

SHRP2 Project C11: Reliability Analysis Tool: Technical Documentation and User's Guide

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This document represents Chapter 3 of the full report:

**SHRP2 Project C11 Final Report:
Development of Tools for Assessing Wider
Economic Benefits of Transportation**

Prepared for:

Transportation Research Board

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July 2013

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CHAPTER 3: RELIABILITY

This chapter was written by Cambridge Systematics and Weris.

3.1 Technical Guide

3.1.1 Introduction and Purpose

The purpose of the Reliability Module is to allow users to assess quickly the effects of highway investments in terms of both typical travel time and travel time reliability. In the past, economic assessments have been made strictly on the basis of typical travel time, but current research shows that travelers also value reliability of travel time. Accounting for this additional benefit means that transportation improvements have even more positive effects on users and the economy than heretofore thought.

The Reliability Module is structured as a sketch planning tool that involves minimal data development and model calibration. It uses the results of other SHRP 2 projects in its methodology as well as methods from earlier studies. The procedure is based on making estimates of recurring and nonrecurring congestion, combining them, and using predictive equations to develop reliability metrics.

Background on Travel Time Reliability

A review of several SHRP 2 projects identified how they defined reliability.

Project C04 (*Improving Our Understanding of How Highway Congestion and Pricing Affect Travel Demand*) defined reliability as “... the level of (un)certainty with respect to the travel time and congestion levels.” It then used statistical measures, primarily the standard deviation of travel time, as the metrics used in subsequent analyses.

Project C05 (*Understanding the Contributions of Operations, Technology, and Design to Meeting Highway Capacity Needs*) defined it as “... the reliability of the performance is represented by the variability that occurs across multiple days.”

Project L02 (*Establishing Monitoring Programs for Travel Time Reliability*) said the following regarding reliability: “It is important to start by observing that travel time reliability is not the same as (average) travel time. ...travel time reliability is about travel time probability density functions (TT-PDFs) that allow agencies to portray the variation in travel time that exists between two locations (point-to-point—P2P) or areas (area-to-area—A2A) at a given point in time or across some time interval. It is about estimating and reporting measures like the 10th, 50th, and 95th percentile travel times.” Functionally, Project L02 used the notion developed in Project L03 that reliability can be measured using the distribution of travel times for a facility or a trip.

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Project L04 (Incorporating Reliability Performance Measures in Operations and Planning Modeling Tools) used this definition: "...models formulated in this research is based on the basic notion that transportation reliability is essentially a state of variation in expected (or repeated) travel times for a given facility or travel experience. The proposed approach is further grounded in a fundamental distinction between 1) **systematic** variation in travel times resulting from predictable seasonal, day-specific, or hour-specific factors that affect either travel demand or network capacity, and 2) **random** variation that stems from various sources of largely unpredictable (to the user) unreliability."

Project L03 (Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies) used an expanded definition of reliability to include not only the idea of variability but failure (or it's opposite, on-time) as well.

In terms of highway travel, the SHRP Reliability Research Program defined reliability this way): "... from a practical standpoint, *travel-time reliability can be defined in terms of how travel times vary over time* (e.g., hour-to-hour, day-to-day). This concept of variability can be extended to any other travel-time-based metrics such as average speeds and delay. For the purpose of this study, travel time variability and reliability are used interchangeably."

A slightly different view of reliability is based on the notion of a *probability or the occurrence of failure* often used to characterize industrial processes. With this view, it is necessary to define what "failure" is, in terms of travel times. In other words, a threshold must be established. Then, one can count the number of times the threshold is not achieved or exceeded. These types of measures are synonymous with "on-time performance" since performance is measured relative to a pre-established threshold. The only difference is that failure is defined in terms of how many times the travel-time threshold is exceeded while on-time performance measures how many times the threshold is not exceeded.

In recent years, some non-US reliability research has focused on this other aspect of reliability – the *probability* of "failure," where failure currently is defined in terms of traffic flow breakdown. A corollary is the concept of "vulnerability" which could be applied at the link or network level: this is a measure of how vulnerable the network is to breakdown conditions.

Project L07 (Identification and Evaluation of the Cost-Effectiveness of Highway Design Features to Reduce Non-recurrent Congestion) used L03's definition.

Project L11 (Evaluating Alternative Operations Strategies to Improve Travel Time Reliability) defined reliability: "Travel-time reliability is related to the uncertainty in travel times. It is defined as the variation in travel time for the same trip from day to day (same trip implies the same purpose, from the same origin, to the same destination, at the same time of the day, using the same mode, and by the same route). If there is large variability, then the travel time is considered unreliable. If there is little or no variability, then the travel time is considered reliable".

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A wide range of viewpoints on the definition of travel time reliability clearly exists, but there is also a great degree of commonality. Travel time reliability relates to how travel times for a given trip and time period perform over time. For the purpose of measuring reliability, a “trip” can occur on a specific segment, facility (combination of multiple segments), any subset of the transportation network, or can be broadened to include a traveler’s initial origin and final destination. Measuring travel time reliability requires that a sufficient history be present in order to track travel time performance.

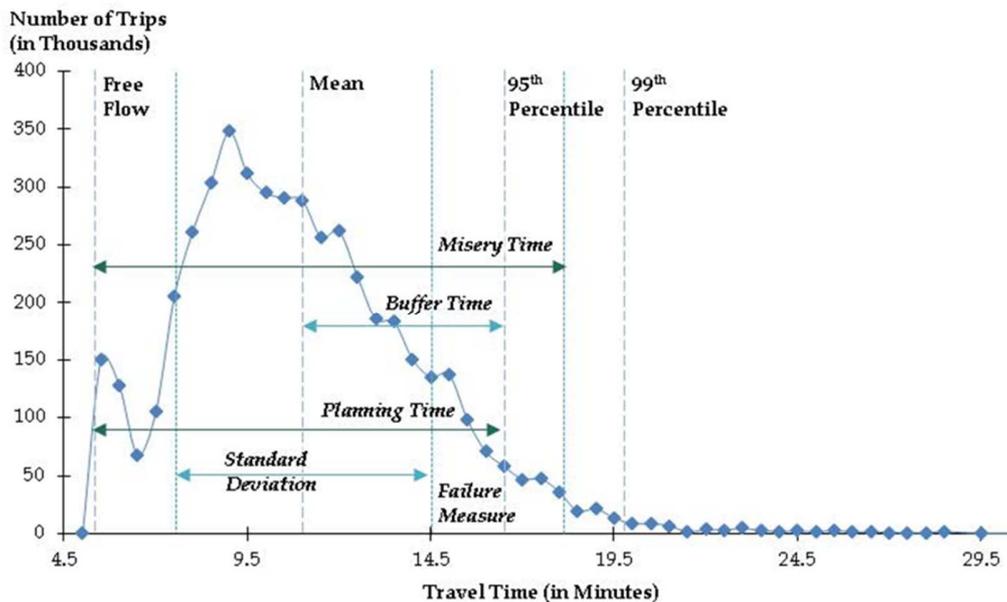
There are two widely held ways that reliability can be defined. Each is valid and leads to a set of reliability performance measures that capture the nature of travel time reliability. Reliability can be defined as:

- 1) The **variability** in travel times that occur on a facility or a trip over the course of time; &
- 2) The number of times (trips) that either “fail” or “succeed” in accordance with a pre-determined performance standard.

In both cases, reliability (more appropriately, unreliability) is caused by the interaction of the factors that influence travel times: fluctuations in demand (which may be due to daily or seasonal variation, or by special events), traffic control devices, traffic incidents, inclement weather, work zones, and physical capacity (based on prevailing geometrics and traffic patterns). These factors will produce travel times that are different from day-to-day for the same trip.

From a measurement perspective, reliability is quantified from the distribution of travel times, for a given facility/trip and time period (e.g., weekday peak period), that occurs over a significant span of time (one year is generally long enough to capture nearly all of the variability caused by disruptions). A variety of different metrics can be computed once the travel time distribution has been established, including standard statistical measures (e.g., kurtosis, standard deviation,), percentile-based measures (e.g., 95th percentile travel time, Buffer Index), on-time measures (e.g., percent of trips completed within a travel time threshold), and failure measures (e.g., percent of trips that exceed a travel time threshold). The reliability of a facility or trip can be reported for different time slices (e.g., weekday peak hour, weekday peak period, and weekend). Figure 3-1 shows an actual travel time distribution derived from roadway detector data, and the metrics that can be derived from it. Note that a number of metrics are expressed relative to the *free-flow travel time*, which becomes the benchmark for any reliability analysis. The degree of (un-)reliability then becomes a relative comparison to the free-flow travel time.

Figure 3-1. The Travel Time Distribution is the Basis for Defining Reliability Metrics



Source: Cambridge Systematics et al. *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies*. SHRP 2 L03. Transportation Research Board of the National Academies, Washington, DC. 2013.

The Value of Travel Time Reliability

Valuing travel time has a long history in transportation modeling and analysis. The value of travel time (VOT) refers to the monetary values travelers place on reducing their travel time. VOT has been long established from a basis in consumer theory where value is related to a wage rate or some portion of it. It is considered one of the largest cost components in benefit-cost analysis of transportation projects because one of the benefits for travelers in a transportation improvement is the reduction of travel time (Vovsha et al. 2011).

In contrast, the value of reliability (VOR) is a relatively new concept. VOR connects the monetary values travelers place on reducing the variability of their travel time. Reliability has most often been considered qualitatively and is associated with the statistical concept of variability (Carrion and Levinson 2010). However, it is clearly recognized by travelers of all types. Travelers account for the variability in their trips by building in “buffers” as insurance against late arrival. This action implies that the consequence of arriving late is “costly” and should be avoided (OECD 2010). Efficiency and productivity lost in these buffers or safety margins represent an additional cost that travelers absorb.

Reliability is of sufficient value to transportation system users that travelers are willing to pay for reduced travel time has been demonstrated by empirical studies. Variability in the costs which are acceptable to different travelers for different trips suggests that this value is not uniform all types of trips (Waters 1992). The difference in value between users and the type of use must be quantified to be understood and applied appropriately.

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For the business traveler and freight shippers, time is money. The just-in-time delivery aspect of the present economy implies a high cost associated with an unreliable transportation system and a corresponding value for travel time reliability. Freight providers are a unique category of transportation users in many aspects; however, the value placed on reliability is consistent with or greater than other travelers.

Past research studies have used the Reliability Ratio (VOR/VOT) as the most convenient way to measure reliability in an empirical study. Table 3-1 summarizes the values of reliability for passenger travel that were included in the reviewed research.

Table 3-1. Past Research on the Value of Reliability: Passenger Travel

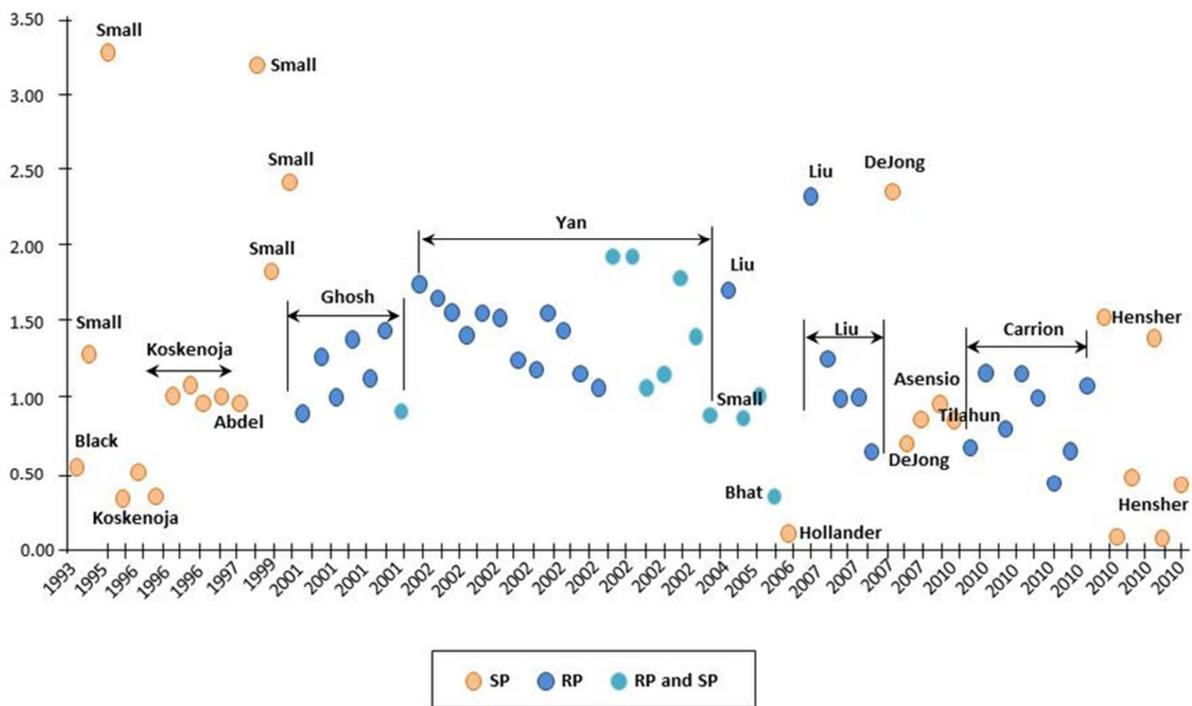
Authors	Study Type	Reliability Ratio (personal auto use)	Reliability Metric/Definition
Brownstone and Small (2005)	RP/SP	1.18	90th - 50th Percentile
Ghosh (2001)	RP	1.17	90th - 50th Percentile
Li et al. (2010)	SP	0.70	Scheduling approach; standard deviation
Börjesson and Eliasson (2008)	SP	1.27	Ratio of sensitivity to standard deviation to sensitivity of the mean
Small et al. (1995)	SP	2.30	Standard deviation
Small and Yan. (2001)	SP	2.51	Standard deviation
Small et al. (2005)	RP	0.91	80 th - 50 th Percentiles
Tilahun and Levinson (2010)	SP	0.89	90th - 50th Percentile
Carrion and Levinson (2010)	RP	0.91	90th - 50th Percentile
De Jong et al. (2007)	SP	1.35	Standard deviation
Fosgerau et al. (2008)	RP	1.00	Standard deviation
Yan (2002)	RP/SP	0.97	90th - 50th Percentile
Asensio and Matas (2008)	SP	0.98	Scheduling approach; standard deviation
Bhat and Sardesai (2006)	RP/SP	0.26	Scheduling approach; standard deviation
Senna (1993)	SP	0.76	Standard deviation
Black and Towriss (1993)	SP	0.55-0.70	Standard deviation
Tilahun and Levinson (2009)	SP	1.0	Scheduling approach; difference between actual late arrival and usual travel time
Ubbels et al. (2005)	SP	0.5	Scheduling approach; difference between early/late arrival time and preferred arrival time
Koskenoja (1996)	SP	0.75	Average schedule delay (late and early)
SHRP 2 C04 (2012)	RP	0.7-1.5	Standard deviation per unit distance
Stogios et al. (SHRP 2 L04 – Pub. Pending)	RP	0.57-2.69	Standard deviation per unit distance

Note: RP= Revealed Preference (based on observed behavior)
 SP = Stated Preference (based on survey responses)

Of these, the Carrion and Levinson work is the most comprehensive. They were selective in their choice of studies as they were using them for a meta-analysis. It is interesting that there is less variation among more recent studies and if the means of each individual study is used, the reliability ratios are grouped in the 0.5 – 1.5 range. Figure 3-2 is taken directly from Carrion and Levinson. Previously, SHRP 2 Project C04 also noted the same range. The SHRP 2 L05 effort more narrowly focused the Reliability Ratio range to 0.9 – 1.25 based on including only the

research with the most rigorous methods. A Florida DOT study recommended a Reliability Ratio range of 0.8 – 1.0, based on their assessment of the most rigorous studies (Elefteriadou and Cui 2007). The authors also mentioned that the value could be “as much as three times higher” if strict schedule adherence is required for the trip.

Figure 3-2. Reliability Ratios from Previous Studies



Source: Carrion, C. and D. Levinson. Value of reliability: High occupancy toll lanes, general purpose lanes, and arterials. Conference Proceedings of 4th International Symposium on Transportation Network Reliability in Minneapolis, MN, 2010.

For the Reliability Module, the 80th – 50th percentile is used as the measure of the reliability space. This produces a conservative estimate of reliability.

3.1.2 Specification of Inputs

Inputs are provided for base condition as well as for one or more improvement scenarios.

Basic Analysis Unit

Highway segments are the basic unit of analysis, and input data pertains to them. Segments can be of any length but it is recommended that they not be so long that the characteristics change dramatically along the segment, or too short that input is burdensome. Reasonable segment lengths would be:

- Freeways: between interchanges

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- Signalized highways: between signals
- Rural highways (non-freeways): 2-5 miles

For the purpose of output, segments are aggregated into highway sections in order to be compatible with the reliability prediction equations.

Inventory Data

- Route
- Beginning milepoint
- Beginning landmark
- Ending milepoint
- Ending landmark
- Highway type
 - Freeway (access controlled)
 - Multilane (non-signalized, non-access controlled)
 - Signalized
 - Rural two-lane
- Number of lanes
- Free flow speed
 - Alternately, the posted speed limit

Traffic Data

- Average Annual Daily Traffic (AADT), current
- Annual traffic growth rate (%)

Truck Data

- Percent trucks in the traffic stream (combinations + single units)

Capacity Data

- Peak capacity as determined with Highway Capacity Manual procedures

Alternately

- G/C ratio (effective green time divided by cycle length) for signalized highways
- Terrain (flat, rolling, or mountainous) for freeways and rural two-lane highways

Time Horizon

- Number of years into the future for which the analysis applies

Analysis Period

- Specify the hours of the day for which the analysis will be run

Economic Analysis Data

- Unit cost of travel time, personal (\$/hour): default = \$19.86 (FHWA 2005)
- Unit cost of travel time, commercial (\$/hour): default = \$36.055
- Reliability Ratio, personal: default = 0.8 (based on Stogios et al. 2013)
- Reliability Ratio, commercial: default = 1.16

3.1.3 Output and Calculations

Output

Outputs are produced for the entire project length in table form. Outputs are displayed for the base condition and all improvement scenarios. A variety of reliability metrics are produced to allow users wide flexibility in interpreting the results. They also permit users to make independent estimates of the value of reliability if they want to use alternative measures of the reliability space, such as:

- Year of Analysis (the future year)
- Recurring delay (hours)
- Incident delay (hours)
- Total delay (hours)
- Overall travel time index
- 95th percentile travel time index
- 80th percentile travel time index
- Percent of trips < 45 mph
- Percent of trips < 30 mph
- Cost of recurring delay
- Cost of unreliability
- Total congestion cost

Calculations are done for *each hour and direction* on the study segments. The results are summed over all segments and reported for the current year and forecast year.

Calculation of future year AADT

Equation 3-1.

$$\text{FutureAADT} = \text{AADT} * (1 + \text{TrafficGrowthRate})^{\text{NumberOfYears}}$$

Calculate HCM* Capacity (if not directly input) for Freeways and Multilane Highways Without Signals

Equation 3-2.

$$\text{Capacity} = \text{IdealCap} * N * F_{\text{HV}}$$

Where: Capacity = One-way capacity; IdealCap = 2,400 pcphpl (passenger cars per hour per lane) if free flow speed ≥ 70 mph, or 2,300 otherwise; N = number of through lanes in one direction; F_{HV} = heavy vehicle adjustment factor-- 1.0/(1.0 + 0.5 HV) for level terrain, 1.0/(1.0 + 2.0 HV) for rolling terrain, 1.0/(1.0 + 5.0 HV) for mountainous terrain (rare in urban areas)--, HV = daily proportion of trucks in traffic stream

Signalized Highways

Equation 3-3.

$$\text{Capacity} = \text{IdealSat} * N * F_{HV} * g/C$$

Where: Capacity = One-way capacity; IdealSat = Ideal saturation flow rate (1,900 pcphpl); N and F_{HV} = same as for freeways; g/C = effective green time divided by cycle length (0.45 for arterials, 0.35 for other highway classes)

Rural Two-Lane Highways

Equation 3-4.

$$\text{Capacity} = \text{IdealCap} * F_{HV} * F_G$$

Where: Capacity = Two-way capacity; IdealCap = 3,200 passenger cars per hour (pcph); F_{HV} = heavy vehicle adjustment factor (1 or 1 + P_T[E_T - 1]); P_T = percent of trucks; E_T = Passenger car equivalents from Table 3-2

Table 3-2. Passenger Car Equivalents for Trucks (E_T)

Two-Way Flow Rates (pcph)	Type of Terrain		
	Level	Rolling	Mountainous
0-600	1.7	2.5	7.2
>600-1,200	1.2	1.9	7.2
>1,200	1.1	1.5	7.2

Note: Flow rates are determined by using the “AADT/C < 7” condition from Table3-3, by combining the AM and PM percentages for the peak hour, which is assumed to be the hour ending at 18:00 (hour 18 in Table3-3).

F_G = grade adjustment factor from Table 3-3

Table 3-3. Grade Adjustment Factors (f_G) for HPMS*

Two-Way Flow Rates (pcph)	Type of Terrain		
	Level	Rolling	Mountainous
0-600	1.00	0.71	0.57
>600-1,200	1.00	0.93	0.85
>1,200	1.00	0.99	0.99

* Highway Performance Measuring System

Calculate AADT/C

Equation 3-5.

$$\text{AADT/C} = \text{FutureAADT/TwoWayCapacity}$$

Note: For all multilane and signalized highways, TwoWayCapacity is the one-way capacity times two.

Calculate Hourly Volumes for Hours to be Used in the Analysis

Multiply AADT and FutureAADT by the appropriate hourly factor from Table 3-4. For multilane highways, the analysis is done by each direction individually. For rural two-lane highways, the

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analysis is done for both lanes combined, i.e., the hourly volume is the sum of the AM and PM directions.

Calculate Free Flow Speed (if speed limit is input in lieu of the actual free flow speed) (from Dowling 1997)

Equation 3-6.

FreeFlowSpeed = (0.88 * SpeedLimit) + 14, for freeways and rural two-lane highways

Equation 3-7.

FreeFlowSpeed = (0.79 * SpeedLimit) + 12, for signalized highways

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Table 3-4. Hourly Traffic Distributions

	Freeway, Weekday						Other, Weekday					
	AADT/C						AADT/C					
	LE 7.0		7.1 - 11.0		GT 11.0		LE 7.0		7.1 - 11.0		GT 11.0	
	Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of
Hour Ending	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume
1	0.42	0.58	0.44	0.57	0.47	0.54	0.34	0.47	0.37	0.47	0.41	0.49
2	0.27	0.33	0.27	0.34	0.27	0.32	0.21	0.28	0.23	0.27	0.24	0.28
3	0.23	0.25	0.22	0.26	0.20	0.24	0.15	0.18	0.17	0.18	0.18	0.20
4	0.23	0.22	0.21	0.21	0.18	0.18	0.14	0.14	0.16	0.15	0.17	0.18
5	0.38	0.29	0.35	0.28	0.31	0.25	0.24	0.18	0.28	0.20	0.33	0.27
6	1.17	0.68	1.12	0.69	1.06	0.72	0.74	0.42	0.81	0.48	1.03	0.67
7	3.26	1.75	3.16	1.90	2.86	2.18	2.23	1.19	2.35	1.27	2.55	1.72
8	4.83	2.90	4.59	3.05	3.90	3.27	4.11	2.28	3.85	2.39	3.57	2.79
9	3.56	2.57	3.80	2.76	3.66	3.04	3.45	2.33	3.42	2.39	3.09	2.78
10	2.58	2.24	2.75	2.30	2.94	2.53	2.64	2.29	2.69	2.31	2.68	2.47
11	2.46	2.33	2.50	2.34	2.68	2.49	2.64	2.56	2.65	2.54	2.62	2.57
12	2.56	2.56	2.61	2.61	2.73	2.69	2.90	3.02	2.90	2.98	2.83	2.89
13	2.65	2.71	2.68	2.75	2.75	2.78	3.20	3.35	3.17	3.30	3.04	3.13
14	2.70	2.77	2.75	2.81	2.82	2.86	3.14	3.24	3.14	3.22	3.06	3.13

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	Freeway, Weekday						Other, Weekday					
	AADT/C						AADT/C					
	LE 7.0		7.1 - 11.0		GT 11.0		LE 7.0		7.1 - 11.0		GT 11.0	
	Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction		Peak Direction	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of	Pct. of
Hour Ending	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume	Daily Volume
15	2.93	3.12	2.93	3.15	2.97	3.15	3.18	3.44	3.116	3.37	3.21	3.34
16	3.26	4.01	3.21	3.87	3.21	3.60	3.40	4.13	3.35	3.93	3.41	3.78
17	3.47	4.81	3.38	4.43	3.28	3.82	3.46	4.78	3.49	4.49	3.47	3.92
18	3.42	4.85	3.32	4.39	3.29	3.77	3.31	4.83	3.45	4.55	3.39	3.86
19	2.66	3.23	2.66	3.20	2.82	3.22	2.68	3.23	2.75	3.31	2.82	3.12
20	1.95	2.23	1.97	2.25	2.12	2.36	2.14	2.41	2.18	2.53	2.28	2.53
21	1.54	1.78	1.54	1.79	1.62	1.86	1.73	1.97	1.75	2.07	1.83	2.09
22	1.40	1.63	1.44	1.69	1.54	1.74	1.49	1.71	1.50	1.77	1.55	1.80
23	1.14	1.30	1.19	1.39	1.27	1.46	1.10	1.26	1.11	1.25	1.22	1.29
24	0.79	0.98	0.83	1.05	0.89	1.07	0.74	0.94	0.75	0.90	0.83	0.97
TOTAL	49.87	50.13	49.92	50.08	49.84	50.16	49.36	50.64	49.67	50.33	49.71	50.29

Source: SAIC and Cambridge Systematics, Roadway Usage Patterns: Urban Case Studies, prepared for VNTSC and FHWA, July 22, 1994.

Calculate Travel Time per Unit Distance (travel rate) for the Current and Forecast Years
Equation 3-8.

$$t = \{(1 + (0.1225 * (v/c)^8))\} / \text{FreeFlowSpeed}, \text{ for } v/c \leq 1.40$$

Where: t = travel rate (hours per mile); v = hourly volume; c = capacity (for an hour, defined above)
Note: v/c should be capped at 1.40 (Cambridge Systematics et al. 1998)

Compute the Recurring Delay in Hours per Mile

Equation 3-9.

$$\text{RecurringDelayRate} = t - (1/\text{FreeFlowSpeed})$$

Compute the Delay Due to Incidents (IncidentDelayRate) in Hours per Mile. The lookup tables from the IDAS User Manual are used to calculate incident delay. This requires the v/c ratio, number of lanes, and length and type of the period being studied, which is set at one-hour (Cambridge Systematics 2003). (For rural two-lane highways, use number of lanes = 2.) This is the base incident delay.

If incident management programs have been added as a strategy **or** if a strategy lowers the incident rate (frequency of occurrence), then the “after” delay is calculated as follows:

Equation 3-10.

$$D_a = D_u * (1 - R_f) * (1 - R_d)^2$$

Where: D_a = Adjusted delay (hours of delay per mile); D_u = Unadjusted (base) delay (hours of delay per mile, from the incident rate tables); R_f = Reduction in incident frequency expressed as a fraction (with $R_f = 0$ meaning no reduction, and $R_f = .30$ meaning a 30 percent reduction in incident frequency); R_d = Reduction in incident duration expressed as a fraction (with $R_d = 0$ meaning no reduction, and $R_d = .30$ meaning a 30-percent reduction in incident duration).

Changes in incident frequency are most commonly affected by strategies that decrease crash rates. However, crashes are only about 20 percent of total incidents. So, a 30 percent reduction in crash rates alone would reduce overall incident rates by 6 percent ($.30 \times .20 = .06$).

Compute the Overall Mean Travel Time Index (TTI_m) (this includes the effects of recurring and incident delay).

Equation 3-11.

$$TTI_m = 1 + \text{FFS} * (\text{RecurringDelayRate} + \text{IncidentDelayRate})$$

Where IncidentDelayRate is either D_u or D_a

Because of the data on which the reliability metric predictive functions do not include extremely high values of TTI_m , it is recommended that TTI_m be capped at a value of 6.0, which roughly corresponds to an average speed of 10 mph. Even though the data included highway sections that were considered to be severely congested, an overall annual average speed of 10 mph for a peak period was never observed. At $TTI_m = 6.0$, the reliability prediction equations are still internally consistent.

Computation of Reliability Metrics Using the SHRP 2 L03 “Data Poor” Equations

The equations for the 80th and 50th percentile TTIs were developed specifically for this module using the original SHRP 2 Project L03 data.

Equation 3-12.

$$\begin{aligned}
 TTI_{95} &= 1 + 3.6700 * \ln(TTI_m) \\
 TTI_{80} &= 5.3746 / \{ (1 + e^{(-1.5782 - 0.85867 * TTI_m)})^{(1/0.04953)} \}; TTI_{80} \geq 1.0 \\
 TTI_{50} &= 4.01224 / \{ (1 + e^{(1.7417 - 0.93677 * TTI_m)})^{(1/0.82741)} \}; TTI_{50} \geq 1.0 \\
 PercentTripsOccuringLT45mph &= 1 - e^{(-1.5115 * (TTI_m - 1))} \\
 PercentTripsOccuringLT30mph &= 1 - \{ 0.333 + [0.672 / (1 + e^{(5.0366 * (TTI_m - 1.8256))})] \}
 \end{aligned}$$

Where:

TTI₉₅ is the 95th percentile TTI

TTI₈₀ is the 80th percentile TTI

TTI₅₀ is the 50th percentile TTI

PercentTripsOccuringLT45mph is the percent of trips that occur at speeds less than 45 mph

PercentTripsOccuringLT30mph is the percent of trips that occur at speeds less than 30 mph

Calculate Travel Time Equivalents Separately for Recurring and Reliability-Related Congestion and for Passenger Cars and Trucks

Equation 3-13.

$$\begin{aligned}
 TTI_{e(Recur,VT)} &= TTI_{50(VT)} \\
 TTI_{e(Rel,VT)} &= a * (TTI_{80(VT)} - TTI_{50(VT)})
 \end{aligned}$$

Where:

TTI_{e(Recur,VT)} is the TTI equivalent on the segment for **recurring congestion**, computed separately for passenger cars (personal travel) and trucks (commercial travel);

TTI_{e(Rel,VT)} is the TTI equivalent on the segment for **reliability-related congestion**, computed separately for passenger cars (personal travel) and trucks (commercial travel)

a is the Reliability Ratio (VOR/VOT) = 0.8 for passenger cars; = 1.1 for trucks

The use of the median to capture the “typical” or “average” condition is to avoid double counting: the mean value from the full distribution has some of the variability built, the median less so.

Compute Total Equivalent Delay Based on the TTIE, Separately for Passenger Vehicles and Trucks and for Recurring and Reliability-Related Congestion

Equation 3-14.

$$\begin{aligned}
 TotalEquivalentAnnualWeekdayDelay_{(VT)} &= ((TTI_{e(VT)} / FreeFlowSpeed - 1 / FreeFlowSpeed) * AVMT_{VT} \\
 TotalEquivalentAnnualWeekdayDelay_{(Recur,VT)} &= TotalEquivalentAnnualWeekdayDelay_{(VT)} * \\
 & \quad (TTI_{e(Recur,VT)} / (TTI_{e(Recur,VT)} + TTI_{e(Rel,VT)}))
 \end{aligned}$$

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$$\text{TotalEquivalentAnnualWeekdayDelay}_{(\text{Rel},\text{VT})} = \text{TotalEquivalentAnnualWeekdayDelay}_{(\text{VT})} - \text{TotalEquivalentAnnualWeekdayDelay}_{(\text{Recur},\text{VT})}$$

Where: *TotalEquivalentAnnualWeekdayDelay_{VT}* is in vehicle-hours, separately for vehicle types (passenger and truck for now); $\text{AVMT}_{\text{VT}} = \text{HourlyVolume} * \text{SectionLength} * \text{Pct} * 260$; *Pct* = percent of trucks in traffic stream (for commercial traffic) or 1 - percent of trucks in traffic stream (for passenger travel)

Compute Congestion and Reliability Costs

Equation 3-15.

$$\text{TotalDelayCost}_{(\text{Recur},\text{VT})} = \text{TotalEquivalentAnnualWeekdayDelay}_{(\text{Recur},\text{VT})} * \text{UnitCost}_{\text{VT}}$$

Equation 3-16.

$$\text{TotalDelayCost}_{(\text{Rel},\text{VT})} = \text{TotalEquivalentAnnualWeekdayDelay}_{(\text{Rel},\text{VT})} * \text{UnitCost}_{\text{VT}}$$

Equation 3-17.

$$\text{AverageDelayCost}_{(\text{VT})} = \text{TotalDelayCost}_{\text{VT}} * (\text{TTI}_{50}/\text{TTI}_{e(\text{VT})})$$

Costs should be computed separately for each vehicle type (passenger vs. commercial) and summed.

Assessing the Impacts of Highway Improvements

Highway improvements of various types need to be translated into changes in the input parameters. Specifically, improvements can affect:

- Capacity
- Volume
- Incident Characteristics

If a capacity analysis is not done offline, then the Module will compute a new capacity for the improvement if there are changes in:

- Number of lanes or truck percentage (freeways)
- Number of lanes, truck percentage, or green-to-cycle ratio (signalized highways)
- Truck percentage of grade (two-lane highways)
- Free flow speed (all highways)

Additional geometric improvements may be considered if the user performs an offline capacity analysis. Examples include lane and shoulder widening, median separation, and turn lane additions at signalized intersections. Offline capacity analysis will also identify the increase in capacity due to signal progression and converting stop sign-controlled intersections to signal control.

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If an improvement changes the Volume (AADT or traffic growth rate), the user needs to indicate the change. This can only be done offline – the module doesn't deal with estimating demand changes.

For Incident Characteristics, the Module uses both incident frequency and incident duration to estimate nonrecurring delay. Incident frequency is primarily affected by reductions in crashes (a subset of total incidents) due to safety improvements. Crash reduction factors for a wide variety of geometric and operating improvements can be found in the *Highway Safety Manual*. Chapter 2 of this document discusses how these are incorporated into the procedure. Note that a safety improvement can also increase capacity – the user should check if this is the case and perform an offline capacity analysis if warranted.

Incident duration is affected by incident management strategies. The information in Table 3-5 can be used to determine the reduction in incident duration.

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Table 3-5. Incident Management Impacts

Improvement	Impact
Incident Management: Improving from no formal IM program to a program that includes detection, verification, and service patrols	<p>Atlanta – Average time between first report and incident verification was reduced by 74% – Average time between verification and response initiation reduced by 50% – Average time between incident verification and clearance of traffic lanes reduced by 38% – The maximum time between incident verification and clearance of traffic lanes was reduced by 60% (1).</p> <p>Houston – Average 30-minute incident duration reduction (2).</p> <p>IDAS Model recommends a default reduction in incident duration of 9% for incident detection, 39% for incident response systems, and 51% for combination incident detection and response systems (3).</p> <p>Georgia (Navigator) – Reduced incident clearance time by an average of 23 minutes, incident response time reduced by 30% (4).</p> <p>Maryland (CHART) – Reduced the blockage duration from incidents by 36%. This translates to a reduction in highway user delay time of about 42,000 hours per incident (5).</p> <p>15% to 38% reduction in all secondary crashes, 4% to 30% reduction in rear-end crashes, and 21% to 43% reduction in severe secondary crashes (4).</p>
RECOMMENDATION	Based on CHART, reduce incident lane-hours lost by 36%.
Improved equipment for incident detection and verification (CCTV)	<p>Brooklyn – Average time required to clear incident from roadway has been reduced by 66% (6).</p> <p>San Antonio (TransGuide) – 20% improvement in response time (21% reduction for major incidents and 19% for minor incidents) (7).</p>
RECOMMENDATION	Based on TransGuide and assuming that incident response time is 20% of incident duration time, reduce incident duration by 4%.
Improved interagency communications for incident detection and verification	Minneapolis/St. Paul (Highway Helper) – Automatic tow truck dispatch program is credited with a 20-minute reduction in incident response and removal times (85% improvement) (8).
RECOMMENDATION	Assuming that response time is 20% of incident duration time, reduce incident duration by 17%.
Improved equipment and service for incident response	<p>Hayward, California – 38% reduction in incident duration – 57% reduction in breakdown duration (9).</p> <p>Northern Virginia – Reduction in duration for all incidents is 2 to 5 minutes for cell phone in response vehicles, 2 to 5 minutes for CAD screens in response vehicles, and 4 to 7 minutes for GPS location for response vehicles (10).</p> <p>Oregon – The duration of delay-causing incidents decreased by approximately 30% on Highway 18, and 15% on Interstate 5 (service patrol addition) (11).</p> <p>Pittsburgh – Service patrol reduced response time to incidents from 17 to 8.7 minutes (12).</p> <p>Washington State – Average freeway incident clearance time for large trucks reduced to 1.5 hours from 5 to 7 hours without the incident response team (13).</p>
RECOMMENDATION	For the implementation of service patrols, reduce incident duration by 38%.

Source: Cambridge Systematics et al., *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies, Report S2-L03-RR-1, Transportation Research Board, 2013.*

3.2 Reliability Module User's Guide and Instructions

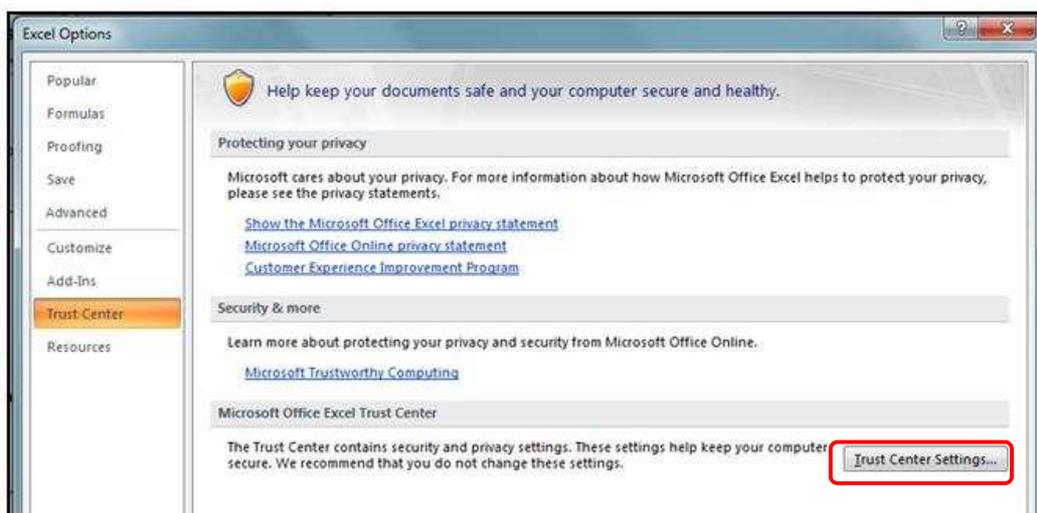
3.2.1 Introduction and Purpose

The Reliability Module is one of the economic analysis tools developed from SHRP 2 Project C11. It is a sketch planning corridor spreadsheet tool based on SHRP 2 Reliability Project L03 research that estimates the benefits of improving travel time reliability for use in benefit/cost analysis. Local travel time reliability data are not required because reliability measures are embedded in the L03 work. Agencies will typically have the required inputs (e.g., traffic volume, roadway capacity, AADT, percent trucks, number of lanes, and growth rate).

Before You Start

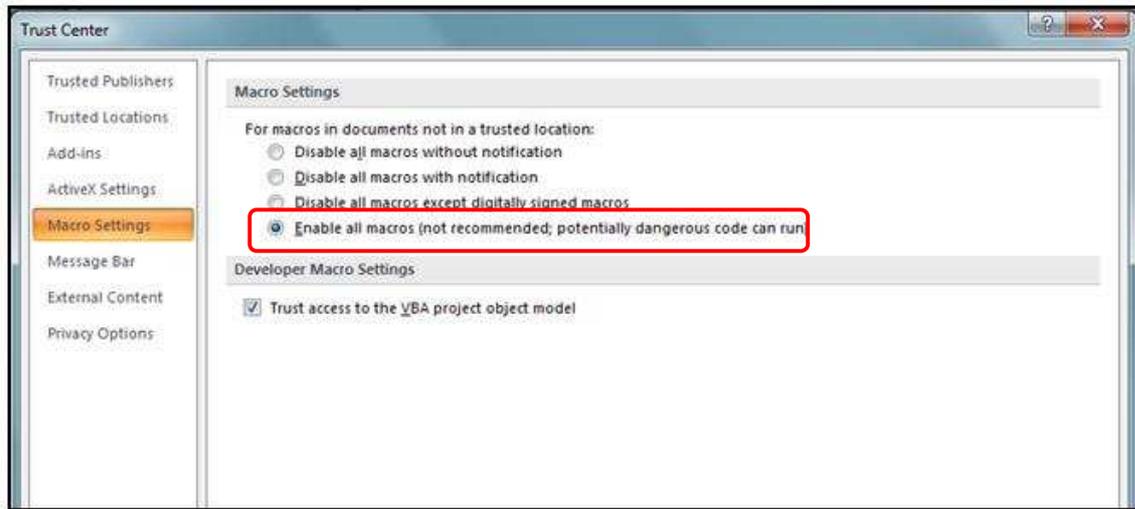
- 1) Download “*SHRP 2 C11 Reliability Module.xlsx*” and open it using Microsoft Excel. (A version number is usually added to the end of this file name such as “SHRP 2 C11 Reliability Module v9.2.xlsx”.)
- 2) **Enable Macros.** If prompted to Enable or Disable Macros when the file opens, be sure to choose Enable. To permanently enable Macros in Microsoft Excel 2007 & 2010, follow these steps:
 - a. For Excel 2007 and 2010, first click on the **Office Button** (upper-left corner).
 - b. Click on **Excel Options**.
 - c. Select the **Trust Center** options and click **Trust Center Settings** (Figure 3-3).

Figure 3-3. Screenshot of Trust Center Settings



- d. In Macro Settings, click the radio button **Enable All Macros** (Figure 3-4).

Figure 3-4. Screenshot of How to Enable All Macros



- e. For earlier versions of Excel, navigate to **Tools>Options**. Go to the **Security Tab** and click **Macro Security**. Select **Low**.
- 3) Be familiar with two key concepts:
- Scenario:** A scenario represents a set of highway and traffic conditions. It is input and named by the user, which is saved and reported on by the tool. These Scenarios are kept even after the program is closed.
 - Session:** A session is consisted of a set of scenarios. If there are Scenarios saved when the Reliability Module is opened, this is considered to be a previous Session. When a new Session is created, all scenarios created in the previous session are deleted. Users can save the Reliability Module under a different file name to retain the previous session.

Quick Start Guide

To create a new Scenario, erasing any Scenarios currently in file, follow these steps:

- 1) Open the file (choose to enable Macros if prompted).
- 2) Choose the tab named **"2 – INPUTS"**.
- 3) Click **Begin a New Session**.
- 4) Click **Yes**.
- 5) Click **Yes** (Reminder: *all* Scenario data will be deleted).
- 6) In the **Scenario Inputs** window, click **New Scenario**.
- 7) In the **New Scenario** window, enter a Scenario name.

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- 8) If using default input values, check **Using Default Values**.
- 9) In the **Scenario Inputs** window, enter all required input data.
- 10) Click **Save Scenario** to save this Scenario.

To create a new Scenario, in addition to Scenarios currently in file, follow these steps:

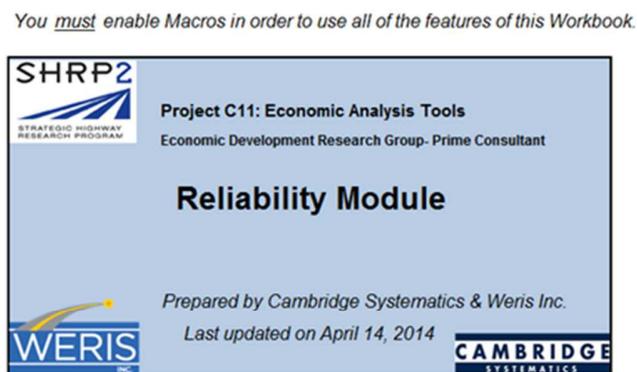
- 1) Open the file (choose to enable Macros if prompted).
- 2) Choose the tab named **"2 – INPUTS"**.
- 3) Click **Resume a Previous Session**.
- 4) In the **Scenario Inputs** window, click **New Scenario**.
- 5) In the **New Scenario** window, enter a Scenario name.
- 6) If using default input values, check **Using Default Values**.
- 7) In the **Scenario Inputs** window, enter all required input data.
- 8) Click **Save Scenario** to save this Scenario.

To View results, click on **Results** while in the **Scenario Inputs** window. Be sure to have entered (and saved) at least one Scenario before attempting to view Results.

3.2.2 Entering Inputs

Figure 3-5 shows the screen that will appear when you open the **Reliability Module** for the first time (Figure 3-5). Here users can see when their version of the **Reliability Module** was last updated, as well as a brief set of instructions for the tool. To begin entering data, click on the tab labeled **"2 – INPUTS"** and follow the instructions listed by each button.

Figure 3-5. Screenshot of Opening Tab of Reliability Module (1-START)

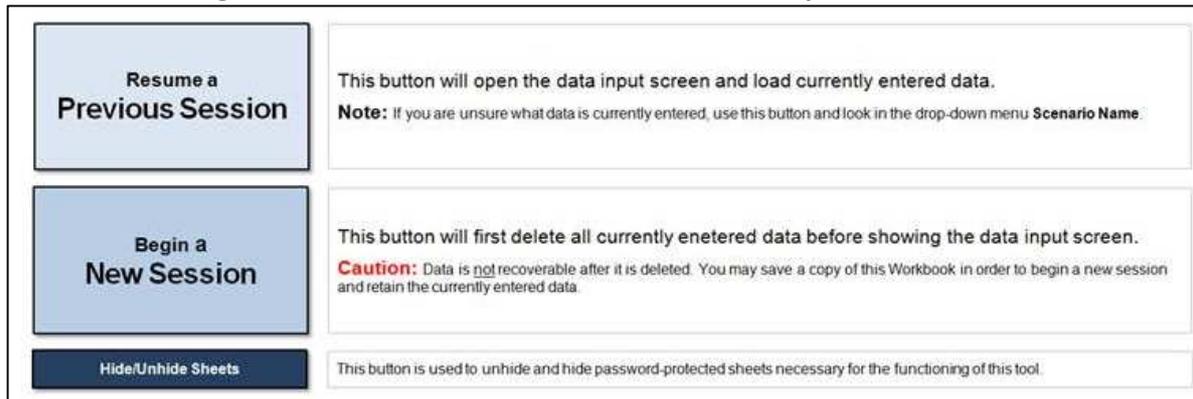


Instructions:

1. Click on tab **2 - INPUTS** to access buttons relating to data input.
Then follow instructions in the sheet to access the proper data input screen.
Follow prompt to save scenario data and view results table.
2. Click on tab **3 - RESULTS** to view result output screen.
Then view and print out estimated regional economic impact.

On the **2 - INPUTS** worksheet, the user is able to open an input window, choosing to either keep or discard data from a previous session (Figure 3-6). There is also the option to unhide (password-protected) sheets used in the background of the tool.

Figure 3-6. Screenshot of First Screen on the Inputs Tab –Tab 2



Using the Scenario Inputs window

Click “Resume a Previous Session” on the **2 – INPUTS** tab to bring up the Scenario Inputs window, shown in Figure 3-7 (Descriptions of the Navigations buttons are in Table 3-6 and inputs and their descriptions are shown in Table 3-7) .

Figure 3-7. Screenshot of the Scenario Inputs Page –Tab 2

The screenshot shows a software window titled "Scenario Inputs". At the top, there is a "Scenario Name" dropdown menu with "Freeway" selected. To its right are four buttons: "New Scenario", "Delete Current Scenario", "Save Scenario", and "Copy Current Scenario". Further right is a "Results" button. Below these is a "Description (optional)" text area. The main content is divided into three columns of input fields:

- Scenario Data:** Time Horizon (30 years), Analysis Period (6:00 AM to 9:00 AM), Highway Type (Freeway), Beg. Milepoint (1), End Milepoint (10), No. of Lanes (One-way) (6), Free Flow Speed (65 mph), and a checkbox for "Using speed limit".
- Traffic Data:** Current AADT (50000), Estimated Annual Traffic Growth Rate (1%), Truck Data (Pct. Trucks in Traffic: 10%), Capacity Data (Peak Capacity: 2100 pcph, Terrain dropdown), and a note: "Enter either one-way capacity based on HCM or select terrain type".
- Travel Time Unit Cost (per vehicle hr):** Personal (19.86 \$/hr), Commercial (36.05 \$/hr). **Effect of Incident Management Strategy:** Reduction in Incident Frequency (20%), Reduction in Incident Duration (20%). **Reliability Ratio:** Value of Reliability over Value of Travel Time (Personal: 1, Commercial: 1). **Route Information (optional):** Route, Beg. Landmark, End Landmark.

Here, the user is able to enter all pertinent information about a specific Scenario. Separate buttons are available to create (new scenario), save, and delete Scenarios, and navigate to the 3 – Results tab.

Table 3-6. Buttons in the Inputs Window – Tab 2

Buttons in the Inputs window	
New Scenario	Brings up a dialogue for creating a new Scenario.
Save Scenario	Saves the currently entered data to the Scenario selected from Scenario Name .
Delete Current Scenario	Permanently deletes the Current Scenario from the Scenario Name drop-down.
Results	Navigates to the Results tab .

Table 3-7. Input Fields and Their Meanings – Tab 2

Field Name	Req?	Description
Scenario Name	Yes	A unique name used to describe a Scenario.
Description	No	An optional description of the Scenario.
Time Horizon	Yes	Number of years into the future for which the analysis applies.

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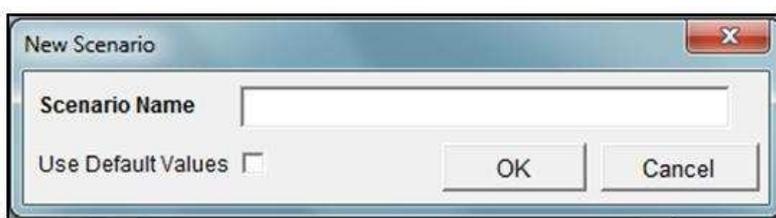
Field Name	Req?	Description
Analysis Period	Yes	Specify the hours of the day for which the analysis will be run
Highway Type	Yes	Freeway, Signalized, or Two-lane Rural.
Beg. Milepoint	Yes	Beginning milepoint is used with end milepoint to determine length of highway to analyze.
End Milepoint	Yes	Ending milepoint is used with begin milepoint to determine length of highway to analyze.
No. of Lanes (One-way)	Yes	The number of lanes in one traffic direction (does not apply to Two-lane Rural).
Free Flow Speed	Yes	Free Flow Speed (FFS) is the average speed that a motorist would travel if there is no congestion or other adverse condition.
Using speed limit	Yes	This is a checkbox. When checked, the FFS field can be used to enter the posted speed limit, which is then used to calculate the FFS.
Current AADT	Yes	Current annual average daily traffic volume
Est Annual Traffic Growth Rate	Yes	Estimated future annual average daily traffic volume
Pct. Trucks in Traffic	Yes	Percent trucks in the traffic stream (combinations + single units)
Peak Capacity	Yes	Peak capacity as determined using <i>Highway Capacity Manual</i> procedures
Terrain	Yes	Flat, Rolling, or Mountainous. Can be used to calculate Peak Capacity.
Personal Travel Time Unit Cost (Vehicle)	Yes	Unit cost of Vehicle travel time, personal (\$/hour): Default = \$19.86
Commercial Travel Time Unit Cost (Vehicle)	Yes	Unit cost of Vehicle travel time, commercial (\$/hour): Default = \$36.05
Reduction in Incident Frequency	Yes	Reduction in incident frequency, expressed as a percentage, due to the addition of an incident management program/ strategy. Default = 0%
Reduction in Incident Duration	Yes	Reduction in incident duration, expressed as a percentage, due to the addition of an incident management program/strategy. Default = 0%
Personal Reliability Ratio	Yes	The ratio of value of travel time reliability over value of travel time for the general motorists. Default = 0.8
Commercial Reliability Ratio	Yes	The ratio of value of travel time reliability over value of travel time for commercial vehicles. Default = 1.1
Route	No	Route name.
Beg. Landmark	No	Name of beginning landmark.

Field Name	Req?	Description
End Landmark	No	Name of ending landmark.

Entering a New Scenario

To enter a new scenario, click the **New Scenario** button in the **Scenario Inputs window**, which brings up the dialog shown in Figure 3-8.

Figure 3-8. Screenshot of New Scenario Input Screen – Tab 2



Here, the user is able to enter a Scenario name and choose whether or not to automatically fill in the default values for several input parameters. Checking **Use Default Values** will fill in default values for the following data fields (Table 3-8).

Table 3-8. Default Values for the Reliability Module

Data Field	Default Value
Personal Travel Time Unit Cost (Vehicle)	\$19.86
Commercial Travel Time Unit Cost (Vehicle)	\$36.05
Reduction in Incident Frequency	0%
Reduction in Incident Duration	0%
Personal Reliability Ratio	0.8
Commercial Reliability Ratio	1.1

Back in the **Scenario Inputs window**, changing the Scenario name within the **Scenario Name** field will save the Scenario under a different name.

NOTE: If there are no Scenarios currently saved, please enter and save a Scenario before attempting to explore the functionality of the Reliability Module. Not doing so may impact the proper running the program!

If there are no Scenarios entered and the program stops working, close the program *without* saving it, reopen the file, and enter a Scenario using the steps outlined above.

3.3.3 Obtaining Results

In the tab labeled “**3 – RESULTS**”, results are displayed for each scenario entered through the **2 – INPUTS** tab. By default, the results are given in a summary form, with scenarios organized in columns. A detailed, hourly view is available for individual scenarios as well. For more detailed

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information about the results, including their calculation, please refer to the Reliability Technical Guide in Chapter 2.

Organization of results

The “Current Year” contains the following:

- a) **Congestion Metrics** - Key measures of congestion, such as overall travel time mean index, 95th and 80th percentile travel time index, and percent of trips that occur at speeds less than 45 mph and 30 mph.
- b) **Total Annual Weekday Delay** - Total annual weekday delay in vehicle-hours, categorized by congestion types (recurring and incident delay) and vehicle types (passenger and truck).
- c) **Total Annual Weekday Congestion Costs** – Total annual weekday delay cost incurred by congestion, categorized by congestion types (recurring and Incident costs) and vehicle types (passenger and truck).

The “Future Year”, which is determined by Time Horizon, contains:

- a) **Congestion Metrics** - Key measures of congestion, such as overall travel time mean index, 95th and 80th percentile travel time index, and percent of trips that occur at speeds less than 45 mph and 30 mph.
- b) **Total Annual Weekday Delay** - Total annual weekday delay in vehicle-hours, categorized by congestion types (recurring and incident delay) and vehicle types (passenger and truck).
- c) **Total Annual Weekday Congestion Costs** – Total annual weekday delay cost incurred by congestion, categorized by congestion types (recurring and unreliability costs) and vehicle types (passenger and truck).

Table 3 9. Buttons in the Results Tab – Tab 3

Buttons in the Results tab	
Scenario Inputs	Brings up the Scenario Inputs window.
Details (if in Summary view)	Displays the hourly results for a particular Scenario.
Summary (if in Details view)	The default view, showing aggregated results for all scenarios.
Ctrl+Shift+D	Pressing Ctrl+Shift+D brings up the Calculation Debugger . The Calculation Debugger is a dialog that shows many more variables, calculated in the background, that are not needed for normal use.

Summary View

In the Summary view (Figure 3-9), aggregated results are shown for all Scenarios. To view the hourly results for a particular Scenario, click in the column containing the desired Scenario and

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then press **Details**. In the case below, pressing **Details** would show hourly results for Scenario “Freeway,” as a cell in the column with the results for “Freeway” has been selected.

Figure 3-9. Screenshot of the Result Summary Page – Tab 3

Scenario Inputs		Details		
Result Summary				
<i>To view results on an hourly basis, select a Scenario by clicking in the corres,</i>				
Current year - 2014	Freeway	Rural	Signalized	
Congestion Metrics				
Overall mean TTI	1.10	1.00	1.02	
TTI ₉₅	1.33	1.02	1.06	
TTI ₈₀	1.14	1.00	1.01	
TTI ₅₀	1.06	1.00	1.00	
Pct. trips less than 45 mph	12.97%	0.64%	2.48%	
Pct. trips less than 30 mph	1.44%	0.56%	0.63%	
Total Annual Weekday Delay (veh-hrs)				
Total Equivalent Delay	37,325	195	1,948	
Recurring Equivalent Delay	35,221	195	1,924	
<i>Passenger Delay</i>	31,763	169	1,671	
<i>Commercial Delay</i>	3,459	26	253	
Incident Equivalent Delay	2,103	0	23	
<i>Passenger Delay</i>	1,830	0	19	
<i>Commercial Delay</i>	274	0	4	
Total Annual Weekday Congestion Costs (\$)				
Total Equivalent Delay	\$391,911	\$4,290	\$42,844	
Recurring Equivalent Delay	\$344,233	\$4,272	\$41,527	
<i>Passenger Delay</i>	\$295,057	\$3,346	\$32,618	
<i>Commercial Delay</i>	\$49,176	\$927	\$8,909	
Incident Equivalent Delay	\$47,678	\$18	\$1,317	
<i>Passenger Delay</i>	\$40,867	\$13	\$958	
<i>Commercial Delay</i>	\$6,811	\$5	\$359	
Future year - 2022	Freeway	Rural	Signalized	
Congestion Metrics				
Future year - 2024	1.57	1.01	1.03	

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Details View

In the Details view (Figure 3-10), hourly results are shown for one specific Scenario. Several input parameters are displayed in italics underneath of the Scenario name, and pertain only to the Scenario being currently viewed.

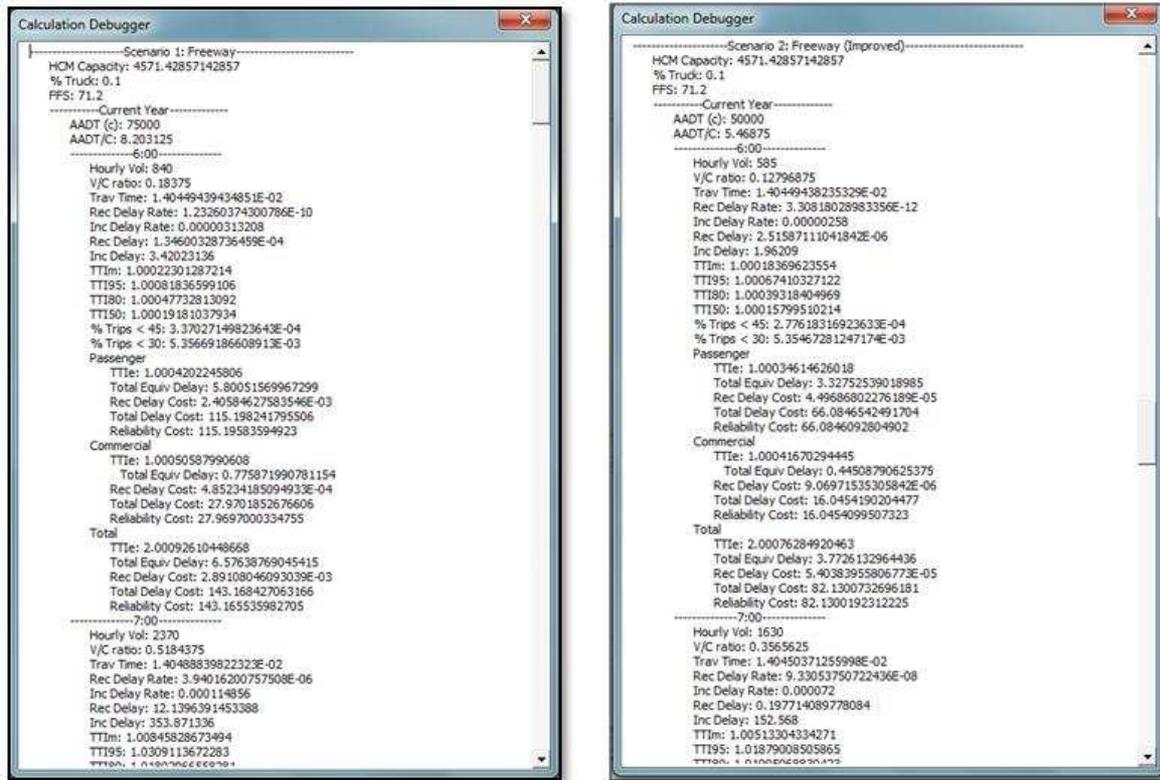
Figure 3-10. Screenshot of the Details View of Results – Tab 3

Scenario Inputs	Summary			
Press Ctrl+Shift+D for Calculation				
Freeway	<i>No. Lanes: 6</i>	<i>Trucks: 10%</i>	<i>FFS/Speed limit: 65 mph</i>	<i>Current AADT: 50000</i>
Freeway	<i>Sec. Length: 9 mi</i>	<i>Unit Cost: Passenger - \$10.00, Truck - \$15.00</i>		<i>Future AADT: 67392</i>
Current year - 2014	6:00 AM	7:00 AM	8:00 AM	9:00 AM
Congestion Metrics				
Overall mean TTI	1.00	1.02	1.26	1.11
TTI ₉₅	1.00	1.08	1.86	1.39
TTI ₈₀	1.00	1.02	1.38	1.15
TTI ₅₀	1.00	1.00	1.18	1.06
Pct. trips less than 45 mph	0.00%	3.45%	32.98%	15.46%
Pct. trips less than 30 mph	0.53%	0.66%	3.26%	1.29%
Total Annual Weekday Delay (veh-hrs)				
Total Equivalent Delay	0	1063	26611	9651
Recurring Equivalent Delay	0	1045	23412	9017
<i>Passenger Delay</i>	0	941	21160	8134
<i>Commercial Delay</i>	0	104	2253	883
Incident Equivalent Delay	0	18	3198	634
<i>Passenger Delay</i>	0	16	2790	551
<i>Commercial Delay</i>	0	2	408	82
Total Annual Weekday Congestion Costs (\$)				
Total Equivalent Delay	\$0	\$11,165	\$279,414	\$101,332
Recurring Equivalent Delay	\$0	\$10,939	\$239,877	\$93,417
<i>Passenger Delay</i>	\$0	\$9,376	\$205,609	\$80,072
<i>Commercial Delay</i>	\$0	\$1,563	\$34,268	\$13,345
Incident Equivalent Delay	\$0	\$226	\$39,537	\$7,915
<i>Passenger Delay</i>	\$0	\$194	\$33,889	\$6,784
<i>Commercial Delay</i>	\$0	\$32	\$5,648	\$1,131

Calculation Debugger

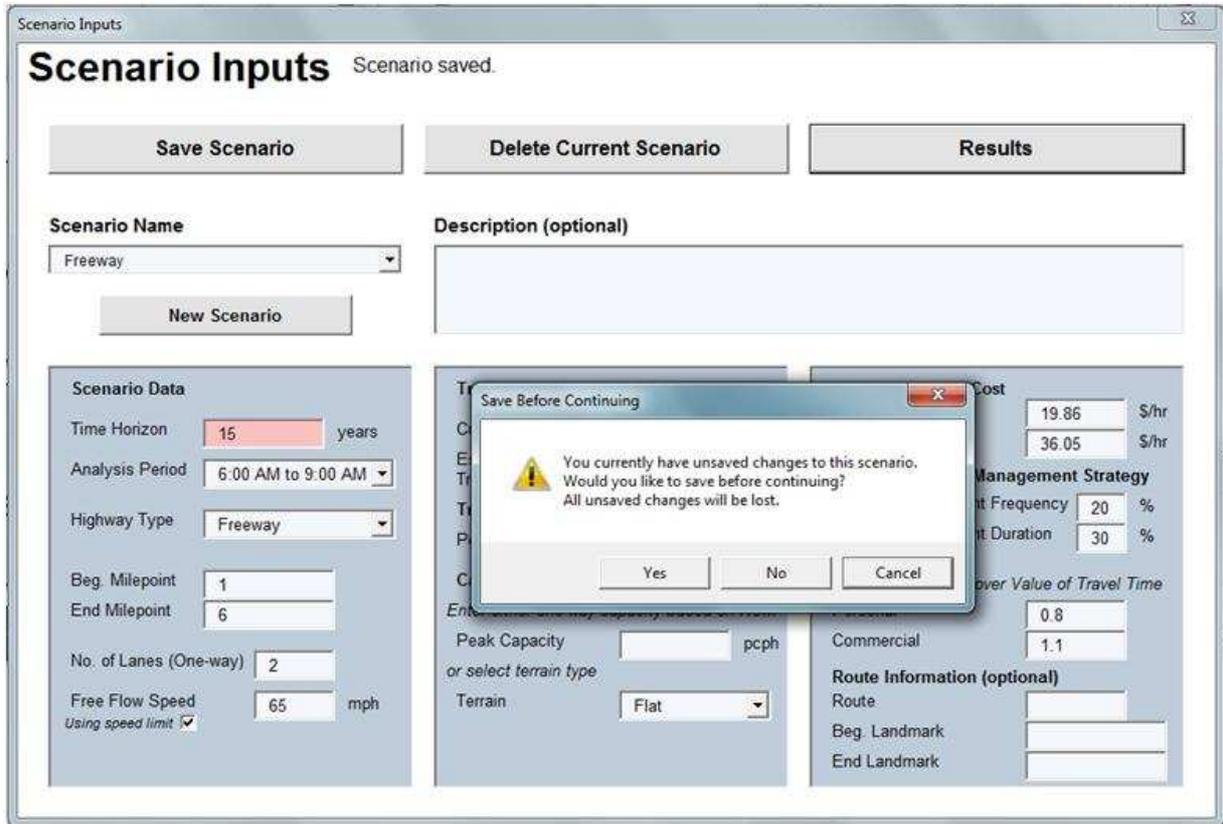
Pressing **Ctrl+Shift+D** while in the **3 – RESULTS** tab brings up the **Calculation Debugger** window. Here, many variables that are used in calculating the results are displayed and organized by Scenario, year, and hour. Below, one can see that by scrolling down through the **Calculation Debugger** window, one can view the data from all Scenarios presently saved in the Module (Figure 3-11).

Figure 3-11. Screenshots of the Calculation Debugger



Note on Saving and Closing the File. Inside the **Scenario Inputs window**, any changes to Scenario data must be saved manually using the **Save Scenario** button (see Figure 3-12). If there are any unsaved changes (to a Scenario) when a user attempts to either create a new Scenario or view Results, the user will first be prompted to save these changes. The field(s) where changes have been made are marked in red, and the user can choose to continue and save the change(s), continue and discard the change(s), or cancel and remain in the **Scenario Inputs window**.

Figure 3-12. Screenshot of Reminder to “Save Before Continuing”



However, upon closing the file, there will never be a prompt to save changes, even if the **3 – RESULTS** tab has been changed from **Summary** to **Details** view (or vice versa). This is because the Reliability Module has been setup to automatically save at points such as this, for the user’s convenience.