User Delay Cost Issues and Proposed Solutions

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User Delay Cost Background

- Monetizes delay
- Calculated for each hour for each segment (TMC):

$$System\ Delay = \frac{Vehicle\ Miles\ Traveled}{Reported\ Speed} - \frac{Vehicle\ Miles\ Traveled}{Free\ Flow\ Speed}$$

$$System\ Delay = \frac{Vehicle\ \cancel{Miles}}{\frac{\cancel{Miles}}{Hour}} - \frac{Vehicle\ \cancel{Miles}}{\frac{\cancel{Miles}}{Hour}} = \text{Vehicle Hours}$$

- Unadjusted Vehicle Miles Traveled (VMT) calculated for each hour for each segment

$$Vehicle\ Miles\ Travel = Volume * TMC\ Length$$

Value of Time Calculations

- User Delay converted to User Delay Cost (UDC) by multiplying it by Value of Time (VOT)

  System UDC = VOT * System Delay

- Separate for passenger and commercial values
- Users can specify costs
- Defaults to TTI Values

Year	Commercial Cost	Passenger Cost
2008	81.52	16.10
2009	89.75	16.01
2010	88.12	16.30
2011	86.81	16.79
2012*	86.81	16.79
2013*	86.81	16.79
2014*	86.81	16.79
2015*	86.81	16.79

* For years we do not have costs for, we use the values from the closest year

User Delay Cost Background

- Sample screen from VPP Suite

Please be advised...

- The volume data used to generate this report may not be precise enough for your analysis. Read more...
- The per-person and per-vehicle costs shown are lower bounds. This algorithm is at its most accurate with contiguous freeway TMCs (as opposed to networks of roads or arterials).

Report parameters

- Vehicle costs
  - 2013 - Passenger: $16.79 Commercial: $86.81
- Percentage of vehicles (weighted on segment length)
  - 2013 - Passenger: 90% Commercial: 10%
- Delay is calculated against the freeflow speed for segments whose speeds fall below average.

Vehicle Type All **Display** Total cost

Total Cost

	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	Daily Totals
1/01/13	$0.3K	$0.3K	$0.1K	$0.3K	$0.4K	$1.3K	$2.6K	$2.8K	$1.5K	$0.6K	$0.5K	$0.2K	$0.4K	$0.7K	$0.7K	$0.9K	$1.3K	$2.2K	$2.8K	$1.3K	$0.6K	$0.7K	$0.6K	$0.5K	$23.6K
1/02/13	$0.3K	$0.2K	$0.1K	$0.1K	$0.1K	$0.1K	$5.3K	$1K	$0K	$0.2K	$0.5K	$1K	$0.2K	$0.3K	$0.2K	$6K	$22.4K	$51K	$16.8K	$1.4K	$0.4K	$0.3K	$0.5K	$0.7K	$109.3K
1/03/13	$0.3K	$0.2K	$0.2K	$0.1K	$0.1K	$0.1K	$6.5K	$13.5K	$7.6K	$1.8K	$11.6K	$2.4K	$0.3K	$1.1K	$3.8K	$6.2K	$33K	$29.4K	$49.3K	$20.8K	$0.6K	$0.6K	$0.5K	$0.5K	$190.5K
1/04/13	$0.2K	$0.2K	$0.2K	$0.2K	$0.1K	$0.1K	$1.9K	$2.1K	$4.9K	$0.1K	$0.1K	$0.3K	$0.1K	$0.5K	$1.2K	$2.7K	$86.3K	$140.4K	$68.2K	$1.6K	$0.6K	$2.5K	$6.1K	$4.5K	$325.1K
1/05/13	$1.3K	$0.4K	$0.2K	$0.2K	$0.2K	$0.2K	$0.4K	$0.2K	$0.1K	$0.3K	$6.7K	$1.2K	$1.8K	$1.2K	$0.2K	$0.4K	$0.3K	$1.5K	$3.6K	$0.9K	$0.8K	$0.8K	$1K	$1K	$24.8K
1/06/13	$0.5K	$0.6K	$0.3K	$0.3K	$0.3K	$0.4K	$0.5K	$0.6K	$0.6K	$0.5K	$0.5K	$0.3K	$0.3K	$0.9K	$0.6K	$0.4K	$0.2K	$0.7K	$1.2K	$1.1K	$2.2K	$1K	$1K	$0.7K	$15.6K
1/07/13	$0.9K	$0.5K	$0.6K	$0.3K	$0.1K	$0.1K	$11.7K	$32.9K	$6.7K	$2.4K	$0.1K	$0.3K	$0.2K	$0.2K	$0.3K	$1.6K	$22.5K	$35.5K	$14.8K	$0.7K	$1.2K	$1.2K	$6.5K	$5.1K	$146.6K
1/08/13	$0.5K	$0.4K	$0.2K	$0.2K	$0.2K	$0.1K	$18.7K	$44.6K	$36.2K	$10.6K	$0.2K	$0.3K	$0.3K	$0.9K	$9.5K	$35.8K	$50.1K	$62.1K	$50.2K	$3.8K	$1.1K	$1.4K	$1K	$0.8K	$329.2K
1/09/13	$0.4K	$0.3K	$0.2K	$0.2K	$0.1K	$0.2K	$7.8K	$17.9K	$28.2K	$5.8K	$0.1K	$0.1K	$0.3K	$0.2K	$6.1K	$39.9K	$38.8K	$88.2K	$36K	$6.6K	$2.9K	$0.3K	$1.6K	$1.1K	$283.2K
1/10/13	$0.3K	$0.3K	$0.1K	$0.1K	$0.1K	$0.1K	$13K	$47.2K	$45.7K	$12K	$0.2K	$0.2K	$0.3K	$0.3K	$2.7K	$24.9K	$50.1K	$80.2K	$42.4K	$1.1K	$0.6K	$0.3K	$1.1K	$0.4K	$323.9K
1/11/13	$0.6K	$0.2K	$0.1K	$0.1K	$0.1K	$0.1K	$16.4K	$43.3K	$14.6K	$0.3K	$0.2K	$0.4K	$0.9K	$1.3K	$40K	$97.8K	$150K	$200.9K	$144.7K	$18.2K	$1.4K	$1.3K	$1K	$1K	$734.8K
1/12/13	$0.9K	$0.9K	$0.3K	$0.3K	$0.2K	$0.2K	$0.3K	$0.3K	$0.1K	$0.3K	$0.1K	$0.3K	$0.3K	$0.1K	$0.3K	$3.6K	$3.2K	$1.2K	$1.2K	$28.2K	$10.1K	$1.7K	$1K	$1K	$56.1K
1/13/13	$0.4K	$0.5K	$0.5K	$0.3K	$0.5K	$0.4K	$0.8K	$0.7K	$0.3K	$0.4K	$1K	$7.3K	$23.2K	$1.5K	$0.8K	$1K	$0.9K	$3.5K	$4.3K	$2K	$1.5K	$1.1K	$0.9K	$0.9K	$54.8K
1/14/13	$0.7K	$0.4K	$0.3K	$0.2K	$0.1K	$1.3K	$49K	$55.1K	$58.4K	$6.6K	$0.3K	$0.2K	$0.3K	$0.6K	$0.1K	$3.7K	$26.2K	$40.4K	$9K	$3.8K	$1.9K	$2.5K	$2.1K	$1.1K	$264.1K

Issues involved in UDC at Network Scale

- Overestimating delay due to inaccurate volumes
- First estimate a system delay …
- Second use average trip statistic to get average user delay.

Gotcha #1

- Formulas imply that vehicles traverse the roadway within the allotted time period
  - Safe assumption if daily, or peak period
  - Dangerous assumption for hourly, 15 minute, etc.

  Ex. 10 mile segment at peak congestion of 5 miles per hour

  Time to traverse section – 2 hours

  GREATER THAN THE REPORTING PERIOD!!!
- UMD caps max delay to evaluation period

Gotcha #2

- Volume from factored HPMS volumes are used
  - Safe for average day or average peak hours calculation
  - Dangerous specific day, specific hour

  Ex. Snow storm in December in DC during rush hour, closes beltway. Reported speed is 7 mph.

  Volume based on HPMS – 6000 vph

  Actual volume – close to zero
- UMD adjusts volume based on traffic flow principles

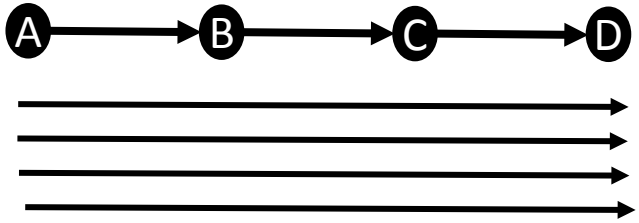
User Delay : Two Methods

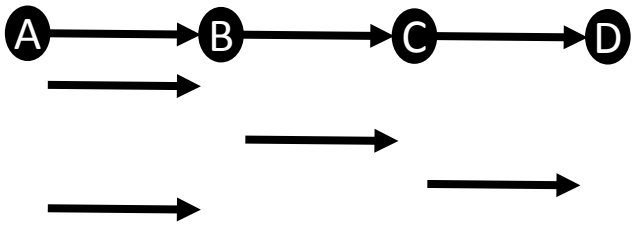
Method A

- Calculates average user delay for each segment
- Sums across all segments
  - Assumes vehicle traverses the whole network

Method B

- Calculates total delay across network
- Divide total delay by total volume
  - Average delay per segment





$$\text{Per User Delay} = \sum_i \sum_j \frac{User\ Delay_{ij}}{Volume_{ij}}$$

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i = time interval j = segment

User Delay Cost Two Different Ways

Segment	Volume (Veh)	Free flow Travel Time (Min)	Actual Travel Time (Min)	Delay (Min)	User Delay (Veh Min)
A->B	600	10	13	3	1800
B->C	1150	20	25	5	5750
C->D	700	15	20	5	3500

Method A

$$\text{Per User Delay} = \sum_i \sum_j \frac{User\ Delay_{ij}}{Volume_{ij}}$$

$$= \frac{1800}{600} + \frac{5750}{1150} + \frac{3500}{700} = 3+5+5$$

i = time interval j = segment

=13 min/user

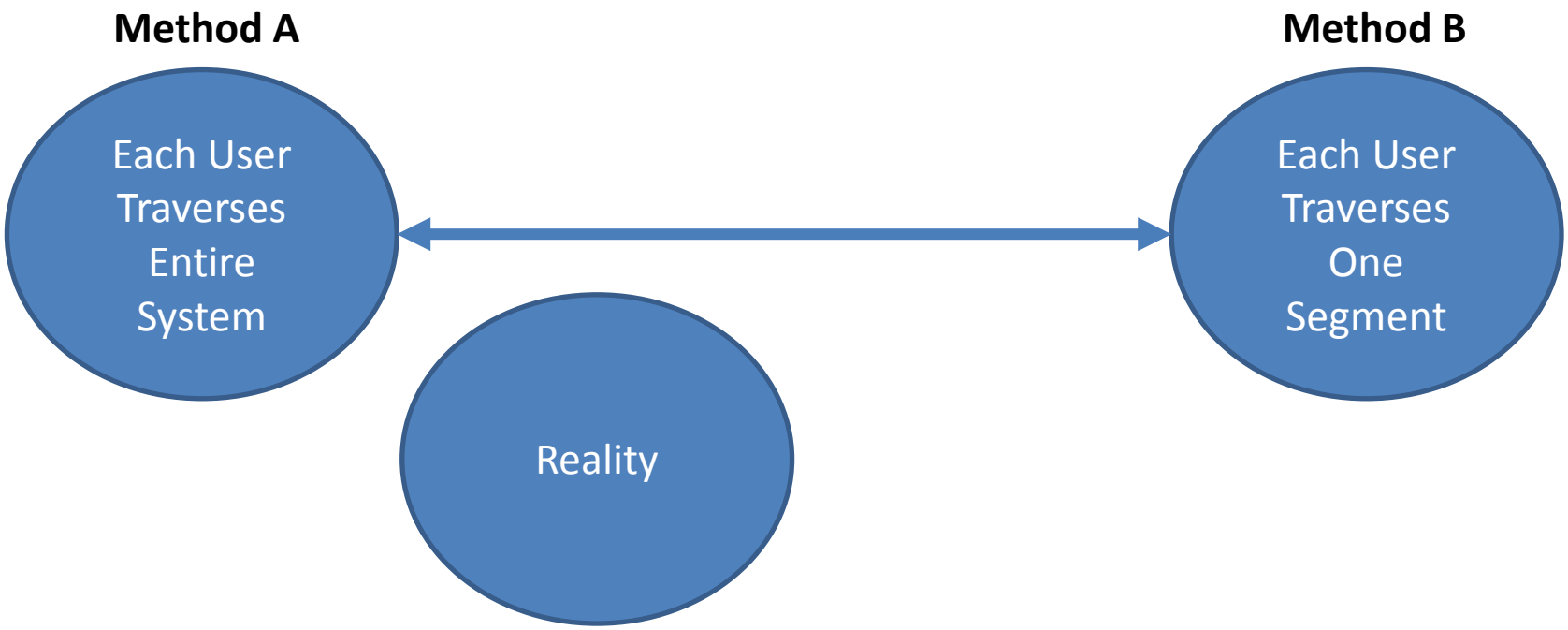
Method B

$$Per\ User\ Delay = \frac{\sum_i \sum_j User\ Delay_{ij}}{\sum_i \sum_j Volume_{ij}}$$

$$= \frac{1800 + 5750 + 3500}{600 + 1150 + 700} = \frac{11050}{2450}$$

= 4.5 min/user

User Delay Cost Spectrum



Gotcha #3

- Previous concepts for UDC defined in a corridor or segment context in which all vehicles are assumed to traverse entire corridor
- On a network level, this assumption is the root cause of the problem.
- Solution – calculate total vehicle delay per VMT, and multiply by average VMT per person

User Delay Costs with Path Data

Path Volume (Vehicles)		To		
		B	C	D
From	A	200	300	100
	B		400	350
	C			250

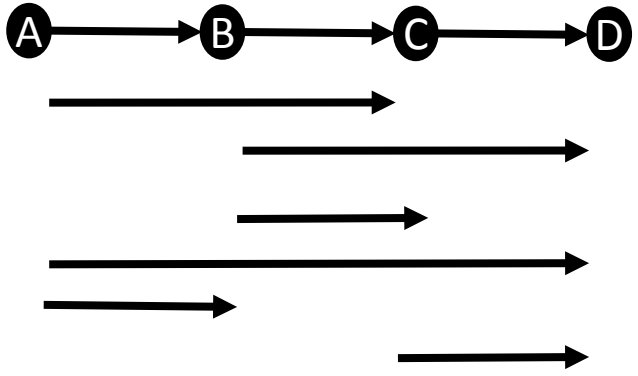
Path Delay (Minutes)		To		
		B	C	D
From	A	3	8	13
	B		5	10
	C			5

$$\text{Per User Delay} = \frac{\sum_i \sum_j Path\ Volume_{ij} * Path\ Delay_{ij}}{\sum_i \sum_j Path\ Volume_{ij}}$$

i = time interval ***j = path***

$$\text{Per User Delay} = \frac{(200*3)+(300*8)\ldots+(250*5)}{\sum_i \sum_j 200+300\ldots+250} = 6.9 \text{ minutes per user}$$

- Weighted average of the paths
- Average user delay cost
- This is what we want
- Only possible with path level data which is not available



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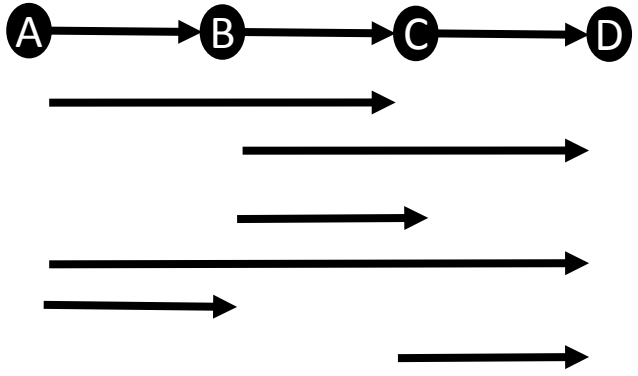

Recommended Approach

- Calculate total delay ✓
- Calculate total VMT ✓
- Calculate per VMT delay

  total delay / total VMT ✓
- Multiply Per VMT delay by average person miles - tricky
  - Need data showing average VMT traveled by user

Recommended Approach

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- Calculate total VMT ✓
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- Multiply Per VMT delay by average person miles - tricky
  - Need data showing average VMT traveled by user

That Exists!!!!!!!

VMT Rate Availability

2009 National Household Travel Survey (NHTS)

Table 30. Daily Travel Statistics by Weekday vs. Weekend
1990 and 1995 NPTS and 2001 and 2009 NHTS.

Daily Travel Statistics	1990		1995		2001		2009		95% CI	
	Weekday	Sat/Sun	Weekday	Sat/Sun	Weekday	Sat/Sun	Weekday	Sat/Sun	Weekday	Sat/Sun
Vehicle Trips per Driver	3.41	2.89	3.81	2.99	3.56	2.85	3.21	2.53	0.03	0.05
% work trips	*27.80%*	*9.70%*	*31.90%*	*12.50%*	*31.20%*	*10.60%*	*30.99%*	*10.14%*	0.58	0.65
% non-work trips	*72.20%*	*90.30%*	*68.10%*	*87.50%*	*68.80%*	*89.40%*	*69.01%*	*89.86%*	0.58	0.65
VMT per Driver	28.54	28.36	33.46	28.87	34.35	28.70	30.55	25.01	0.89	1.05
Average Vehicle Trip Length	8.47	9.96	8.85	9.73	9.75	10.22	9.62	10.03	0.26	0.46
Average Time Spent Driving (in minutes)	50.68	46.07	59.48	48.05	64.79	52.39	59.83	46.68	0.84	1.32
Person Trips	3.82	3.60	4.43	3.96	4.18	3.86	3.91	3.51	0.04	0.07
Person Miles of Travel	32.6	40.64	37.68	41.14	39.41	42.31	35.76	37.05	1.33	3.32
Average Person Trip Length	9.47	11.51	8.63	10.53	9.60	11.18	9.37	10.80	0.34	0.99

Note:

- Average time spent driving includes all drivers, even those who did not drive a private vehicle on the day in which the household was interviewed.
- Average trip length is calculated using only those records with trip mileage information present.
- 1990 person and vehicle trips were adjusted to account for survey collection method changes (see 2001 Summary of Travel Trends Appendix 2).
- "% Work Trips" also includes Work-Related Business.
- NPTS is Nationwide Personal Travel Survey. CI is Confidence Interval. VMT is Vehicle Miles of Travel. PMT is Person Miles of Travel.

National Household Travel Survey

http://nhts.ornl.gov/2009/pub/stt.pdf

VMT Rate Availability

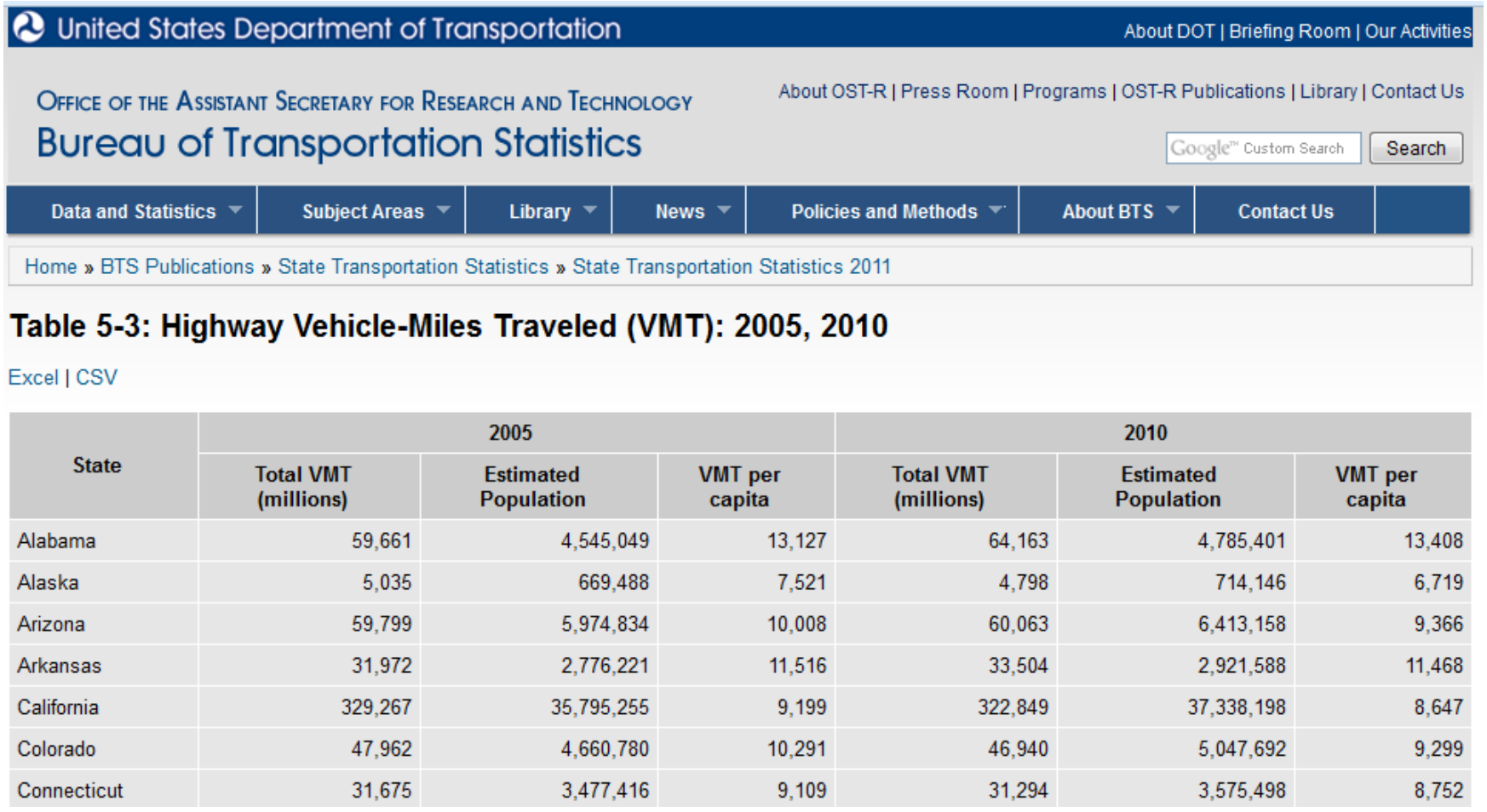

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Table 5-3: Highway Vehicle-Miles Traveled (VMT): 2005, 2010

Excel | CSV

State	2005			2010		
	Total VMT (millions)	Estimated Population	VMT per capita	Total VMT (millions)	Estimated Population	VMT per capita
Alabama	59,661	4,545,049	13,127	64,163	4,785,401	13,408
Alaska	5,035	669,488	7,521	4,798	714,146	6,719
Arizona	59,799	5,974,834	10,008	60,063	6,413,158	9,366
Arkansas	31,972	2,776,221	11,516	33,504	2,921,588	11,468
California	329,267	35,795,255	9,199	322,849	37,338,198	8,647
Colorado	47,962	4,660,780	10,291	46,940	5,047,692	9,299
Connecticut	31,675	3,477,416	9,109	31,294	3,575,498	8,752

Bureau of Labor Statistics

http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/state_transportation_statistics/state_transportation_statistics_2011/html/table_05_03.html

Solution

- Calculate per VMT Delay

$$\text{Per VMT Delay} = \frac{\sum_i \sum_j User\ Delay_{ij}}{\sum_i \sum_j Volume_{ij} * Segment\ Length_j}$$

i = time interval j = segment

- Multiply by average VMT for a person to get average delay per person
- Multiply by value time to get User Delay Cost

Thank you

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