
Night Time Construction	30	28	0	0	0	0	0	0	58
Other	1	1	0	0	0	0	0	0	2
Road Obstruction	2	2	1	1	0	0	0	0	6
Special Event	0	0	1	1	0	0	1	1	4
Vehicle Collision	263	196	90	116	16	0	5	1	702
Maint & Constr	40	48	10	9	0	0	2	1	110
Unplanned	303	242	102	131	21	17	6	2	824

*Incidents Recorded in Traffic Incident Management System (TIMS) by Incident Type and Facility Direction

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Incident Labels / Flags*

Incident Type	I-40 EB	I-40 WB	I-440 EB	I-440 WB	I-540 EB	I-540 WB	Wade EB	Wade WB	Total
Congestion	800	717	188	10	0	39	0	0	1834
Construction	1500	6721	0	0	0	0	0	0	8221
Disabled Vehicle	95	203	47	86	36	6	12	6	491
Fire	25	55	6	12	29	0	0	0	127
Maintenance	918	12021	599	5368	0	Unknown	13	0	18919
Night Time Construction	23077	17613	0	0	0	0	0	0	40690
Other	287	287	0	0	0	0	0	0	574
Road Obstruction	54	29	12	18	0	0	0	0	113
Special Event	0	0	109	109	0	Unknown	150	149	517
Vehicle Collision	3345	4674	885	1795	238	307	60	0	11304
Maint & Constr	25495	36355	708	5477	0	0	163	149	68347
Unplanned	4686	5965	1138	1921	303	352	72	6	14443
Total	30181	42320	1846	7398	303	352	235	155	82790

*Number of 5-minute intervals out of 21,654,720 total

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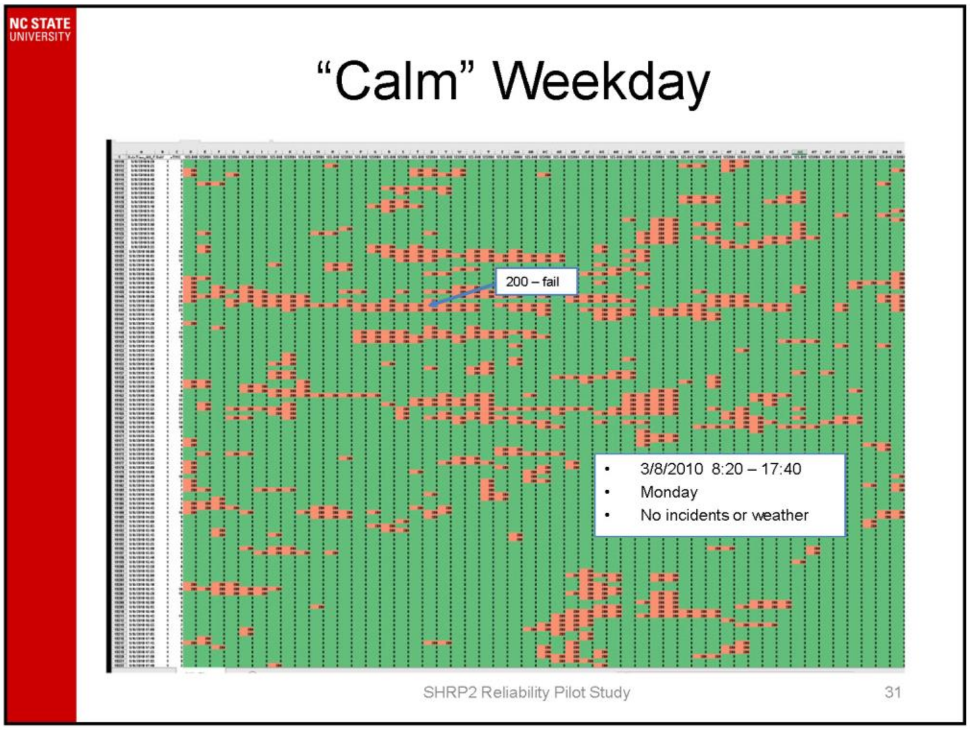
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"Calm" Weekday
200 – fail
3/8/2010 8:20 – 17:40
Monday
No incidents or weather
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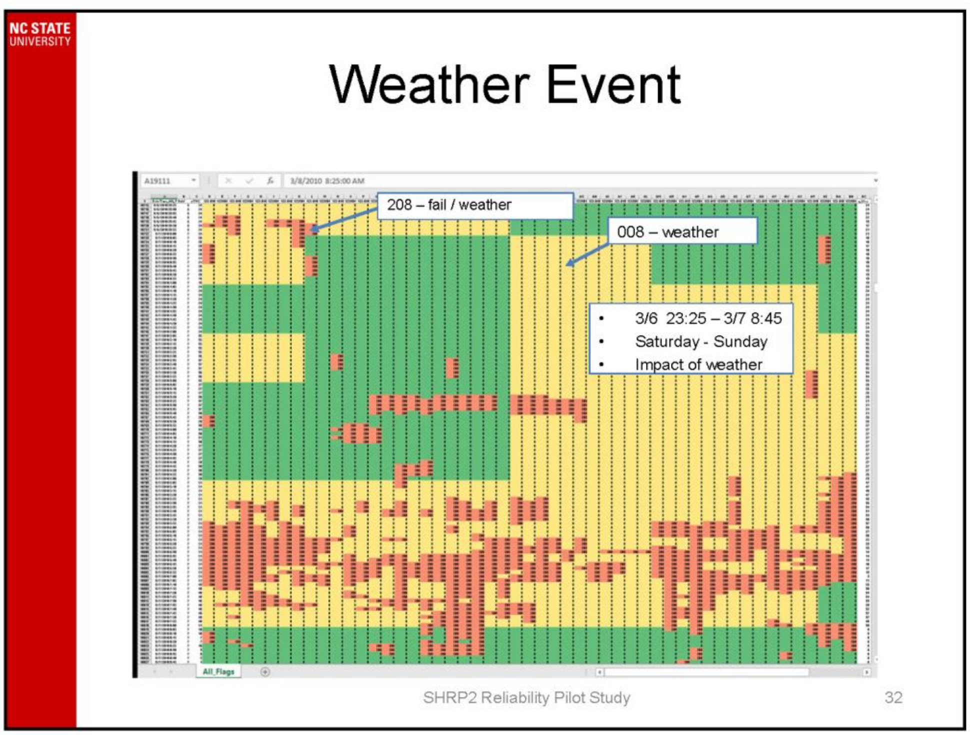
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Weather Event
208 – fail / weather
008 – weather
3/6 23:25 – 3/7 8:45
Saturday - Sunday
Impact of weather
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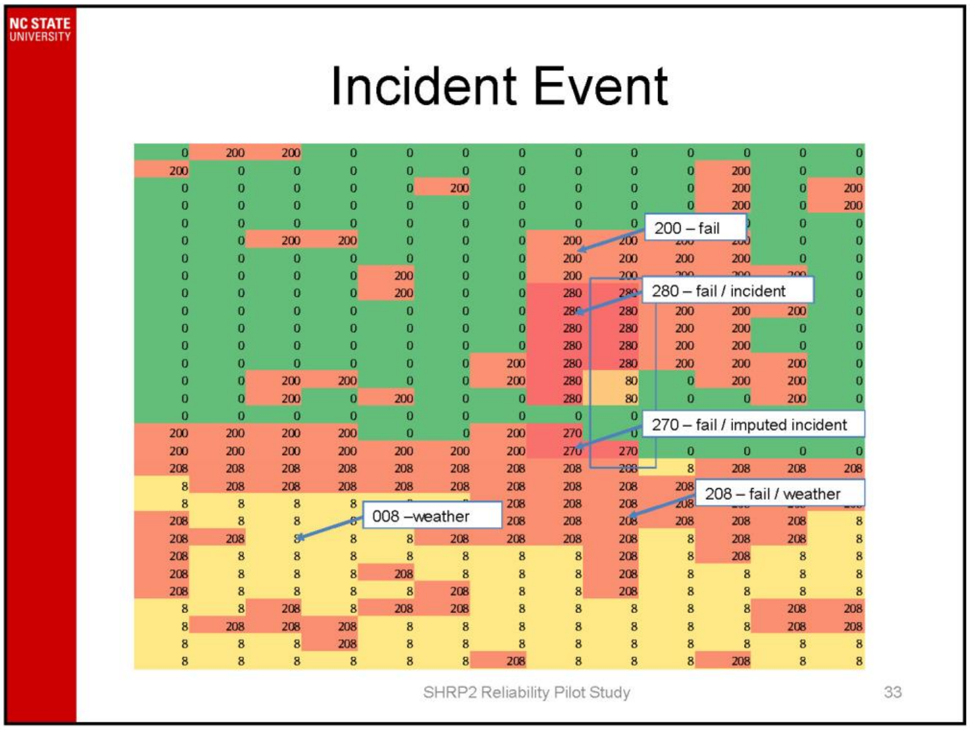
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Incident Event
200 – fail
280 – fail / incident
270 – fail / imputed incident
208 – fail / weather
008 –weather
SHRP2 Reliability Pilot Study
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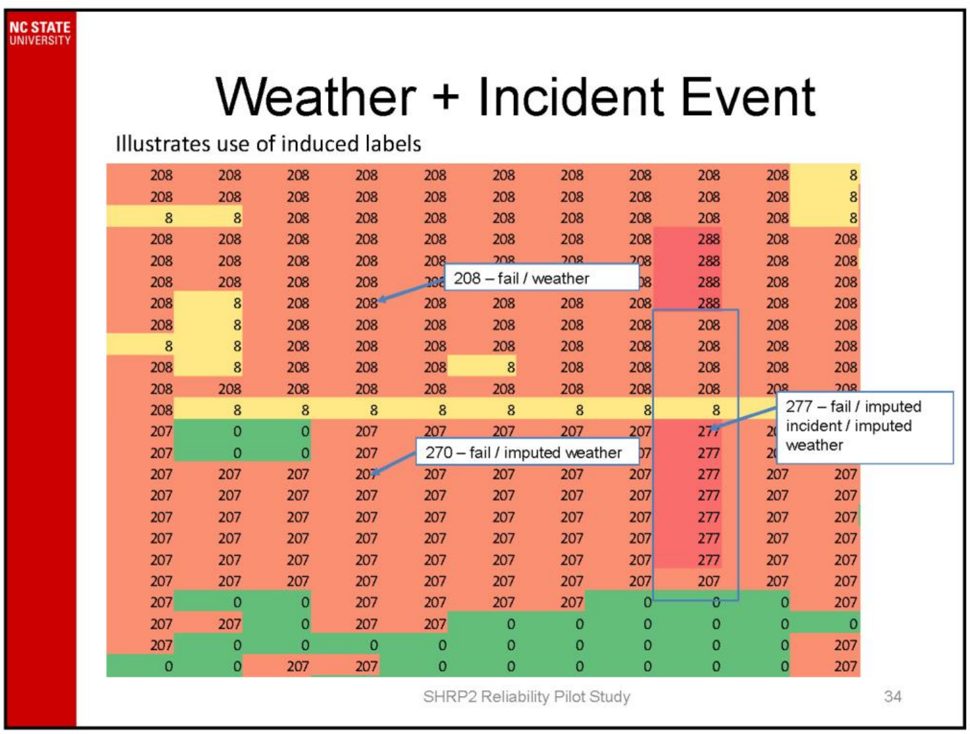
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Weather + Incident Event
Illustrates use of induced labels
208 – fail / weather
277 – fail / imputed incident / imputed weather
270 – fail / imputed weather
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Complex Event

008 –weather

208 – fail / weather

207 – fail / imputed weather

weather

288 – fail / incident /weather

280 – fail / incident

1/13/2010 8:25	3	51	8	208	208	8	8	208	288	288	288	208	208	8	8	8
1/13/2010 8:30	3	51	8	8	8	208	208	208	288	288	288	208	8	208	8	8
1/13/2010 8:35	3	51	8	8	[illegible]	[illegible]	[illegible]	208	288	288	288	208	8	8	8	8
1/13/2010 8:40	3	51	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	288	208	8	208	8	8
1/13/2010 8:45	3	51	8	8	8	208	208	[illegible]	[illegible]	[illegible]	288	8	8	208	208	208
1/13/2010 8:50	3	51	8	208	208	208	[illegible]	[illegible]	[illegible]	[illegible]	288	8	8	8	8	8
1/13/2010 8:55	3	51	8	8	208	208	208	208	288	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	8
1/13/2010 9:00	3	51	8	8	208	208	208	[illegible]	288	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	8
1/13/2010 9:05	3	50	0	207	207	207	207	207	280	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8	8
1/13/2010 9:10	3	49	0	0	207	207	207	207	280	80	88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1/13/2010 9:15	3	49	0	0	207	207	207	207	280	80	88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1/13/2010 9:20	3	51	207	207	207	207	207	207	280	80	288	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1/13/2010 9:25	3	51	207	207	207	207	207	207	280	280	288	8	208	208	8	8
1/13/2010 9:30	3	51	207	207	207	207	207	207	280	280	[illegible]	[illegible]	[illegible]	208	208	8
1/13/2010 9:35	3	51	207	207	207	207	207	207	280	[illegible]	[illegible]	[illegible]	[illegible]	208	208	208
1/13/2010 9:40	3	51	207	207	207	207	207	207	[illegible]	80	88	8	8	8	8	8
1/13/2010 9:45	3	50	0	207	207	207	207	207	280	80	88	8	8	8	8	8
1/13/2010 9:50	3	50	0	207	207	207	207	207	280	80	88	8	8	208	208	208
1/13/2010 9:55	3	50	0	207	207	207	207	207	280	80	88	208	8	8	8	208
1/13/2010 10:00	3	49	0	0	207	207	207	207	280	280	288	208	208	8	8	8
1/13/2010 10:05	3	11	0	0	200	200	200	200	280	280	80	207	207	0	0	0
1/13/2010 10:10	3	13	200	200	200	200	200	200	280	280	80	207	0	0	0	0
1/13/2010 10:15	3	14	0	200	200	200	200	200	280	280	80	0	0	0	0	207
1/13/2010 10:20	3	18	0	0	200	0	200	200	280	280	280	0	0	0	207	0
1/13/2010 10:25	3	19	0	0	0	200	200	200	280	280	280	0	0	0	0	0
1/13/2010 10:30	3	15	0	0	0	200	200	200	280	280	280	0	0	0	0	0
1/13/2010 10:35	3	14	0	0	0	0	0	200	280	80	80	0	0	0	0	0
1/13/2010 10:40	3	13	0	0	0	200	0	0	0	0	0	0	0	0	0	0
1/13/2010 10:45	3	9	0	0	0	0	0	0	0	270	277	0	0	0	0	0
1/13/2010 10:50	3	17	0	0	0	200	200	0	0	270	277	0	207	0	207	0
1/13/2010 10:55	3	17	0	0	0	200	0	0	0	0	0	207	207	0	0	0
1/13/2010 11:00	3	16	0	200	0	200	200	0	0	0	0	0	0	0	0	0

Highlights value of imputed labels

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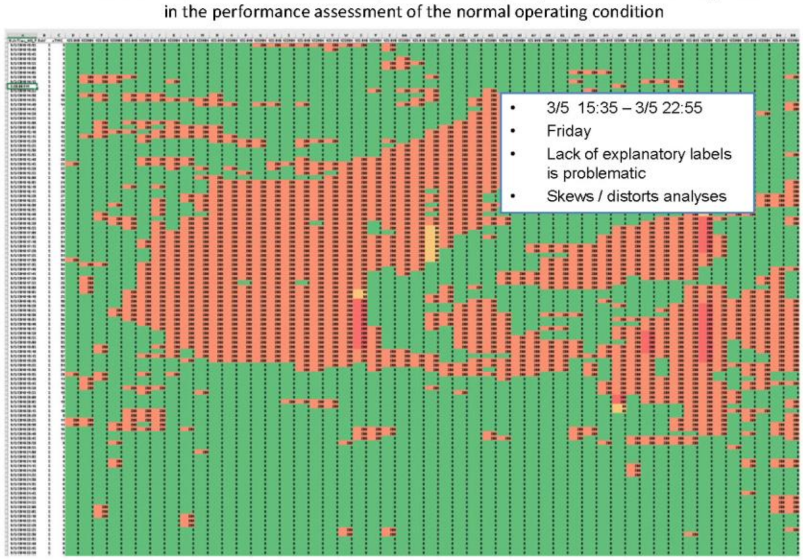
Unexplained Event

Such events are problematic. Because they are not labeled, they can create misleading biases in the performance assessment of the normal operating condition



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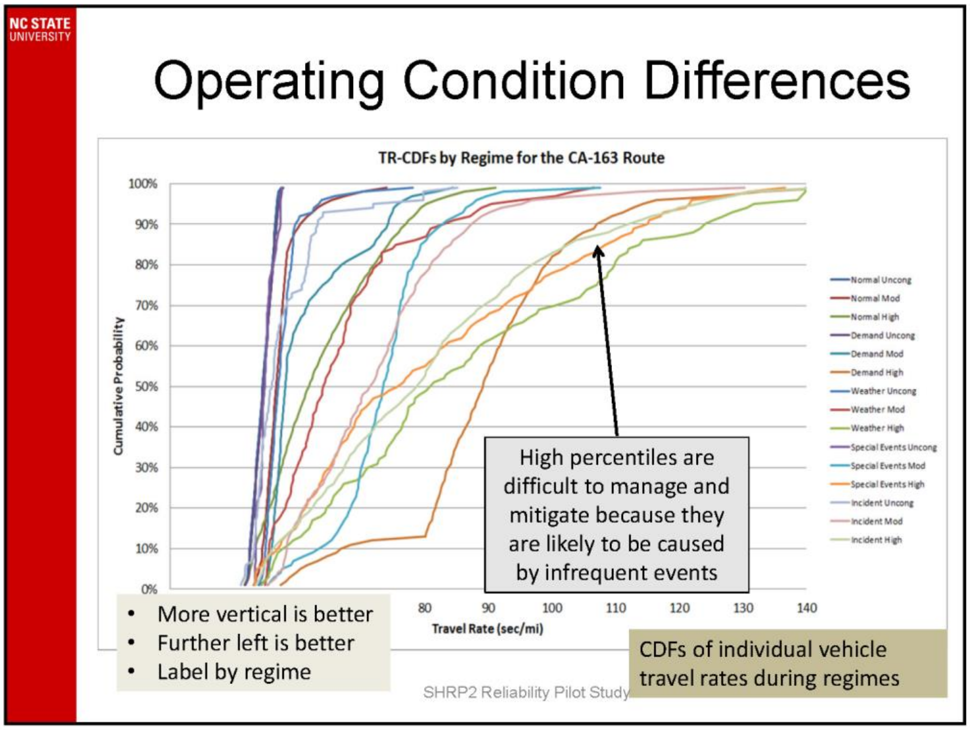
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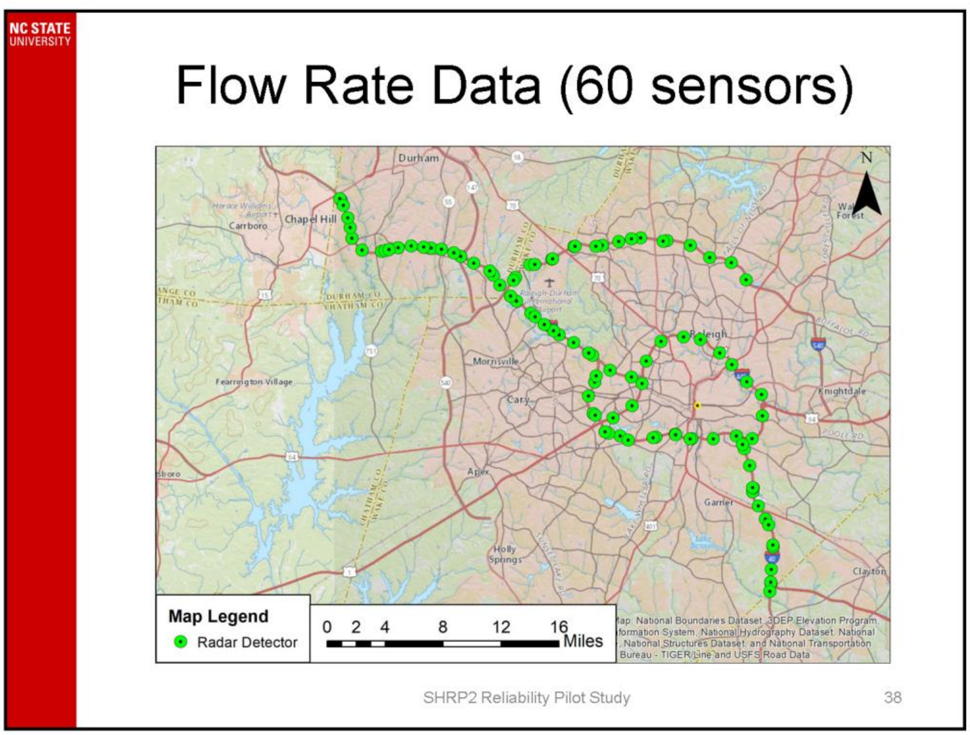
Operating Condition Differences
TR-CDFs by Regime for the CA-163 Route
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
80
90
100
110
120
130
140
Travel Rate (sec/mi)
Normal Uncong
Normal Mod
Normal High
Demand Uncong
Demand Mod
Demand High
Weather Uncong
Weather Mod
Weather High
Special Events Uncong
Special Events Mod
Special Events High
Incident Uncong
Incident Mod
Incident High
High percentiles are difficult to manage and mitigate because they are likely to be caused by infrequent events
• More vertical is better
• Further left is better
• Label by regime
CDFs of individual vehicle travel rates during regimes
SHRP2 Reliability Pilot Study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Flow Rate Data (60 sensors)
Durham
Chapel Hill
Carrboro
Morrisville
Cary
Raleigh
Knightdale
Fearrington Village
Apex
Garner
Holly Springs
Clayton
N
Map Legend
Radar Detector
0 2 4 8 12 16 Miles
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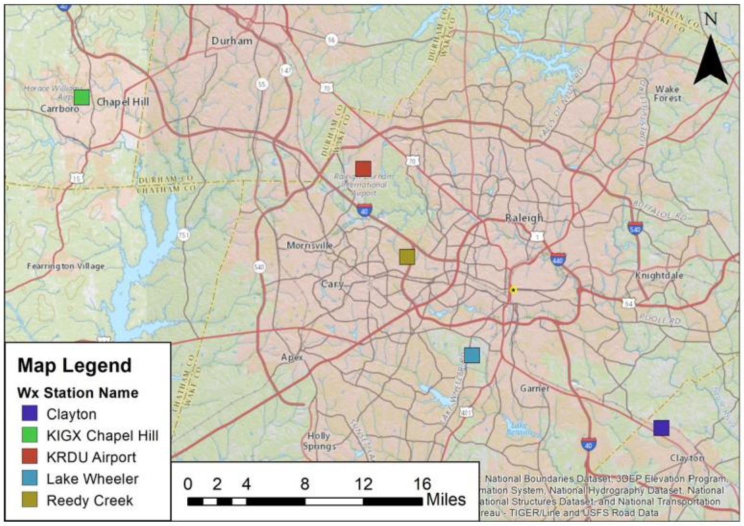
Weather Data



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Weather Data Summary

	CLAY	LAKE	REED	KRDU	KIGX	S.D.
Station Type	ECONet	ECONet	ECONet	ASOS	ASOS	N/A
Number of valid observations	105,085 (99.97%)	105,001 (99.89%)	105,073 (99.96%)	104,917 (99.81%)	103,321 (98.33%)	1.34°
Number of intervals w/ air temp < 32° F	7,884 (7.50%)	8,604 (8.19%)	8,736 (8.31%)	8,292 (7.90%)	8,808 (8.52%)	1.22°
Number of intervals w/ air temp < 30° F	5,328 (5.07%)	6,096 (5.81%)	6,336 (6.03%)	5,784 (5.51%)	6,240 (6.04%)	1.18°
Number of intervals w/ air temp < 25° F	1,704 (1.62%)	2,160 (2.06%)	2,292 (2.18%)	2,184 (2.08%)	2,268 (2.20%)	1.24°

Data by station

TMCs by station

	CLAY	LAKE	REED	KRDU	KIGX
I-40 EB	2	16	8	17	8
I-40 WB	3	16	8	17	7
I-440 EB	0	10	20	0	0
I-440 WB	0	10	20	0	0
I-540 EB	0	0	3	13	0
I-540 WB	0	0	3	13	0
Wade EB	0	0	6	0	0
Wade WB	0	0	6	0	0
TOTAL:	5	52	74	60	15

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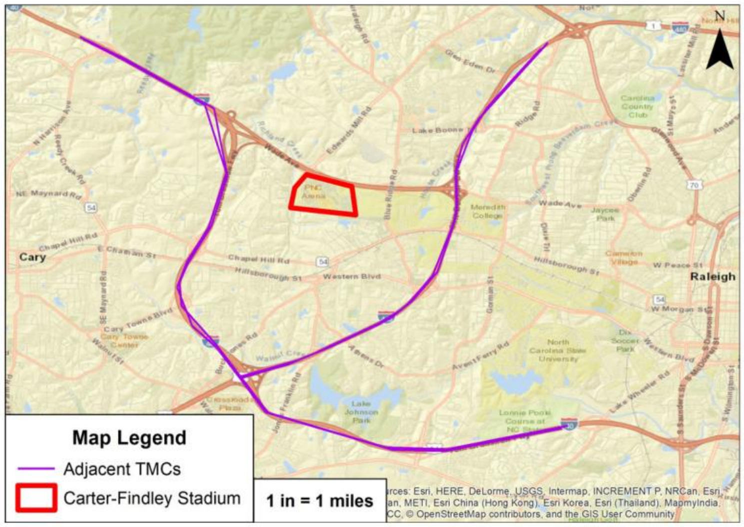
Event Data (e.g., Football Game)



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Facility Studies

- I-40 eastbound and westbound
- "End-to-end" and TMC-specific performance
- Normal and abnormal conditions
  - Abnormal: incidents, weather, unusually high flow rates, special events
  - Normal: "the rest"
- Interested in finding problematic TMCs

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TMC-level Analysis

- 51 TMCs, 365 days, 5-minute intervals
- Whole year (365*24*12*51 = 5,361,120 intervals)

16% fail

– 000:	4,043,637 (75.4%)
– 008:	451,048 (8.4%)
– 080:	19,878 (0.37%)
– 088:	1,459 (.03%)
– 200:	724,746 (13.52%)
– 208:	109,517 (2.04%)
– 280:	10,309 (0.19%)
– 288:	526 (0.01%)

- ~ 89% - normal
- ~ 75% - normal / no fail
- ~ 14% - normal / fail (16% of normal)
- ~ 11% - abnormal
- ~ 9% - abnormal / no fail
- ~ 2% - abnormal / fail (10% of abnormal)

- Workdays (249*24*12*51 = 3,657,312 intervals)

14% fail

– 000:	3,803,404 (76.6%)
– 008:	301,897 (8.25%)
– 080:	16,454 (0.45%)
– 088:	1,262 (0.03%)
– 200:	458,604 (12.54%)
– 208:	66,357 (1.81%)
– 280:	8,871 (0.24%)
– 288:	463 (0.01%)

- ~ 89% - normal
- ~ 77% - normal / no fail
- ~ 12% - normal / fail (11% of normal)
- ~ 11% - abnormal
- ~ 9% - abnormal / no fail
- ~ 2% - abnormal / fail (10% of abnormal)

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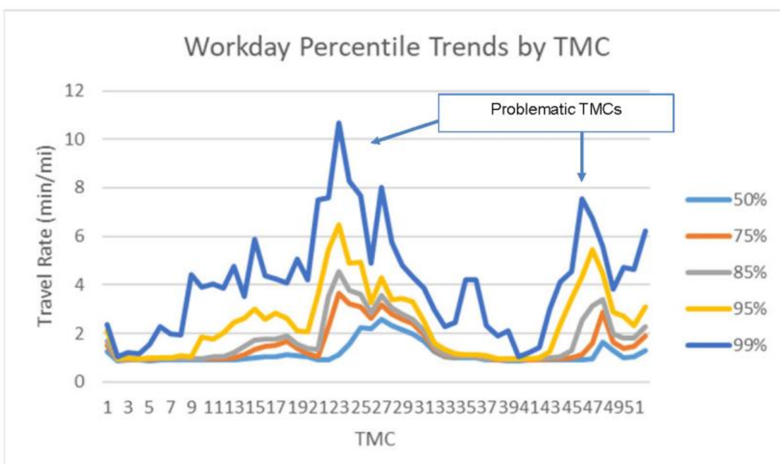
TMC Specific Performance

For each of the 51 TMCs on I-40 westbound, the plot shows the percentage of 5-minute intervals that have travel rates less than the specified value



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Three Illustrative TMCs

Frequency of External Event Factors	125-04870	125-04857	125N04836
Intervals with abnormal travel rates			
24-hour	1,823	3,268	3,106
AM Peak Period	424	501	298
PM Peak Period	152	220	4
Weekends	283	240	28
Intervals with incidents			
24-hour	57	40	63
AM Peak Period	32	9	0
PM Peak Period	16	18	40
Weekends	0	0	4
Intervals with planned events			
24-hour	181	0	0
AM Peak Period	0	0	0
PM Peak Period	0	0	0
Weekends	181	0	0

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Three Illustrative TMCs (2)

Frequency of external factor events	125-04870	125-04857	125N04836
Intervals with weather events			
24-hour	10,751	11,645	10,658
AM Peak Period	0	122	99
PM Peak Period	0	2	2
Weekends	3,415	3,800	3,545
Intervals with unusually high flow rates			
24-hour	6	0	0
AM Peak Period	0	0	0
PM Peak Period	0	0	0
Weekends	1	0	0

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TMC Speed Distributions

This is the information needed for MAP-21 performance assessments

Speed Range	125-04870	125-04857	125N04836	Facility
24-hour (all times)				
60+	97.51%	72.29%	93.94%	92.19%
55 - 60	1.53%	15.09%	2.07%	3.82%
45 - 55	0.43%	8.46%	1.09%	1.57%
40 - 45	0.10%	1.55%	0.47%	0.42%
30 – 40	0.15%	1.04%	1.12%	0.73%
15 - 30	0.16%	1.17%	1.12%	0.97%
0 - 15	0.12%	0.41%	0.20%	0.29%
AM Peak Period				
60+	96.73%	78.88%	98.75%	95.37%
55 - 60	1.20%	15.68%	1.03%	2.85%
45 - 55	0.43%	3.51%	0.17%	0.89%
40 - 45	0.19%	0.46%	0.02%	0.19%
30 – 40	0.39%	0.62%	0.01%	0.26%
15 - 30	0.63%	0.57%	0.01%	0.28%
0 - 15	0.43%	0.28%	0.02%	0.15%
PM Peak Period				
60+	96.17%	29.75%	72.77%	77.85%
55 - 60	2.29%	25.57%	4.63%	6.59%
45 - 55	0.63%	32.68%	4.81%	4.62%
40 - 45	0.11%	7.26%	2.78%	1.63%
30 – 40	0.19%	3.07%	6.76%	3.33%
15 - 30	0.32%	1.40%	7.06%	4.90%
0 - 15	0.29%	0.27%	1.19%	1.08%

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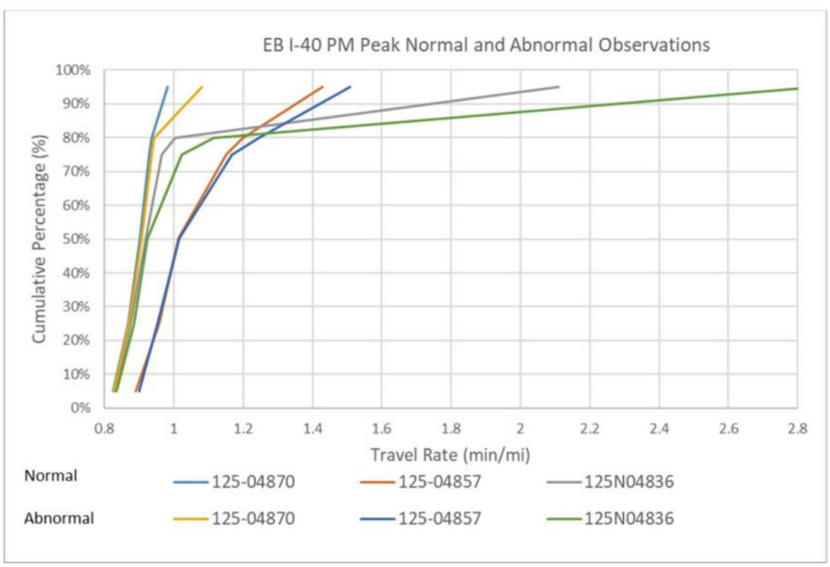
I-40 Eastbound PM Peak



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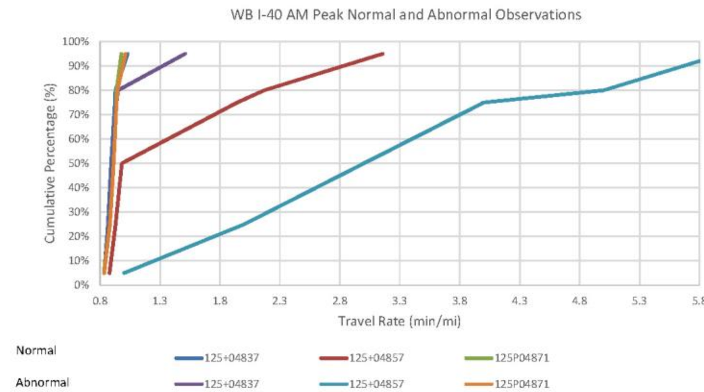
I-40 Westbound AM Peak



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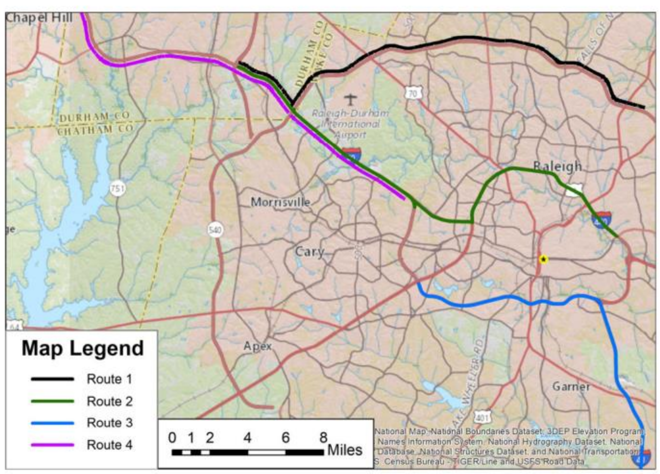
Route Assessments



US 1/I-540 to I-40/Davis Dr. (RTP)

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Route Characteristics

Route Description	I-40 WB	I-540 WB	Entire Route
Number of TMC Segments	7	16	23
Total distance of TMCs (mi)	2.7167	15.9796	18.6963
First TMC Segment	125P04863	125N05083	125N05083
Last TMC Segment	125P04866	125-04896	125P04866

Number of Flags	Incidents Only	Weather Only	Flow Only	F & I	I & W	F & W	All
> 0	139	14414	762	137	137	762	137
> 1	110	13780	446	110	110	446	110
> 2	56	13630	204	52	56	204	52
> 3	35	11815	55	25	35	55	25
> 4	23	11716	12	7	23	12	7
> 5	21	11570	3	2	21	3	2

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Route Performance

Speed Distribution	24-Hour	AM Peak	PM Peak	Off-Peak	Weekend
Normal					
60+	88.06%	78.80%	89.02%	88.90%	90.09%
55-60	10.35%	11.32%	10.02%	10.73%	9.52%
45-55	0.99%	5.82%	0.66%	0.28%	0.28%
40-55	0.20%	1.13%	0.15%	0.05%	0.07%
30-40	0.23%	1.58%	0.08%	0.04%	0.04%
15-30	0.16%	1.23%	0.07%	0.00%	0.00%
0-15	0.01%	0.11%	0.00%	0.00%	0.00%
Abnormal					
60+	86.78%	78.89%	84.66%	88.48%	88.18%
55-60	10.72%	11.99%	13.97%	11.01%	8.85%
45-55	1.60%	4.92%	0.87%	0.47%	2.07%
40-55	0.37%	1.24%	0.09%	0.02%	0.59%
30-40	0.28%	1.27%	0.09%	0.02%	0.31%
15-30	0.21%	1.39%	0.32%	0.00%	0.00%
0-15	0.04%	0.30%	0.00%	0.00%	0.00%

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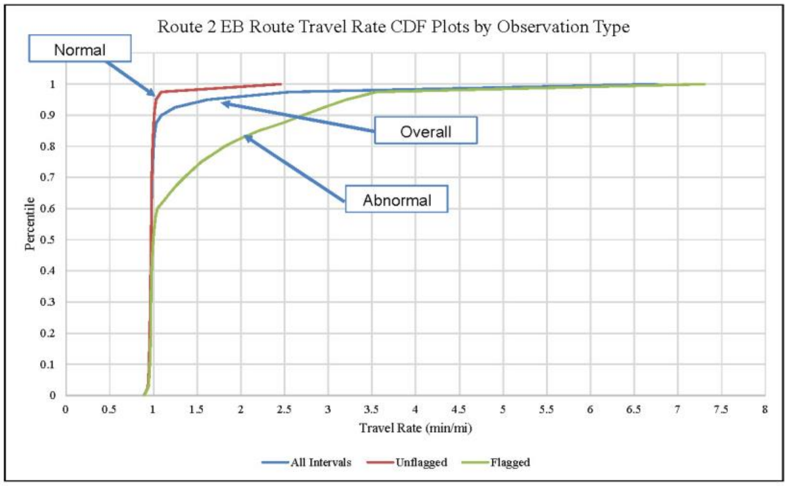
Route Travel Rates



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Abnormal Condition Analysis

- Questions
  - Are they the same / different
  - In what ways are they different
  - What are the compound effects : additive?
- Analysis
  - I-440 Eastbound
  - All "abnormal events"
    - incidents, weather, unusually high flow rates, special events
  - Comparison with "all" and "normal" conditions

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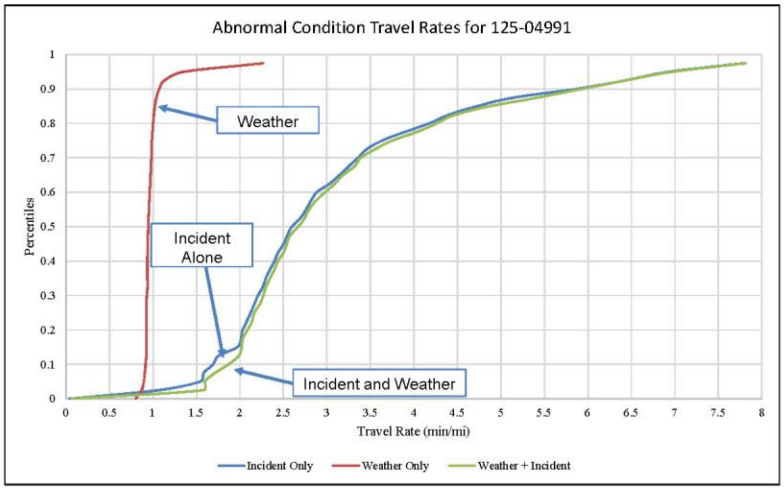
Differences Among Conditions



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Special Event Analysis

- Football game at Carter-Findley Stadium
- Overlap with PM peak
- Examination of select TMCs
- Impacts of ingress / egress

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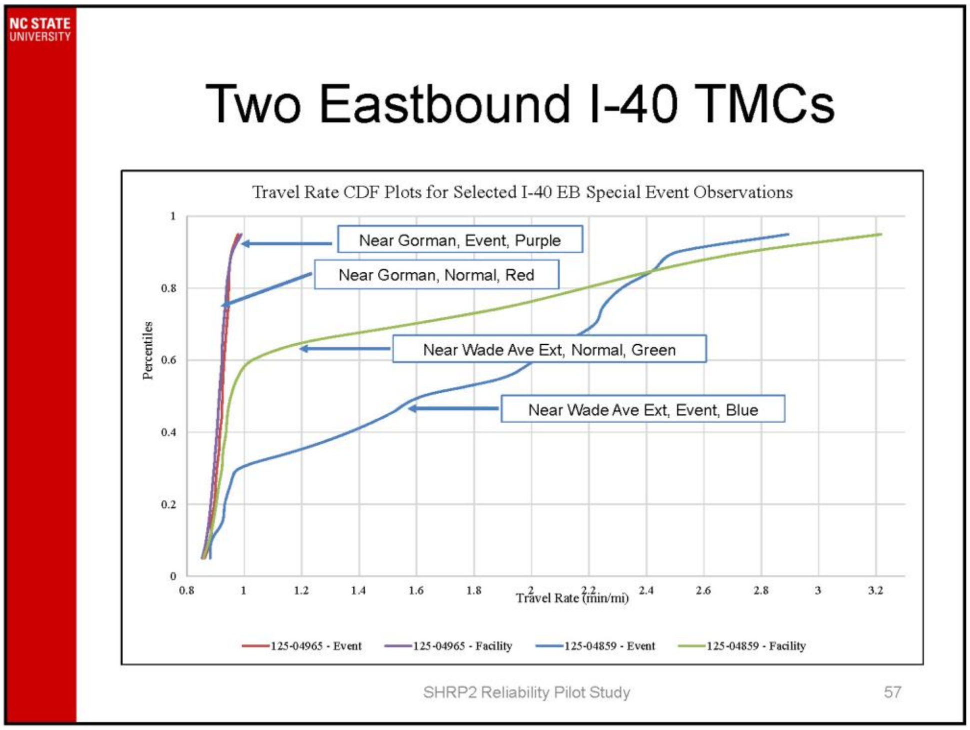
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Two Eastbound I-40 TMCs
Travel Rate CDF Plots for Selected I-40 EB Special Event Observations
Near Gorman, Event, Purple
Near Gorman, Normal, Red
Near Wade Ave Ext, Normal, Green
Near Wade Ave Ext, Event, Blue
Percentiles
Travel Rate (min/mi)
125-04965 - Event
125-04965 - Facility
125-04859 - Event
125-04859 - Facility
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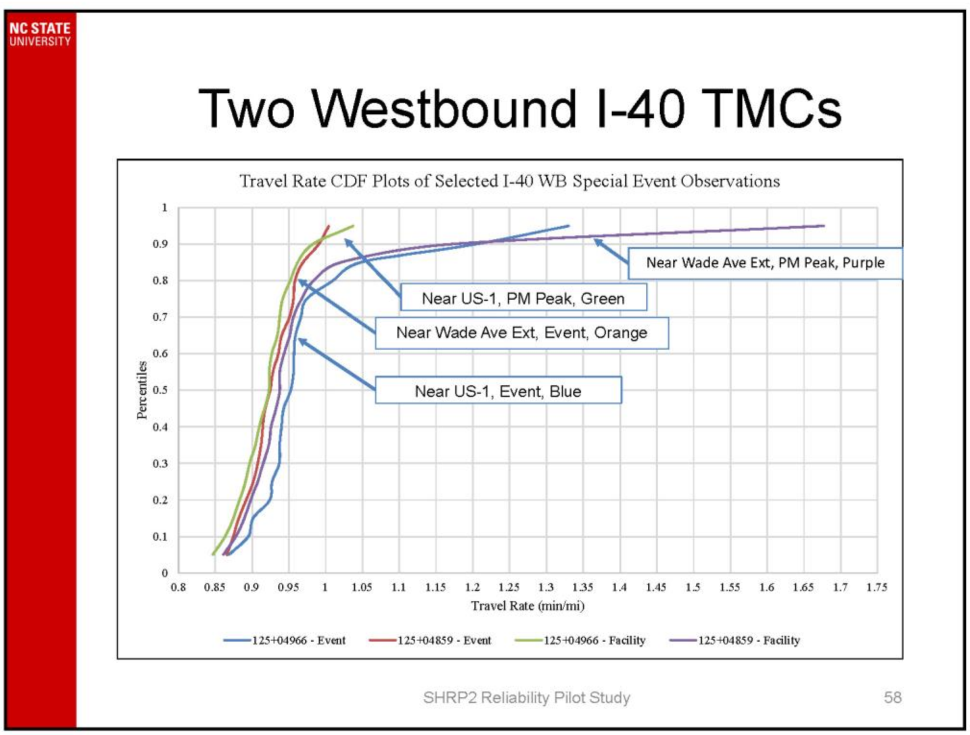
57


NC STATE UNIVERSITY
Two Westbound I-40 TMCs
Travel Rate CDF Plots of Selected I-40 WB Special Event Observations
Near Wade Ave Ext, PM Peak, Purple
Near US-1, PM Peak, Green
Near Wade Ave Ext, Event, Orange
Near US-1, Event, Blue
Percentiles
Travel Rate (min/mi)
125+04966 - Event
125+04859 - Event
125+04966 - Facility
125+04859 - Facility
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Concluding Remarks

- Assembling / collecting the data is feasible to do
- Labeling the observations is very important and useful
- Clustering the data by operating conditions is important
  - Understand the cause-effect relationships
  - Identifying actions to take
- PDFs and CDFs are very helpful
  - Learning how to "read" the shapes is a learnable skill
  - Understanding the statistical details is not critical
- Examining segments (TMCs) and routes are both important
- Automating the "external" data collection is valuable
  - Avoid losing / missing perishable data
- Further enhancements will increase value

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Thank You

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Important Concepts

- Conceptual perspective
- Monitoring points
- Reliability metrics
- Operating environment events and labels
- Operating conditions / regimes

May 29, 2018 SHRP2 Reliability Pilot Study 3

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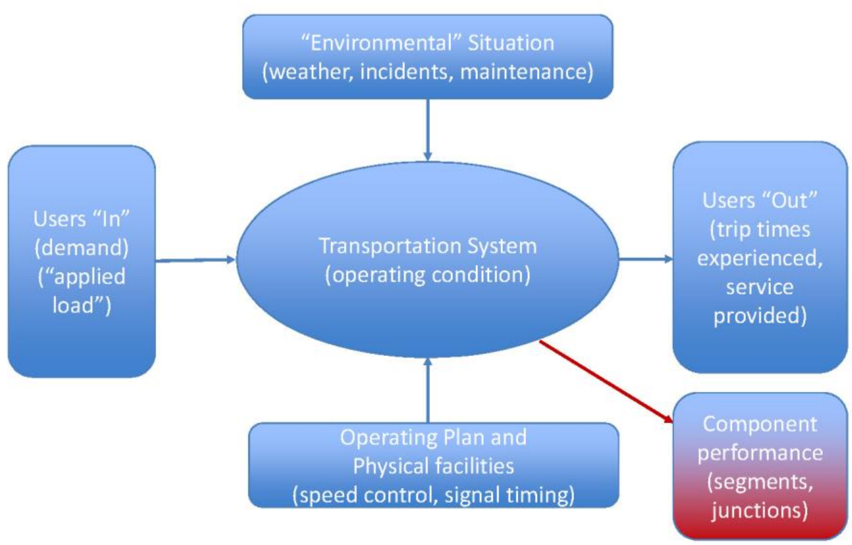
Conceptual Perspective



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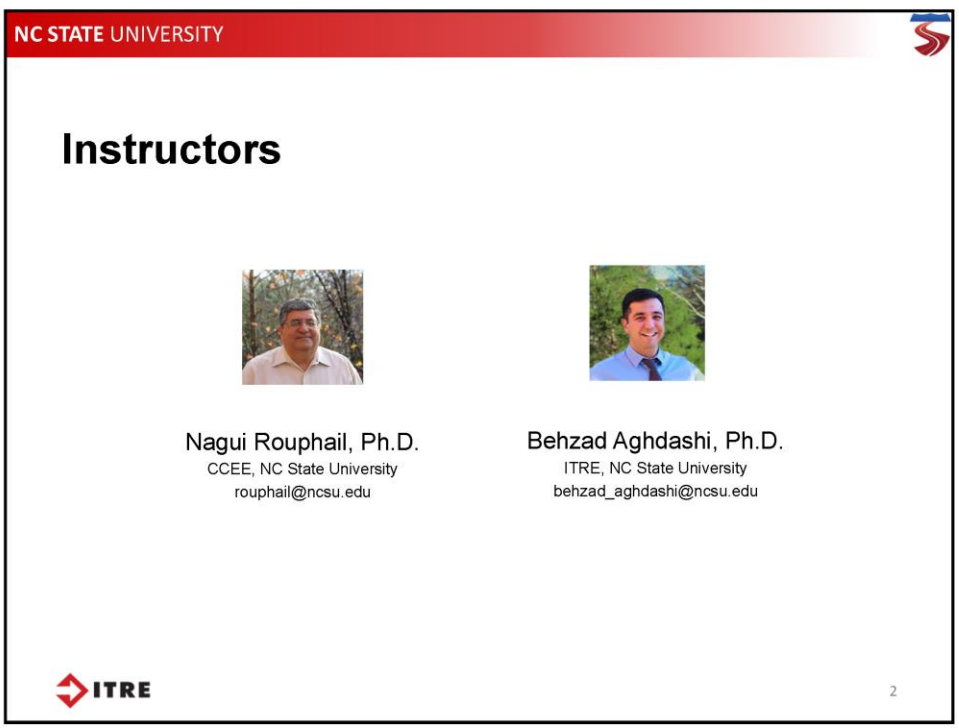
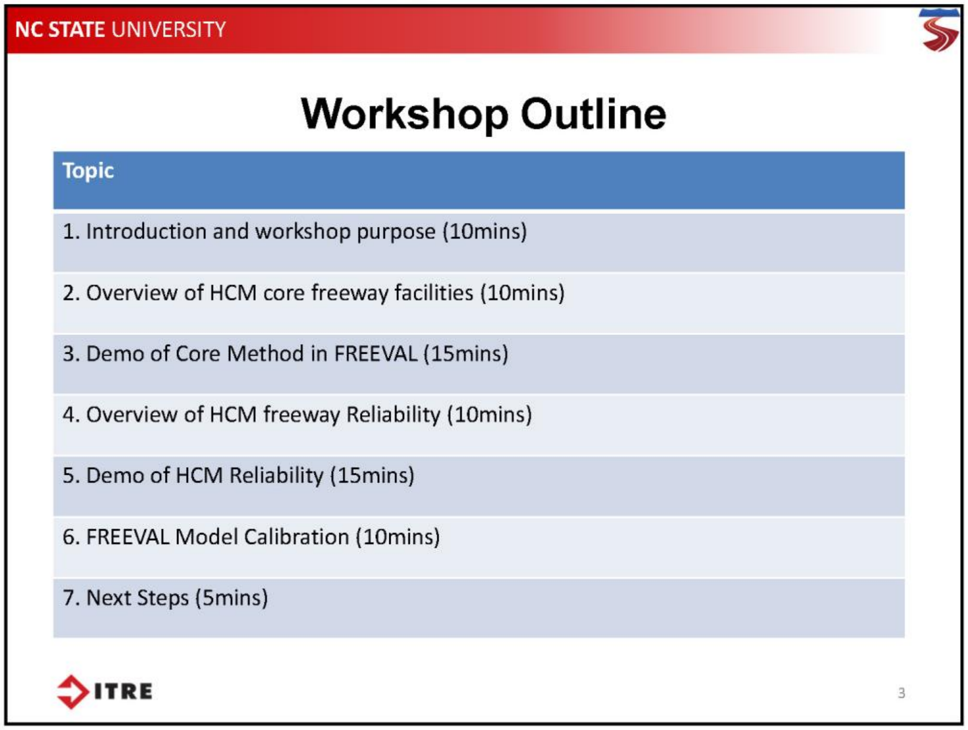
Webinar on Travel Time Reliability Modeling Tools – Presentation Slides

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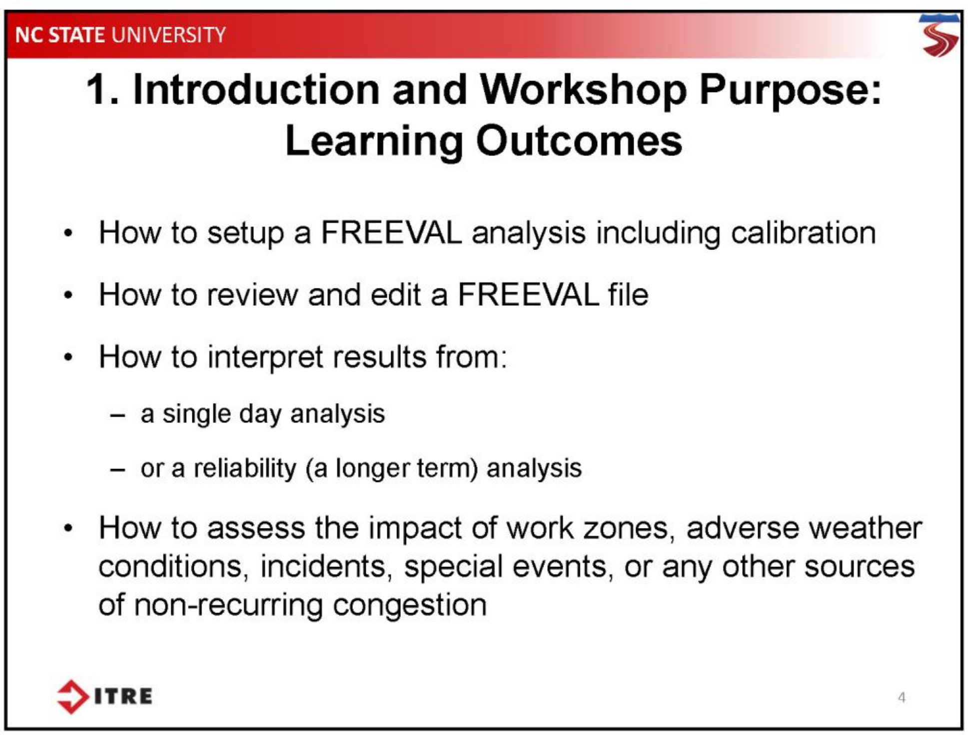
Workshop Outline
Topic
1. Introduction and workshop purpose (10mins)
2. Overview of HCM core freeway facilities (10mins)
3. Demo of Core Method in FREEVAL (15mins)
4. Overview of HCM freeway Reliability (10mins)
5. Demo of HCM Reliability (15mins)
6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)
ITRE
3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1. Introduction and Workshop Purpose: Learning Outcomes
• How to setup a FREEVAL analysis including calibration
• How to review and edit a FREEVAL file
• How to interpret results from:
– a single day analysis
– or a reliability (a longer term) analysis
• How to assess the impact of work zones, adverse weather conditions, incidents, special events, or any other sources of non-recurring congestion
ITRE
4

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Review of Important Resources

- This Presentation
- http://freeval.org
  - To download the latest version of FREEVAL executable code
- FREEVAL User Guide
  - A reference material to operate FREEVAL tool
- YouTube videos (http://go.ncsu.edu/freeval)
  - Short videos to get a big picture idea on what different FREEVAL analyses are all about

ITRE 5

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What is FREEVAL?

- FREEVAL was developed in the late 1990s, and has been continuously improved and expanded since that time
- It is the official computational engine of the HCM to perform freeway segment, facility and reliability analyses
- It encompasses all freeway segment methods (basic, merge, diverge, and weave) as well as managed lanes, work zone, reliability etc. analyses
- It is able to model oversaturated conditions and queue formation and dissipation over time and space, subject to HCM methodology limitations

ITRE 6

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What can FREEVAL do?

- Can perform the following analyses:
  - Segment and Facility Level
  - Travel Time Reliability
  - Work Zone
  - Managed Lanes
  - Active Traffic Management
    - Ramp Metering
    - Hard Shoulder Running
    - Incident Management
    - Traffic Diversion

ITRE

7

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Different Versions of FREEVAL

FREEVAL 2015-E
- Integrates all HCM Freeway Chapters (Core Method)
- Managed lanes, Reliability, ATDM

FREEVAL - WZ
- NCDOT sponsored planning-level interface (demand profiles)
- Explicit modeling of work zone scenarios and user cost
- Customized report generation functionality

FREEVAL-DSS
- Dynamic Strategy Selection (DSS) for ATDM strategy implementation
- Modeler and operator modes to assess reaction to congestion in near real-time

FREEVAL
- Integrates all Prior Features and additional customization
- Adds Google Map Integration for Segmentation
- Enhanced ATDM Interface (Ramp Metering, Hard Shoulder Running, etc.)

FREEVAL-NC
- Integrates all Prior Features and additional customization
- Access to the online segmentation database
- Enhanced reporting features

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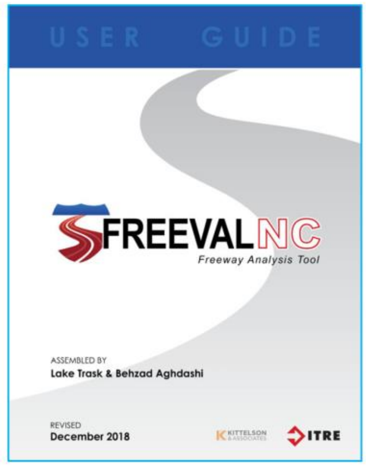
FREEVAL User Guide

- Accessible at http://freeval.org
- You can invoke the user guide by pressing F1 key when the software window is selected.



ITRE 9

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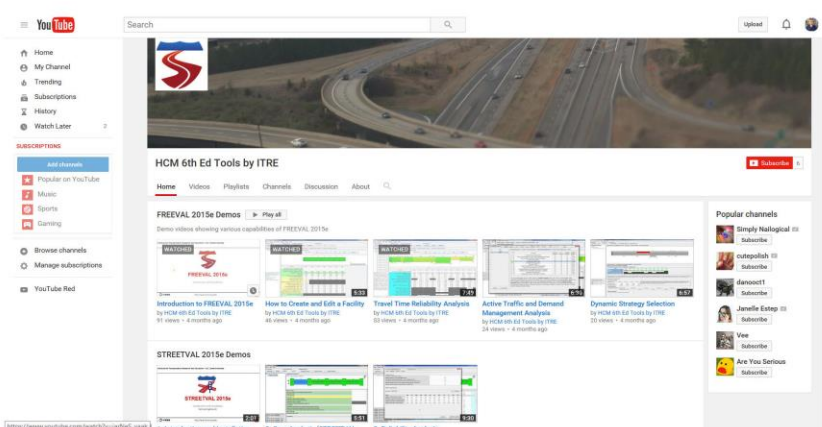
FREEVAL YouTube Videos

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



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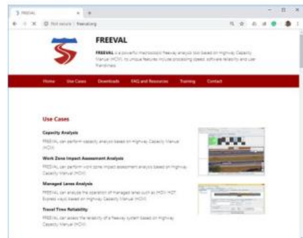
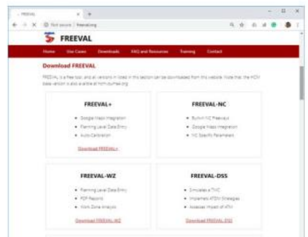
freeval.org

- freeval.org is a central place to host latest versions of FREEVAL along with any supporting material
  - Users Guide
  - Useful links to external websites
  - Q&A
- Base FREEVAL-2015E version is accessible through HCM Volume IV (hcmvolume4.org) as well.





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Overview of HCM Core Freeway Facilities Method

SESSION #2

12

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Workshop Outline

Topic
1. Introduction and workshop purpose (10mins)
2. Overview of HCM core freeway facilities (10mins)
3. Demo of Core Method in FREEVAL (15mins)
4. Overview of HCM freeway Reliability (10mins)
5. Demo of HCM Reliability (15mins)
6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)

ITRE 13

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Overview of Analyses Types Supported

- FREEVAL can perform any freeway analyses cited in the 6th edition of HCM.
- Also includes methods from other research projects:
  - Planning Level Data Entry
  - Auto-Segmentation (or extraction from online segmentation database)
  - Facilitated Calibration
  - Work zone analysis

Image Sources: Kittelson & Associates, ITRE

ITRE 14

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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

ITRE 15

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Why Analyze Freeways as Facilities?

Photo: Bastian Schroeder

ITRE 16

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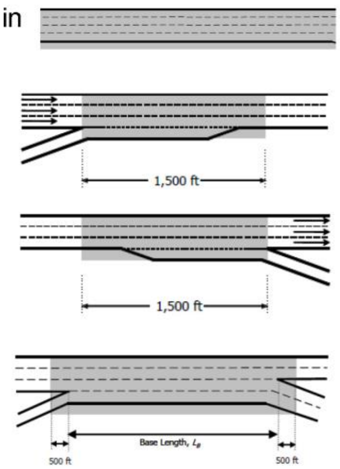
Spatial Unit of FREEVAL Analysis

- The smallest spatial building block of freeways in FREEVAL are "HCM Segments"
- HCM Segment Types:
  - Basic Freeway Segments
  - Weaving Segments
  - On-ramp (merge) and Off-Ramp (diverge) Segments
  - Overlapping Segments
  - Managed Lane Segments
- HCM Segments are different than Traffic Message Channel (TMC) Segments!



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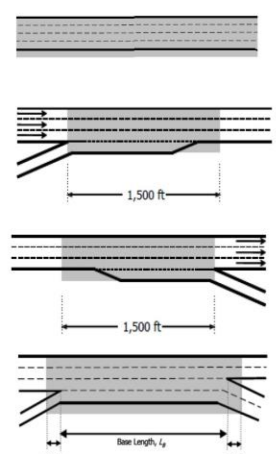
How to do Segmentation?

- For any existing freeway, embedded maps can be called, and Auto-Segmentation Wizard will guide you to generate HCM segments *in Google Maps.*
- HCM Chapter 10 procedures and definitions need to be used to split the freeway facility into HCM segments when Auto-segmentation is not invoked.
- The latest version of FREEVAL has access to online segmentation database.



ITRE 18

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Managed Lanes Segments

Continuous Access | Buffer 1 | Buffer 2 | Barrier 1 | Barrier 2

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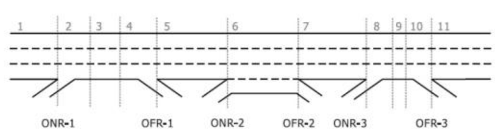
Other Details …

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



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Methodology Capabilities

- Enables the modeling of oversaturated & under-saturated conditions in an extended time-space domain (24 hrs.)
- 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
  - *Hall, F., D. May, N. Rouphail, L. Blomberg and B. Eads (2000) "Validation Results for four Models of Over saturated Freeway Facilities", Journal of the Transportation Research Board 1710, pp. 161-170. Best Paper Award for TRB A3A10 Committee.*

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Be Cautious!

- HCM methods do not account for spillback onto the freeway mainline due to off-ramp congestion from the surface street
- Not reliable in reporting the effect of multiple overlapping queues with very high Demand to Capacity ratio.
- Requires demand input manipulation for the analysis of extended facilities (free-flow travel time greater than 15 minutes)

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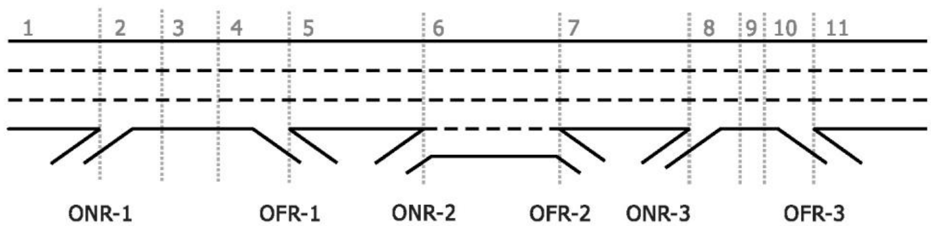
An Illustrative Example



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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Other Details …

- 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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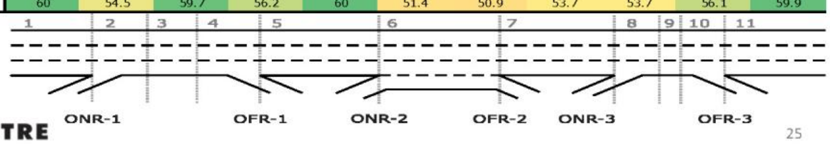
FREEVAL Outputs

Time period	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

Time period	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 period	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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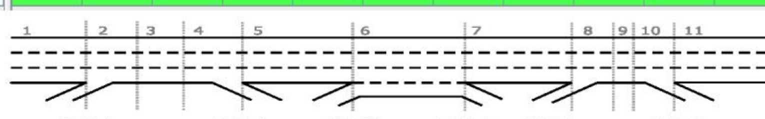
FREEVAL Outputs

- Density Based 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

- Demand Based 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											
#2 17:15 - 17:30											
#3 17:30 - 17:45								F	F	F	F
#4 17:45 - 18:00											
#5 18:00 - 18:15											



ITRE

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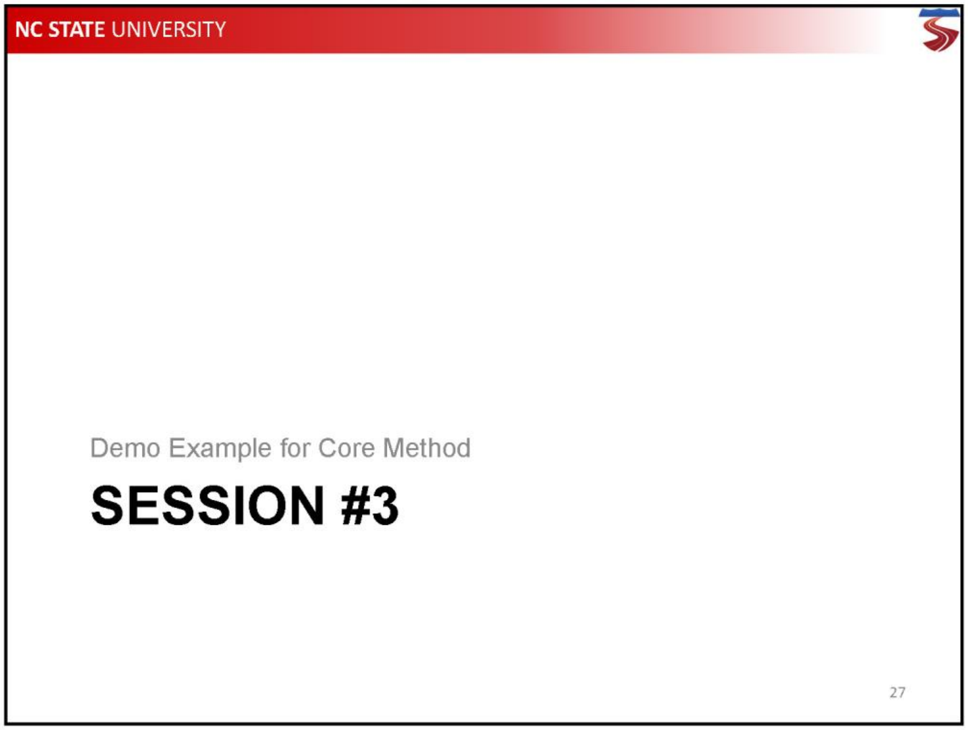
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Demo Example for Core Method
SESSION #3
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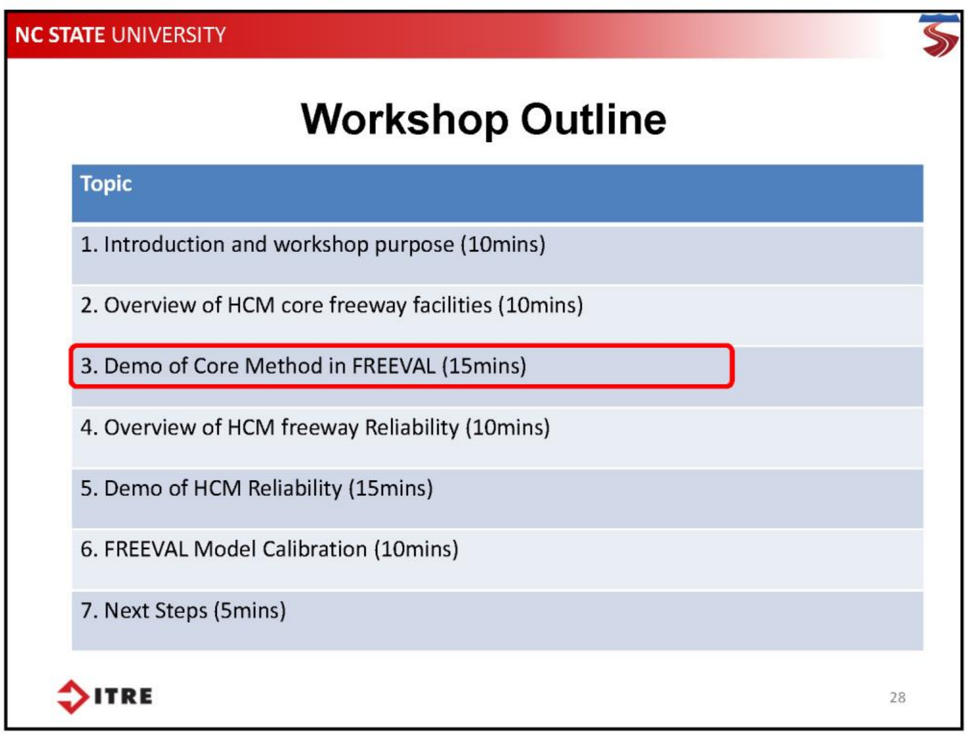
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Workshop Outline
Topic
1. Introduction and workshop purpose (10mins)
2. Overview of HCM core freeway facilities (10mins)
3. Demo of Core Method in FREEVAL (15mins)
4. Overview of HCM freeway Reliability (10mins)
5. Demo of HCM Reliability (15mins)
6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)
ITRE
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Installation Process

- Make sure you have downloaded FREEVAL from freeval.org and have unzipped the files into a single folder on your computer
- Double click on "RunFREEVAL" file and execute the application

ITRE 29

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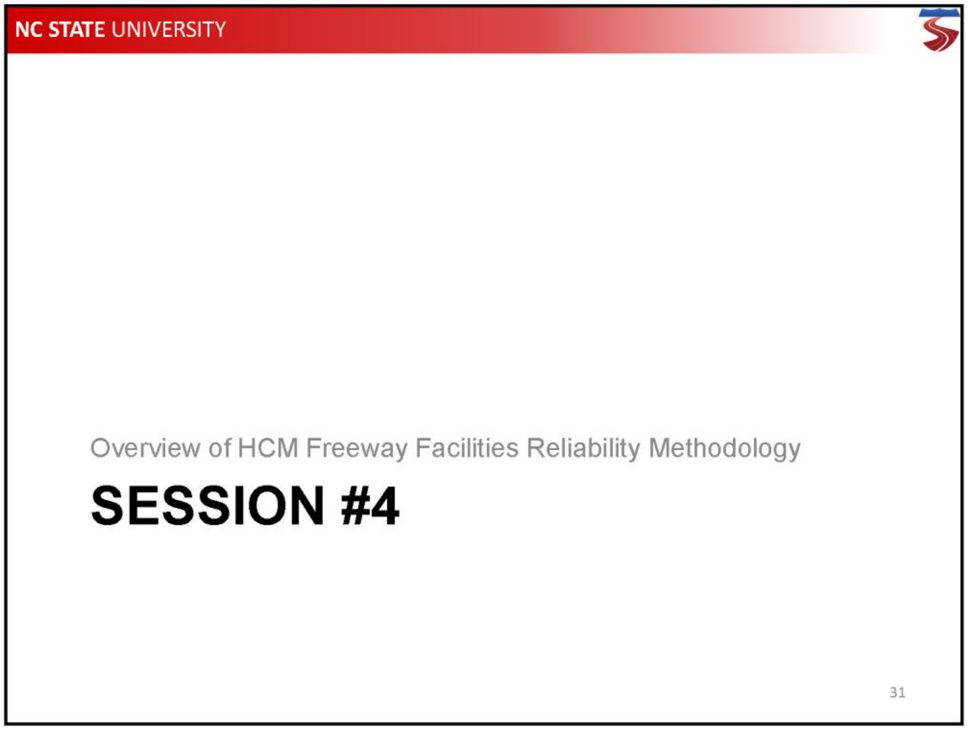
Example Scope

- I-540 WB facility in North Carolina will be modeled
- Geometric information will be collected from 'Online Segmentation Database'
- A work zone will be modeled and its impact will be quantified

ITRE 30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Overview of HCM Freeway Facilities Reliability Methodology
SESSION #4
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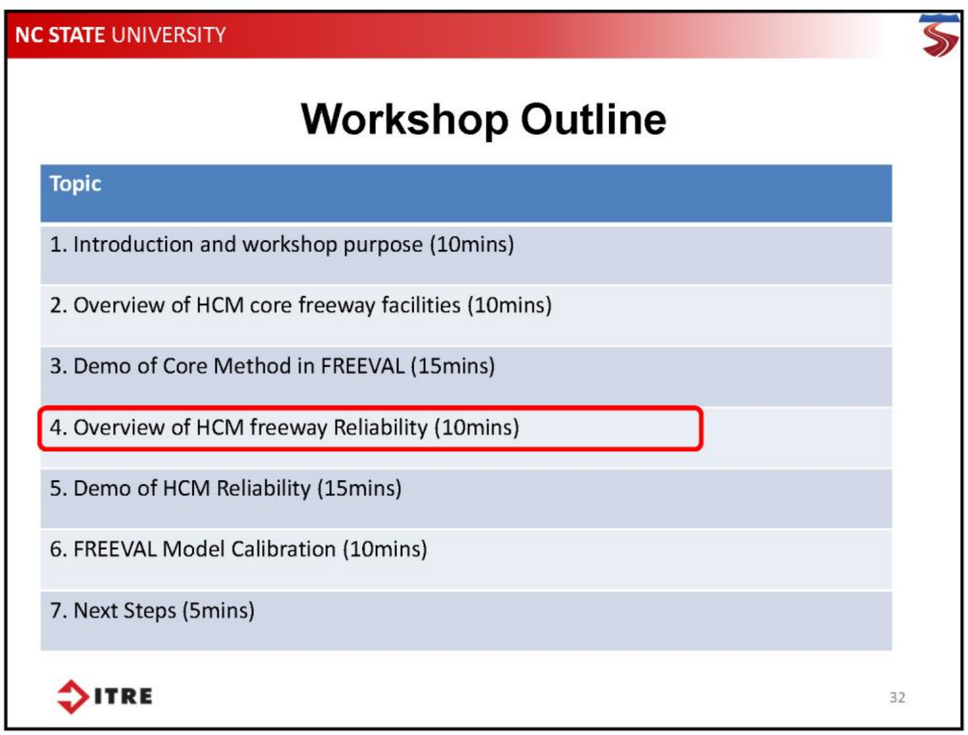
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6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)
ITRE
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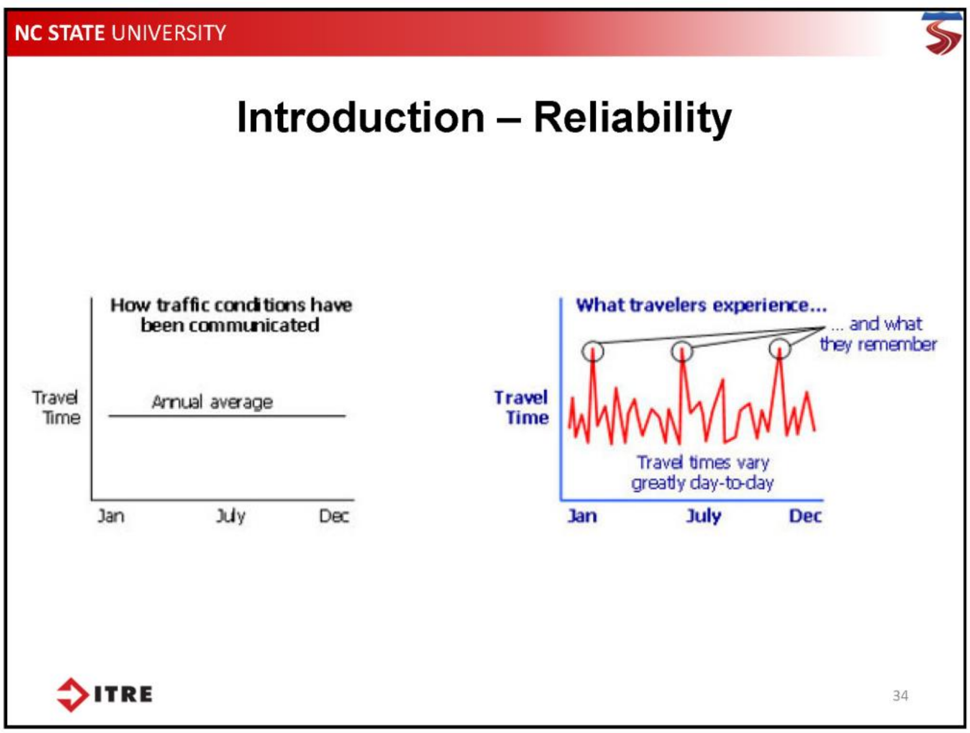
WHY DO WE CONTINUE TO
ANALYZE THE AVERAGE DAY?
33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Introduction – Reliability
How traffic conditions have been communicated
Travel Time
Annual average
Jan
July
Dec
What travelers experience...
... and what they remember
Travel Time
Travel times vary greatly day-to-day
Jan
July
Dec
ITRE
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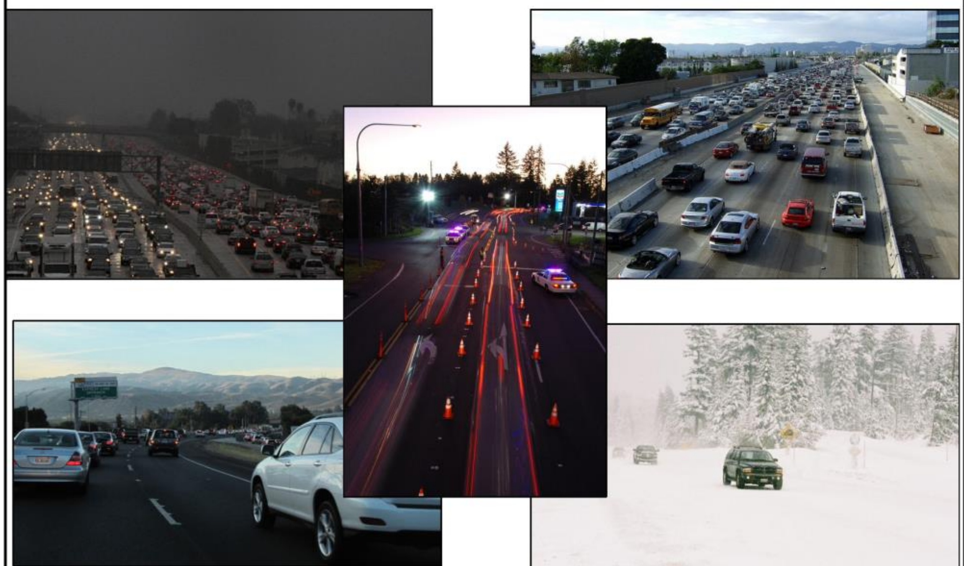
Sources of (Un)Reliable Travel



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Recurring and Non-Recurring Sources of Congestion

- 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.)
    - Adverse Weather Conditions
    - Work Zones
    - Demand Surges (special events)
- Demand is allowed to vary between the 15 min analysis periods

ITRE 36

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Reliability Analysis in the HCM

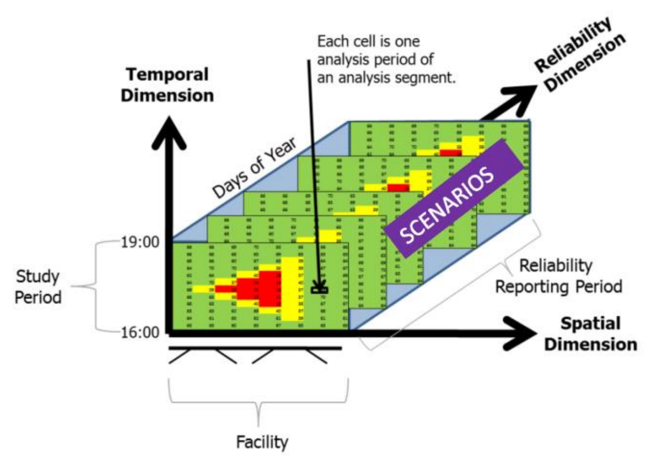

Exhibit 11-1
Schematic Representation of Freeway Reliability Analysis Time–Space Domain

Source: Zegeer et al. (1)

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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
- Method uses both deterministic and stochastic modeling in an optimization scheme to generate scenarios.
- Demand is entered according to the calendar (20 weekdays per month)

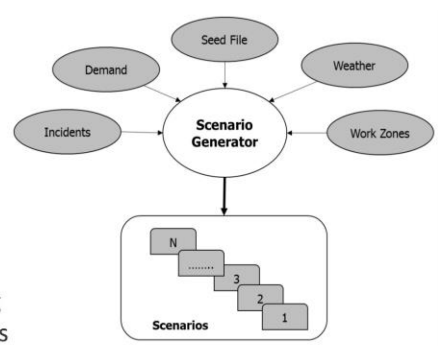

Exhibit 11-4
Schematic of the Freeway Scenario Generation Process and Impacting Factors

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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 base time unit, then replicates this combination several times
- Recommended number of replications depends on the duration of 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 weather and incident events is allowed

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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Evaluating Scenarios and Method 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

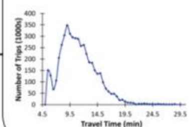
Base Dataset
Segment geometry
Managed Lane Data
Segment type
Base demands
Demand patterns
Weather and incident history
Reliability reporting period
Work zones

Scenario Generator
Demand
Weather
Incidents

Base Dataset Adjustments
Demand adjustment factors
Capacity adjustment factors
Speed adjustment factors
Number of Lane Adjustments

Core HCM Facility Method
Chapter 10: Freeway Facilities

Travel Time Distribution



Performance Measures
Planning time index
80th percentile travel time index
Reliability rating
On-time performance
Semi–standard deviation
etc.

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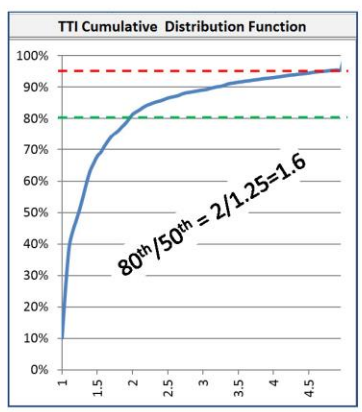
Reliability Performance Measures

- 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 the **Travel Time Index (TTI)** distribution.



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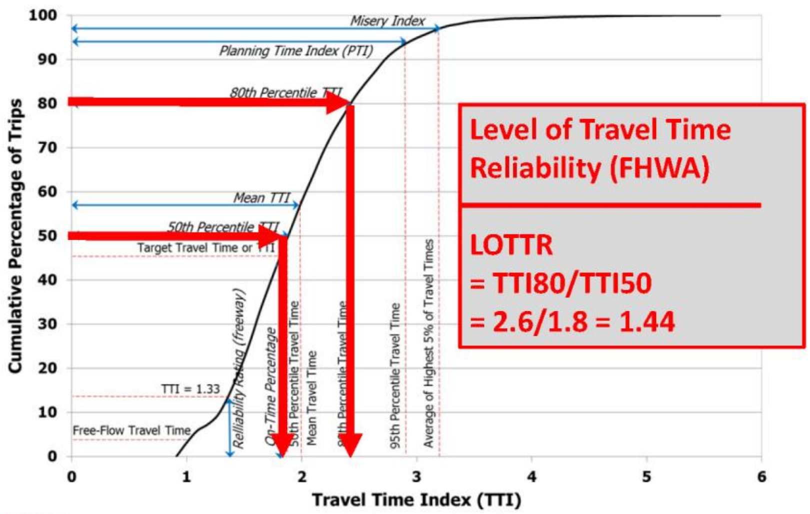
Reliability Performance Measure Examples



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Reliability Performance Measures from the TTI Distribution

- Key Reliability Performance Measures from TTI 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 of all facility vehicle-miles traveled at TTI greater than 2

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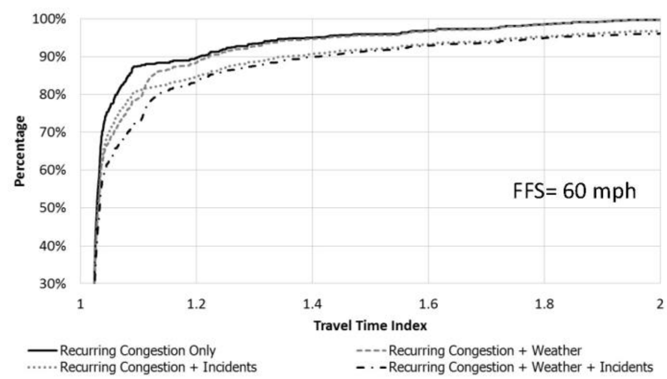
The Effect of Different Sources on Reliability

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



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Demo Example for Reliability Method

SESSION #5

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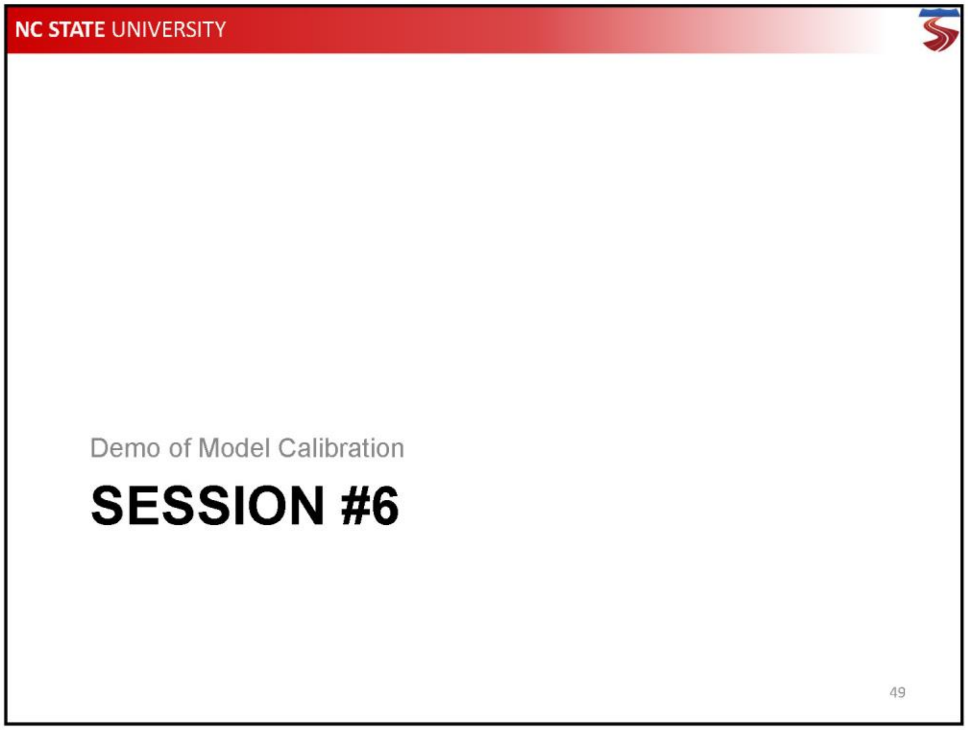
Workshop Outline

Topic
1. Introduction and workshop purpose (10mins)
2. Overview of HCM core freeway facilities (10mins)
3. Demo of Core Method in FREEVAL (15mins)
4. Overview of HCM freeway Reliability (10mins)
5. Demo of HCM Reliability (15mins)
6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)

Scope of Example

- Continue on I-540WB example and predict its reliability across a year
- Model a "Incident Management" strategy which will reduce crash frequency
- Compare reliability MOEs and interpret the results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Demo of Model Calibration
SESSION #6
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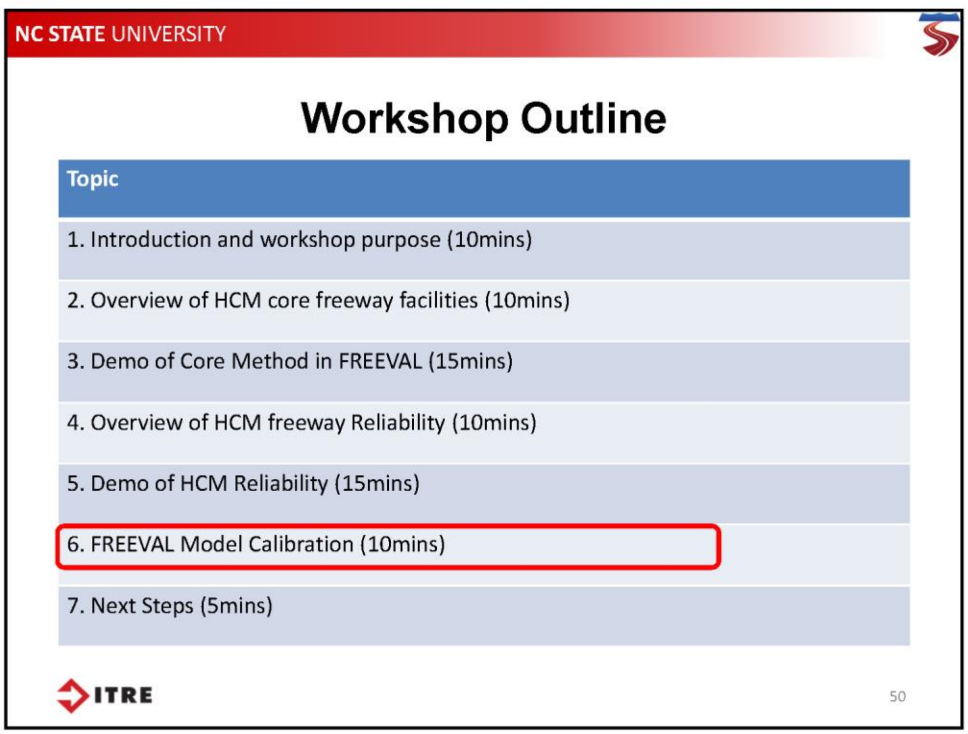
NC STATE UNIVERSITY
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5. Demo of HCM Reliability (15mins)
6. FREEVAL Model Calibration (10mins)
7. Next Steps (5mins)
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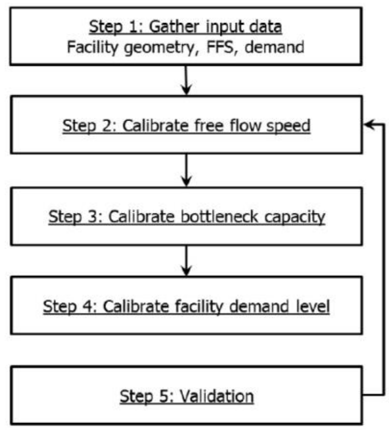
Example Scope

- Demo different means of calibration in FREEVAL
  - Manual Calibration
  - Auto-Calibration
    - Find Bottleneck Segment (up to 2)
    - Adjust CAF for Bottleneck Segment
    - Adjust DAFs and CAFs via a GA for a Generic Calibration



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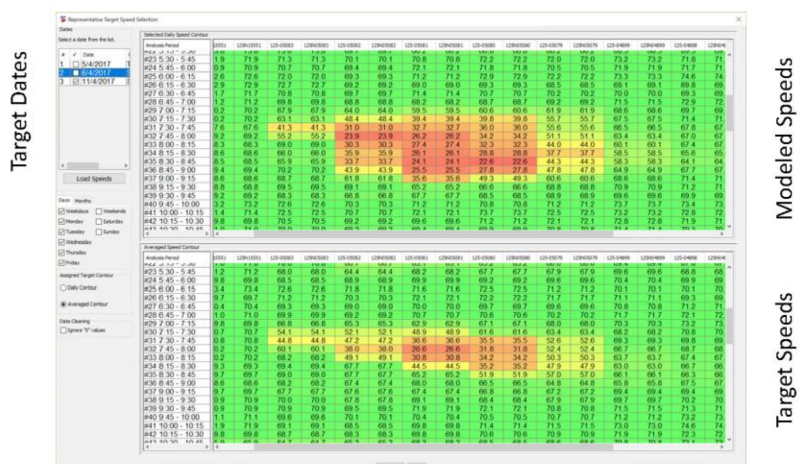
Selecting Target Dates for Calibration Module



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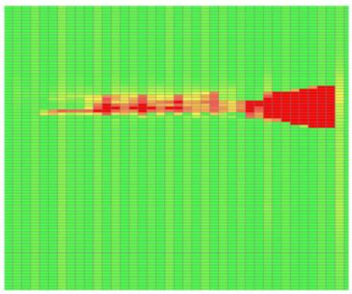
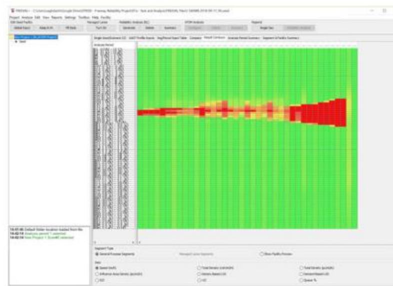
Manual FFS Calibration

- Change Free Flow Speed Adjustment Factor in FREEVAL to match high speeds from Here.com or INRIX



Target Speed



Modeled Speed

ITRE

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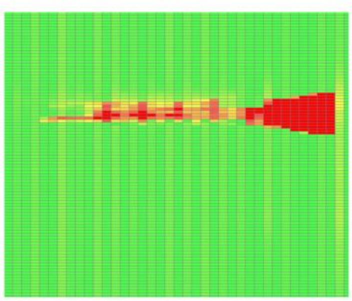
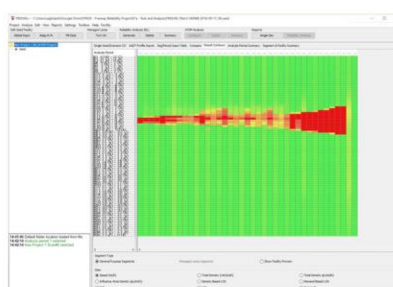
Manual CAF Calibration

- Change Segment Capacity using CAF in FREEVAL to match the congested area



Target Speed



Modeled Speed

ITRE

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CLOSING DISCUSSION

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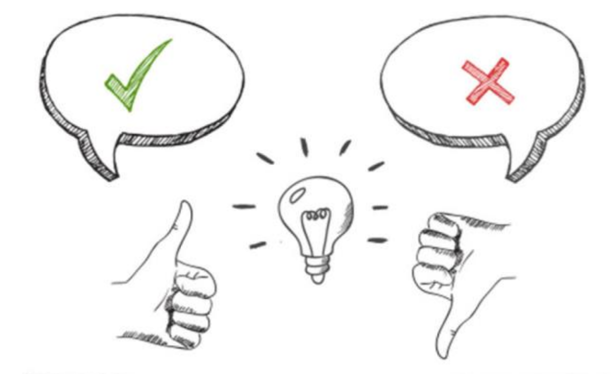
Feedback



ITRE

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