Addendum to Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness

Reliability Analysis Guidance Addendum

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The government task managers were Neil Spiller and John Halkias.

16. Abstract
This addendum presents the results of an investigation into the appropriate definition, interpretation, and computation of measures of effectiveness (MOEs) for traffic operations and capacity improvements. Information and guidance on which MOEs should be produced, how they should be interpreted, and how they are be defined and calculated in traffic analysis tools are detailed in this report. The document includes a basic set of MOEs that can help rapidly assess the current problems and benefits of alternative improvements at the system level in a form readily understandable by the decisionmaker. This basic set of MOEs for decisionmaking consists of five basic measures: 1) throughput, 2) mean delay, 3) travel time index, 4) freeway segments at breakdown, and 5) surface street intersections with long queues, turn bay overflows, and exit blockages. The report provides suggestions that vehicle trajectories should be used as the common denominator for comparison of results between tools and methods between field data collection and analytical tools (*Highway Capacity Manual*, microsimulation, etc.). At this microscopic level, the analyst can compare field data with analysis tool outputs, whether the tool is microscopic or macroscopic. Finally, this report concludes by illustrating the computation and interpretation of the recommended systemwide MOEs for a freeway and an urban arterial street.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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CHAPTER 1. PURPOSE

This document is an addendum to *Traffic Analysis Toolbox Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness* (Federal Highway Administration Report No. FHWA-HOP-08-054)[1] and reflects up-to-date guidance on incorporating travel time reliability (TTR) in the Traffic Analysis Toolbox (TAT). The addendum consists of:

- Updates to the existing Toolbox volume text.
- Additional content to be appended to the Toolbox volume.

[1]Dowling, R. 2007. *Volume VI: Definition, Interpretation, and Calculation of Traffic Analysis Tools Measures of Effectiveness*. Report No. FHWA-HOP-08-054. Washington, DC: Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop08054/index.htm, last accessed January 10, 2023.

CHAPTER 2. UPDATES TO EXISTING TOOLBOX VOLUME VI TEXT

INTRODUCTION

Page 2:

- With reference to measures of effectiveness (MOE): travel time variance:
  - Although transportation professionals do not use travel time variance very often, they now often use related measures such as travel time index (TTI), buffer time, planning time index (PTI), and probability of on-time arrival. The authors encourage expanded use of such measures.

Page 4:

- With reference to *simulation of MOEs* in table 1:
  - Although transportation professionals do not frequently use travel time variance, they now often use related measures such as TTI, buffer time, planning time index, and probability of on-time arrival. The authors encourage expanded use of such measures.

Page 6:

- With reference to *simulation of MOEs* travel time variance usage in table 2 in Volume VI:
  - TTR loosely defined as consistent proximity to the free-flow speed, is expressed through numerous performance metrics and visualizations. It has become common for transportation analysts to use probe data field measurements (e.g., via Bluetooth® and Wi-Fi).

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- With reference to *simulation of MOEs,* travel time variance usage in table 3 in Volume VI:
  - Computation of travel time variance and related measures (e.g., TTI, buffer time, planning time index, probability of on-time arrival) is now more common. More predictive tools are now capable of producing these measures.
  - When vehicles are queued on a road segment, travel time variation can still be significant compared with other days, weeks, and months.

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- With reference to *simulation of MOEs* TTI usage in table 4 in Volume VI:
  - More simply, TTI can also be computed as mean travel time divided by free-flow travel time. The Texas Transportation Institute defines a commuter TTI as only applicable to the peak direction of travel. Refer to chapter 3 for discussion of additional reliability MOEs.

CHAPTER 3. ADDITIONAL CONTENT TO BE APPENDED TO THE TOOLBOX VOLUME VI

TRAVEL TIME RELIABILITY MEASURES

The Transportation Research Board's (TRB) second Strategic Highway Research Program (SHRP2) report S2-L03-RR-1, *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies* (SHRP2 L03), lists the following travel time reliability measures:[2]

- Mean, standard deviation, median, mode, minimum, and percentiles (10th, 80th, 95th, and 99th) for both the travel time and TTI.
- Buffer indices (based on mean and median), planning time index, skew statistic, and misery index.
- On-time percentages for thresholds of median-plus-10-percent and median-plus-25-percent and average speeds of 30, 45, and 50 miles per hour (mph).

The most effective methods of measuring TTR are 90th or 95th percentile travel times, buffer index, and planning time index.[3] Several statistical measures, such as standard deviation and coefficient of variation, have been used to quantify TTR. However, they are not easy for a nontechnical audience to understand and would be less effective as communication tools. They also treat early and late arrivals with equal weight, but studies have determined that the public is concerned much more about late arrivals.

Decision MOE: Planning Time Index

- **Use**—Planning time index is the factor applied to the free-flow time needed to ensure on-time arrival 95 percent of the time (i.e., late 1 day of the month). It differs from the buffer index because it includes recurring and unexpected delays.
- **Definition**—Because reliability is related to the distribution of travel rates, the 95th percentile indicates an excessively high travel rate, one that only 5 percent of all travel rates exceed for the time period under consideration.
- **Computation**—Planning time index can be computed as the 95th percentile travel time divided by the free-flow travel time.
- **Reporting—**Texas Transportation Institute says that, statistically, the "worst day of the month" is the 95th percentile travel time.

[2]National Academies of Sciences, Engineering, and Medicine. 2012. *Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies*. Report No. S2-L03-RR-1. Washington, DC: The National Academies Press. https://doi.org/10.17226/22806, last accessed March 23, 2023.

[3]Federal Highway Administration. 2006. *Travel Time Reliability-Making It There on Time, All the Time*. Report No. FHWA-HOP-06-070. Texas Transportation Institute with Cambridge Systematics, Inc. https://ops.fhwa.dot.gov/publications/tt_reliability/brochure/ttr_brochure.pdf, last accessed March 23, 2023.

- **Interpretation**—The planning time index can be used to specify a travel time that will ensure on-time arrival 95 percent of the time, inclusive of both recurring and unexpected delay.

Decision MOE: Misery Index

- **Use**—Misery index is the average of the highest 5 percent of travel times divided by the free-flow travel time. It is sometimes referred to as the 97.5-percent TTI.

- **Computation**—Misery index can be computed as the 97.5th percentile travel time divided by the free-flow travel time.

Decision MOE: Buffer Index (AKA Buffer Time)

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

- **Computation**—$BI=(TT_{95\%}-TT_{MEAN})\div TT_{MEAN}$.

- **Reporting**—Texas Transportation Institute says that, statistically, the "worst day of the month" is the 95th percentile travel time.

- **Interpretation**—Buffer index can be used to determine a time cushion that will ensure on-time arrival 95 percent of the time (i.e., late 1 day of the month).

Decision MOE: Planning Time Failure/On-Time Measures

- **Use**—Planning time failure/on-time measures describe the percentage of trips with travel times within a certain factor of the median travel time.

- **Computation**—Common thresholds include: 1.1×median travel time or 1.25×median travel time. Other formulations of these measures denote the percentage of trips with average space mean speeds below a specified threshold; for example, 50, 45, or 30 mph.

SHRP2 L03 noted that buffer time and misery index measures that are based on the mean may not be appropriate due to underlying skewed distribution; it discussed that two standard measures are used to express the unevenness of distributions:

- **Skewness** is a measure of symmetry, or more precisely, a lack of symmetry. A distribution, or dataset, is symmetric if it looks the same to the left and right of the center point.

- **Kurtosis** is a measure of whether the data are peaked or flat relative to a normal distribution. That is, datasets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Datasets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case of low kurtosis.

Two measures that describe the size and shape of the travel time distribution include:

- A skewness statistic, defined as (90th percentile−median)÷(median−10th percentile).
- A width statistic, defined as (90th percentile−10th percentile)÷median.

TRB's second SHRP2 report, S2-L04-RR-1, *Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools* (SHRP2 L04), recommends the measures listed in Figure 1 for different analysis types.[4]

Data Characteristics and Performance Measures		**Analysis Level**		
		Network	**O-D**	**Path/Segment/Link**
Characteristics	**Trvel times for vehicles**	**Not comparable**	**Comparable**	**Comparable**
	Travel	**Different**	**Different**	**Identical**
Applicable Measures	Distance-normalized measures (Type A)	• Average of travel times per mile (TTPMs) • Standard deviation of TTPMs • 95^{th}/90^{th}/80^{th} percentile TTPM	• Average of travel times per mile (TTPMs) • Standard deviation of TTPMs • 95^{th}/90^{th}/80^{th} percentile TTPM	• Average of travel times per mile (TTPMs) • Standard deviation of TTPMs • 95^{th}/90^{th}/80^{th} percentile TTPM
	Measures for comparable travel times (Type B)	Not applicable	• Average travel time • Standard deviation of travel times • Coefficient of variation *Standard deviation of travel times/mean travel time* • 95^{th}/90^{th}/80^{th} percentile travel time • Buffer Index (95^{th} percentile travel time- median travel time)(median travel time -10^{th} percential travel time) • Percent on-time arrival *Percent of travel times <1.1 median travel time*	• Average travel time • Standard deviation of travel times • Coefficient of variation *Standard deviation of travel times/mean travel time* • 95^{th}/90^{th}/80^{th} percentile travel time • Buffer Index (95^{th} percentile travel time- median travel time)(median travel time -10^{th} percential travel time) • Percent on-time arrival *Percent of travel times <1.1 median travel time*
	Measures for the same trvel distance (Type C)	Not applicable	Not applicable	• TTI (Travel Time Index) *Mean travel time/free-flow travel time* • PTI (Planning Time Index) *95^{th} percentile travel time/free-flow travel time* • Misery Index *Mean of the highest 5% of travel times/free-flow travel time* • Frequency of congestion *Percent of travel times > 2 free-flow travel time*

O-D = origin-destination

Figure 1. Screenshot. Reliability measures for different analysis types.

[4]National Academies of Sciences, Engineering, and Medicine. 2014. *Incorporating Reliability Performance Measures Into Operations and Planning Modeling Tools*. Report No. S2-L04-RR-1. Washington, DC: The National Academies Press. https://doi.org/10.17226/22388, last accessed March 23, 2023.

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