Average Vehicle Occupancy Factors for Computing Travel Time Reliability Measures and Total Peak Hour Excessive Delay Metrics (April 2018)

1   Summary

In this document, Federal Highway Administration (FHWA) provides average vehicle occupancy (AVO) factors for computing:

(1) Travel Time Reliability measures[1]; and
(2) Total Peak Hour Excessive Delay (PHED) metrics[2].

For computing Travel Time Reliability measures, 23 CFR 490.509(d) requires the AVO factors needed to calculate the measures must come from the most recently available data tables published by FHWA, unless using other allowed data source(s). 23 CFR 490.511(e)(2) provides that if a State DOT does not elect to use FHWA supplied AVO factor, that State DOT must report AVO factor(s) for the Travel Time Reliability measures to Highway Performance Monitoring System (HPMS)[3]. The FHWA provides an AVO factor for computing Travel Time Reliability measures is provided in Table 1 below.

Table 1 - Average Vehicle Occupancy Factor for Travel Time Reliability Measures

Vehicle Type	Average Vehicle Occupancy Factor
All vehicles	1.7

For computing PHED metrics, 23 CFR 490.709(e) requires State DOTs to develop AVO factors for cars, buses, and trucks in applicable urbanized areas[4] using either: (1) FHWA provided AVO factors factor values; or (2) State DOT developed estimates that are more specific than the data provided by FHWA. The FHWA provides AVO factors for computing PHED metrics are provided in Table 2 below.

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[1] 23 CFR 490.513(b) and (c)
[2] 23 CFR 490.711(b) and (e)
[3] HPMS Field Manual Supplemental Guidance: Travel Time Metric Data Reporting Requirements & Specifications: https://www.fhwa.dot.gov/tpm/guidance/pm3_hpms.pdf
[4] Applicable Urbanized Areas for CMAQ Traffic Congestion Measures (PHED and Percent of Non-Single Occupancy Vehicle Travel Measures) - determined in October 2017 for the first performance period. A list of applicable urbanized areas and corresponding State DOTs and MPOs are provided in Table 6 in this website - https://www.fhwa.dot.gov/environment/air_quality/cmaq/measures/cmaq_applicability/page04.cfm

Table 2 - Annual Average Vehicle Occupancy Factors for Cars, Buses and Trucks for PHED Metrics

Vehicle Types	Applicable Area	Average Vehicle Occupancy Factors
Cars	All	1.7
Buses	Atlanta, GA	10.3
	Baltimore, MD	15.9
	Boston, MA-NH-RI	12.2
	Charlotte, NC-SC	8.5
	Chicago, IL-IN	10.9
	Cincinnati, OH-KY-IN	8.1
	Cleveland, OH	9.6
	Columbus, OH	5.7
	Dallas-Fort Worth-Arlington, TX	5.1
	Denver-Aurora, CO	9.2
	Detroit, MI	10.7
	Houston, TX	10.3
	Indianapolis, IN	5.8
	Las Vegas-Henderson, NV	14.5
	Los Angeles-Long Beach-Anaheim, CA	13.9
	Memphis, TN-MS-AR	7.2
	Milwaukee, WI	8.2
	Minneapolis-St. Paul, MN-WI	9.8
	New York-Newark, NY-NJ-CT	16.8
	Philadelphia, PA-NJ-DE-MD	13.3
	Phoenix-Mesa, AZ	6.8
	Pittsburgh, PA	10.8
	Portland, OR-WA	12.6
	Riverside-San Bernardino, CA	7.1
	Sacramento, CA	7.7
	Salt Lake City-West Valley City, UT	6.1
	San Diego, CA	9.5
	San Francisco-Oakland, CA	12.8
	San Jose, CA	12.2
	San Juan, PR	5.4
	Seattle, WA	14.8
	St. Louis, MO-IL	6.9
	Washington, DC-VA-MD	8.9
Trucks	All	1.0

2 Methodology

Section 2 provides methodology used to develop the average vehicle occupancy (AVO) factors in Tables 1 and 2. The data sources for deriving AVO factors are listed below.

- 2017 National Household Travel Survey (NHTS) Data[5] for deriving AVO factor for cars;
- 2016 National Transit Database[6] for deriving AVO factor for buses;
- The third national performance management measures final rule[7] for trucks; and
- 2016 Highway Statistics[8] for aggregating AVOs for cars, buses, and trucks to estimate an AVO factor for "all vehicles."

2.1 Average Vehicle Occupancy Factor for Travel Time Reliability Measures in Table 1

The average vehicle occupancy factor provided in Table 1 is a result of aggregating AVO factors for cars, buses, and trucks.

2.1.1 Cars

Data Table "trippub" in the 2017 National Household Travel Survey (NHTS) Data was used to derive AVO for cars. Each record in Data Table "trippub" represents a trip that was reported by a household member[9]. Prior to computing AVO for cars, the following query[10] was performed on Data Table "trippub" to select the relevant records.

- DRVR_FLG = 1 AND
- TRPTRANS = 3, 4, 5, 6, 8, 9, or 18 AND
- TRPMILES >= 0

The query ensures obtaining the trip records satisfy criteria of: (1) a household member was the driver (DRVR_FLG = 1); (2) privately operated vehicles (TRPTRANS = (3, 4, 5, 6, 8, 9, 18)) such as cars, sports utility vehicles, vans, pickup trucks, motorcycles, recreational vehicles, motorcycles; and (3) exclude records with trip distance coded "not ascertained"[11] (TRPMILES >= 0).

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[5] NHTS: https://nhts.ornl.gov/

[6] National Transit Database (NTD) - TS2.1 – "Service Data and Operating Expenses Time-Series by Mode" Spreadsheet: https://www.transit.dot.gov/ntd/data-product/ts21-service-data-and-operating-expenses-time-series-mode-2

[7] Page 6021 (2nd column) of the Final Rule on "National Performance Management Measures; Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program": Docket No. FHWA–2013–0054, RIN 2125–AF54, Federal Register - Vol. 82, No. 11, Pg. 5970 - January 18, 2017: https://www.gpo.gov/fdsys/pkg/FR-2017-01-18/pdf/2017-00681.pdf.

[8] 2016 Highway Statistics - Table VM-1: https://www.fhwa.dot.gov/policyinformation/statistics/2016/vm1.cfm

[9] Section 6.3 of the of the 2017 NHTS Data User Guide: https://nhts.ornl.gov/assets/2017UsersGuide.pdf

[10] Sections 3.3 and 7.5 of the 2017 NHTS Data User Guide: https://nhts.ornl.gov/assets/2017UsersGuide.pdf

[11] "Not Ascertained" is coded TRPMILES = -9. Please see Cookbook – 2017 NHTS: https://nhts.ornl.gov/assets/codebook.pdf

Subsequently, an AVO factor for cars was computed with following equation from the queried data.

$$\text{AVO}_{\text{cars}} = \sum_{r=1}^{R} \frac{([\text{TRPMILES}]_r \times [\text{NUMONTRP}]_r \times [\text{WTTRDFIN}]_r)}{([\text{TRPMILES}]_r \times [\text{WTTRDFIN}]_r)}$$

Where,

AVO_{cars} = average vehicle occupancy factors for cars;
"r" = a record in the queried "trippub" data;
"R" = total number of records in the queried "trippub" data;
$[\text{TRPMILES}]_r$ = trip distance, in miles for the data record "r";
$[\text{NUMONTRP}]_r$ = number of people on trip including respondent for the data record "r"; and
$[\text{WTTRDFIN}]_r$ = final trip weight for the data record "r". Please see section 5.3 of the 2017
          NHTS Data User Guide;

Using the methodology described above yielded the following:

$$\text{AVO}_{\text{cars}} = 1.7$$

2.1.2   Buses

The Average Vehicle Occupancy factors for buses was derived from a dataset[12] (a spreadsheet) in the 2016 National Transit Database[13]. For more information about the National Transit Data, please see 2016 National Transit Summary and Trends[14] (NTST) document published by Federal Transit Administration (FTA).

Transit operator reported Vehicle Revenue Miles (VRM) data in "VRM" Spreadsheet and Passenger Miles Traveled (PMT) data in "PMT" Spreadsheet were used to derive an average number of passengers per vehicle. Vehicle Revenue Miles is the total miles that vehicles traveled while in revenue service (in vehicle-miles), and Passenger Miles Traveled (PMT) is the total number of miles traveled by passengers (in passenger-miles). The 2016 NTST document provides a description[15] of computing the Average Number of Passengers Per Vehicle (or Annual Average Vehicle Occupancy Factors for Buses), which is Passenger Miles Travelled (PMT) divided by Vehicle Revenue Miles (VRM).

The following data queries were performed on "VRM" Spreadsheet and "PMT" Spreadsheet for data preparation:

(1) "VRM" Spreadsheet was joined to the data in "PMT" Spreadsheet by using the values in the "X4_Digit_NTDID", "Agency_Name" ("Agency.Name"), "Mode", "Service" Fields;

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[12] NTD - TS2.1 – "Service Data and Operating Expenses Time-Series by Mode" Spreadsheet:
https://www.transit.dot.gov/ntd/data-product/ts21-service-data-and-operating-expenses-time-series-mode-2
[13] NTD Data - https://www.transit.dot.gov/ntd/ntd-data
[14] 2016 NTST (October 2017): https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/ntd/66011/2016-ntst.pdf
[15] Page 23 in 2016 NTST: 2016 NTST: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/ntd/66011/2016-ntst.pdf

(2) Filter out (exclude) records with zero or NULL PMT values in the joined dataset[16]; and

(3) select records with "Mode" Field value is equal to "CB", "MB", "RB", or "TB" for obtaining records that are only pertain to buses.

The 2016 NTST document classified buses into 4 categories, and those bus categories are defined in the 2016 NTST document as follow:

- **Commuter Bus (CB)** is a fixed-route bus mode that primarily connects outlying areas with a central city through bus service that goes at least five miles of closed-door service.
- **Bus (MB)** includes a variety of rubber-tired passenger vehicles operating on fixed routes and schedules over roadways.
- **Bus Rapid Transit (RB)** is a fixed-route bus mode that operates frequent service (short headways), has at least 50 percent of its route on exclusive guideways, and includes features that emulate rail transit modes.
- **Trolleybus (TB)** is an electric rubber-tire bus system powered by overhead catenaries that operates on streets in mixed traffic.

Subsequently, an average vehicle occupancy factor for buses was computed with following equation from the queried data.

$$\text{AVO}_{buses} = \sum_{r=1}^{R} \frac{([2016\,\text{PMT}]_r)}{([2016\,\text{VRM}]_r)}$$

Where,

AVO_{buses} = average vehicle occupancy factors for buses;
"r" = a record in the queried data;
"R" = total number of records in the queried data;
$[2016\,\text{PMT}]_r$ = Passenger Miles Traveled in 2016 for the data record "r"; and
$[2016\,\text{VRM}]_r$ = Vehicle Revenue Miles in 2016 for the data record "r";

Using the methodology described above yielded the following:

$$\text{AVO}_{buses} = 10.7$$

2.1.3   Trucks
The discussion section for 23 CFR 490.709 of the third national performance management measures final rule[17] indicated that FHWA would provide a default occupancy factor of 1.00 for trucks.

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[16] Applicable transit agencies are required to submit VRM annually, but not all of those agencies are required to report PMT annually.

[17] Page 6021 (2nd column) of the Final Rule on "National Performance Management Measures; Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program": Docket No. FHWA–2013–0054, RIN 2125–AF54, Federal

Consequently, the FHWA provides an AVO factor for trucks of 1.00:

$$AVO_{trucks} = 1.0$$

2.1.4 Aggregation

Average Vehicle Occupancy factors for cars, buses, and trucks (determined in Sections 2.1.1, 2.1.2, and 2,1,3, respectively) were aggregated to compute an AVO factor for "all vehicles." The aggregation was done by using the vehicle miles traveled data provided in the Table VM-1 in the 2016 Highway Statistics[18]. Hence the following equation was used to compute the AVO factor for "all vehicles."

$$AVO_{all\ vehicles} = \frac{(AVO_{cars} \times VMT_{cars}) + (AVO_{buses} \times VMT_{buses}) + (AVO_{trucks} \times VMT_{trucks})}{(VMT_{cars} + VMT_{buses} + VMT_{trucks})}$$

Where,

$AVO_{all\ vehicles}$ = average vehicle occupancy factors for all vehicles;
AVO_{cars} = average vehicle occupancy factors for cars (determined in Section 2.1.1);
AVO_{buses} = average vehicle occupancy factors for buses (determined in Section 2.1.2);
AVO_{trucks} = average vehicle occupancy factors for trucks (determined in Section 2.1.3);
VMT_{cars} = vehicle miles traveled in Table VM-1 for motorcycles and all light-duty vehicles (2016 Total Rural and Urban), in millions of vehicle-miles;
VMT_{buses} = vehicle miles traveled in Table VM-1 for buses (2016 Total Rural and Urban), in millions of vehicle-miles; and
VMT_{trucks} = vehicle miles traveled in Table VM-1 for single and combination trucks (2016 Total Rural and Urban), in millions of vehicle-miles.

Consequently, the Average Vehicle Occupancy Factor for "all vehicles" is:

$$AVO_{all\ vehicles} = \frac{(1.7 \times 2,870,164) + (10.7 \times 16,350) + (1.0 \times 287,895)}{(2,870,164 + 16,350 + 287,895)} = 1.7$$

2.2 Annual Average Vehicle Occupancy Factors for Cars, Buses and Trucks for PHED Metrics in Table 2

For the PHED metrics, the AVO factors for cars and trucks are the same as determined AVO factors for the Travel Time Reliability measures in Sections 2.1.1 and 2.1.3, respectively.

Register - Vol. 82, No. 11, Pg. 5970 - January 18, 2017: https://www.gpo.gov/fdsys/pkg/FR-2017-01-18/pdf/2017-00681.pdf.

[18] 2016 Highway Statistics - Table VM-1: https://www.fhwa.dot.gov/policyinformation/statistics/2016/vm1.cfm

The Average Vehicle Occupancy factors for buses for each applicable urbanized area[19] was derived from the same dataset[20] (a spreadsheet) used in Section 2.1.2.

The following data queries were performed for data preparation for obtaining an AVO for buses for each applicable urbanized area:

(1) "VRM" Spreadsheet was joined to the data "PMT" Spreadsheet by using the values in the "X4_Digit_NTDID", "Agency_Name" ("Agency.Name"), "Mode", "Service" Fields;
(2) Filter out (exclude) records with zero or NULL PMT values in the joined dataset[21]; and
(3) select records with "Mode" Field value is equal to "CB", "MB", "RB", "TB" or "PB"[22] for obtaining records that are only pertain to buses.

Subsequently, an AVO for buses for each urbanized area was computed by grouping the values in "UZA_Name" Field in the queried dataset with equation provided below.

$$(AVO_{buses})_{UZA} = \sum_{r=1}^{R} \frac{([2016 \, PMT]_r)_{UZA}}{([2016 \, VRM]_r)_{UZA}}$$

Where,

$(AVO_{buses})_{UZA}$ = average vehicle occupancy factor for buses for an applicable urbanized area;
"r" = a record in the queried data for an applicable urbanized area;
"R" = total number of records in the queried data for an applicable urbanized area;
$([2016 \, PMT]_r)_{UZA}$ = Passenger Miles Traveled in 2016 for the data record "r" for an applicable urbanized area; and
$([2016 \, VRM]_r)_{UZA}$ = Vehicle Revenue Miles in 2016 for the data record "r" for an applicable urbanized area.

As indicated previously, the NTD data (including PMT and VRM) is updated annually. Consequently, computed Average Number of Passengers Per Vehicle values vary year to year. Bus occupancy trends

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[19] Applicable Urbanized Areas for CMAQ Traffic Congestion Measures (PHED and Percent of Non-Single Occupancy Vehicle Travel Measures) - determined in October 2017 for the first performance period. A list of applicable urbanized areas and corresponding State DOTs and MPOs are provided in Table 6 in this website - https://www.fhwa.dot.gov/environment/air_quality/cmaq/measures/cmaq_applicability/page04.cfm.
[20] NTD - TS2.1 – "Service Data and Operating Expenses Time-Series by Mode" Spreadsheet: https://www.transit.dot.gov/ntd/data-product/ts21-service-data-and-operating-expenses-time-series-mode-2
[21] Applicable transit agencies are required to submit VRM annually, but not all of those agencies are required to report PMT annually.
[22] For computing bus occupancy factor for San Juan, PR Urbanized Area, Público system (PB) data was included. The Público system is a transit mode unique to Puerto Rico, and provides fixed route services predominantly in Puerto Rico's urbanized areas. The Público system is the largest public transportation system in Puerto Rico. The biggest distinction between the Público service and other transit modes is the way in which Públicos operate. Drivers own their vehicle and are given exclusive rights to the route where they provide service. For computing bus AVO for Travel Time Reliability measures in Section 2.1.2, Público system data was excluded because this transit mode is unique to Puerto Rico.

for Years 2011 through 2016 for each applicable urbanized area is provided in a USDOT Website[23]. Note the trends are for information only. If a State DOT elects to use the FHWA provided AVO factors for PHED metrics, that State DOT must use the values provided in Table 2.

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[23] Bus Occupancy Trends from 2011 through 2016 (based on NTD Data):
https://explore.dot.gov/views/BusOccupancy/OccupancyTrendbyUZA?iframeSizedToWindow=true&:embed=y&:showAppBanner=false&:display_count=no&:showVizHome=no