

Speed Differences between Cars and Trucks on Freeways

Alon Bassok¹, Maren L. Outwater, P.E.², Jeff Frkonja³ and Chris Johnson⁴

Abstract

This research seeks to define the relationship between passenger vehicle and truck speeds. Misestimation of the speed differential can lead to erroneous results in both travel demand and air quality modeling. Previous approaches for this type of analysis have relied on expensive methods that are not easily replicated or on simple ones with potentially questionable assumptions. Three separate methodologies are employed for analyzing the speed gap along freeways in the Puget Sound region based on 1) GPS speed data, 2) 20-second loop detector data and 3) 5-minute loop detector data. The GPS data is used to compare directly observed speeds while the loop data attempts to separate out vehicle classes and use lane location as proxy for vehicle type. We find that (regardless of the method) truck speeds are consistently slower than passenger vehicles, though the size of the difference is dependent on the chosen methodology, specific facility, time of day and congested direction. The most promising analysis is simple to replicate and could be utilized by other regions to refine their own modeling efforts. In general, we find that heavy vehicle speeds are 10% slower than passenger cars on freeways.

¹ (Corresponding author), Associate Freight/Economics Analyst, Puget Sound Regional Council, 1011 Western Ave, Suite 500, Seattle, WA 98104, abassok@psrc.org

² Director of Data Systems and Analysis, Puget Sound Regional Council, moutwater@psrc.org

³ Program Manager for Applications, Puget Sound Regional Council, jfrkonja@psrc.org

⁴ Principal Modeler, Puget Sound Regional Council, cjohnson@psrc.org

Problems with misspecification of passenger vehicle and truck speed differences

The difference in speeds between passenger cars and heavy vehicles is generally significant with trucks traveling between 2 to 5 miles per hour (mph) slower than cars on freeways (Carlos, 2000; McMurtry et al, 2007). A variety of studies employing different methodologies consistently report truck speeds to be lower than that of passenger cars. Speeds on freeway connectors in Houston are found to be 5 to 10 miles slower for large trucks (Voigt et al, 2003). In Australia the light to heavy speed differential is 3 mph, while the South African differential is shown to be between 12-18 mph (Bester and Geldenhuys, 2007). The large discrepancy in these ranges is largely due to the truck fleet—i.e. the newer, better performing truck fleets reduce the differential. Further, the gap is larger under free-flow conditions than in congested conditions (Sun et al, 2007).

There are a variety of reasons that help to explain slower truck speeds on freeways. The three main causes include acceleration, deceleration and speed maintenance due to operating characteristics of trucks (Highway Capacity Manual, 2000). For example, trucks may operate at lower speeds since they require twice the stopping distance of cars (Perrin et al, 2007). In addition, grade must also be considered since trucks climb at a slower rate than passenger cars. However, in congested conditions and on level terrain large vehicle operate similarly to cars.

Misspecification of the speed gap has negative implications to several types of modeling applications. In travel demand models, an under-representation (or none at all) of the gap overestimates truck volumes on freeways. Conversely, a gap that is too large (over-specifying truck delay) places too many trucks on the arterial network. Further, since speed is often a part of passenger vehicle equivalency (PCE) calculations and PCEs are used to consider the impact of trucks on road conditions, erroneous depictions of truck speeds may skew modeling results (Kanargolou and Buliung, 2006). Air quality models similarly suffer from improper representation of the gap. Since trucks emit more than cars, emissions are affected by different speeds and speed is an input to modeling, it is crucial to properly specify the gap.

Truck Speeds within the Puget Sound Regional Council's Modeling Framework

The Puget Sound Regional Council's (PSRC) travel model currently does not differentiate between speeds for trucks from those of passenger vehicles. There are a series of

validation tests to determine if the truck model is producing reasonable results. Each of these involves comparing truck counts to estimated truck volumes from the model for a category of roads. Table 1 presents the summary of truck counts to modeled truck volumes by facility type, area type, and county.

Table 1: Validation of Trucks by Facility Type, Area Type and County

	Count	Volume	Locations	Difference	Percent Difference
Facility Type					
Freeways	552,755	960,468	186	407,714	74%
Arterials	679,012	267,427	581	(411,585)	-61%
Total	1,231,767	1,227,895	767	(3,871)	0%
Area Type					
Metropolitan Cities	133,081	242,469	154	109,388	82%
Core Cities	257,932	287,717	184	29,785	12%
Larger Cities	57,724	68,765	40	11,041	19%
Smaller Cities	109,757	118,726	52	8,969	8%
Rural	503,212	382,137	233	(121,075)	-24%
Unincorporated	252,714	215,052	92	(37,662)	-15%
Total	1,314,420	1,314,867	755	447	0%
County					
King	641,174	657,174	395	16,001	2%
Kitsap	34,463	71,501	54	37,038	107%
Pierce	298,734	294,377	149	(4,357)	-1%
Snohomish	257,923	205,823	174	(52,100)	-20%
Total	1,232,294	1,228,876	772	(3,419)	0%

While in aggregate, the modeled results are nearly identical to observed volumes, there are some important differences to note. The model tends to overestimate trucks on freeways and underestimate trucks on arterials. This research on the speed differential between cars and trucks on freeways is intended to correct for this discrepancy, but there may need to be additional changes to the models to validate this more closely. Some of the differences may be because freeways often use estimated counts as a percentage of total average daily traffic and these may be underestimating the actual truck count percentages. Further data evaluation on the freeway counts may assist in this determination.

The model overestimates trucks in metropolitan cities and underestimates trucks in rural areas. This may be correlated to the overestimation on freeways, since there will be more

freeway locations at higher volumes in metropolitan cities than in rural areas, but it may also indicate a bias in the models towards denser areas. A closer review of the locations where the model overestimates trucks will assist in determining next steps for validation tests.

The truck model validates well in King and Pierce counties, where the majority of the truck activity occurs, but underestimates trucks in Snohomish and overestimates trucks in Kitsap. Again, individual review of the truck count locations in these counties may aid in determining the cause or model parameters that can best address this issue.

There is another validation test that assists in the time of day model, which is to compare counts and volumes by time period. Table 2 shows the results of this test, which reflects that all time periods, are within +/- five percent of the estimate percent of trucks by time of day. These results may be used to adjust the time of day factors used in the truck model to improve upon these results. This validation test uses a subset of total counts (at 164 locations) because many truck counts are reported only for average daily conditions. The total counts indicate that the model is significantly under-estimating trucks at these locations. Additional research on the counts themselves as well as the model volumes in these locations may help to determine the cause of this underestimation.

Table 2: Validation of Trucks by Time Period

	Miles Traveled per Day		Percent by Time of Day		
	Count	Volume	Count	Volume	Difference
AM Peak	64,830	28,415	19%	22%	3%
Midday	123,525	51,577	37%	39%	3%
PM Peak	72,420	30,682	21%	23%	2%
Evening	43,894	10,610	13%	8%	-5%
Night	32,736	9,314	10%	7%	-3%
Total	337,406	130,598	100%	100%	0%

Approaches

A variety of approaches have been utilized to determine the speed gap. These methodologies differ in the representation of vehicles (direct measurement, observation or proxy), the spatial extent of the analysis and the purposes for the data. There is a clear tradeoff between required resources (in time and monetary terms) and the precision of data sets. The following discussion describes previously used methods for comparing vehicle speeds.

Global Positioning System (GPS) devices have been employed in many studies to estimate truck speeds. The use of GPS devices has the advantage of providing a real-time, accurate measure of speed and travel times (wolf et al, 1999; Quiroga and Bullock, 1998; Kane, 2004). However, there are a variety of issues related to the acquisition of such data; chief among them is the ability to have enough vehicles equipped with the devices to provide an accurate representation of speed across temporal and spatial dimensions (McCormack and Hallenbeck, 2006). This problem is particularly acute for trucks with a potential bias presented by the selection of the trucking firms to be used for a study. Further, commercial drivers have an expert understanding of the roadways they traverse and may choose less congested routes, which would potentially lead to reporting of higher speeds. Finally, it may be difficult to obtain GPS data for both cars and trucks over the same time periods and locations.

Rather than measure speed on the vehicles directly, several methods employ observation techniques to capture vehicle speeds. Radar guns may be used on the side of a road or on overpasses to measure speed. Aside from the operational cost, this method is prone to bias as vehicle operators who recognize the presence of the device may slow down and reported speeds would be artificially low (Hassan, 2003). A 'chase' car method has been effectively employed in a speed difference study in Iowa (Hallmark and Isebrands, 2005). With this method, a research vehicle follows a vehicle of interest between selected points on a road segment and can record travel time from which speed can be derived. Given the time limitations of carrying out such data collection, this method seems most appropriate for a limited number of facilities and time frame. Similarly, a 'floating car method' (used in southern California) by which a research vehicle travels a given road segment, passes as many vehicles as pass it and records travel time is prone to the same limitation. An attempt to use vehicles that normally operate on the roadway (freeway service patrol vehicles) eliminating the need for a researcher to conduct chase or float car studies has been shown to be unsuccessful (Moore et al, 2002).

A third set of approaches utilizes data from automated data collections sites. A study in Ontario, Canada utilized five tube counters to classify vehicle types and calculate speeds along three curved road sections. The promising results of this work suggest that as long as vehicle

classification is possible, speed trap data available in multiple locations across the region could be used for a large scale analysis across many corridors. In the absence of classification data, lane speeds from speed traps may be used as a proxy for vehicle types. In general, trucks tend to use the outer most lanes (especially if forced to do so by regulation) and tend to prefer the second lane in the presence of many merging vehicles (Fancher and Campbell, 1995; SCAG, 2002). This approach has been utilized in Missouri and findings suggest that the inner most lanes have the highest speed followed by the middle lanes, which are slower due to truck volumes and the outermost lanes, which are the slowest due to truck volumes but also merging vehicles (Haefner et al, 1996).

Analysis

Three separate methods are utilized for determining the speed gap between passenger cars and trucks on Puget Sound's freeways: GPS speed, short and long vehicle and in versus out lane comparisons. Available data included truck speeds gathered by GPS units as well as 20-second and 5-minute aggregate speed trap data. The results from each of the methods as well as the limitations of utilizing these approaches are discussed in the subsequent sections.

GPS Data

Five-second location and speed data from 25 portable GPS devices mounted on heavy trucks was acquired from the Washington State Transportation Center (TRAC). The data represent information from eight trucking firms operating in the Puget Sound, collected between March 2003 and June 2004 (For a further discussion of the data collection, please see McCormack and Hallenbeck, 2006). A total of 360,482 unique observation points were located on the Metropolitan Transportation System (MTS).

Fourteen individual routes were selected for the study along Interstates 5, 90, 405 and State Route 167 and 520. The data were separated by their location on a specific route—e.g. I-5 from Seattle to Everett and by three time periods: AM (6:00 a.m.-8:59 a.m.), Midday (9:00 a.m. - 14:59 p.m.) and PM (15:00 p.m. -17:59 p.m.). Only data between Tuesdays and Thursdays was considered to more accurately capture standard roadway conditions. In order to avoid overestimation of slow moving trucks or congested days, a daily average was calculated for all observations on a given segment and specific direction. The segment speed was then

represented as the average over all of the daily averages. In several instances, gaps in the data along a route prohibit the calculation of an average speed. For example, little data was available on the Evergreen Point Bridge along SR 520 in the AM period. The lack of data on these route portions suggests that truck volumes are low on these segments (or that these particular trucking firms do not choose to utilize these roadways during these time periods) and ones with fewer than 50 observations were removed from the analysis.

Unfortunately, no readily comparable data set was available for car speeds. The most useful information available from previous model assignment validation efforts (Cambridge Systematics, 2007) represents general purpose travel times (converted to speed) for the segments of interest for 2000. Since general purpose speeds include truck movements, the results of this analyses would be expected to show a smaller gap than if car and truck speeds were compared directly.

Table 3 shows the general purpose and heavy truck speeds by time period for the selected segments. An examination of the results reveals an unexpected finding, where 23 of the 34 comparisons have higher truck speed values than those for general purpose traffic.

Table 3: GPS Truck Speed Comparison Results

Corridor	Direction	Description	AM Speed		Midday Speed		PM Speed	
			GP	Truck	GP	Truck	GP	Truck
I-405	NB	from NE 8th to NE 170th	57.9	51.6	43.8	55.9	36.6	45.5
I-405	NB	from I-5 to NE 8th	27.1	41.5	32.5	44.6	42.0	36.6
I-405	SB	from NE 8th to I-5	46.7	43.3	33.7	43.4	31.6	34.9
I-405	SB	from 170th to NE 8th	57.9	38.5	44.1	53.4	36.6	29.0
I-5	NB	from 184th to Olive	34.8	43.4	46.0	47.7	42.3	49.5
I-5	NB	from Olive to SR 526	58.3	54.3	43.3	56.5	37.1	46.9
I-5	SB	from Olive to 184th	53.1	53.2	46.0	54.4	42.0	47.0
I-5	SB	from SR 526 to Olive	36.3	44.7	43.7	52.5	45.5	45.0
I-90	EB	I-5 to Issaquah	53.2	*	51.6	49.6	50.0	*
I-90	WB	Issaquah to I-5	48.4	*	52.0	39.8	47.0	*
SR 167	NB	84th to 15th	41.0	47.6	44.6	50.2	50.0	40.1
SR 167	SB	15th to 84th	59.7	53.2	43.1	55.1	32.3	41.0
SR-520	EB	I-5 to 148th	40.0	*	37.1	39.5	49.0	*
SR-520	WB	104th to I-5	43.3	*	34.6	41.3	27.4	*

Bold indicates truck speeds higher than general purpose speeds

* Insufficient GPS data

There are several potential reasons to explain the discrepancy in these results. First, the GPS and GP data were collected over different time periods, perhaps making them unsuitable for comparison. However, the truck speeds were collected later and it is unlikely that traffic conditions across all of these segments would have improved over a 3 to 4 year period to such an extent. A second potential reason is that the GPS data is not entirely representative of road conditions on these segments. Since truckers and trucking firms have access to real-time (or near to) information about road conditions, this sample of observations may represent the best possible routing choices on the given days of travel. Finally, the data from which the GP speeds were derived artificially caps speeds at 60 MPH—i.e. any observed speed over 60 MPH is reduced to a reported 60 MPH. While caps are useful for some types of analysis they cannot reflect true speed conditions, especially so since speeds often exceed posted speed limits under free flow conditions (Bernardin, 2007). Whatever the reason, in the absence of a more suitable data set for car speeds (preferably GPS data collected over the same days and locations) a different approach must be utilized in order to attain more realistic results.

Short and Long Vehicles

Twenty-second aggregate data from the Washington State Department of Transportation's (WSDOT) mainline loop detectors (speed traps) is available along Puget Sound's major freeways. The obtained data provides an average speed for the time interval and a count for the number of vehicles within four vehicle length classes. The first class of lengths less than 26 feet was used as a proxy for cars while the remaining classes (over 26 feet) were combined to represent trucks. Despite potential undercount or loop error issues, the long vehicle classification is a reasonable means by which to gather information on trucks (Zhang et al, 2005).

While other long vehicles—e.g. buses or RVs also fall into the latter classification bins, their contribution to overall volumes is relatively small. For example, on south bound I-5 at milepost 184 north of Lynnwood there are slightly over 5,500 long vehicles in the AM period with less than 100 buses, slightly less than 2%. As a further illustration, on northbound I-405 north of milepost 9 and south of I-90 there are slightly over 1,200 long vehicles in the AM period, but only 21 buses, again, less than 2%. Buses also possess an advantage over trucks on

freeways in that they may utilize HOV facilities, which are outside the scope of this analysis. On mainline freeway lanes, buses are assumed to travel in a similar manner to trucks suggesting RVs are of greater concern. Since RVs possess a smaller passenger car equivalency (PCE) value than trucks (1.2 and 1.5 respectively), the absence of an explicit treatment of them in the analysis would yield slightly higher truck speeds than would otherwise be the case. However, RV operators are not professional drivers, which impacts their performance and in the presence of a 5:1 truck to RV ratio, their performance can be assumed to be identical (Highway Capacity Manual, 2000). As such, no attempt was made to explicitly address the different types of long vehicles. It should be noted that this analysis does not consider light trucks since it would be impossible to separate small commercial vehicles from ones for personal use in the short vehicle category. However, this issue is of minor concern since the speed for light trucks has been shown to be virtually the same as for passenger cars (Hallmark et al, 2004).

Prior to conducting an analysis of the speed gap for short and long vehicles, a comparison was made between the GPS data and the speed trap data for trucks (long vehicles in bins 2-4). Points from the GPS dataset that were adjacent to a speed trap (within ¼ mile ahead of the monitor for each travel direction) were averaged utilizing the previous methodology to represent the GPS truck speeds. Speed trap data for the same days and time periods as the observations from the GPS dataset were retrieved. Observations with faulty data were removed and only observations with bins 2, 3 and or 4 were considered. An average speed was calculated for each day and then again averaged over all of the days. As an illustration, speed trap ES-167D at I-5 and 145th St, which consistently reports accurate data, yielded 59 unique GPS observation points over 6 days (for Tuesday through Thursday only). While there is some daily variability (see Table 4) between the results of the two methods, the average speeds are quite similar (within less than 3%). These findings are replicated elsewhere along the network, with all average speeds using the long vehicle classification being within 5% of the GPS truck speeds.

Table 4: Comparison of GPS Truck and Long Vehicle Speeds

Date	GPS		Bins 2, 3 & 4	
	Speed	Observations	Speed	Observations
6/18/2003	51.0	9	44.2	283
6/25/2003	42.3	11	48.1	301
7/1/2003	53.6	7	56.2	322
9/9/2003	42.6	12	41.4	291
9/23/2003	52.0	10	43.1	295
5/25/2004	33.2	10	35.8	260
Average of days	45.8		44.8	

Since the long vehicle speeds appeared comparable to the speeds derived from the GPS data, a full analysis was conducted over all routes previously considered. Speed trap data was examined for Tuesdays through Thursdays in April, 2006. The specific month and days were chosen as they most accurately represent normal roadway conditions. Data was used from 90 monitoring locations (representing 97,200 observations) along five highways, (I-405, I-5, I-90, SR 167 and SR 520). All ramp counters and observation on HOV lanes were not considered and faulty readings were omitted. The average speed by day, vehicle type and time period was calculated for each of the monitoring locations resulting in a final averaged figure over all days. A weighted average based on road segment length was then used to calculate speeds for specific highway corridors.

Only observations for which cars or trucks were present, but not both, were used for the analysis. The aggregation of the data to 20-second intervals removes the ability to utilize individual classification observations. The exclusion of all other observations thus allows for an estimation of speeds isolated by vehicle class, which would more closely resemble the information that could be obtained from direct observation or GPS data as discussed in the comparison of the speed trap and GPS data. However, since a significant amount of observations are omitted, the final results may potentially be skewed to represent only the fastest moving cars and the slowest moving trucks.

Unlike the results from the GPS analysis, the speed trap truck speeds are consistently lower than car speeds across time periods and different facilities (see Table 5). When considering all segments, the AM difference in speeds is 8.6 MPH while for the PM it is 10.2

MPH. The higher difference for the PM period reflects the generally lower overall speeds and higher congestion levels. When only the congested direction is considered in each time period, trucks move even slower than cars in the AM period with a difference of 11.6 MPH while the PM difference remains constant. This result is somewhat counterintuitive since in congested times all vehicles travel at slower speeds and the gap in speeds is expected to be smaller.

Table 5: Short and Long Vehicle Speed Differences

			Speed			T-Test Results	
			Minimum	Mean	Maximum	t	P
All Segments	AM	Cars	45	58	64	2.41	0.025
		Trucks	29	49	61		
Congested Direction Only	PM	Cars	36	55	63	2.98	0.007
		Trucks	21	44	58		
Congested Direction Only	AM	Cars	45	53	61	2.42	0.036
		Trucks	29	42	53		
Congested Direction Only	PM	Cars	36	52	63	1.61	0.138
		Trucks	21	42	58		

While trucks are slower than cars on all facilities, the difference is considerably larger on some facilities (see Table 6). I-90 has the highest differential in the AM, while SR 167 does so in the PM. SR 167 has the lowest spread in the AM with I-5 has the lowest in the PM. In general, higher car speeds reflect a bigger differential. However, some facilities encounter more variability than others with SR 520 (which has considerably fewer truck trips in the peak periods than the other facilities) experiencing the least, while SR 167 encounters the most.

Table 6: Speed differences (car - truck) from Short and Long Vehicle Analysis

Corridor	Description	AM Peak				PM Peak			
		AM short	AM long	Difference	Percent Difference	PM short	PM long	Difference	Percent Difference
I-405	NB from NE 8th to NE 170th	61.5	55.5	6.1	-10%	48.4	36.5	11.9	-25%
I-405	NB from I-5 to NE 8th	47.5	30.9	16.6	-35%	57.4	54.2	3.7	-5%
I-405	SB from NE 8th to I-5	58.0	53.3	4.7	-8%	36.0	21.3	14.7	-41%
I-405	SB from 170th to NE 8th	45.5	28.9	16.6	-37%	57.1	49.8	6.8	-13%
I-5	NB from 184th to Olive	51.3	41.5	9.8	-19%	53.5	46.4	7.1	-13%
I-5	NB from Olive to SR 526	63.6	60.2	3.4	-5%	55.4	45.5	10.0	-18%
I-5	SB from Olive to 184th	62.5	58.2	4.3	-7%	55.5	49.2	6.4	-11%
I-5	SB from SR 526 to Olive	59.7	52.6	7.1	-12%	57.5	48.7	8.8	-15%
I-90	EB from I-5 to Issaquah	61.3	49.7	11.6	-19%	62.9	57.8	5.1	-8%
I-90	WB from Issaquah to I-5	61.5	50.3	11.1	-18%	60.3	45.4	14.9	-25%
SR 167	NB from 15th to 84th	54.1	45.5	8.2	-16%	55.4	35.5	19.9	-36%
SR 167	SB from 84th to 15th	64.4	61.0	3.4	-5%	55.7	42.5	13.2	-24%
	Average Weighted	57.1	46.8	10.3	-18%	53.7	42.5	11.2	-21%

Although the relationship of truck to car speeds meets the expectation that trucks travel slower, the overall gap is consistently larger than would be expected. As noted earlier, 2-5 MPH would be the general range for the gap, while this analysis finds the gap to be between 3.4 and 19.9 MPH (the mean gap is 9.5; the standard deviation is 4.4) or 18% and 21% in the AM and PM periods, respectively. These results suggest that either conditions on the selected roadways are close to free-flow allowing for general speeds above the posted limits or the exclusion of all observations where both cars and trucks were present led to a biased sample.

In order to address the first problem, the same methodology was utilized for April, 2000. The 2000 analysis replicates the finding that trucks travel slower than cars. However, across all routes and modes, the 2006 speeds were higher than those for 2000. This comparison over time clearly identifies a methodological flaw since the opposite should be true as congestion did not improve across these routes over the 6-year time frame. An attempt was made to account for all of the data that had been previously excluded. A simple OLS regression on speed as a function of the percentage of cars including all 20-second observation not just those with car or trucks only again indicates that trucks travel slower than cars at all locations. A comparison of car speeds (100% cars) to the mean observed fleet mix intuitively yields a smaller gap than a

comparison of car and truck speeds. For example, on northbound I-5 from Seatac to Seattle in the AM period, the regression speed gap is 2.2 MPH, while the gap for car/truck only observations is 9.8 MPH. Figure 1 illustrates the distribution of observation points at two speed trap locations along I-5 with respect to the percent of cars and speed. These results are instructive but cannot separate out the average speed for cars and that for trucks, which would be necessary for determining the gap.

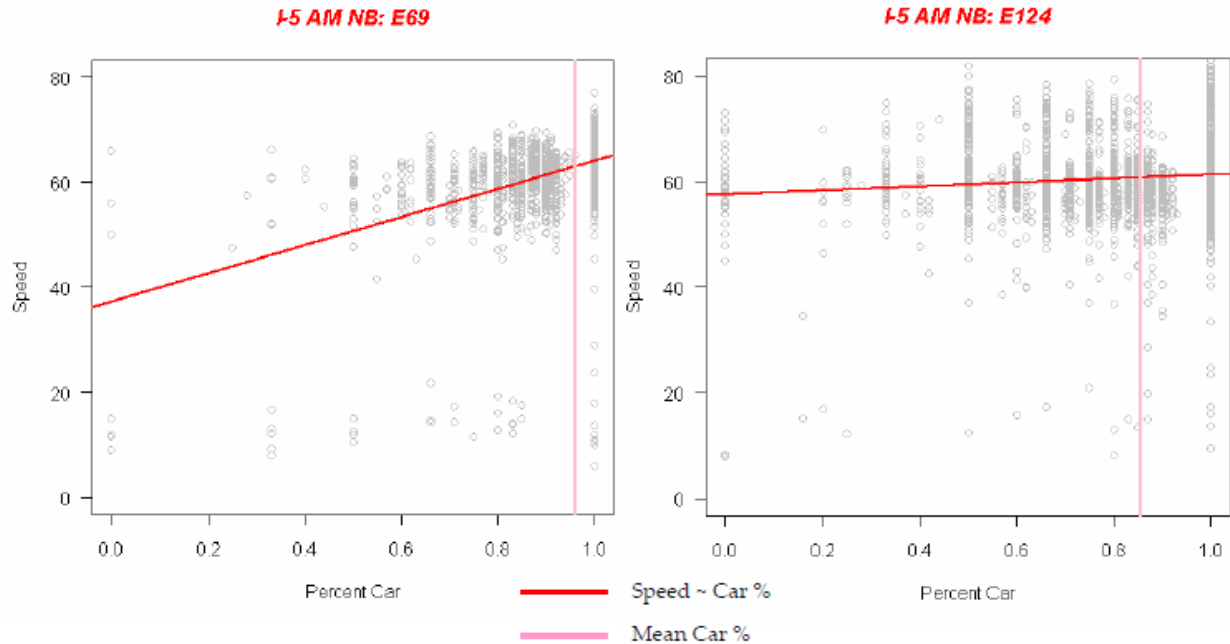


Figure 1: Speed and Car Percent at Select Speed Traps

While a comparison of the speed differences could be conducted with classification information, it requires data that is disaggregated to individual observations. Despite the rich source of information offered by the 20 second aggregation, it is not possible to sufficiently isolate truck and car movements for the purposes of comparing the speed gap. As such, a third approach is considered to address the question.

In and Out Lanes

As previously mentioned, since trucks and cars generally occupy different lanes of a freeway facility, it is possible to compare the most non-HOV inner lane (a proxy for cars) with the outer most lane (a proxy for trucks). This approach circumvents the necessity to classify vehicles allowing for the use of all available data on a given roadway segment. Further, over

large time periods—e.g. the PM peak, there is no reason to consider disaggregate data at 20-second intervals.

5-minute speed averages at 54 locations were retrieved from WSDOT's Northwest Region Traffic Data for Tuesday through Thursday in March of 2006 for the same highways as previously considered. The 5-minute data is aggregated from 20-second observations, are retrievable through the CDR (Compact disc Data Retrieval) Analyst tool and can be aggregated to any time period—e.g. PM peak (for a further discussion of this data set and the CDR analyst please see Nee et al, 1999). To maximize the accuracy of utilizing lane speeds as a proxy for vehicle types, the analysis consciously deviated from the theoretical framework by considering the second lane as opposed to the outermost lane for the truck speed measure since the outermost lane may be representative of truck speeds, but also merging traffic.

At each sampling location an average speed across all days was calculated by time period and lane. A weighted average by road segment length was utilized to obtain the speeds across larger freeway sections. Similar to the findings attained by the short and long vehicle analysis, all truck speeds are predictably lower than car speeds. However, the gap in speeds is considerably smaller and is well within the range of gaps found in similar regions in the US, falling between .2 and 12.8 MPH (the mean is 5.1; the standard deviation is 3.1) or 11% and 9% for the AM and PM periods, respectively. Further, when individual corridor gaps are compared to the regressed results accounting for all observation in the 20-second data set, the findings are virtually identical. For example, on northbound I-5 from Seatac to Seattle the speed gaps are 2.7 and 2.2 MPH respectively, a notable improvement over the short and long vehicle method.

The size of the gap again varies widely by time of day and individual facilities. The smallest gap is seen on westbound I-90 from Issaquah to Seattle in the PM, while the largest gap is on the same facility in the AM eastbound direction (See Table 7). Further, northbound I-405 into Bellevue has the lowest speeds but the largest gap in the AM while eastbound I-90 has the highest speeds and largest gap in the PM. Over all of the facilities the gap is 5.6 mph in the AM peak and 4.5 mph in the PM peak. In the peak direction, the average gap is 5 mph in the AM peak and 5.5 mph in the PM peak. While it is expected that the gap would be larger in the non-

congested direction, there is only a slight positive relationship between car speeds and the size of the gap.

Table 7: Speed Differences (Car - Truck) from In and Out Vehicle Analysis

Corridor	Description	AM Peak				PM Peak			
		AM short	AM long	Difference	Percent Difference	PM short	PM long	Difference	Percent Difference
I-405	NB from NE 8th to NE 170th	54.4	52.1	2.3	-4%	48.8	47.0	1.7	-4%
I-405	NB from I-5 to NE 8th	46.4	35.7	10.7	-23%	54.5	49.3	5.2	-10%
I-405	SB from NE 8th to I-5	53.0	49.1	4.0	-7%	45.5	38.0	7.5	-17%
I-405	SB from 170th to NE 8th	51.6	46.8	4.9	-9%	54.5	49.1	5.3	-10%
I-5	NB from 184th to Olive	48.7	46.0	2.7	-6%	54.5	52.7	1.8	-3%
I-5	NB from Olive to SR 526	60.4	56.0	4.3	-7%	54.5	51.5	3.1	-6%
I-5	SB from Olive to 184th	61.3	54.0	7.3	-12%	55.0	48.8	6.2	-11%
I-5	SB from SR 526 to Olive	51.0	43.6	7.4	-15%	56.1	48.8	7.3	-13%
I-90	EB from I-5 to Issaquah	63.9	51.1	12.8	-20%	64.4	56.8	7.6	-12%
I-90	WB from Issaquah to I-5	55.4	52.1	3.3	-6%	58.3	58.1	0.2	0%
SR 167	NB from 15th to 84th	55.0	53.8	1.2	-2%	57.9	56.7	1.2	-2%
SR 167	SB from 84th to 15th	59.3	52.8	6.4	-11%	55.2	48.3	6.9	-12%
	Average Weighted	54.7	48.6	6.1	-11%	54.7	50.0	4.7	-9%

Given the contradictory results found in the short and long vehicle analysis comparison over time, the in and out lane method was repeated for March of 2000. The temporal comparison of the in and out method leads to reasonable results and most corridors have higher speeds in the earlier year. The gap in speeds remains unchanged in the AM and grew by slightly over 1 MPH in the PM. The gain in the PM gap is solely attributed to improved speeds for cars as the truck speeds remain unchanged perhaps suggesting that worsening congestion/travel times have not had a significant impact on truck movements on these selected corridors. It is worth noting that while the short/long vehicle analysis did not yield reasonable estimates of the speed gap, the two methods compare favorably in terms of the overall relationships of speeds on selected routes (See Figure 2)

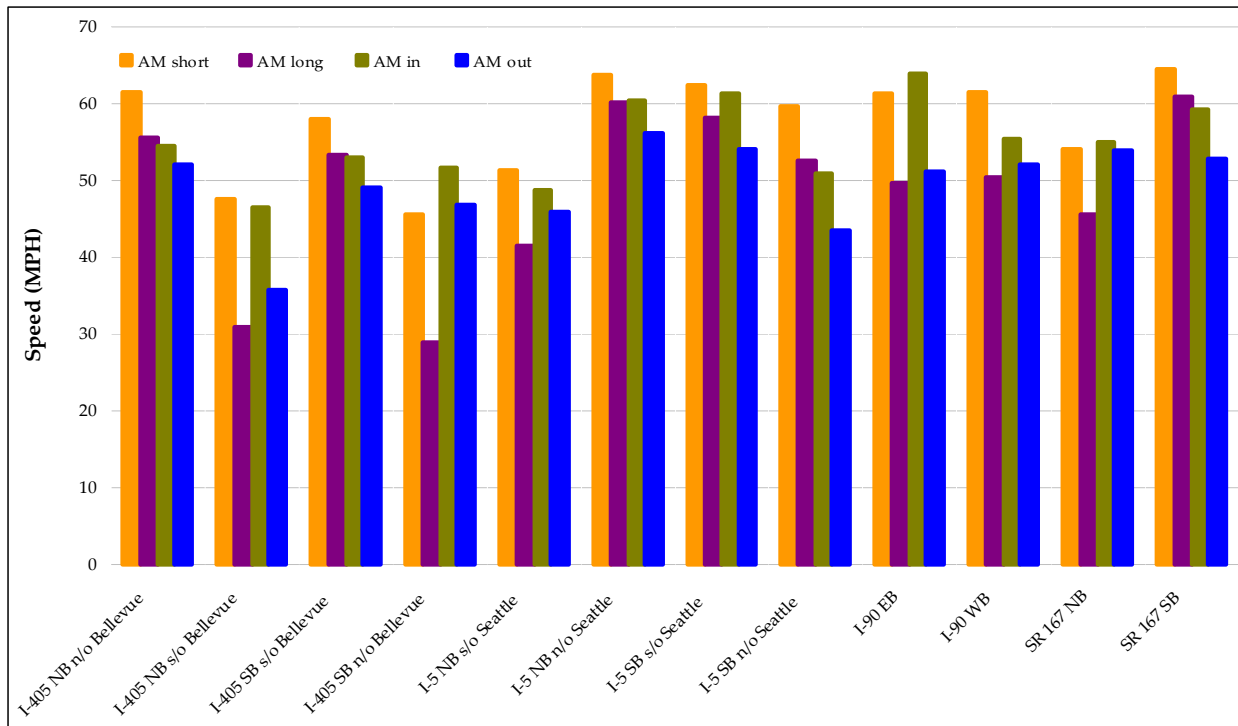


Figure 2: Method Comparison – AM 2006: Long/Short Vehicles & In/Out Lanes

Summary

Of the three methods attempted in this research, the in and out lane comparison yields the most promising results. This method, while having the limitation of relying on several assumptions rather than direct observation is the simplest to conduct and provides the most reasonable estimates, given the reliance on existing data sources. For the specific freeway segments considered in 2006, trucks traveled by an average of 10% slower than cars. This gap is virtually unchanged from 2000. As such, it is suggested that the model represent truck speeds as being 10% slower than car speeds across freeway facilities.

Undoubtedly, it would also be useful to systematically compare the speed difference on other facilities—e.g. arterials, though secondary data sources are not readily available to carry out such an analysis. However, with proper estimation of the speed gap on freeway facilities,

the gap on arterials is of less import as trucks and cars would be subject to the same road (e.g. queuing) conditions, especially on one-lane roadways.

While the short and long vehicle speed comparison yielded suspect results, the methodology deserves further exploration. The data from speed traps is aggregated to 20-second intervals out of a necessity to reduce disk storage capacity. If a coordinated data collection effort is possible, it would be useful to collect disaggregate speed data and repeat this analysis with a fully classified data set. In order to keep the storage and transmittal of an immense data set to a minimum, specific days and time periods could be considered as was done for this analysis. Nonetheless, in the absence of such data, the in/out lane analysis is sufficient in order to provide a rough estimate of the overall gap.

References

BERNARDIN, LOCHMUELLER & ASSOCIATES, INC. (2007) The I-69 Evansville to Indy study prepared for the Indiana Department of Transportation. Tier 1, Draft EIS, Appendix 5.

BESTER, C. & GELDENHUYS, F. (2007) Speed trends on major roads in South Africa, 26th Annual Southern African Transport Conference, CSIR International Convention Centre, Pretoria, South Africa, Document Transformation Technologies, pp. 600-609.

CAMBRIDGE SYSTEMATICS, INC. (2007) PSRC Travel Model Documentation (for Version 1.0) Updated for Congestion Relief Analysis.

CARLOS, S. (2000) An investigation in the use of inductive loop signatures for vehicle classification, California PATH Research Report: UCB-ITS-PRR-2000-4.

FANCHER, P. & CAMPBELL, K. (1995) FHWA Comprehensive Truck Size and Weight (TS&W) Study. Phase 1 - Synthesis. Vehicle Characteristics Affecting Safety and Truck Size and Weight Regulations. Working Papers 1 and 2 Combined. 45 p. Report No. FHWA Docket No. 95-5.

HAEFNER, L., LI, M. & PORRELLO, A. (1996) Preliminary data collection and analysis for traffic flow management on a freeway corridor, Semiquicentennial Transportation Conference Proceedings, Iowa State University, Ames, Iowa.

HALLMARK, S. & ISEBRANDS, H. (2005) Evaluating speed differences between passenger vehicles and heavy trucks for transportation-related emissions modeling, *Journal of the Air and Waste Management Association*, 55, pp. 1441–1450.

HALLMARK, S., KNAPP, K. & GRANT, C. (2004) Evaluating speed differences between cars, light-duty trucks, and van for emissions modeling, *Journal of Transportation Engineering*, 130, pp. 814–817.

HASSAN, Y. (2003) Traffic and speed characteristics on two-lane highways: field study, *Canadian Journal of Civil Engineering*, 30, pp. 1042–1054.

HIGHWAY CAPACITY MANUAL (2000) National Research Council, Washington, DC.

KANAROGLOU, P. & BULIUNG, R. (2008) Estimating the contribution of commercial vehicle movement to mobile emissions in urban areas, *Transportation Research Part E*, 44, pp. 260–276.

KANE, T. (2004) GPS Technology Improves Travel Time Data Collection. TMIP Connection. Federal Highway Administration, Spring, pp. 2.

MCCORMACK, E. & HALLENBECK, M. (2006) ITS devices used to collect truck data for performance benchmarks, *Transportation Research Record*, 1957. pp. 43–50.

MCMURTRY, A., KNIPLING, R. & HARWOOD, D. (2007) Compatibility of trucks and buses with the roadway environment, *Transportation Research Board*, *Transportation research circular number E-C117: The domain of truck and bus safety research*, pp. 138–146.

MOORE, J., CHO, S & MEZGER, D. (2002) Feasibility of using service patrol trucks as probe vehicles, *Journal of Transportation Engineering*, 128, pp. 528–536.

NEE, J., ISHIMARU, J. & HALLENBECK, M. (1999) Evaluation tools for HOV lane performance monitoring, *Washington State Transportation Center (TRAC)*, Report: WA-RD 473.2

PERRIN, D., CLARKE, R., KNEE, H., KREEB, R., PEREL, M., RAU, P. & SVENSON, A. (2007) Vehicle design and technology, in *The domain of truck and bus safety research*, *Transportation Research Circular number E-C117* pp.123–137.

QUIROGA, C.A. AND BULLOCK, D. (1998) *Travel Time Studies with Global Positioning System and Geographic Information Systems: An Integrated Methodology*. *Transportation Research Part C: Emerging Technologies*, 6C, pp. 101-127.

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS (2002) *Goods movement truck count study*.

SUN, X., CHEN, Y., HE, Y., LIU, X. & HU, J. (2007) Characteristics of traffic crashes on freeways in China, *Transportation Research Record*, 2038, pp. 148–155.

VOIGT, A., FENNO, D. & BORCHARDT, D. (2003) Evaluation of vehicle speeds on freeway-to-freeway connector ramps in Houston, Texas *Transportation Institute*, Report 4318-1.

WOLF, J., S. HALLMARK, M. OLIVEIRA, R. GUENSLER, AND W. SARASUA. (1999) Accuracy Issues with Route Choice Data Collection Using GPS. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1660, TRB, National Research Council, Washington, D.C., pp. 66-74.

ZHANG, X., NIHAN, N. & WANG, Y. (2005) Improved dual-loop detection system for collecting real-time truck data, *Transportation Research Record*, 1917, pp. 108–115.