Improving National Travel Estimates for Combination Vehicles

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In each annual publication of *Highway Statistics*, FHWA estimates overall travel by broad type of vehicle and type of highway, in the VM-1 table, based on estimates of travel provided by each of the states. These published vehicle miles of travel (VMT) estimates provide control totals for policy and research studies throughout U.S. Department of Transportation (DOT) and by outside the department. Several sources of systematic bias, which together create a tendency to overcount combination vehicles, have been reported and analyzed in a series of studies. In addition, FHSA's inclusion of vehicles towing light trailers along with other combination vehicles produces some misunderstanding and misapplication of data. If light vehicles were excluded from FHWA's combination truck VMT estimates, the published numbers would be closer to VMT estimates from other sources, notably those of the Truck Inventory and Use Survey (TIUS). If FHWA further compensated for the temporal distribution bias that appears to be prevalent in state classification studies, its published numbers would be very close to TIUS estimates of combination truck VMT. This paper presents several recommendations that FHWA may wish to consider in order to improve its estimates of truck VMT, especially for combination vehicles.

This paper explores the possible problem of overestimating combination vehicle travel and suggests methods usable in the short and long terms to compensate for this overcounting. In this discussion, we begin by evaluating alternative vehicle miles of travel (VMT) estimates and describing specific mechanisms which contribute to a possible overestimation of combination vehicle travel. We then describe how combination vehicle travel estimates would decrease if we exclude light combination vehicles. Finally, we recommend ways to improve vehicle class travel estimates in FHWA's VM-1 table, focusing especially on estimates of combination vehicle travel.

The VM-1 table annually published in *Highway Statistics*, derived from travel estimates reported by the states, contains the official FHWA estimate of overall travel by broad type of vehicle and type of highway, as well as vehicle population, person-miles of travel, and fuel consumption by type of vehicle. These numbers provide control totals for virtually all FHWA policy studies, and for many other studies and programs throughout the U.S. Department of Transportation (DOT). NHTSA, for example, derives accident rates using their accident figures and the travel estimates in VM-1.

The widespread use of VM-1 requires FHWA to proceed with caution in revising the table or the methods used to derive the numbers. By the same token, many users inside and outside DOT deserve to expect the highest level of accuracy possible in the numbers published in VM-1.

In a previous analysis in 1991, sponsored by the Association of American Railroads (AAR), we critically reviewed the main source for the VM-1 table: the Highway Performance Monitoring System (HPMS) areawide travel reporting form, focusing on heavy trucks.

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We surveyed the states to find out more about how they derive the data reported to FHWA (*1*).

In a 1992 study, we suggested that FHWA might consider eliminating the areawide form and moving instead to a system of having states submit raw classification data, as they now submit raw truck weight data (*2*). This would shift the analysis burden to FHWA, but would allow better knowledge of the likely accuracy of combination vehicle VMT estimates.

In a third study, we analyzed 1 year's worth of 24-hr classification data from six stations in Southern California to assess the temporal variation in travel by various types of vehicles. Most of the stations were in either a heavily urbanized or fringe urban area in a single state, so we cannot generalize the results, but we found that the classification sampling times favored by nearly all states would have resulted in substantial overcounting of combination of vehicles at these six stations. We also found significantly different time-distribution patterns even on these nearby Interstate highways.

In addition to these evaluations, we made extensive use of available WIM data as part of an earlier research contract sponsored by FHWA to review and enhance cost allocation methods (1990–1991). We found many inconsistencies between the axle data and the classification of the vehicle, and recommended to FHWA a procedure to correct classification data based on our findings.

All of these studies share a common thread in finding that the procedures currently used by the states to report travel data to FHWA may tend to be overcount combination vehicles, or at least heavy combination vehicles.

EVIDENCE OF THE PROBLEM

Raw vehicle classification data reported by states under the HPMS areawide reporting system contains many apparent anomalies and inconsistencies. As previously reported in studies cited above, reported travel by combinations in some states fluctuates wildly from year to year. One state, for example, reported that overall combination vehicle travel quintupled from one year to the next. Statewide combination travel comprised 5.3 percent of statewide total traffic one year, whereas the next year it comprised 28 percent of statewide total traffic.

Also as reported previously, few states compensate for the systematic bias caused by weekday classifications, when trucks comprise a larger portion of the traffic stream than they do on weekends. FHWA cannot adequately compensate for the states' failure to account for this bias because of inadequate data and insufficient information submitted by the states.

Not surprisingly, given the poor raw material, FHWA-truck VMT estimates on the VM-1 table disagree substantially with other notable national truck VMT estimates.

The Census Bureau's quinquennial Truck Inventory and Use Survey (TIUS) provides perhaps the most reliable (but unfortunately only periodic) alternative source of national VMT estimates. Table 1 compares 1987 TIUS estimates with 1987 Highway Statistics VM-1 truck VMT estimates. As shown in the table, FHWA and TIUS estimates for pickup and van VMT agree very closely, whereas FHWA overestimates other single-unit truck VMT by 36 percent, and combination VMT by 51 percent compared with TIUS. We derived the TIUS-based estimates from the public use tape, adjusting to account for off-road travel, travel by combination power units without trailers, and travel by government vehicles.

How accurate are TIUS estimates? No one really knows, since no good alternative source exists. The large sample of vehicles included in TIUS, however, should produce accurate estimates of annual miles of travel by vehicle type, absent systematic bias in the responses.

FHWA has often contended that survey respondents underreport miles of travel and that actual counts produce more reliable answers. They base this assessment on experience with household surveys and reporting of individual trips. Consider, however, the findings of the University of Michigan's Transportation Research Institute (UMTRI), in their National Truck Trip Information Survey (NTTIS). UMTRI compared (*a*) actual truck odometer readings, (*b*) operators' estimates of annual miles, and (*c*) annual mileages implied by quarterly single-day trip reports.

Affirming FHWA's conventional wisdom that trip surveys tend to underreport miles traveled, UMTRI found that truck drivers reported fewer miles in trip logs than could explain their odometer readings (by 35 percent for single units and 33 percent for combinations). More important for our analysis, however, UMTRI found that operators systematically overestimated annual mileages (by 38 percent for single units and 28 percent for combinations). This implies that any systematic bias in TIUS may overestimate travel, not underestimate it.

To further support TIUS estimates, consider diesel fuel consumption. When you replace missing and invalid responses on the TIUS data tape with averages for particular vehicle types, TIUS estimates diesel consumption in 1987 at 16.62 billion gallons for vehicles within its scope. When you add diesel-burning private and commercial buses (0.51 billion gallons), diesel automobiles (1.24 billion gallons), and spillage/evaporation (0.09 billion gallons), you get a TIUS-based estimate of 18.46 billion gallons of taxable diesel consumption in 1987, slightly above the 18.42 billion gallons reported by *Highway Statistics*. In other words, TIUS reports sufficiently high VMT to explain reported diesel fuel consumption.

As further evidence of the problem, consider our recent brief analysis of data from continuous classification stations. We obtained 24-hr classification data for 12 full weeks (the first complete week of each month) throughout the year for six stations in California. We tabulated the weighted average percent trucks for all hours, and then for the common hours during which various states take typical classification counts for reporting HPMS areawide data.

Some states classify for 14–16-hr periods, some for 6–8 off-peak hours, and some collect data only during the summer months. Virtually all states classify only on weekdays; some also avoid Mondays and Fridays.

TABLE 1 Comparison of 1987 Travel Estimates (in Millions of Miles)

Vehicle Type	Adj TIUS	VM-1	Difference
Pickups and Vans	417,612	416,008	- 0.4%
Single-Unit Trucks	36,571	49,613	+35.7%
Combination Trucks	57,268	86,334	+50.8%

This analysis produced striking findings. As shown Table 2, every candidate period of classification produced overestimates of truck travel. We interpret these findings as evidence of the systematic time period bias that occurs because of weekday daylight-hour traffic counting. This systematic error ranges from an overcounting of combinations of from 14 to 61 percent for these particular six traffic classification stations.

This analysis may or may not typify the national situation, and reliable state-by-state correction factors obviously require much more analysis. This analysis implies, however, the need for very large correction factors to state-reported HPMS areawide data. If a state classifies for 10 hr on all weekdays during the summer months, for example, they should reduce combination travel estimates by 30 percent and single-unit truck travel estimates by 16 percent. If a state classifies for only 6 hr on Tuesdays to Thursdays, they need to reduce combination travel estimates by 56–61 percent.

In summary, we have found ample evidence to suggest significant overreporting of truck VMT on the VM-1 table. TIUS, comparisons with diesel consumption, and the nature of the classification sampling process itself all suggest very large overestimates of combination vehicle travel and slightly smaller overestimates of single-unit truck travel.

DEFINITION OF COMBINATION VEHICLES

Part of the problem of overreporting may stem directly from differing definitions of combination vehicles. The HPMS Field Manual defines 13 vehicle classes for which states report areawide classification data. Three of these classes include light passenger vehicles, one includes buses, three include single-unit trucks, and the remaining six include combination trucks.

The six combination truck classes include all vehicles with a power unit (either a tractor or straight truck) and one or more additional units (either full or semi trailers). Two-axle, four-tire power units with "recreational or other light trailers" are not included as combinations but are retained in one of the light passenger vehicle classes.

Except for two-tire, four-axle trucks towing medium or heavy trailers, the HPMS field manual draws the boundary between light passenger vehicles and single-unit trucks based on the number of tires. If a vehicle has six or more tires, it is a single-unit or combination truck. If it has four tires, it is not.

TABLE 2 Truck Overcount Ratios by Time Period

Sample Time Period			Single-Units	Combinations
6 to 8	M to F	All Months	1.050	1.141
6 to 8	M to F	May to Sept	1.104	1.201
6 to 8	T to Th	All Months	1.089	1.180
6 to 8	T to Th	May to Sept	1.139	1.232
8 to 6	M to F	All Months	1.114	1.244
8 to 6	M to F	May to Sept	1.159	1.304
8 to 6	T to Th	All Months	1.148	1.283
8 to 6	T to Th	May to Sept	1.185	1.332
0 to 4	M to F	All Months	1.380	1.508
0 to 4	M to F	May to Sept	1.428	1.567
0 to 4	T to Th	All Months	1.426	1.558
0 to 4	T to Th	May to Sept	1.462	1.605

As described previously, the manual draws the line between single-unit trucks and combinations based on whether or not the power unit is towing a trailer. If it is a truck, and if it is towing a trailer, the vehicle is a combination truck. Tractors operating without trailers are single-unit trucks. A U-haul truck towing an automobile is a combination truck, as is a utility truck with a wood chipper behind it.

In contrast to the HPMS field manual, FHWA policy studies tend to limit the class of vehicles known as "combinations" to only those vehicles with a heavy or cargo-carrying trailer. Although the 1982 Federal Highway Cost Allocation Study grouped light and heavy combinations, subsequent cost allocation studies, truck size and weight studies, and revenue forecasting studies appear to have settled on a new, common definition of vehicle classes.

In the current classification system, combinations are divided by whether they are tractor-semitrailer or truck-trailer combinations. Further, truck-tractors include only trucks with full trailers, and specifically exclude utility trailers.

EXCLUDING VEHICLES WITH LIGHT TRAILERS FROM COMBINATION TRAVEL ESTIMATES

One of the most promising ways to achieve greater consistency between the VM-1 table and other estimates of combination truck travel may be to exclude vehicles with light trailers from the combination truck category. We have analyzed both TIUS and Truck Weight Study data to gain further insight into how great a difference this might make in combination travel estimates, as well as to what types of such vehicles are currently classified as combinations for VM-1 purposes.

Our TIUS analysis first focused upon single-unit trucks towing trailers. Table 3 summarizes the miles of on-road vehicle travel indicated in TIUS for various types of truck-trailers.

Trucks with utility trailers should be classified as combinations, according to the HPMS Field Manual, but were excluded from the earlier TIUS-based estimate of 57.268 billion VMT. Therefore, the estimated combination base travel from TIUS would be 62.233 billion miles for 1987. As derived from the table above, trucks with utility trailers and truck-trailer combinations with average weights less than 26,000 lb together comprise 8.44 percent of that estimate.

In addition to excluding trucks with utility trailers and truck-trailers with average weights less than 26,000 lb, we probably should exclude truck-trailers with average weights greater than 26,000 lb if they consist of a heavy single-unit and a light trailer. Unfortunately, TIUS does not indicate separate weights for the trailers and power units.

Similarly, TIUS collects information only about the most common configuration in which a truck operated during the survey year. Since trailers are detachable, we should expect that some of the miles attributed to truck trailers actually apply to single unit trucks, and vice versa. The implicit assumption is that these two phenomena precisely balance, but this assumption may be far in error.

TABLE 3 1987 TIUS VMT (in Billions)

	Average Weight (Thousand Pounds)				
Type of Trailer	<10	10-16	16-26	>26	Total
One Semi-Trailer	0.002	0.002	0.006	0.021	0.031
Double Trailers	0.000	0.000	0.000	0.004	0.004
One Full Trailer	0.033	0.073	0.173	0.904	1.183
Utility Trailer	3.083	0.546	0.462	0.875	4.965

As another way of approaching the problem, we analyzed truck weight data collected by the states and submitted to FHWA. As part of a research project with FHWA several years ago, we analyzed two million "seven-card" format truck weighings to estimate the classification error rates for each of the truck classes used by FHWA's Office of Policy. We recompiled our findings for this project to analyze the ratio of light vehicles in each of the truck trailer and tractor-semitrailer combination truck classes, and present our findings in Table 4.

In this table, we have included only those weighings with light axle loadings or implausibly long axle spacings, under the assumption that either of these occurrences indicates either a light combination or an erroneous grouping of two or more vehicles. Also, we used a hierarchy, looking first for light axles and then for long spacings, so the two categories are mutually exclusive.

Notice that the apparent inclusion of light vehicles or vehicles towing light trailers in each vehicle class ranges from 2.18 percent (for vehicles classed as triples) to 90.45 percent (for vehicles classified as five-axle truck-trailers). Also notice that about 80 percent of the weighings came from the predominant five-axle tractor-semitrailer class.

To develop an overall estimate of the inclusion of vehicles with light trailers in the combination class of the VM-1 table, we must combine the class-by-class results in the previous table. Table 5 compares three methods of combining these results, with the results of each method underlined and placed to the right.

Method 1 simply averages the 11 class rates of light trailer inclusion, and derived an estimate of overall light-trailer inclusion of 26.32 percent. Although this method is popularly used, it is mathematically indefensible. We included it here to indicate how far you can err by closing your eyes and spitting out numbers.

Method 2 groups all the weighings without regard to vehicle class, which is equivalent to assuming that the weighings analyzed here represent travel by the various vehicle classes. Using this method, we derived an estimate of 12.84 percent. This method is better than the first, but the implicit weighting resulting from using raw data can be improved upon by some type of stratification.

Method 3 stratifies the weighings by HPMS vehicle class. The HPMS classes for 5 and 6 axle doubles had to be combined because the Office of Policy classes, the basis for the original analysis, also combine these vehicles. We then weighted the resulting light trailer estimates by the 1990 VMT of each of these classes.

TABLE 4 Inclusion of Light Vehicles with Combinations as Indicated by Weighings in Truck Weight Study

Vehicle Class	Total Weighings	Light Axles	Long Spacings	Percent Light
CS3	25900	6590	207	26.24
CS4	117454	52027	3869	47.59
CS5	1234272	70533	12592	6.73
CS6	19679	1299	190	7.57
CT4	19511	11005	412	58.52
CT5	30770	4977	22853	90.45
CT6	3275	28	550	17.65
DS5	78712	2754	7825	13.44
DS7	13692	718	50	5.61
DS9	5025	591	89	13.53
TS7	3944	83	3	2.18

TABLE 5 Alternative Estimates of Overall Inclusion of Light Vehicles

Method 1: Unweighted Average of 11 Vehicle Classes: 26.32%

Method 2: Sum of Weighings, Ignoring Class:

Total Weighings	Light Axles	Long Spacings	
1552234	150605	48640	12.84%

Method 3: Subtotal and Weight by State-Reported Classifications:

HPMS Class	Weighings	Light Axles	Long Spacings	Percent Light	1990 VMT
4A1T_CMB	162865	69622	4488	45.50%	20547.4
5A1T_CMB	1265042	75510	35445	8.77%	76177.4
6A1T_CMB	22954	1327	740	9.00%	2801.5
5A2T_CMB	78712	2754	7825	13.44%	5157.7
6A2T_CMB					913.8
7A2T_CMB	22661	1392	142	6.77%	1752.2
			Weighted Average:		16.04%

We derived the VMT estimates from the state-reported classification data compiled by FHWA on their "VCVMT90" spreadsheets, combining all states and highway types. The resulting estimate is that 16.04 percent of all combination VMT reported by FHWA in the VM-1 table results from vehicles towing light trailers. If FHWA decided to reclassify such vehicles as either passenger vehicles or as single-unit trucks, they would have to reduce their reported combination VMT estimates on the VM-1 by this amount.

Note that reducing VM-1 combination travel by 16.04 percent in 1987 would have narrowed about half the gap between VM-1 and TIUS, lowering the reported VM-1 travel from 86,331 million VMT to 72,484 million VMT, compared with the TIUS heavy combination VMT of 57,268 million. We would still have to lower FHWA VM-1 VMT another 21 percent to match TIUS exactly, but this appears to be a modest decrease compared with the temporal variation analysis presented earlier. In fact, the Southern California monitoring stations suggest a decrease of at least 30 percent. Thus, the entire gap between the combination VMT reported by FHWA and by TIUS can be explained by these two factors alone.

RECOMMENDATIONS

None of the analyses presented above should be construed as complete enough to accurately adjust current VM-1 estimates. Nevertheless, the results of these analyses indicate a need for improvements in the way FHWA derives VM-1 estimates, and we have several ideas that FHWA may wish to consider in their efforts to improve these estimates for combination vehicles.

Specifically, we recommend that FHWA consider implementing the following:

- Systematic consideration of temporal count variations,
- A new definition of combination vehicles,
- New guidance to states, and
- When necessary, FHWA corrections to state-reported data.

The California data, as have other such 24-hr data, indicate a strong need to consider and adjust for the consequences of using short time period classification data (defined as anything less than 24-hr, 7-day, 4-season data). Ideally, each state should use its 24-hr monitoring stations as a basis for the areawide classification data reported annually to FHWA. Only 24-hr, 7-day data can account for the systematic temporal variations in travel by various vehicle classes.

Clearly, the limited geographic coverage of 24-hr classification stations requires that they be supplemented by shorter duration counts at many more locations. We suggest that each state needs to develop a set of characteristic distribution curves covering highways of various types and locations, and this may not be quite as easy as it sounds. Even primitive temporal correction, however, is undoubtedly better than no temporal correction, which is the normal case now.

Our second recommendation is based on our assessment that the inclusion of light vehicles and vehicles towing light trailers in the VM-1 entry for combinations is widely misinterpreted and misconstrued. Many sources use the VM-1 table as a basis for estimates of combination travel, and the fact that this includes an uncommon definition of combinations is usually not well understood. We recommend two courses of action: (*a*) include estimates for travel by truck-trailers separate from estimates for tractor-trailer combinations and (*b*) exclude light trailers and light trucks from either category.

We realize that developing a separate estimate for truck trailers requires a change in the HPMS areawide VMT reporting form, but we view it as desirable. States are now inconsistent in their definition and determination of truck trailers, and FHWA must annually clarify to and quiz the states on how they classify various types of truck trailers. We suggest that it might be easier for everyone to have a consistent definition and one that allows distinction between the two types of vehicles.

Similarly, we think it would be desirable to exclude light trailers from the estimates for truck trailers. Light trailers are often of dubious interest for the kinds of policy studies or other known FHWA studies using VM-1 data. We think it much more important to be able to distinguish between single-unit trucks and combination trucks.

We also suggest that FHWA may find it desirable to instruct and give more guidance to the states on the need for good quality VMT and classification data. The Traffic Monitoring Guide certainly is a

good step in that direction, but the next steps are to tighten up the classification data requirements and work to help states implement them.

Finally, the quality of VM-1 data would improve if FHWA were to more actively evaluate the data submitted by each state, considering its derivation and comparing it with other sources, to the extent possible. We suggest that FHWA take on a new willingness to adjust the state-submitted data as required to compensate for its shortcomings and inconsistencies. If a state classifies only during summer daylight weekday hours, for example, FHWA might want to use a regional or national correction factor to adjust the state numbers.

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