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16. Abstract

Research has shown that nighttime seat belt use is lower than daytime use. There is also an overrepresentation of fatal crashes at night. Therefore a proper estimate of statewide nighttime seat belt use would be beneficial to understanding the problem of nighttime driving risk. Some early research efforts have attempted to provide such an estimate but these have fallen short in that they failed to address two issues related to a statewide night estimate: a decrease in traffic volume that is variable across functional class, and the large percentage of night traffic made up commercial vehicles (particularly large trucks) primarily on higher volume roadways. This report provides States with options regarding how to estimate statewide seat belt use at night. It also provides a detailed description of how to conduct night observations.

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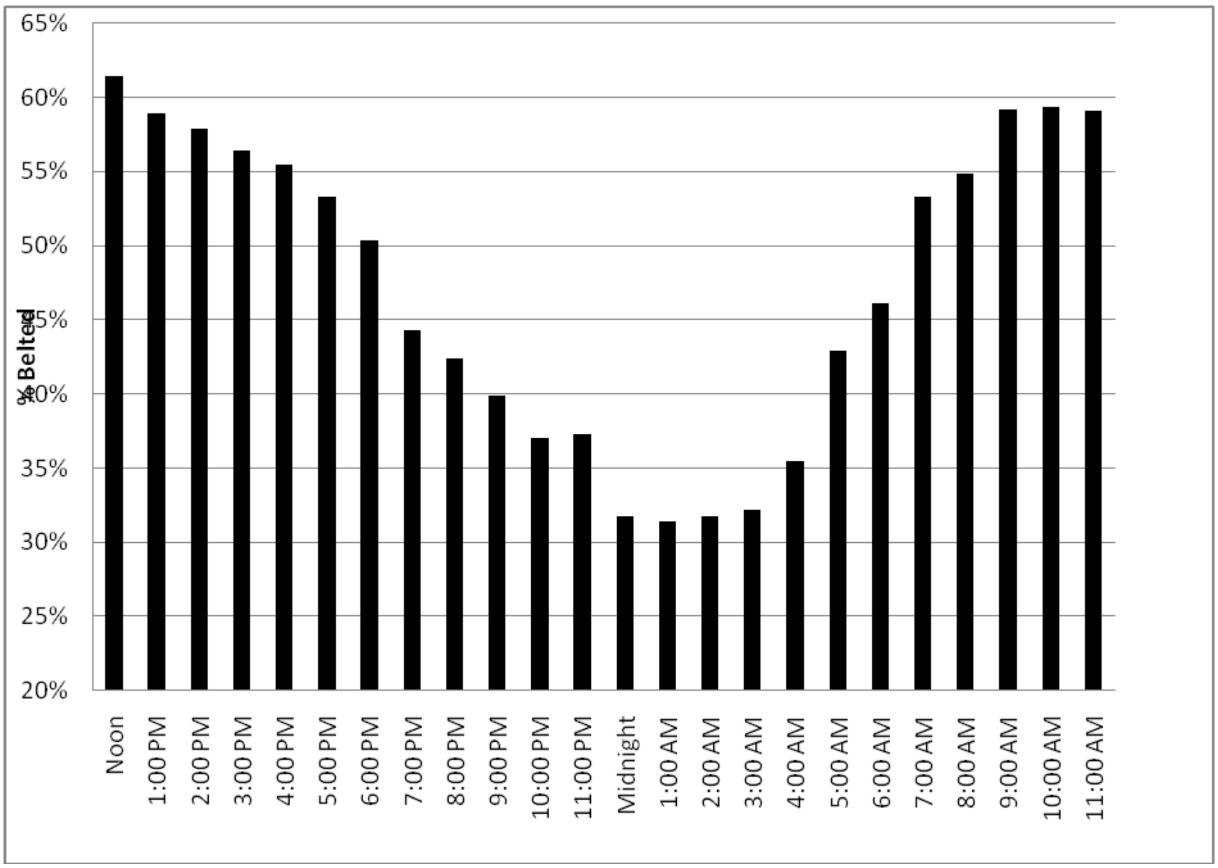
I. Introduction

Belt use rates among front-seat occupants of passenger vehicles are substantially lower at night than during the day. Figure 1 shows the pattern of belt use among fatally injured occupants of passenger vehicles using FARS (Fatality Analysis Reporting System) for the three years starting in 2006 and ending in 2008. The figure shows national belt use was lowest between midnight and 3:59 a.m. These data also show that 27% of the fatalities occurred between 9 p.m. and 2:59 a.m. These hours represent 25% of the day but likely less than 15% of the total daily traffic volume (see Hallenbeck et al., 1997).



Source: FARS 2006-2008

Figure 1. Percentage Belt Use for Fatally Injured Front-Seat Outboard Occupants of Passenger Vehicles

The National Highway Traffic Safety Administration standardized the way States measure seat belt use by introducing probability-based procedures and guidelines for selecting observation locations and weighting data collected at those sites (*23 CFR Part 1340 Uniform Criteria for State Observational Surveys of Seat Belt Use*). The weighting served to make the observations representative of statewide seat belt use based on both traffic volume and population. The sampling and weighting with regard to traffic volume primarily used 24-hour traffic information. The fact that volume information is based on all the hours of the day, though observations were done only in daylight, was not an issue given that the large majority of traffic occurs during the daytime hours.

The estimates generated by these surveys provide a good measure of belt use during the day. Research (Tison et al., in press) has shown that daytime observation methods correlate well with daytime FARS belt use, and less well with nighttime FARS belt use. These results provide more evidence that day belt use is different from night belt use. As such, a protocol designed to generate a stand-alone statewide estimate of nighttime seat belt use would be useful.

The goal of this paper is to provide States with options and guidelines to obtain a statewide estimate of nighttime seat belt use.

A. Background

There is consistent evidence that nighttime seat belt use is lower than daytime use. FARS data (Figure 1) shows this trend clearly. Observation data has also shown the difference. Observations in Connecticut (Chaudhary & Presser, 2006), Pennsylvania (Chaudhary et al., 2005), New Mexico (Solomon et al., 2007) and Indiana (Vivoda et al., 2007) all show that belt use was generally lower at night than during the day.

Some recent studies have attempted to provide an estimate of statewide nighttime seat belt use. Generally, however, they failed to properly account for certain aspects of changes in traffic from night to day. Not surprisingly there are fewer motor vehicles on the roadways at night as compared to the day. However, the drop-off in volume is not consistent between different functional classes of roadways (Chaudhary & Preusser, 2006; Hallenbeck et al., 1997). Higher volume roadways (e.g., interstates and freeways) tend to retain more of their volume at night than lower volume roadways (e.g., local roads and collectors). One study (Hallenbeck et al., 1997) showed that large-truck traffic remains relatively constant on higher volume roadways. Therefore it is unclear if the differences in decreased volume across different functional roadway classes are due to a disproportionate change among passenger vehicles across the different functional classes, steady commercial vehicle traffic on higher volume roadways, or a combination of these factors.

A New Mexico study (Solomon et al., 2007) used the same sites as New Mexico's statewide daytime survey but observed them at night. The weighting employed for this study only adjusted for variation in the number of observations made per site and was not meant to create an estimate representative of the night belt use for the entire State.

An Indiana study (Vivoda et al., 2007) attempted to estimate statewide seat belt use by using the daytime weighting scheme on nighttime data. The guidelines require that weighting be representative of traffic volume and traffic distribution across functional class and population. The problem with applying the daytime weighting unaltered to the nighttime observation data is that the distribution of the traffic across functional class at night is unlikely to be the same as it is during the day (Chaudhary & Preusser, 2006). Therefore, the weighting will over-represent the influence of some functional classes and underestimate the influence of others.

A third study (Chaudhary & Preusser, 2006) attempted to estimate statewide belt use in Connecticut at night. As with the previous two studies, all observations were conducted at the daytime sites. The weighting of the night data used a modified version of the daytime weighting. Specifically, vehicle miles traveled (VMT) used in the weighting were recalculated using counts of traffic during the night hours. This method attempted to address the change in traffic distribution at night, but it did not account for the likely disproportionate number of large trucks making up the traffic, particularly on high-volume roads (e.g., interstates), at night. Truck traffic is included in the daytime weights but, because it makes up a relatively small proportion of the total traffic, it is unlikely to significantly influence the overall weighting scheme. Hallenbeck (1997) showed that in some parts of the country the volume of trucks remains relatively constant across all hours of the day. This study also showed that trucks make up a very large portion of the traffic on highways at night. These trucks are included in the unadjusted 24-hour traffic volume data used for the weighting in typical belt use calculations. Therefore, the Connecticut study was only partly successful in adjusting the relative influence of the roadway functional classes.

A properly weighted night survey is important. A statewide estimate of nighttime belt use might help explain the disproportionate number of motor vehicle occupant fatalities occurring during the night hours. Other research has shown the impact of night and day enforcement on nighttime seat belt use (e.g., Chaudhary et al., 2005; Lund et al., 1989; Wells et al., 1992) and it would be important to know the impact of such enforcement on a statewide level. A very recent study examining Maine's upgrade to a primary seat belt law (Chaudhary et al., in press) showed that the impact of the law change was greater for nighttime seat belt use than for daytime seat belt use.

There are basically two issues to be contended with to ensure a valid nighttime statewide survey: (1) where to observe and how to appropriately weight the observation to make them representative of statewide nighttime seat belt use; and (2) how to observe seat belt use at night. The goal of this paper is to provide States with a set of guidelines and tips to estimate their statewide nighttime belt use rates. These guidelines are based on taking the existing approved design under the uniform criteria for estimating (daytime) belt use and adjusting the weighting to accommodate differences in nighttime traffic volumes. For States having comprehensive hour-by-hour traffic volumes, there are also guidelines to draw an entirely new sample of observation sites, based on nighttime traffic data, to use in estimating nighttime seat belt use.

This paper will discuss the reasons for differences in method and weighting between daytime and nighttime surveys. It will discuss the method for selecting a new nighttime sample (optional). The guidelines will include details on conducting night observations—such as, issues related to scheduling, special equipment, and procedures needed for night observations, and weighting the data to account for nighttime passenger vehicle traffic. The weighting will follow two steps: (1) adjusting volume to account for passenger vehicles, and (2) adjusting volume to account for night traffic. There will be examples provided based on actual data collected from Connecticut and Pennsylvania. These two States use very different weighting methods and may provide useful examples for States to weight their own data.

II. Re-Sampling Based on Night Data

States may opt to draw an entirely new sample on which to conduct night observations. This new sample would be independent from the day survey. States should consider drawing a new sample of road segments for their nighttime survey only if the appropriate data are available. Specifically, a State would need to have a measure of hourly traffic volume by vehicle type for all roadways eligible to be sampled. If such data are available, a State may opt to then follow the same procedures used in drawing the sample for the daytime survey, but base selection probabilities on the nighttime passenger vehicle volumes (i.e., exclude buses and heavy trucks) rather than the 24-hour traffic volumes used for daytime sample selection. Details are available for the Uniform Criteria from NHTSA, but a brief overview will be presented here.

Typically, each State has a daytime belt use survey design approved by NHTSA as meeting the requirements of the Uniform Criteria. The survey design includes specific instructions as to how the design is structured and how potential sites are identified. For example, a design that calls for a State to:

1. Select the most populous counties that together have at least 85% of the State's population; optionally, sampling from those counties to produce a sample of 13 to 16 counties to be included in the belt use measurement.
2. Identify all road segments within those counties (typically excluding local roads).
3. Group road functional classes into a small number of functional class strata such as interstates and freeways, other primary arterials, minor arterials, and collectors.
4. Calculate VMT values (road segment length x AADT) for each road segment in the counties and functional class strata included in the State's design.
5. Tally VMT values for county-functional class strata, counties, strata across counties, and statewide (typically excluding the excluded counties and local roads).
6. Determine how many road segments in each county-functional class stratum will be needed in the full observation design (typically totaling 100 to 150 segments).
7. Select the segments for observation, typically with probability of selection proportional to each segment's VMT.

For States that have hour-by-hour passenger vehicle volumes available for every road segment in Step 4 above, it is possible to draw a new sample of road segments for nighttime belt observations. Note that the term "passenger vehicles" includes all vehicles eligible to be observed in the daytime survey. In certain States "eligible vehicles" may include vehicles not typically considered to be passenger vehicles, such as emergency vehicles for example. For convenience and comparability the nighttime sample would follow the daytime design in terms of how many road segments, of what types, and in what counties.

In order to draw the new sample, the State would need to repeat Step 7 using nighttime passenger vehicle VMT instead of the 24-hour VMT used originally.

III. Re-Weighting Daytime Plan for Nighttime Observations

A. Overview

Most States will not have the data necessary to draw a completely new sample for night observations. Therefore, they will need to start with their existing daytime sample. The formulas that are used to combine all data into a statewide daytime belt use estimate will need to be adjusted for nighttime belt use computation. The adjustment is simple in concept: replace the 24-hour weights with new weights based on nighttime passenger vehicle traffic. This section describes how to reweight the existing daytime weighting spreadsheet[1] to estimate statewide nighttime belt use from nighttime observation data.

Data weighting methods differ greatly from State to State. The purpose of this section is to provide general guidelines for weighting nighttime observation data to produce an unbiased estimate with minimal variance. The main issues are:

- change in proportion of traffic occurring on individual functional classes from day to night, and
- over-representation of large truck traffic at night compared to day.

The new weighting will start from the existing weighting spreadsheet for a State's daytime survey. The traffic volume data used to make the daytime data representative of statewide (daytime) belt use is inappropriate for weighting nighttime observation data and producing an estimate of statewide nighttime seat belt use. Specifically, patterns of traffic volumes change at night such that the distribution of traffic on various functional classes of roadways may be different during the day than at night. A second problem is that the percentage of traffic (particularly on high-volume roadways) that comes from large trucks is much greater at night than during the day. Thus, VMT[2] data will need to be adjusted to make the weights representative of night traffic in terms of passenger vehicle distribution across functional classes.

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[1] States typically have an automated procedure such as a spreadsheet or statistical analysis package command stream, which converts raw observation data into final State belt use measures. For convenience, "spreadsheet" is used in this report to refer to that automated procedure.

[2] If the State's daytime belt use design is based on AADT, for example, substitute that measure in this discussion and in actual calculations.

This should be the only necessary adjustment, because population, the other variable typically used in weighting, is constant across time of day.

The adjustments should be made in one of two ways depending on what data are available to the State. If the State can access hourly traffic volume data (i.e., vehicle counts from each road segment for each hour of the day), then the weighting will be done slightly differently than if the State only has access to total 24-hour (i.e., daily) volume for each segment. Note that the segments described here are not just the observation sites but the complete sample of all roadways in the State used to calculate State VMT. These data are usually collected by the State DOT planning offices.

Both methods will require "clicker counts" (actual counts of traffic volume) to estimate the volume of passenger vehicles at night. The hourly data will likely result in more reliable estimates of night traffic volume, and therefore some effort should be invested into obtaining this data if available.

If the hourly volume data are available, traffic counts (at the statewide seat belt survey observation sites) will require a dual clicker system where clicker counts are made of all vehicles that would be included in the seat belt survey (i.e., passenger vehicles as the State defines them) and a separate count of vehicles that would be excluded (i.e., large trucks or commercial vehicles).

If hourly data are not available, then manual volume counts (clicker counts) need only include passenger vehicles. There is no need to count the vehicles that would be excluded from the seat belt survey.

The following sections will describe steps for reweighting under each situation (hourly versus daily data availability) and provide examples from two States. The general purpose of the steps is the same for all States, but the steps may need to be adjusted to achieve their goals depending on the weighting scheme for any individual State. The two States, Pennsylvania and Connecticut, were chosen because they have very different weighting schemes and they have had nighttime statewide observations conducted and thus have data that can be used as both standard and atypical examples.

B. Example States

Pennsylvania's weighting scheme is somewhat standard and should resemble the weighting used in most States. For the belt use design, the State was divided into four geographic regions. Counties with 85% of the State's population were identified, from which sample counties were randomly selected in each region. Four road functional class strata were identified, target numbers of sites were established, 150 segments were selected and observation site locations were chosen on each segment. Each observation site has an individual weight based on its own VMT and then there are weights based on the VMTs for the region or county for each functional class.

Connecticut's weighting scheme is not a typical weighting scheme. The weights include AADT (as well as VMT) and are based on only the volume data from the sites included in the survey. There are no county or regional factors in Connecticut's design, which is based on 100 sites.

It is important to note that not all the required data were available for these examples. Therefore the examples do not produce actual weighting values for the States.

C. Manual Volume Counts (Clicker Counts)

In order to reweight a daytime spreadsheet to make it more representative of nighttime traffic volume, VMT (or AADT) values need to be adjusted to make them represent the miles travelled by passenger vehicles only[3] (pVMT). In order to achieve this adjustment, an estimate of the percentage of traffic belonging to passenger vehicles on relevant functional class roadways must be obtained. If a State has actual data for pVMT, then those data should be used in place of this estimation process.

Manual counts of vehicles will be used to adjust VMT into pVMT. Manual counts will be conducted regardless of whether hourly data are available. Passenger vehicle traffic clicker counts should be made at night for each site included in the daytime seat belt survey. If hourly traffic counts are being used for the reweighting, then an additional separate count of ineligible vehicles (e.g., non-passenger vehicles) should be made simultaneously. The counts need to be conducted in such a way that a night traffic estimate for each functional class can be made for each hour included in the night observations. That is, there should be at least one count for interstates (for example) at each hour included in the survey. If there are 10 interstates included in the survey and observations occur from 9 p.m. to 3:59 a.m., then there should be at least one set of counts for each hour (with 3 hours having more than 1 observation). The same distribution of counts should be made for all functional classes. If this is not possible the counts should be as evenly distributed across the hours as possible. If there were only five interstates in the survey, for example, then there should be at least one count at every other hour (9 p.m., 11 p.m., 1 a.m. and 3 a.m.) with the final count filling in one of the gaps.

Counts can be taken at the same time as the first set of night belt observations for greatest efficiency. Counts can be taken: (1) during the observations by a second person; (2) during the same time and weekday of the observation the week following (during similar weather conditions); or (3) for 15 minutes before and 15 minutes after the observations (and doubled to represent the full hour). For sites with relatively low volume, the actual observations can be substituted for separate clicker counts. That is, if observations are being made for nearly 100% of the traffic during the normal course of a night observation, there is no need to obtain a separate count of eligible vehicles. However a tally or count of ineligible vehicles will still need to be made if the State has hourly vehicle volume data. If observation data are used it is important to

[3] The adjustment is necessary primarily to remove the effect of large trucks, as other commercial vehicles tend to follow the same pattern of volume across time as do passenger vehicles.

record unknown belt use so that all eligible vehicles are included. If observations are made on off ramps, counts of traffic volume should be taken on the actual roadway.

D. Estimating Passenger Vehicle Volume With Hourly Data (Preferred)

This process should be identical for all States regardless of how they weight their data. Therefore only one example is included (Connecticut). Some States may stop at an earlier point in the process. Specifically, some States may need only AADT adjustments (and not VMT), so the step converting AADT into VMT can be skipped.

The counts of passenger vehicles and ineligible vehicles should be combined to calculate the percentage of passenger vehicles at each site. The %pV (percentage of passenger vehicle volume) is calculated using the formula below:

$$\%pV = \frac{pV}{pV + oV}$$

where pV is observed volume of passenger vehicles and oV is the observed volume of other vehicles.

Ideally, there would be more than one %pV for each hour on each road class stratum for each county or region. Most States are unlikely to have enough sites to accomplish this. Thus, the calculations described to estimate the average %pV for a given road class stratum and hour will include what to do if just one (or even fewer) %pV is available for a given hour/road class stratum.

Step 1 is to average the %pV values within each hour and road class stratum (e.g., 10 p.m./collectors) (see Table 1). If there is only one %pV, use it as the average. If there are missing %pV values for some hours, the value should be interpolated by taking the average of the closest two non-missing values with one being later and the other being earlier. For the latest and earliest hours, the next closest non-missing hour should be used. This should be done separately for each road class stratum in the belt use observation design. Within each stratum, separate estimates can be conducted by county, group of comparable counties, or region, with this grouping including enough sites to have minimal missing data.[4]

Table 1 shows hypothetical counts (based on volume and observation data) for collectors in Connecticut. Connecticut's plan has 14 collectors; all are combined into a single volume estimation example. The sites were distributed across all the hours included in their night

[4] Note that this method of estimating average %pV may be non-robust when traffic volume is small. As discussed in the limitations section, this problem may be solved by combining data across multiple years.

observation plan (9 p.m. to 2:59 a.m.). There were multiple counts per hour, so the final column is the average of the percentages for that hour. If not enough sites were present, then the average of the two closest times would be used. For example, if there were no actual 11 p.m. counts conducted in the Connecticut example displayed in Table 1, an average of the 10 p.m. (88.5%) and the 12 a.m. (97.0%) would produce an 11 p.m. estimate of 92.8% (rounded).

Table 1. Hypothetical Manual Counts for Collectors in Connecticut

Time	Site	Passenger Volume (pV)	Non-passenger Volume (oV)	%pV for Site	Average %pV
9 p.m.	Site 1	112	30	78.87%	83.3%
	Site 2	72	10	87.80%	
10 p.m.	Site 3	54	8	87.10%	88.5%
	Site 4	90	10	90.00%	
11 p.m.	Site 5	43	4	91.49%	95.7%
	Site 6	4	0	100.00%	
12 a.m.	Site 7	2	0	100.00%	97.0%
	Site 8	35	2	94.59%	
	Site 9	27	1	96.43%	
1 a.m.	Site 10	27	2	93.10%	88.9%
	Site 11	7	1	87.50%	
	Site 12	25	4	86.21%	
2 a.m.	Site 13	13	1	92.86%	96.4%
	Site 14	2	0	100.00%	

The next step is to use the average %pV (final column in Table 1) to adjust the AADT values for each segment used to calculate VMT in the weighting spreadsheet. This requires detailed data usually obtained from the State's DOT Planning Office. Specifically AADT (disaggregated by hours included in the night observation survey) and segment lengths are needed for each segment used to calculate the VMTs included in the State's weighting spreadsheet. Note that with the exception of rare cases such as Connecticut, these segments are not limited to the ones being observed but are typically the population of segments from which the sample segments were drawn (i.e., all roadway segments with counts).

Then for each segment the estimates of average %pV for each hour are used to adjust the matching hour's volume to estimate passenger vehicle volume for a given hour. These adjusted volumes are then summed across observation hours to estimate the volume of traffic on a given segment during all hours of the night survey.

Next, if VMT estimates are required, this volume is multiplied by segment length (in miles) to estimate nVMT (night VMT) for a given segment.

Finally the nVMT values for all segments within a given roadway class stratum (and region stratum if enough sites are available) are summed to produce total nVMT for the roadway class stratum (or region/road class stratum).

This value will replace the 24-hour VMT currently used in the State's weighting spreadsheet. Table 2 outlines the steps used in these calculations using Connecticut data. In a typical State all segments in the roadway class (in this case, collectors) would be included in the table. Thus the final calculations would include segments 6 to n-1 (excluded here for space considerations). The % values used for average %pV are from Table 1. The values in the spreadsheet are calculated as follows:

$$pV = Average\ \%pV * tV$$

Where pV is passenger vehicle volume, and tV is total volume as provided by the State's planning office for a given segment and hour.

Table 2. Calculations for Passenger Vehicle Night Vehicle Miles Traveled Using Connecticut Data

		9 p.m.	10 p.m.	11 p.m.	12 a.m.	1 a.m.	2 a.m.	Night Passenger Traffic Count	Segment Length	pnVMT
Average %pV		83.3%	88.5%	95.7%	97.0%	88.9%	96.4%			
Segment 1	tV	172	127	111	114	85	100			
	pV	143	112	106	111	76	96	645	1.8	1160
Segment 2	tV	79	82	70	75	50	57			
	pV	66	73	67	73	44	55	378	4	1511
Segment 3	tV	81	69	57	49	45	42			
	pV	68	61	55	48	40	41	311	2	622
Segment 4	tV	148	137	117	102	92	81			
	pV	123	121	112	99	82	78	616	0.3	185
Segment 5	tV	18	15	11	10	11	11			
	pV	15	13	11	10	10	11	69	6	413
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Segment n	tV	32	23	23	23	15	20			
	pV	27	20	22	22	13	19	124	2.2	273
							Night ADT	**2142**	**Night VMT**	**4164**

Night Passenger Traffic Count is the estimated number of passenger vehicles traveling through that segment for the hours included in the night survey. It is the night weighting equivalent of AADT and is calculated by adding the pV values for each hour for a given segment.

Segment Length should be available from the planning office for each segment. This value may come from the office as a length in feet instead of miles. It should be converted to miles or kilometers to calculate VMT or VKT (vehicle kilometers traveled) depending on what is used in the daytime weighting spreadsheet.

Finally, pnVMT is the passenger vehicle night vehicle miles traveled for a given segment. This is calculated at follows:

$$pnVMT = Night\ Passenger\ Traffic\ Count * Segment\ Length$$

This adjusted VMT (or AADT) would replace the volume data in the State's weighting spreadsheet, and night observation data can then be entered into the adjusted spreadsheet to obtain a statewide estimate of nighttime seat belt use.

The steps outlined in Table 1 and Table 2 should be repeated for each roadway class used in the daytime weighting spreadsheet.

E. Estimating Passenger Vehicle Volume With 24-Hour Data

Most States will not have hourly traffic volume for each road segment. Rather, they will have daily traffic counts only. With daily counts only, it is not necessary to determine what percentage of vehicles within any given hour of the day are "eligible" passenger vehicles versus ineligible trucks, buses etc. It is only necessary to determine the eligible passenger vehicle count for each functional class for each of the night hours. The result is a simpler procedure.

This procedure requires manual counts, as above, except that the counts are only of qualified passenger vehicles. These counts are used to estimate what percentage of the total 24-hour volume (i.e., the AADT) that hour represents. This is done for all hours within each roadway class stratum to estimate the percentage of the AADT for a given roadway class that represents passenger vehicle traffic during the nighttime observation period.

To do this, the clicker counts of passenger vehicles (i.e., eligible vehicles) are divided by the site's AADT to obtain %pDV estimates (percent daily volume). Unlike the %pV described above, this is the percentage of the total daily traffic that is eligible during a given hour; the %pV described above is the percentage of that hour's traffic that is passenger vehicle traffic. Ideally, there would be more than one %pDV estimate for each hour for each road class stratum for each county, group of counties, or region, as described above. Most States however are unlikely to have enough sites to accomplish this. Thus, the calculations described to estimate the average %pDV for a given road class stratum and hour will include what to do if only one (or even fewer) %pDV for a given hour/road class stratum is available.

This step requires data that may be present in the daytime weighting spreadsheet or may need to be obtained (usually) from the State's DOT planning office. Specifically, AADT information for the sites used in the observations will be needed. For a given site the clicker counts will be divided by the AADT to estimate the percentage of the daily traffic volume represented by passenger vehicles during that hour (%pDV). If multiple sites are counted from the same roadway class stratum, then the percentages will be averaged to get an estimate for that roadway class stratum for that hour. If there are missing %pDV values for some hours, the value should be interpolated by taking that average of the closest two non missing values, with one being later and the other being earlier. For the latest and earliest hours, the next closest non-missing hour should be used. This should be done separately for each road class stratum in the belt use observation design. Within each stratum, separate estimates can be conducted by county, group of comparable counties, or region, with this grouping including enough sites to have minimal missing data.

Table 3 uses data and estimated values from Connecticut's night observations to illustrate this process for Interstates. The segments included in Table 3 are from the sites included in the survey only. The AADT values may be available from the weighting spreadsheet or may need to be obtained from the State's planning office. In this example, the counts taken were for ½ hour only, so the values were doubled to be representative of one full hour. The counts may be taken for 15 minutes before and 15 minutes after an actual observation, again with the raw count doubled to represent a full hour. If the actual seat belt observations gather data on all passing passenger vehicles, then the total vehicle count from the actual observation data may be substituted for clicker counts.

The pV value is the passenger vehicle volume for the indicated hour. The %pDV value is the estimated percentage of AADT traffic that takes place during the indicated hour. It is calculated as:

$$\%pDV = \frac{pV}{AADT}$$

Average %pDV is the average of the %pDV values for a given time period. The average %pDV values for all hours of the nighttime observation period are added to estimate the percentage of AADT traffic that represents passenger vehicle traffic occurring during the nighttime hours. This percentage will be used to modify the aggregate VMT or AADT values included in the weighting spreadsheet to make them representative of night traffic for passenger vehicles.

The steps in Table 3 should be carried out for all roadway classes to get an estimate of the passenger traffic at night for each roadway class. Table 4 shows a mock-up of estimating the percentage of AADT for passenger vehicles at night for all the roadway classes using data from Connecticut's survey. Table 5 shows how these data are applied to the first 22 sites of Connecticut's weighting spreadsheet. Note that Connecticut's survey uses AADT as its primary weighting measure and weights each site's data. Other States may use VMT and weight based on Statewide data for a given roadway class. Table 6 shows %pDV at night from Pennsylvania's data and Table 7 shows how it is applied to VMT data. Note that in the case of aggregate VMT and AADT, since segment lengths will be constant, the percentage change in AADT will be the same as the percentage change in VMT. Therefore the percentages calculated from AADT can be used to adjust VMT.

Table 3. Calculation of Average Percentage of AADT Traffic Based on Connecticut Data

Time	AADT	1/2 Hour Counts	Est. Hourly Counts (pV)	%pDV	Average %pDV
9 p.m.	43200	2178	4356	10%	7.53%
	118600	4003	8006	7%	
	78600	2258	4516	6%	
10 p.m.	36500	1023	2046	6%	3.39%
	91800	1689	3378	4%	
	133800	1658	3316	2%	
	136700	2036	4072	3%	
	122000	1359	2718	2%	
11 p.m.	138300	1775	3550	3%	2.42%
	160100	1730	3460	2%	
	78600	997	1994	3%	
12 a.m.	100900	623	1246	1%	1.56%
	152600	1036	2072	1%	
	74700	1306	2612	3%	
	129600	798	1596	1%	
	138000	333	666	0%	
1 a.m.	125900	616	1232	1%	1.18%
	33800	325	650	2%	
	62100	199	398	1%	
2 a.m.	134000	359	718	1%	0.79%
	113800	432	864	1%	
	125900	456	912	1%	
	33800	360	720	2%	
	62100	77	154	0%	
	60500	99	198	0%	
% of AADT that is passenger vehicles at night:					**16.87%**

Table 4. Connecticut Mock-Up of Percentage of AADT Traffic for Passenger Vehicles at Night for All the Roadway Classes.

Roadway Class	%pDV at Night
Interstate	16.87%
Other Arterial	5.30%
Collector	3.90%
Other/Local	1.90%

Table 5. Calculations for Adjusted AADT Using Connecticut Data.

Site	Functional Class	AADT	%pDV at Night	New Adj AADT
1	Other/Local	14,500	1.90%	213.79
2	Other Arterial	6,000	5.30%	241.54
3	Other Arterial	350	5.30%	14.09
4	Other/Local	16,800	1.90%	247.7
5	Collector	15,000	3.90%	460.88
6	Collector	23,800	3.90%	731.27
7	Collector	14,900	3.90%	457.81
8	Collector	6,700	3.90%	205.86
9	Other/Local	19,800	1.90%	291.93
10	Collector	4,400	3.90%	135.19
11	Interstate	91,800	16.90%	12,282.32
12	Interstate	36,500	16.90%	4,883.49
13	Interstate	43,200	16.90%	5,779.91
14	Other Arterial	2,200	5.30%	91.82
15	Other/Local	23,900	1.90%	352.38
16	Interstate	133,800	16.90%	17,901.68
17	Interstate	138,300	16.90%	18,503.75
18	Interstate	134,000	16.90%	17,928.44
19	Collector	7,100	3.90%	218.15
20	Other/Local	9,400	1.90%	138.59
21	Other/Local	17,200	1.90%	253.59
22	Other/Local	76,600	1.90%	1,129.38

Table 6. Pennsylvania Clicker Counts Used to Estimate Percentage of Passenger Vehicle Traffic at Night.

Roadway Class	%pDV at Night
Interstate	6.9%
Other Principle Arterials	5.0%
Minor Arterials	2.7%
Collectors	2.3%

Table 7. Adjusted Volume Calculations Using Pennsylvania Data

County Name	Roadway Class	Regional VMT	%pDV at night	Night pVMT
Allegheny	Interstate	6,415,454	6.9%	442,666
Allegheny	Other Principle Arterials	5,983,664	5.0%	299,183
Allegheny	Minor Arterials	5,087,735	2.7%	137,369
Allegheny	Collectors	2,193,072	2.3%	50,441
Beaver	Interstate	530,946	6.9%	36,635
Beaver	Other Principle Arterials	984,231	5.0%	49,212
Beaver	Minor Arterials	819,404	2.7%	22,124
Beaver	Collectors	553,000	2.3%	12,719
Blair	Interstate	836,792	6.9%	57,739
Blair	Other Principle Arterials	853,785	5.0%	42,689
Blair	Minor Arterials	588,868	2.7%	15,899
Blair	Collectors	603,461	2.3%	13,880
Butler	Interstate	1,445,184	6.9%	99,718
Butler	Other Principle Arterials	997,432	5.0%	49,872
Butler	Minor Arterials	1,288,673	2.7%	34,794
Butler	Collectors	743,929	2.3%	17,110

Finally, the adjusted volumes calculated (as in Tables 5 and 7) will replace the comparable daytime values in the weighting spreadsheet. Nighttime observation data can then be entered into the spreadsheet to estimate nighttime seat belt use.

IV. How to Conduct Nighttime Observations

A. Daytime Versus Nighttime Observations

It is important to keep the procedures for night observations as similar as possible to those used for day observations. However, this is not always possible. Some changes that may be needed during night observations are described below.

- States should use two-person observation teams at night, for safety and to accommodate additional demands on the observers. Generally one person should observe traffic and relay verbally the results of the observation to the other person who will record the observation. This is especially important when night vision equipment is being used (see below).
- Consider moving the observation site for factors such as safety, better lighting, and slower-moving traffic. Any such move should remain within the same "road segment." That is, if it is desirable to move a site under a nearby overhead light, the new site should be part of the same traffic stream—it should not occur after a major change in traffic as might occur on the other side of a major intersection for instance.
- When normal lighting is not adequate (very frequently the case), special equipment will need to be used. Night vision equipment and infrared spotlights have been employed to observe vehicles when there is a complete (or nearly) complete absence of ambient light. In prior research the infrared technology was only needed in roughly 30 to 40% of observation sites. Details regarding special field equipment can be found below.
- If traffic volume is very light, a State may consider extending the observation period. If there are very few vehicles observed at a given site then the variability of that site's data will be greater. See below for details regarding the observation period length.
- On a multi-lane roadway, if daytime procedures call for observing only one lane at a time and if lower traffic volume permits, a State may consider observing traffic in all lanes at once.

Traffic observation:

In general, the same traffic observation plans should be employed for both daytime and nighttime surveys. That is, the process for choosing a vehicle to be observed should be the same during the day and night. For example, some designs call for observation of selected lanes on multilane roadways. Sometimes observations are always made for only one lane of traffic. Other methods may call for observing all traffic lanes at once or each lane for a specified period of time. All of these techniques are designed to get a representative sample of the vehicles at the site. At night, traffic volumes are usually lower than in daytime. To increase the total number of observations on a multi-lane road, if traffic volumes are low enough at night, observation of all lanes at the same time is recommended. If the volume is too much to observe all lanes effectively, the same method used in daytime surveys should be employed during the nighttime observations.

Ideally, day and night observers will observe vehicles at the same locations. This is not always possible, because overhead lighting is preferred for night observations. Moving to a site with better lighting, as long as it is still within the same road segment, is acceptable.

Observation period length:

For adequate accuracy and reliability of the nighttime belt use measurement it is important to have an adequate number of observations at each site. However, traffic volume decreases at night, particularly after midnight. One way to increase the number of vehicles observed is to increase the amount of time spent observing. It may be necessary to increase the number of vehicles observed, because too few observations may render the data from that site unstable. An extreme example is where only 2 cars are observed. There are only 3 possible outcomes for that site: 0% belt use, 50% belt use, and 100% belt use. The addition of only a few more cars may drastically change the outcome of the percentage belt use from that site. Thus, extending the observation time by 20 minutes (or more) might be helpful.

If increasing the amount of time spent observing is needed, the time increase may lead to cost increases and scheduling difficulties. If the State's weighting formulas for belt use calculation begin by computing belt use rates for individual sites, it may be possible to increase observation period length only at sites with extremely low traffic without biasing the results. Unfortunately, a State will not know which sites have very low volume until after observations are completed. As such, future night observations may need to be adjusted in terms of length of observations. The question of what constitutes "extremely low volume" is difficult to answer. In one study (Chaudhary et al., in press), sites with fewer than 5 observations were excluded from analyses, but increased time at sites with fewer than 10 would also be reasonable in order to increase the number of observations.

Interstate and other high-volume (high-speed) segments:

Some States conduct their interstate observations on the actual Interstates, while others conduct their observations on exit ramps. When possible, night observations should follow the daytime procedure. Frequently there will not be adequate light (even with night vision equipment) to observe vehicles on high-speed roadways. In these cases, observations may need to be moved to a better lighted location (within the segment described by the volume data). The observations may be moved to an exit ramp if this is not possible.

B. Field Equipment

Observation locations at night may need to be moved along the road segment to find a lighted location (e.g., near a street light, in front of a well-lit parking lot, at a rest stop). If such a location cannot be found, observers may need to use infrared vision goggles. These goggles need to have "autogated technology" to allow for observation in the sudden light changing conditions created by vehicle headlights. Earlier generation and many current generation night vision goggles would be "blinded" by the vehicle headlights, but current models with "autogated technology" remain effective in headlight glare. There are at least 2 light amplification tubes that will serve this purpose: the XR-5 tube and the XD-4 tube.

Most of these goggles (or monocles) come equipped with built-in infrared lights to enhance vision, but these built-in lights are not typically bright enough to adequately illuminate approaching vehicles and their occupants. Therefore, handheld infrared spotlights of 1 to 2 million candlepower should be used in conjunction with the goggles to allow observers to view occupant belt use in very dark conditions. Care must be taken to use only infrared spotlights. The infrared light is virtually invisible to motorists and therefore will not distract or degrade their vision the way a visible-spectrum spotlight would. The use of the goggle/spotlight combination requires extensive practice to gain the hand-eye coordination necessary to properly observe occupants. Additionally, the required level of concentration and use of the spotlight make recording observations difficult. It is suggested that two people be used for nighttime observations—one to observe and the other to record.

Safety of the observers is critical, another benefit of two-person teams. Retroreflective vests to enhance conspicuity at night should be required. Observers may also be asked wear bright colored hard hats with retroreflective patches or markings. Additionally, reflective material on wrists and ankles (or shoes) will help drivers identify that the objects are people and that they should use caution. Furthermore, signs may be placed a short distance up the traffic stream warning of "survey crews" (for example) to enhance observer safety. This last may also slow traffic a bit and allow easier observation. The goal is to make the observers appear as a DOT road crew.

C. Night Observation Scheduling

It is very important to the accuracy of the weighting that sites within a given roadway functional class stratum and, to the extent possible, within each primary grouping (e.g., county-functional class combination) are distributed evenly across all hours covered by the night survey. Realistically this may be difficult given the desire to cluster site observations based on proximity, but some inefficiency should be accepted in order to create a reasonable facsimile of this equal distribution of functional class across survey hours. For some States this may be impossible (e.g., if there are not enough of a given grouping within an area to span every observation hour); guidelines for this situation were previously discussed. This distribution becomes very important to obtain seamless data used for estimating night volume as described earlier.

Observations at a given site should also be scheduled to match the day of week for the day and night surveys to allow comparisons between the two estimates. The night sites should be made on the night *preceding* the day observations. This is important when considering weekend observations. A Friday night (Saturday early morning) is more representative of weekend travel than a Friday daytime observation. Therefore Friday night should be matched with Saturday daytime.

Most recent published studies (Chaudhary & Preusser, 2006; Solomon et al., 2007; Vivoda et al., 2007) have defined night hours as the 7 hours from 9 p.m. to 3:59 a.m. The start time was chosen since 9 p.m. is dark most of the year and most typical daytime activities (e.g., work) have ceased. The 4 to 4:59 a.m. hour, not included in the survey, is a transition hour where most people out socializing the night before are likely to be home and some people may be starting their commutes to work. Nationally, belt use among fatally injured occupants of passenger vehicles is lowest from midnight through 3:59 a.m. and next lowest from 9 p.m. to midnight (see Figure 1). Thus these hours contain high-risk drivers engaged in typical nighttime activities and are recommended for use. However, individual States may have compelling reasons to modify these times slightly: current Connecticut surveys, for example, run from 9 p.m. to 2:59 a.m.

Observations will need to be accompanied by traffic volume “clicker counts,” at least for the first time they are done. These were described in detail earlier in this paper, but schedulers should keep this requirement in mind during the scheduling process.

D. Night-Specific Techniques (and Hints)

There are some important points that can make observations with night vision devices more effective. Observations cannot be conducted in rain or fog. The infrared light beam is reflected off the raindrops and will fail to penetrate into the observed vehicle. Observations may be difficult through tinted glass. It is important to have the infrared spotlight fully charged so that enough light penetrates tinted windows to allow for observation of occupants.

Observations from very close to the roadway are more difficult than those made from a few feet back from the roadway primarily due to the angle of observation and speed of the vehicle. Also, observation through the windshield may not be possible as UV protection on windshield may hamper the infrared light’s ability to penetrate the windshield (this is a problem with a 1-million candlepower light but is not with a fully charged 2-million candlepower light). It can be more effective for observations to be made through either the passenger or driver side window. The observer should be safely away from the road, of course, and perhaps even observing traffic in the second lane (traveling in the opposite direction of the nearest lane). Viewing from a slightly elevated position may also aid observation.

It is extremely difficult to observe belt use in vehicles traveling at high rates of speed, particularly at night. Moving observation points within the road segment to a location where traffic moves more slowly, such as near a signal, may be useful; observations of highway/Interstate/Freeway traffic may need to be conducted at off ramps.

V. Limitations and Concerns

The main limitation with these estimates is that relatively few volume counts are used to estimate volume change on a Statewide or regional level within a functional class. This may be even more relevant for small collector roads where traffic counts at 1 a.m. or later may result in zero cars counted. Multiple counts throughout a period of time can help increase the likelihood that the volumes used to estimate night passenger volume are more representative of the general traffic flow on a given roadway and not subject to chance occurrences (weather, construction, local events, etc.). Collecting new data each time the survey is conducted and averaging the values may also help increase the reliability of the counts.

Night observations can be expensive. They generally require two observers. Adding time for volume counts will increase costs even more. Repeating the volume counts each time the survey is conducted will cause some of these costs to be maintained.

Safety during night observation is also an issue. Observation sites may be located in high-crime areas which during the day may pose minimal risk to an observer. Observations taking place at 1 a.m. in a high-crime location may make the risk unacceptable without appropriate safeguards. During some night observations in Philadelphia for instance, off-duty (plain clothes) police officers were hired to deter interference with the observers. This is a worthwhile additional cost that States may consider before implementing a night observation program. From a scientific point of view, selecting site observation times based on crime prevalence may not be appropriate, as a more random selection of time slots is preferred to remove any systematic error.

VI. Summary/Recap

The general steps used to perform a statewide estimate of nighttime seat belt use are to (1) keep everything the same as the daytime estimate except for the few things required to make it possible to conduct the observations, and (2) make the observations representative of nighttime traffic.

Some enhanced procedures need to be implemented during nighttime observations primarily because it is usually dark and difficult to see at night. Judicious adjusting of site locations, special equipment, observer/recorder teams, and enhanced safety measures will overcome most of the obstacles posed for seat belt observations at night.

Strategies to make the observations representative of night traffic include drawing an entirely new sample based on night traffic volume data (not possible for most States); and making the volume data already included in the standard weighting spreadsheet represent night passenger vehicle volume. Depending on which data are available to the State, this can be done using hourly volume data collected by the State and then estimating what percentage of that volume belongs to passenger vehicles. If only daily volume figures are available, then the estimates involve deciding what percentage of the daily volume belongs to passenger traffic occurring in the night hours.

Data from these night observations will be entered into the adjusted spreadsheet (Table 7) to produce a statewide estimate of nighttime seat belt use.

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