Overview of Performance Measures: Travel Time Reliability (NHPP) and Annual Hours of Peak Hour Excessive Delay (CMAQ)

Rich Taylor, Office of Operations
Chris Chang, Office of Infrastructure

Phoenix, AZ

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HOW WE GET THERE

New 23 CFR Part 490 Subparts E&G

- Subpart E: Measures to Assess the Performance of the National Highway System (NHS)
  - Percent of the Person-Miles Traveled on the Interstate That Are Reliable
  - Percent of the Person-Miles Traveled on the Non-Interstate NHS That Are Reliable
- Subpart G: Measure to Carry Out the Congestion Mitigation and Air Quality Improvement (CMAQ) Program
  - Annual Hours of Peak Hour Excessive Delay Per Capita (PHED)

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Introduction – What We'll Cover

- General Definitions
  - Introduction to Metrics, Measures and Targets and other terms
- Measure Definitions
  - Data requirements for each of the measures
  - Precise step-by-step procedures for calculating the metrics and measures
    - Under the National Highway Performance Program NHPP:
      - Travel time reliability – 2 measures
    - Under the Congestion Mitigation and Air Quality (CMAQ) Improvement (CMAQ) Program:
      - Annual hours of peak hour excessive delay
- (Time Permitting) Suggestions for:
  - NPMRDS and PM3 Measures (New)
  - Assembling a master database to handle all the measures
  - Creating epoch-level traffic volumes

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Definitions

- *Metric:* a quantifiable indicator of performance or condition
- *Measure:* an expression based on a metric that is used to establish targets and to assess progress toward achieving the established targets
- *Target:* a quantifiable level of performance or condition, as a value for the measure, to be achieved within a time period required by FHWA

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Definitions

- *National Performance Management Research Data Set (NPMRDS):* a data set derived from vehicle/passenger probe data (sourced from Global Positioning Station [GPS], navigation units, cell phones)
  - Covers the National Highway System (NHS)
  - Includes average travel times representative of all traffic and average travel times for freight trucks
  - Individual records represent 5-minute time periods for a travel time segment (can also be downloaded as 15-minute time periods), measured continuously throughout the year

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Definitions

- *Highway Performance Monitoring System (HPMS)*: A national level highway information system that includes data on the extent, condition, performance, use, and operating characteristics of the nation's highways

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Definitions

- *Reporting segment:* the length of roadway the DOT and MPOs define for metric calculation and reporting; comprised of one or more travel time segments
- *Travel time segment:* a contiguous NHS stretch for which average travel time data are summarized in the travel time data set
- *Traffic Message Channel (TMC):* segmentation of roadway by TMC length in NPMRDS v1 and v2

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Definitions

- *Travel time reliability:* the consistency or dependability of travel times from day to day or across different times of the day
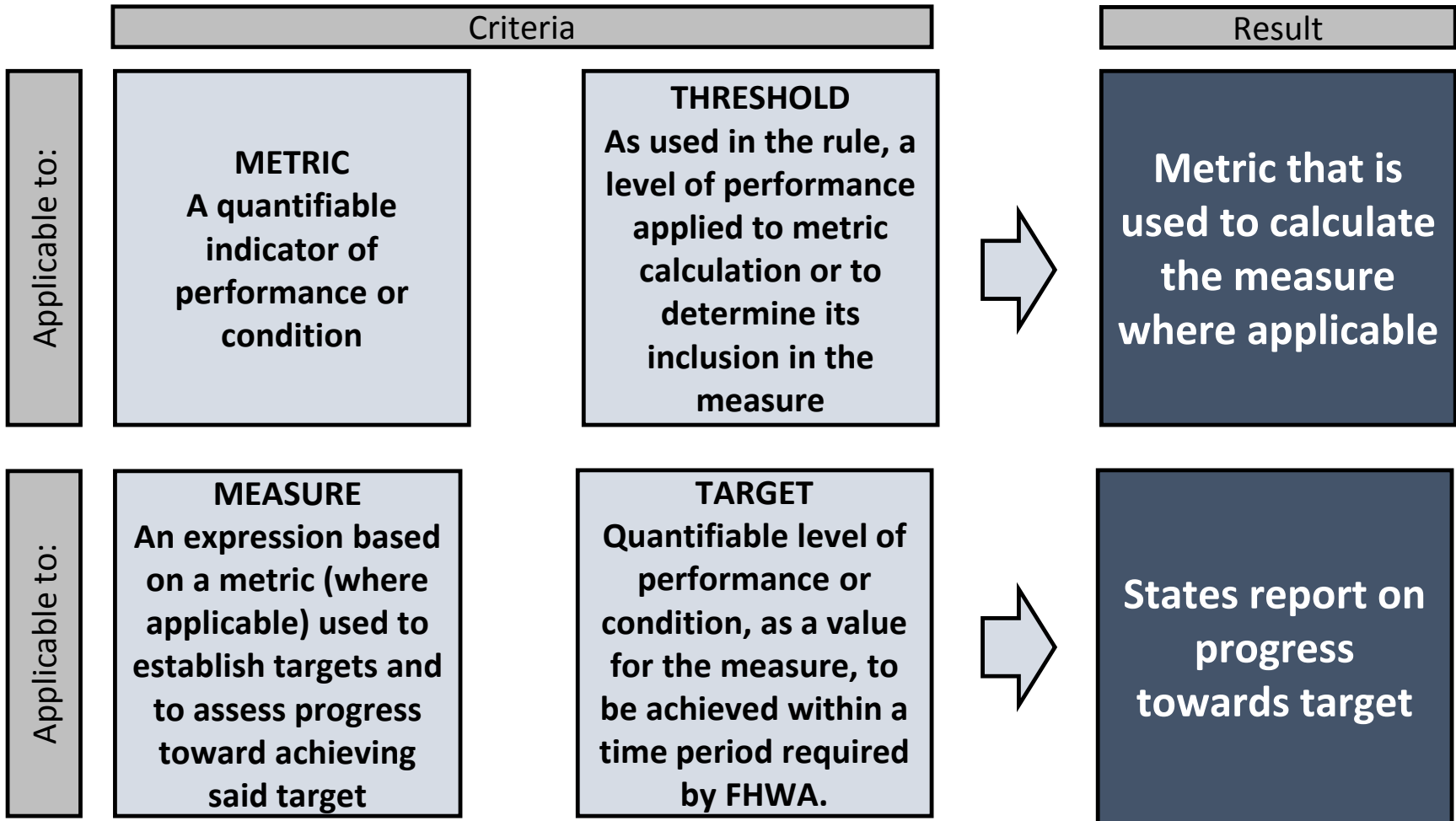
Acronyms/Terms

- Average Annual Daily Traffic (AADT)
- Congestion Mitigation and Air Quality Improvement Program (CMAQ)
- Level of Travel Time Reliability (LOTTR)
- Metropolitan Planning Organization (MPO)
- National Highway Performance Program (NHPP)

- Conflation
- Directional Factor
- Occupancy Factor
- Short counts/continuous vehicle counts
- Vehicle Counts by Classification

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Metrics, Thresholds, Measures and Targets

Criteria		Result

Applicable to:

METRIC
A quantifiable indicator of performance or condition

THRESHOLD
As used in the rule, a level of performance applied to metric calculation or to determine its inclusion in the measure

➡ **Metric that is used to calculate the measure where applicable**

Applicable to:

MEASURE
An expression based on a metric (where applicable) used to establish targets and to assess progress toward achieving said target

TARGET
Quantifiable level of performance or condition, as a value for the measure, to be achieved within a time period required by FHWA.

➡ **States report on progress towards target**

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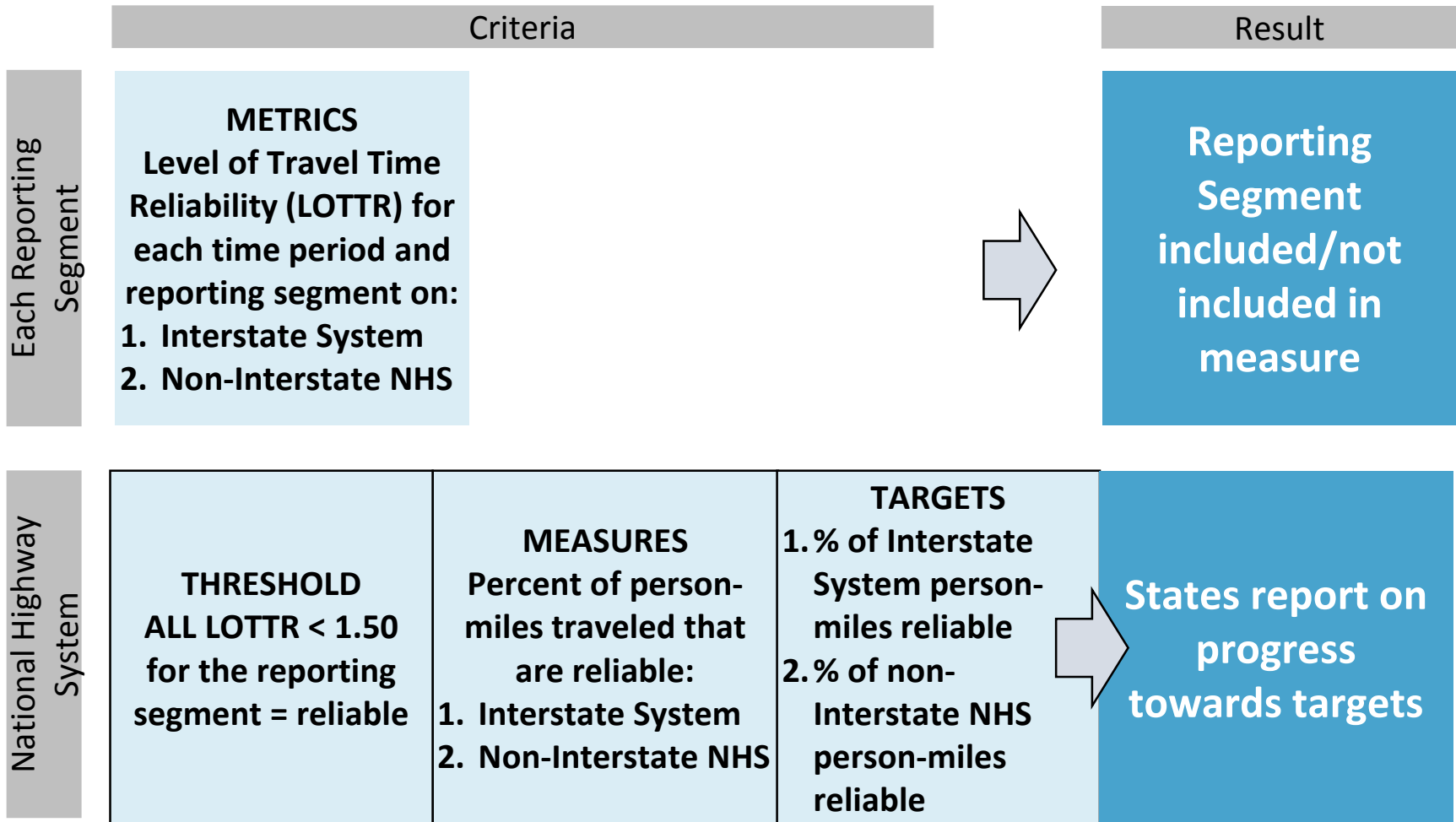# National Highway Performance Program (NHPP) Reliability Measures

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§ 490.507 Travel Time Reliability Measures

	Criteria			Result

Each Reporting Segment

METRICS
Level of Travel Time Reliability (LOTTR) for each time period and reporting segment on:
1. **Interstate System**
2. **Non-Interstate NHS**

⇒ **Reporting Segment included/not included in measure**

National Highway System

THRESHOLD
ALL LOTTR < 1.50 for the reporting segment = reliable

MEASURES
Percent of person-miles traveled that are reliable:
1. **Interstate System**
2. **Non-Interstate NHS**

TARGETS
1. **% of Interstate System person-miles reliable**
2. **% of non-Interstate NHS person-miles reliable**

⇒ **States report on progress towards targets**

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NHS Example

National Highway System: Massachusetts

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Required Data for Reliability Measures

- Travel time segment length

- Epoch (time interval, i.e., 15-minutes)

- Travel time: all vehicles

- Highway type (Interstate and non-Interstate NHS)

Required Data for Reliability Measures

- Metropolitan Planning Area boundary designation (for MPO reporting)

- AADT for each segment (HPMS)

- Average vehicle occupancy for all vehicles by specified area (provided by FHWA or locally derived)

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MPO Planning and Urbanized Boundaries

- Census Bureau defines urbanized boundaries
  - Usually adjusted slightly by MPOs and state DOTs to "smooth" the boundaries and capture roadways that operate as urban facilities
- Many MPOs extend their planning boundaries beyond the adjusted Census urbanized area boundaries so they can do comprehensive planning
  - This is known as the Metropolitan Planning Area

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MPO Planning and Urbanized Boundaries

- For the Reliability measures, the **Metropolitan Planning Area boundary** is used
- For the PHED measure, the adjusted **Census urbanized area boundary** is used
- Agencies need to identify travel time segments within these boundaries

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Level of Travel Time Reliability (LOTTR) Metrics

- Calculated for each reporting segment
- Calculated for each of 4 time periods for the entire year (nearest hundredth)

$$LOTTR_i = \frac{80th\ Percentile\ Travel\ Time_i}{50th\ Percentile\ Travel\ Time_i}$$

Where *i* is the time period:

1. 6 a.m. – 10 a.m., weekdays
2. 10 a.m. – 4 p.m., weekdays
3. 4 p.m. – 8 p.m., weekdays
4. 6 am. – 8 p.m., weekends

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LOTTR Example: Select the 80th and 50th percentile travel times

No. of Epochs

Travel Time (seconds)

Legend:
- 50th Percentile
- 80th Percentile

tt = 28

tt = 54

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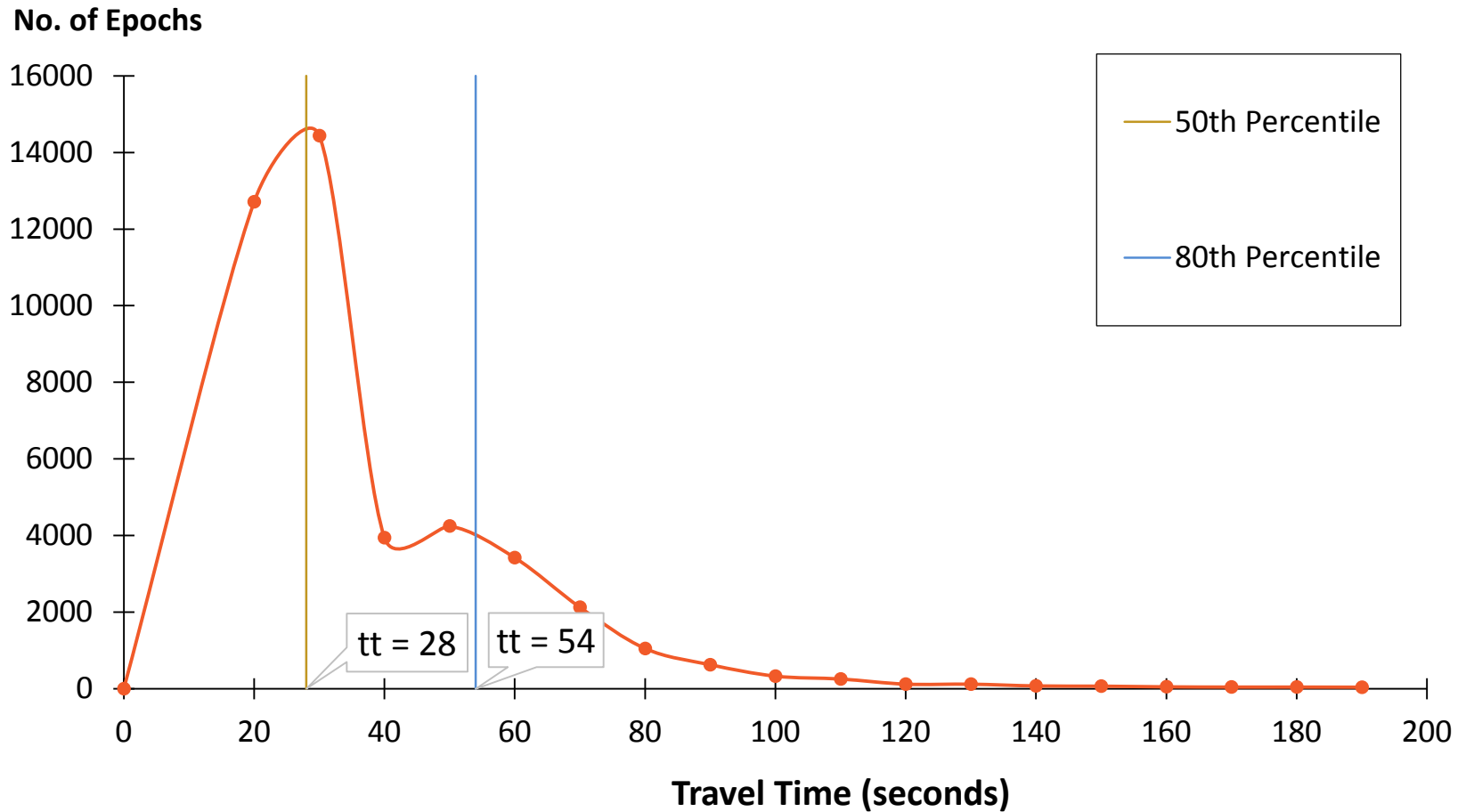
LOTTR Example: Metric

$$\frac{\text{Longer Travel Time (80th)}}{\text{Normal Travel Time (50th)}} = \frac{\text{\# seconds}}{\text{\# seconds}} = \text{Level of Travel Time Reliability Ratio}$$

Level of Travel Time Reliability (LOTTR)		
(Single Segment, Interstate Highway System)		
Monday – Friday	6am – 10am	$\text{LOTTR} = \frac{44 \text{ sec}}{35 \text{ sec}} = 1.26$
	10am – 4pm	LOTTR = 1.39
	4pm – 8pm	LOTTR = 1.54
Weekends	6am – 8pm	LOTTR = 1.31
Must exhibit LOTTR below 1.50 during **all** of the time periods		**Segment IS NOT reliable**

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Interstate and Non-Interstate NHS Travel Time Reliability Measures (TTRM)

- System measure is computed from the reporting segment level LOTTR-values
  - One measure is Interstate reporting segments
  - One measure is Non-Interstate NHS reporting segments
- Ratio of person-miles of travel that are reliable to total person-miles of travel
- A segment is reliable if *all four* LOTTR metrics are < 1.50
- Reported to the nearest 0.1%

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TTRM

$$TTRM = \frac{\sum_{r=1}^{R} SL_i \times AV_i \times OF_j}{\sum_{t=1}^{T} SL_i \times AV_i \times OF_j}$$

SL_i = the segment length of Interstate or Non-IS NHS reporting segment i

AV_i = annual traffic volume of reporting segment i
= $AADT \times Directional\ Factor \times 365$ (366 for leap yr)

Directional Factor = factor for splitting AADT by direction (default = 0.5)

OF_j = occupancy factor for vehicles on the NHS within a specified geographic area j within the State/Metropolitan planning area

TTRM

$$TTRM = \frac{\sum_{r=1}^{R} SL_i \times AV_i \times OF_j}{\sum_{t=1}^{T} SL_i \times AV_i \times OF_j}$$

R = total number of Interstate reporting segments exhibiting an LOTTR below 1.50 for **all** 4 time periods
T = total number of Interstate or Non-IS NHS reporting segments

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Travel Time Reliability Measure: Complete Example

Reliable

Occupancy Factor = 1.1

Annual Volume: 31M   32M   41M   25M

Length: 0.331   0.567   0.414   1.780

LOTTR (4 periods)

1.45	1.52	1.32	1.71
1.33	1.71	1.17	1.80
1.03	1.33	1.03	1.45
1.12	1.45	1.21	1.51

Unreliable
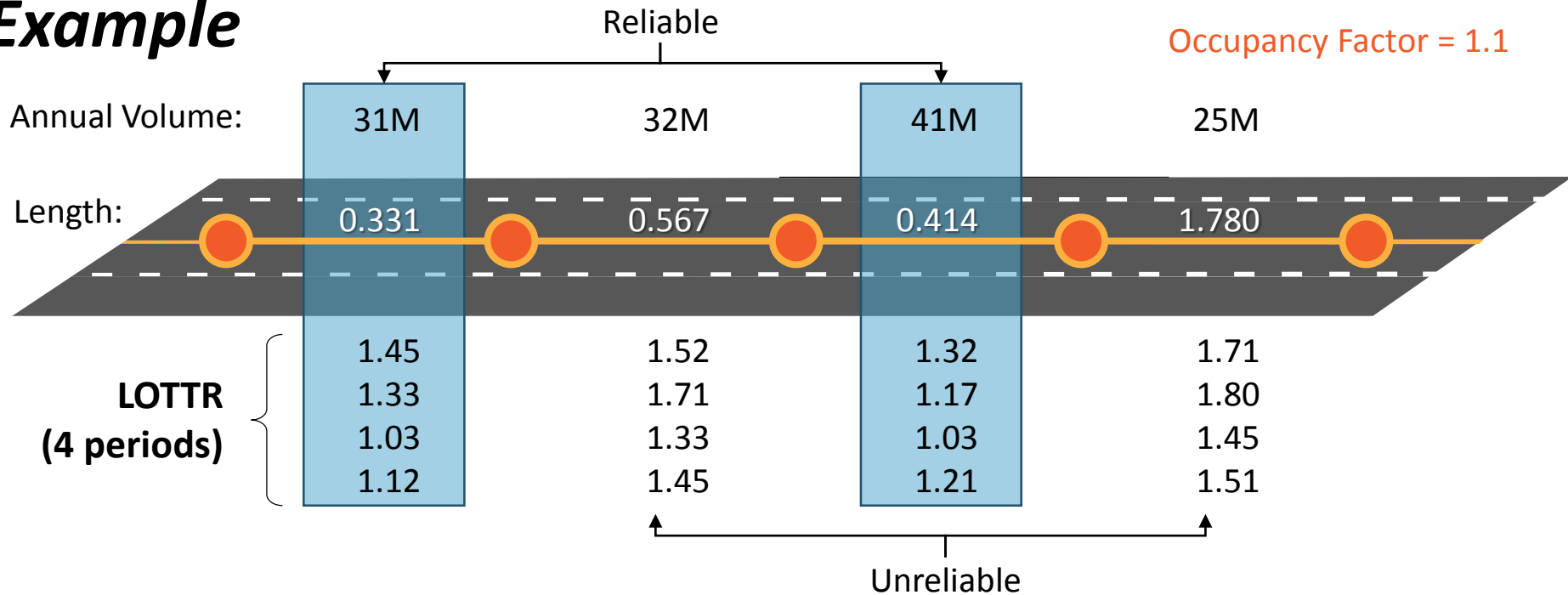
Travel Time Reliability Measure

$$= \frac{(0.331 \times 31 \times 1.1) + (0.414 \times 41 \times 1.1)}{(0.331 \times 31 \times 1.1) + (0.567 \times 32 \times 1.1) + (0.414 \times 41 \times 1.1) + (1.780 \times 25 \times 1.1)}$$

$$= \frac{11.287 + 18.671}{11.287 + 19{,}958 + 18.671 + 48.950}$$

$$= \frac{29.958}{98.866}$$

$$= 30.3\%$$

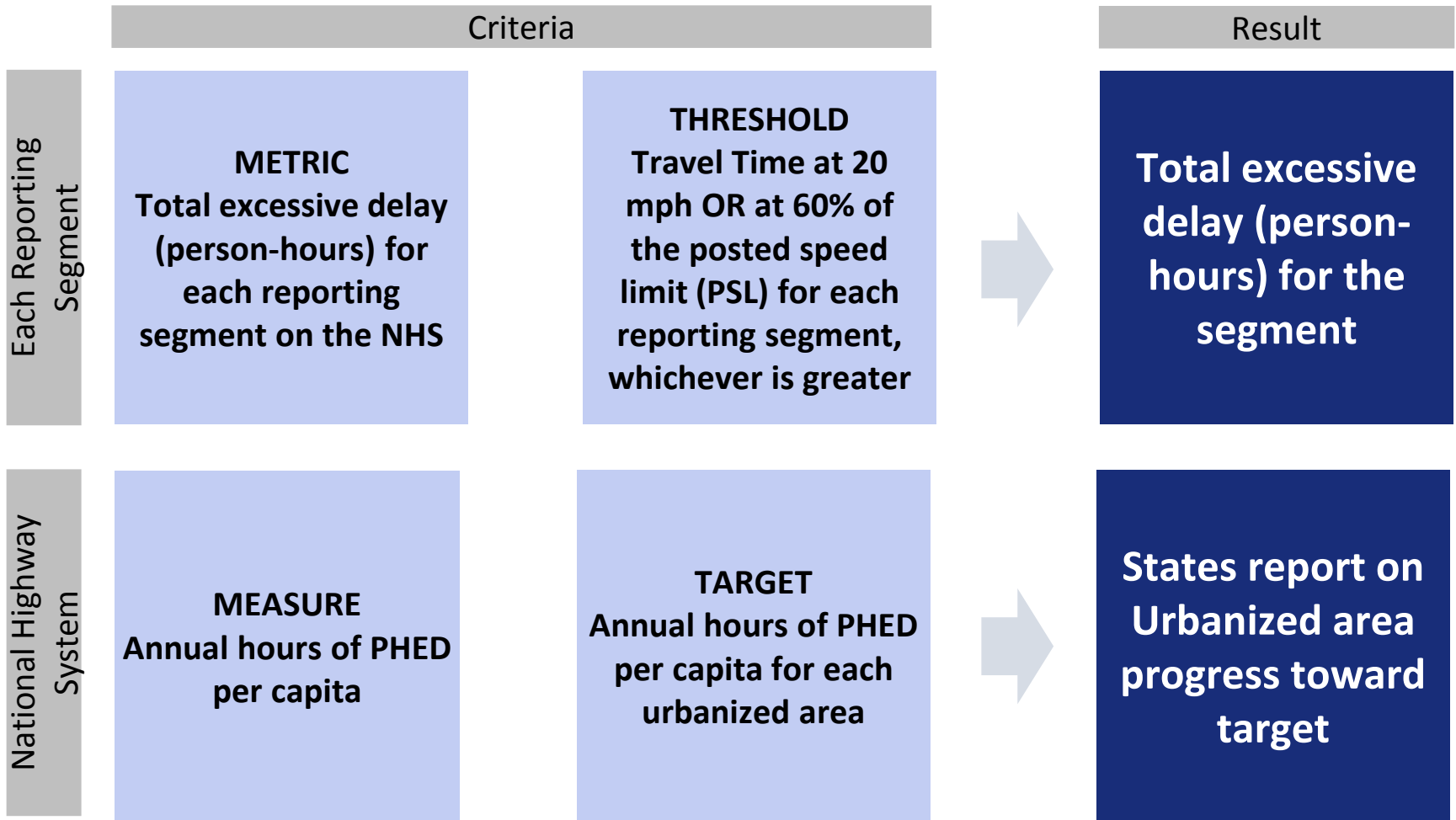# *Exercise – Calculate Reliability Metric and Measure (Worksheet)*

- Provide 80th and 50th percentiles for 8 segments (depict graphically)
- Calculate LOTTR for each segment for each time period
- Determine if reporting segment is included in the measure calculation (reliable person miles)
- Provide occupancy factors and volumes for each segment
- Add up weighted reliable person miles of travel
- Add up weighted person miles of travel for all reporting segments
- Calculate the measure for the 8 segment "system"

§ 490.707 Peak Hour Excessive Delay (PHED) Measure

	Criteria		Result
Each Reporting Segment	**METRIC** Total excessive delay (person-hours) for each reporting segment on the NHS	**THRESHOLD** Travel Time at 20 mph OR at 60% of the posted speed limit (PSL) for each reporting segment, whichever is greater	**Total excessive delay (person-hours) for the segment**
National Highway System	**MEASURE** Annual hours of PHED per capita	**TARGET** Annual hours of PHED per capita for each urbanized area	**States report on Urbanized area progress toward target**

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PHED Required Data

- Travel time segment length
- Epoch (time interval, i.e., 15-minute units)
- Travel time: all vehicles
- Posted speed limit
- Urbanized area designation

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PHED Required Data

- 15-minute volume for each segment and epoch (peak hours only)
- Percent of total traffic for: (1) cars, (2) buses, and (3) trucks on the segment
- Average vehicle occupancy for (1) cars, (2) buses, and (3) trucks on the segment (agency or FHWA supplied)
- Urbanized area population

Urbanized Areas: Boundaries & Population

- Boundaries may be attained from the U.S. Census Bureau:
  - https://www.census.gov/geo/maps-data/data/cbf/cbf_ua.html
- FHWA-approved urbanized area boundaries submitted to HPMS by a state DOT may also be used
- Urbanized area population, for use in measure calculation, is provided via the 5-year estimates from the American Community Survey (Census)

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Definition of Excessive Delay

- The extra amount of time spent in congested conditions defined by speed thresholds that are lower than a normal delay threshold
- For the purposes of this rule, the speed threshold is 20 miles per hour (mph) or 60% of the posted speed limit, whichever is greater

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Definition of Peak Periods

- Calculations only need to be done for the following hours for ***weekdays*** (total 8 hours per day)
    - Morning Peak Hours are 6:00 a.m. – 10 a.m.
    - Afternoon Peak Hours are either (agency choice):
        - 3:00 p.m. – 7:00 p.m. or
        - 4:00 p.m. – 8:00 p.m.

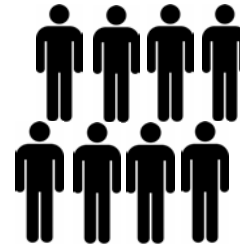# Overview: PHED Metric: Example

0.500 Mile Reporting Segment

Average of 105 seconds for a 15-min. segment per vehicle

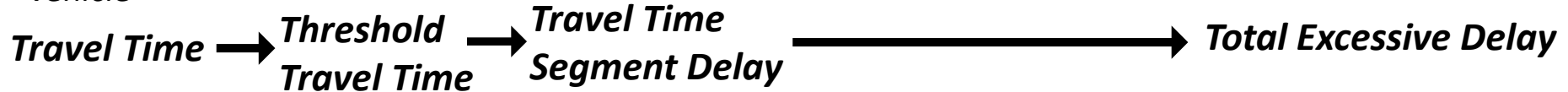Excessive Delay Threshold: **90 seconds**

105 - 90 = **15 seconds**

500,000 people traveling during **peak hours**

For all **peak periods** in a full calendar year

= 863.025 person-hours

Travel Time → *Threshold Travel Time* → *Travel Time Segment Delay* → *Total Excessive Delay*

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PHED Metric Calculation

$$1.\ EDTTT_S = \left(\frac{SL_S}{Threshold\ Speed_S}\right) \times 3{,}600$$

$EDTTT_s$ = Excessive Delay Threshold Travel Time

= travel time on the segment above which delay would be incurred

SL_s = length of the segment

$Threshold\ Speed_s$ is the larger of:

- *20 mph, or*
- *Posted Speed Limit x 0.6*

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PHED Metric Calculation

$$2. \quad RSD_{s,b} = Travel\ Time_{s,b} - EDTTT_s$$

$RSD_{s,b}$ = travel time segment delay for segment s and 15-minute bin b

$Travel\ Time_{s,b}$ = travel time of all vehicles on segment s and 15-minute bin b

PHED Metric Calculation

3. $ExcessiveDelay_{s,b} =$

$$\begin{cases} \dfrac{RSD_{s,b}}{3{,}600} & when\ RSD_{s,b} \geq 0 \\ or \\ 0\ when\ RSD_b < 0 \end{cases}$$

Excessive Delay is in hours (nearest hundredth)

4. $Total\ Excessive\ Delay_s$

$$= \quad AVO$$

$$\times \sum_{d=1}^{TD} \sum_{h=1}^{TH} \sum_{b=1}^{TB} \left(ED_{s,b,h,d} \right.$$

$$\left. \times \frac{hourly\ volume}{4}\ s, h, d \right)$$

$Total\ Excessive\ delay_s$ = person-hours of delay (nearest hundredth) for the entire year for segment s

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PHED Metric Calculation

AVO = Average Vehicle Occupancy

$$= (P_c \times AVO_c) + (P_b \times AVO_b)$$
$$+ (P_t \times AVO_t)$$

P_c = percent of cars in the traffic stream

P_b = percent of buses in the traffic stream

P_t = percent of trucks in the traffic stream

AVO_c = average vehicle occupancy for cars

AVO_b = average vehicle occupancy for buses

AVO_t = average vehicle occupancy for trucks

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PHED Metric Calculation

s = reporting segment

d = a day of the reporting year

TD = total number of days in a year

h = hour of the day (pre-defined peak hours only)

TH = total number of hour intervals in day d

b = 15-minute bin for hour h

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PHED Metric Calculation

TB = total number of 15-minute bins with travel times present in peak hour *h*

Excessive Delay$_{s,b,h,d}$ = excessive travel time (hundredths of an hour) for segment *s*, bin *b*, peak hour *h*, and day *d*

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PHED Measure Calculation

$$Annual\ Hours\ of\ PHED\ per\ capita$$

$$= \frac{\sum_{s=1}^{T} Total\ Excessive\ Delay_s}{Total\ Population}$$

Total Population = the total population in the urbanized area from the most recent annual population published by the U.S. Census

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PHED METRIC Calculation: Example

Date	Start Time	Speed Threshold	Segment Length	Travel Time	15-Min Volume
3/15/2013	7:00	36	0.52	45	1,220
3/15/2013	7:15	36	0.52	51	1,220
3/15/2013	7:30	36	0.52	63	1,220

For 7:30:

$$EDTTT = \left(\frac{0.52}{36}\right) \times 3{,}600$$
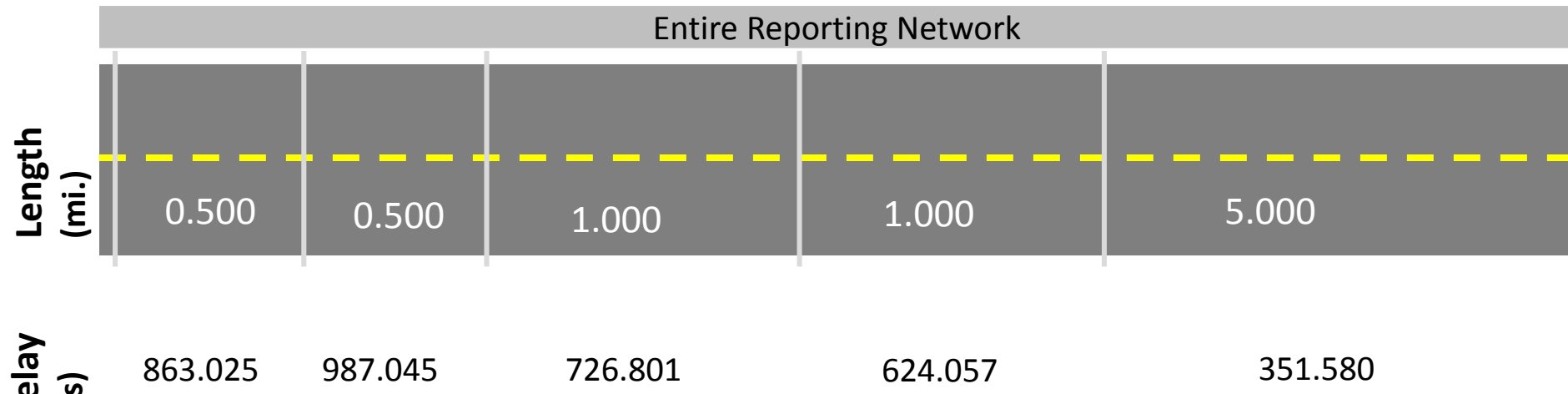
$$= 52 \text{ sec}$$

$$RSD = 63-52$$

$$= 9 \text{ sec}$$

$$\text{Excessive Delay} = \frac{9}{3{,}600}$$

$$= 0.003 \text{ hrs}$$

Total Excessive Delay $= 0.003 \times 1{,}220 \times 1.1 \text{ AVO}$

$$= 3.66 \text{ vehicle-hrs}$$
$$\times 1.1 \text{ AVO}$$

$$= 4.03 \text{ person-hours}$$

PHED MEASURE Calculation: Example

Entire Reporting Network				

Length (mi.)

| 0.500 | 0.500 | 1.000 | 1.000 | 5.000 |

Excessive Delay (person-hours)

| 863.025 | 987.045 | 726.801 | 624.057 | 351.580 |

$$\frac{\text{4.46M person-hours excessive delay}}{\text{1.05M urbanized area population}}$$

= 4.3 hours per capita

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PHED Example Discussion

	Original Data Set						Calculated Data Elements				
TMC	Date	Start Time	Speed Threshold (mph)	TMC Length (mi)	Travel Time (all vehs, sec)	Hourly Volume	Ex. Delay Thresh. Travel Time, EDTTT (sec)	Travel Segment Delay, RSD (sec)	Excessive Delay, ED (hrs)	Average Vehicle Occpancy (AVO)	Total Excessive Delay, TED (veh-hrs)
130N09999	3/15/2013	6:00	35	0.52	30	3,850	53	-23	0.000	1.2	0.00
130N09999	3/15/2013	6:15	35	0.52	30	3,850	53	-23	0.000	1.2	0.00
130N09999	3/15/2013	6:30	35	0.52	29	3,850	53	-24	0.000	1.2	0.00
130N09999	3/15/2013	6:45	35	0.52	28	3,850	53	-25	0.000	1.2	0.00
130N09999	3/15/2013	7:00	35	0.52	31	4,125	53	-22	0.000	1.2	0.00
130N09999	3/15/2013	7:15	35	0.52	34	4,125	53	-19	0.000	1.2	0.00
130N09999	3/15/2013	7:30	35	0.52	42	4,125	53	-11	0.000	1.2	0.00
130N09999	3/15/2013	7:45	35	0.52	55	4,125	53	2	0.001	1.2	0.69
130N09999	3/15/2013	8:00	35	0.52	49	4,450	53	-4	0.000	1.2	0.00
130N09999	3/15/2013	8:15	35	0.52	62	4,450	53	9	0.003	1.2	3.34
130N09999	3/15/2013	8:30	35	0.52	60	4,450	53	7	0.002	1.2	2.60
130N09999	3/15/2013	8:45	35	0.52	65	4,450	53	12	0.003	1.2	4.45
130N09999	3/15/2013	9:00	35	0.52	67	3,975	53	14	0.004	1.2	4.64
130N09999	3/15/2013	9:15	35	0.52	75	3,975	53	22	0.006	1.2	7.29
130N09999	3/15/2013	9:30	35	0.52	67	3,975	53	14	0.004	1.2	4.64
130N09999	3/15/2013	9:45	35	0.52	62	3,975	53	9	0.003	1.2	2.98
									TOTAL		30.61

Accessing Travel Time and Other Data via NPMRDS v2

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- Live demonstration of npmrds.ritis.org

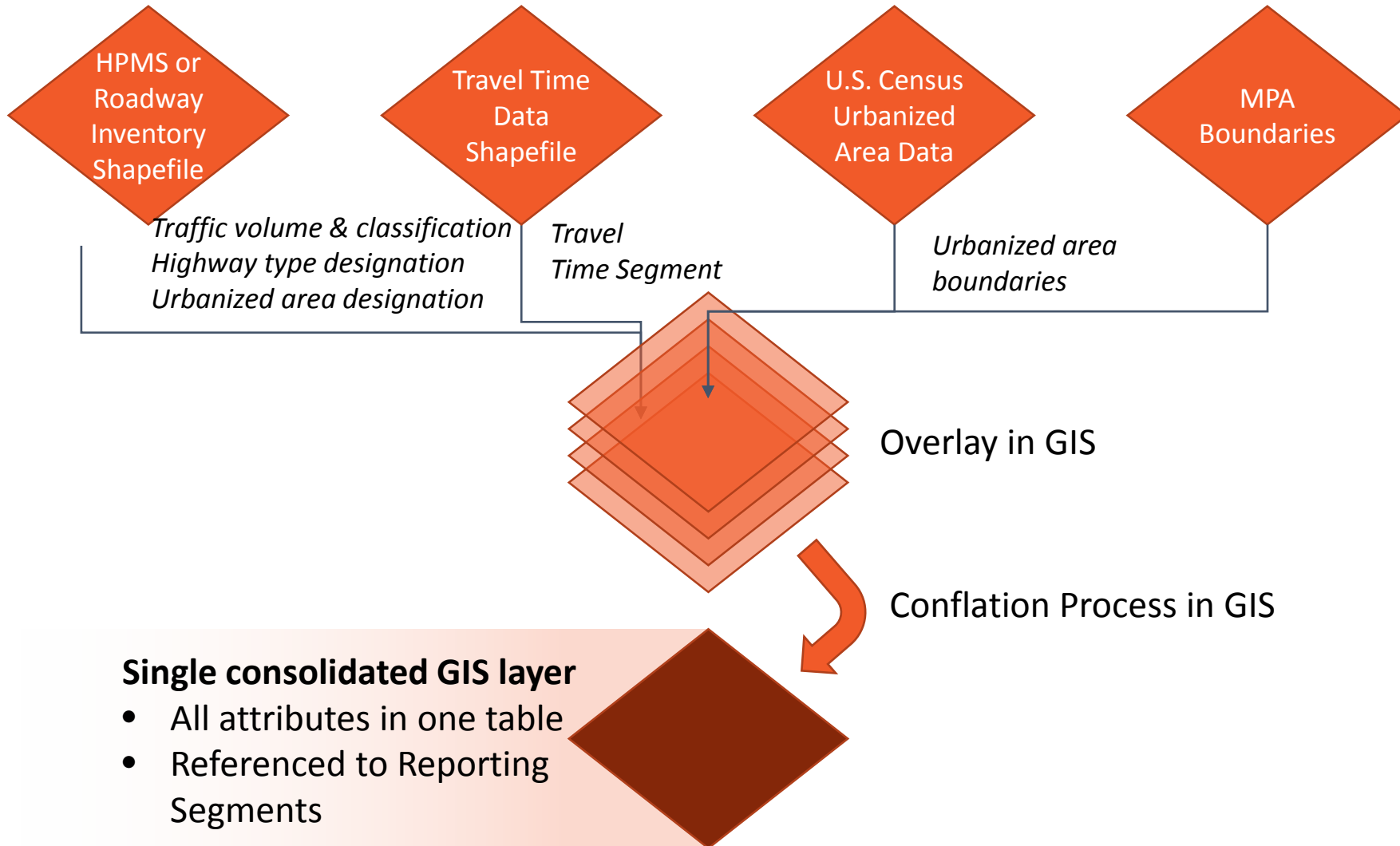# Suggestions for Data Processing Methods to Develop the Performance Measures

Introduction

- A suggested approach: create a single master data set from which to compute the *travel time-based* measures:
  - Interstate and non-Interstate Travel Time Reliability Measures
  - Annual Hours of Peak Hour Excessive Delay (PHED) per Capita

Assemble Travel Time/Volume Data Set

- Not all measures use all the data, but it's simpler to assemble a single master set
  - Travel time data set (15-minute time interval)
  - Traffic volume data set
    - Annual Average Daily Traffic (AADT)
    - Vehicle classes: cars, buses, and trucks
  - Other characteristics
    - Urban and Metropolitan Planning Area boundaries
    - Posted speed limit

Conflation

HPMS or Roadway Inventory Shapefile

Travel Time Data Shapefile

U.S. Census Urbanized Area Data

MPA Boundaries

Traffic volume & classification
Highway type designation
Urbanized area designation

Travel Time Segment

Urbanized area boundaries

Overlay in GIS

Conflation Process in GIS

Single consolidated GIS layer
- All attributes in one table
- Referenced to Reporting Segments

Final Data Set Structure to Cover Both Travel Time-Based Measures

For each record: travel time segment and 15-minute epoch

- Travel time segment length
- Travel time: all vehicles + trucks
- Posted speed limit
- Highway type (Interstate or non-Interstate NHS)
- Urbanized area designation
- Metropolitan Planning Area boundary designation
- AADT derived from HPMS for each segment
- 15-minute volume
- Average vehicle occupancy for (1) cars, (2) buses, and (3) trucks
- Percent of total traffic for: (1) cars, (2) buses, and (3) trucks

Final Data Set Structure: Detail

Attribute	Description
Reporting segment	Unique identifier for Reporting Segment. In most cases, this will be the TMC
Reporting segment length	Length of Reporting Segment (miles, to the nearest hundredth mile)
Date	Date value from Travel Time Data Set
Epoch	Time value from Travel Time Data Set
Travel time – all vehicles	5-minute average travel time value for all vehicles from the Travel Time Data Set (seconds, to nearest second)
Travel time – freight vehicles	5-minute average travel time value for freight vehicles from the Travel Time Data Set (seconds, to nearest second)

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Final Data Set Structure: Detail

Attribute	Description
Highway type designation	Highway type designation for Reporting Segment. Required to summarize performance measures into 2 categories: Interstate System and non-Interstate NHS
Urbanized area designation	The urbanized area in which the reporting segment is located
Metropolitan planning area designation	The MPO planning area in which the reporting segment is located
Traffic volume	The estimated traffic volume occurring on the reporting segment for the epoch
Posted speed limit	Posted speed limit for Reporting Segment (miles per hour)

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Final Data Set Structure: Detail

Attribute	Description
Average vehicle occupancy for (1) cars, (2) buses, and (3) trucks on the segment	FHWA will supply value,s or they can be developed locally
Percent of total traffic for: (1) cars, (2) buses, and (3) trucks on the segment	These values are obtained from the agency's vehicle classification count program

Suggested Approaches for Determining Epoch-Level Traffic Volumes

- Only required for Annual Hours of Peak Hour Excessive Delay measure
- Assign actual (measured) 15-minute or hourly volumes for the reporting segment (rare). If hourly volumes, divide by 4 to get volumes in each epoch for an hour. **Or…**
- Assign AADT to each segment and decompose to 15-minute epochs using factors
- States define and report the method they choose

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Suggested Approaches for Determining Epoch-Level Traffic Volumes

- Short-count based AADTs are the vast majority of volume data
- AADT value can come from HPMS (or other data) that has been assigned to a reporting segment (e.g., TMC) by conflation
- Then, a series of factors are applied to break down the AADT to each 15-minute epoch for each day
- Use permanent count data to develop factors

Suggested Approach for Developing 15-Minute Epoch Volumes

1. If AADT is bidirectional, divide by 2 to get the directional AADT for the reporting segment

2. Apply monthly factors to adjust for monthly differences in traffic

3. Apply day of week factors to the monthly AADT, resulting in 84 AADT values (12 x 7) for each month/day of week combination

4. Apply hourly distributions to get the traffic volume for each hour

5. Divide the hourly volumes by 4 to get the 15-minute epoch traffic volumes within each hour

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Example: Day of Week Factors (Applied to Monthly AADT)

Day of Week	Adjustment Factor
Monday - Thursday	105%
Friday	110%
Saturday	90%
Sunday	80%

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Example: Weekday Temporal Distributions

Note that distributions peak in the AM or PM
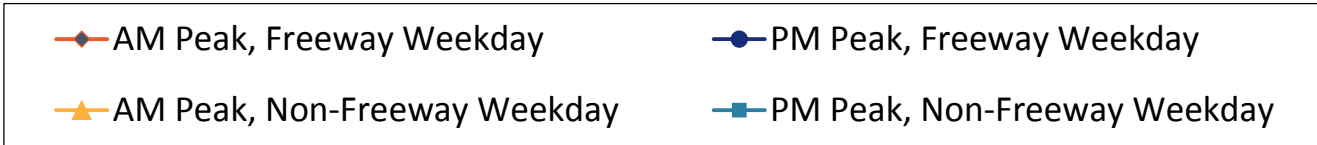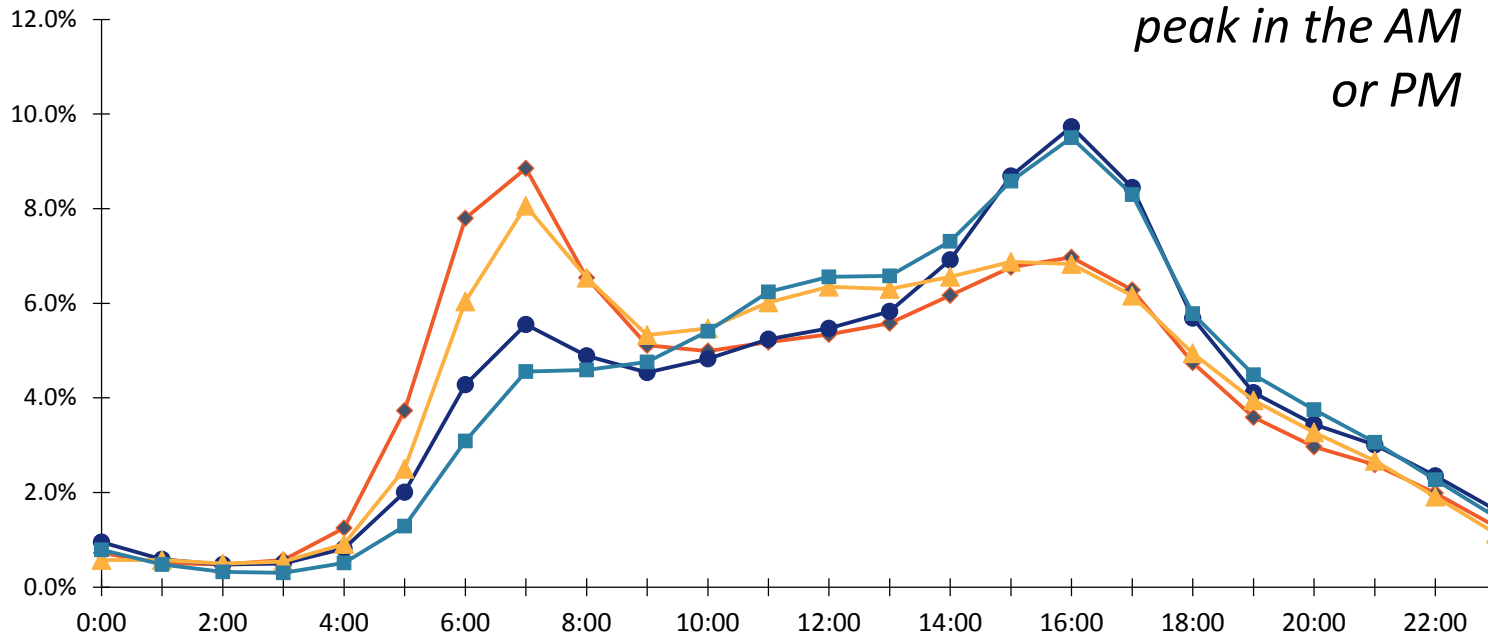
Example: Determining Epoch-Level Traffic Volumes

Hour	Epoch (start)	Directional AADT for Month and DOW	Hr. Directional Factor	Epoch Volume (hr. vol./4)
7	7:00	30,000	0.0357	268
7	7:15	30,000	0.0357	268
7	7:30	30,000	0.0357	268
7	7:45	30,000	0.0357	268
8	8:00	30,000	0.0309	232
8	8:15	30,000	0.0309	232
8	8:30	30,000	0.0309	232
8	8:45	30,000	0.0309	232

Contacts

For questions or more information, please contact:

Rich Taylor, Office of Operations, Rich.Taylor@dot.gov, 202-366-1327
Chris Chang, Office of Infrastructure, Chris.Chang@dot.gov, 202-366-4657

Questions?