Counting Motorcycles

final report

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prepared by:

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1.0 Introduction

Motorcycle safety is receiving increased attention because of dramatic increases in motorcycle ridership and crashes. As transportation safety professionals increase their focus on motorcycle safety, questions about the quality of data related to state motorcycle miles traveled are arising. Off-the-shelf vehicle classification systems often are unable to capture motorcycle traffic accurately, and equipment vendors have traditionally not addressed this deficiency.

The focus of this research is to evaluate and report on existing technical methods for estimating motorcycle vehicle miles traveled (VMT). This research summarizes current literature and research, and interviews with both collectors and users of motorcycle VMT estimates. It includes an evaluation of biases that may exist in counting technologies that are in current use and the identification of technologies that appear to be capable of producing more accurate counts of Class 1 vehicles. Recommendations are presented for the next steps to accomplish the mission of more accurate motorcycle VMT estimates to support safety analyses.

Most systems for classifying highway vehicles, including the 13-class system used by the Federal Highway Administration (FHWA), use Class 1 to represent all two and three-wheel motorized vehicles, with motorcycles constituting the principle component of this class. In this report, the terms "motorcycle" and "Class 1 vehicle" are used interchangeably.

Although classification counters generally are designed to produce separate counts of Class 1 vehicles, the small size and narrow width of these vehicles makes them more difficult to detect than vehicles with four or more wheels. As a result, many of the detectors in current use undercount Class 1 vehicles and some technologies, such as single-probe magnetic detectors, miss more than 50 percent of them.[1] On the other hand, technologies, such as road tubes, that classify on the basis of axle spacing are likely to classify many subcompact automobiles as Class 1 vehicles. The estimation of vehicle-miles of travel (VMT) of Class 1 vehicles is also affected by the seasonal and day-of-week (DOW) patterns of motorcycle use, which are distinctly different from those of all other classes of vehicle, complicating the process of converting vehicle counts into estimates of VMT.

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[1] Dan Middleton and Ryan Longmire, ***Implementation Efforts Pertaining to a Statewide Traffic Monitoring Equipment Evaluation and Demonstration Facility,*** Texas Transportation Institute, prepared for the Texas Department of Transportation, Project 5-4664-01, December 2008, http://tti.tamu.edu/publications/catalog/record_detail.htm?id=30213, accessed September 10, 2009.

In recent years, estimates of motorcycle VMT have grown much more slowly than motorcycle registrations,[2] either because of changes in counting technologies used or because of a decline in annual VMT per motorcycle. Possible reasons for a decline in annual VMT per motorcycle include the "toy" effect, changes in behavior, or an increase in the number of vehicles owned per operator.

Currently, there are two primary uses for counts of Class 1 vehicles:

1. For planning, particularly in areas where periodic motorcycle rallies result in increased volumes of these vehicles; and

2. As the basis for estimating the VMT of Class 1 vehicles.

The VMT estimates, in turn, are used as a measure of exposure for deriving motorcycle-related safety statistics such as crash rates, injury rates, and fatality rates. Particular concerns about the possible undercounting of Class 1 vehicles are that: any resulting underestimates of Class 1 VMT produce overestimates of these rates; and any secular increases in the extent of undercounting produce overestimates of the rates at which the crash, injury, and fatality rates are increasing.

One option for producing improved estimates of crash and fatality rates is to identify and use vehicle-detection technologies that produce more accurate counts of these vehicles and to develop improved procedures for using these counts to estimate VMT. A less desirable, but also less expensive, option is to adjust counts collected by existing equipment to correct for the tendency of that equipment to undercount or overcount these vehicles. A third option is to implement procedures for estimating the VMT of Class 1 vehicles that do not require vehicle counts. The first two options, but not the third, will also improve the estimates of motorcycle volumes used in planning applications.

This report addresses issues relating to the detection and counting of Class 1 vehicles and the estimation of the VMT of these vehicles. The body of this report is divided into seven sections. Following this Introduction are two sections that describe surveys that were conducted: a survey of traffic safety professionals that addressed the uses they make and would like to make of motorcycle VMT estimates and their related needs for accuracy at various levels of disaggregation; and a survey of state traffic-monitoring offices that obtained information about current procedures for counting motorcycles and for estimating the VMT of Class 1 vehicles. These two sections also include brief summaries of the most significant results of these surveys. More extensive summaries of these results are presented in Appendices A and B.

Section 4.0 presents a review of technologies that are currently used for collecting classification counts or that have been proposed for use in counting motorcycles and a

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[2] Between 2000 and 2007, motorcycle registrations increased by 64 percent but estimated VMT increased by only 30 percent. (FHWA, ***2007 (and 2000) Highway Statistics,*** Table VM-1, http://www.fhwa.dot.gov/policy/ohpi/qftravel.cfm, accessed November 25, 2009).

discussion of available information about the quality of motorcycle counts produced by these technologies. Section 5.0 discusses issues relating to the use of these counts to estimate the VMT of Class 1 vehicles and presents procedures for addressing these issues; and Section 6.0 presents procedures for using registration and/or insurance-company data for estimating the VMT of these vehicles without the use of count data. The concluding section presents several recommendations for improving the quality of motorcycle counts and of VMT estimates for Class 1 vehicles, as well as suggestions for additional research.

The report also contains: two appendices presenting the results of the two surveys that were conducted; a Bibliography listing all relevant material reviewed in the course of this project; and a list of abbreviations.

2.0 Survey of Data Users

The first task of the study consisted of conducting a survey of current and potential users of estimates of motorcycle VMT. This task was intended to provide an understanding of the need for estimates of motorcycle VMT and the uses of these estimates. Toward this end, a list of questions was prepared and used as the basis of interviews with 18 safety professionals.

Face-to-face interviews were conducted at the Traffic Records Forum in Phoenix, Arizona, and at an FHWA training session in Orlando, Florida. Following a review of responses obtained from 10 respondents in the first two sets of interviews, two questions were added to the list of questions, and eight additional interviews were conducted by telephone.

A total of 18 interviews were conducted. Seven respondents work for state safety offices, including five office heads. The other respondents have a variety of relevant backgrounds, as summarized in Table 2.1.

Table 2.1 Organizations Represented by Survey Respondents

State Safety Offices	7
State – Other	3
Metropolitan Planning Organizations	2
FHWA – Division Offices	2
FHWA – Office of Safety Programs	1
University Researcher	1
Governors' Highway Safety Association	1
American Motorcyclist Association	1

Key findings from the survey responses are:

- Fourteen respondents use statewide VMT estimates as a measure of exposure for deriving fatality rates, and 12 do so for crash rates. Two representatives of (different) Metropolitan Planning Organizations (MPOs) expect to use these estimates when developing their next transportation planning documents. One state respondent would like to use these estimates if they were of better quality, and one indicated that their state chooses not to use rates and reports only the actual number of crashes and fatalities.

- Of the eight respondents that were asked if they would prefer statewide VMT estimates derived from registration data to estimates derived from traffic counts, only one (the respondent that does not currently use VMT estimates because of quality concerns) stated a preference for registration-based estimates. A second respondent discussed the trade-offs between the alternatives (including the inability of a registration-based system to provide VMT estimates by road system) without stating a preference.

- Most respondents indicated a preference for count-based estimates to registration-based estimates, indicating a variety of concerns about registration-based estimates. These included concerns about: the use of a two-year cycle for registrations; the need for additional infrastructure for collecting the data; distrust of the accuracy of self-reported odometer readings in states where motorcycles are not subject to periodic safety or emissions inspections (particularly if odometer readings are also used as the basis for a proposed VMT tax); and the inability of a registration-based system to take seasonal factors into account. Only one respondent indicated a concern that a registration-based system would not provide any information about VMT by road system.

- Most of the respondents that were asked about the value of having separate motorcycle VMT estimates for urban roads and rural roads relative to that of having them by functional system without any urban/rural distinction said that the lack of an urban/rural distinction would reduce the value of the estimates, and some stated that, without this distinction, the value of functional-system distinctions would be lost.

- Most of the respondents indicated that estimates of VMT by type of Class 1 vehicle (available from a registration-based system but not from a count-based system) would be of some value.

- When asked what other ways of disaggregating motorcycle VMT estimates would be useful, interest was expressed in disaggregation by demographic variables, specifically age and/or gender. Other variables that were mentioned include: season, sub-state region, motorcycle size, speed, helmet/no-helmet, wet/dry, behavior, and vehicle-hours of travel (VHT) on motorcycles.

Perceptions of the quality issues that apply to current state estimates of motorcycle VMT were quite variable. Six respondents made explicit reference to these issues while one person responded to several questions about types of data of interest with the observation that the state already provides that information.

A complete summary of responses is presented in Appendix A. The first four questions in that summary were asked of all respondents, while the last two were only asked during the eight telephone interviews.

3.0 Survey of Traffic Monitoring Offices

A survey of State Traffic Monitoring Offices was conducted to learn about the current state of the practice in estimating motorcycle VMT, and, in particular, to learn of any successful technology and procedures that may be in current use. Toward that end, a short written survey was prepared, reviewed with the Panel, revised to reflect Panel comments, and distributed by e-mail to Traffic Monitoring Offices in all 50 states and the District of Columbia.

Responses to the survey were received from 24 states, including one from a state that does not currently count Class 1 vehicles, and three from other states that do not currently report VMT estimates for these vehicles to FHWA. Further follow-up was conducted with several of the respondents, providing additional useful information. Key findings from the survey responses are:

- All 20 states that report VMT estimates for Class 1 vehicles develop these estimates from classification counts.

- Sixteen states classify vehicles on the basis of number of axles and axle spacing, five on the basis of number of axles and length, and one on the basis of length alone. (Two states that do not report estimated VMT of Class 1 vehicles did not answer this question.)

- One state considers the quality of its estimates of Class 1 VMT to be “excellent,” six “good”, nine “fair,” and five “poor.”

- Six states currently use seasonal and day-of-week (DOW) factors derived solely from continuous counts of Class 1 vehicles to convert short counts of Class 1 vehicles to estimates of AADT. (Since use of Class 1 vehicles is subject to substantially greater seasonal and DOW variation than use of vehicles in other classes, use of factors derived solely from continuous counts of Class 1 vehicles usually is a necessary condition for producing reasonable estimates of the AADT of these vehicles.) One additional state will start deriving factors solely from continuous counts of Class 1 vehicles in 2009, and two plan to do so in the future. Five additional states provided ambiguous answers to this question. Ten states develop VMT estimates for Class 1 vehicles without using factors derived solely from counts of Class 1 vehicles and did not indicate any plans for changing this procedure.

Table 3.1 summarizes survey information about the number of states that have tested and/or currently use various technologies for detecting and counting Class 1 vehicles. Of the 23 states that currently count these vehicles, 20 use road tubes for short counts and 17 use piezo cable for continuous counts. The survey did not include a specific request as to which states use a combination of piezo sensors and loops for classification counting, though three states volunteered that that this is what they do. One state uses inductive loop signatures at continuous classification sites; and one other state has tested both inductive loop signatures and quadrupole loops, but is not currently using either of these technologies.

Table 3.1 Numbers of States That Have Tested/Used Various Technologies

	Short Counts		Continuous Counts	
Technologies	Tested	Used	Tested	Used
Piezo Cable	3	4	9	17
Piezo Film	1	0	4	3
Quadrupole Loops	1	0	1	0
Inductive Loop Signatures	1	0	2	1
Conventional Inductive Loops	6	2	4	8
Road Tubes	13	20	–	–
Manual	0	1	–	–
Fiberoptic Cable	0	0	0	0
Radar	7	3	4	5
Video	1	2	2	1
Infrared (including TIRTLs)	5	0	4	3
Magnetometer	1	0	2	0
Ultrasonic	0	0	0	0
Acoustic	1	0	2	0

4.0 Counting Class 1 Vehicles

This section reviews and evaluates several technologies that may be used for counting motorcycles and other Class 1 vehicles. The review focuses on technologies that are currently used for collecting classification counts, that have been suggested for possible use for counting motorcycles, or that have been previously tested and evaluated for such use. More elaborate (and expensive) systems for classifying vehicles at toll booths[3] are not reviewed.

The first subsection below discusses the use of conventional intrusive technologies – inductive loops, piezoelectric sensors, and road tubes – for counting Class 1 vehicles. The second subsection discusses the use of some promising or interesting nonintrusive technologies for performing these counts – video, radar, and infrared "TIRTLs."

For general use, the best technology for counting Class 1 vehicles appears to be the use of wide inductive loops and full lane-width piezos. For more specialized uses at limited numbers of locations, consideration may be given to overhead video with separate cameras for each lane. Pole-mounted video and radar systems also appear to be appropriate for collecting short counts at locations where truck volumes are low; but they produce significant undercounts of Class 1 vehicles at locations where there are appreciable volumes of large trucks, and they are likely to produce significant overcounts when the percentage of motorcycles in the traffic stream is very low.

The third subsection identifies three current federally funded research projects that have as a goal the development of an improved technology for detecting and counting motorcycles. And the concluding subsection presents some observations about the performance of the classification technologies that currently are most widely used.

■ 4.1 Intrusive Technologies

Currently the most widely used vehicle-classification technologies are piezoelectric sensors, usually in conjunction with inductive loops, and portable road tubes. These technologies are discussed in the first two subsections below, with the third subsection providing a briefer discussion of the use of magnetic detectors.

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[3] E.g., Transport Data Systems Model 200 series Automatic Vehicle Classification Systems, which include Doppler radar and a laser scanner and, optionally, treadles and a dual-tire detection system, http://www.transportdatasystems.com/, accessed September 17, 2009.

Inductive Loops and Piezoelectric Sensors

Continuous vehicle classification designed to distinguish the 13 FHWA vehicle classes currently is most commonly performed using either a pair of piezoelectric sensors or inductive loops and piezoelectric sensors in a loop-piezo-loop or piezo-loop-piezo configuration; and a pair of loops can also be used without piezos for continuous classification of vehicles by length class. These loop and piezo configurations are also in common use for collecting short classification counts, particularly on roads whose traffic volumes make the use of road tubes difficult.

In concept, classification counts collected using any of these four detector configurations include separate counts of Class 1 vehicles. However, the characteristics of Class 1 vehicles make it more difficult for piezos and loops to detect these vehicles than for them to detect the larger vehicles belonging to other FHWA classes, with the result that loop and piezo detectors frequently produce significant undercounts of these vehicles. In particular, Class 1 vehicles are smaller, lighter and contain appreciably less metal than other motorized vehicles, and they do not necessarily drive in the center of a lane.

The last characteristic, lack of lane discipline, may be the most significant cause of errors in the counting of Class 1 vehicles, and it is relatively easy to address. In order to maximize the probability that the wheels of a Class 1 vehicle will be detected by a piezoelectric sensor, the sensor should extend, as nearly as possible, across the entire lane. This means replacing the 6.5-foot sensors that are commonly used for traffic counting by full-lane-width sensors. It also means that (unless modified) weigh-in-motion (WIM) installations that use separate piezos for each wheel path cannot be used for counting Class 1 vehicles (though they are an excellent source of classification counts for the other vehicle classes).

Similarly, in order to maximize the probability that inductive loops detect the presence of Class 1 vehicles, the loops should extend nearly across the full width of the lane. This means replacing the six-foot by six-foot (and smaller) loops that are in common use by wide loops that come within a few inches of the edges of the lane and using high performance loop boards that minimize crosstalk. The Virginia Department of Transportation (VDOT)[4] worked with Peek Traffic to develop a four-channel loop board that meets the required performance standard and also a piezocard that provides improved detection of motorcycle axles by analyzing complex waveforms and rejecting energy from adjacent lanes.

VDOT also attributes their ability to detect motorcycles to their installation standards for loops and piezos. Loops are installed with four turns of wire and no splices, using wire that meets International Municipal Signal Association (IMSA) Specification 51-7; and they are now installing two piezos stacked in a single sawcut.

[4] Thomas O. Schinkel, Virginia Department of Transportation, personal communications, August 2009.

Another cause of errors in the counting of Class 1 vehicles is that axle spacing is often used to distinguish these vehicles from automobiles, even at sites at which loops are installed. Because of unavoidable measurement errors, it is difficult to use axle spacing as a reliable basis for distinguishing these two classes of vehicle. The axle spacings of current models of Harley-Davidson motorcycles, for example, are between 63 and 66 inches. These spacings are only a few inches shorter than those of the recently introduced Smart ForTwo, which has an axle spacing of only 73.5 inches; and they are only two to three feet shorter than those of several more conventional small subcompacts (such as the MINI Cooper, Honda Fit and Toyota Yaris) that have been introduced in the last few years and that generally have axle spacings of 97 to 102 inches. It is likely that, when using axle spacing to distinguish between these two vehicle classes, the small differences in axle spacings result in some small automobiles being misclassified as Class 1 vehicles.

Motorcycles can be more reliably distinguished from subcompacts on the basis of length. There are two reasons for this. One is that differences between the lengths of motorcycles and the lengths of small cars are generally somewhat greater than the differences between the axle spacings of these two types of vehicles. The shortest of the conventional subcompacts, the MINI Cooper, is 146 inches long, four feet longer than currently available Harley-Davidsons, which are only 98 inches long. (An exception is the Smart ForTwo, which is intended primarily for use in congested urban areas and is 106 inches long, only eight inches longer than the Harleys.)

The second reason is that inductive loops do not measure the physical length of vehicles, but rather their "magnetic lengths". The magnetic length of a vehicle is almost always shorter than its physical length, with the difference in length significantly influenced by the amount of metal at the front and rear ends of the vehicle. This characteristic of magnetic length is particularly desirable when using this measurement as the basis for distinguishing motorcycles from automobiles. The low metal content of motorcycles generally results in magnetic lengths that are at least three feet shorter than their physical length, increasing the usefulness of magnetic length for distinguishing motorcycles from small cars. VDOT uses a magnetic length of seven feet for making this distinction; however, some other observers recommend setting the threshold at six feet.[5]

VDOT takes one additional step to reduce the undercounting of Class 1 vehicles. Instead of using a single bin for all vehicle counts that cannot be classified, VDOT uses six bins for this purpose.[6] One of these bins, Bin 21, is used for vehicles whose length is less than seven feet but for which fewer than two axles are detected. On two-lane two-way roads, this condition almost always indicates that the piezo at a classification site has begun to fail and did not detect one or both of the axles of a Class 1 vehicle. Accordingly, on these roads, Bin 21 vehicles can be assigned to Vehicle Class 1.

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[5] Earl B. Hoekman, EL Enterprises, Roseville, Minnesota, personal communication, September 2009.

[6] Thomas O. Schinkel, "Mid-Atlantic Successes and Challenges", presented at North American Travel Monitoring Exhibition and Conference (NATMEC), August 2008.

On roadways that have two or more lanes in the same direction, Bin 21 counts can result from either the above condition or from a vehicle that is changing lanes; and the split between these two causes is likely to vary with motorcycle usage over the course of a year. On these roadways, an unusual increase in the number of vehicles assigned to Bin 21 during the motorcycle travel season is a good indication that a piezo has begun to fail and should be replaced. Counts of Class 1 vehicles collected at such a site probably should be rejected as unreliable. Alternatively, the increase in the number of vehicles assigned to Bin 21 could be taken as an estimate of the number of missed Class 1 vehicles and used to produce an estimate of the count of such vehicles at the site.

The use of wide loops and full lane-width piezos (or wide loops alone) will do much to reduce errors in counts of Class 1 vehicles. However, two sources of undercounting are likely to remain. One source is the tendency of motorcycle groups to travel in a 12-foot lane as if it were a pair of six-foot lanes, with pairs of motorcycles often traveling side-by-side. It has been suggested that, at increased cost, full-waveform processing might improve the ability of loops to count motorcycles under these conditions.[7] Also, piezos that are installed diagonally across a lane offer some potential advantages in being able to count motorcycles that are traveling side-by-side[8] as a pair of motorcycles.

The other remaining source of undercounting is the practice, in some areas where congestion is common, of motorcycle operators minimizing their delay by traveling between lanes or on roadway shoulders – roadway locations where these vehicles are likely to be missed by loops and piezos. Locations at which significant congestion is common are undesirable for most automated classification systems (since these systems require reasonably constant speeds to estimate vehicle length and/or axle spacing). For this reason, current practice in the collection of vehicle classification data is not to use data collected during periods of significant congestion. Motorcycle counting should follow the same principal, with data collected during congested periods being thoroughly investigated prior to utilization.

One additional source of error occurs when loops are used without piezos, particularly on roads with two or more lanes in the same direction. On these roads, some vehicles that are changing lanes will appear to be shorter than they actually are and, in some cases, may incorrectly be assigned to Class 1. The resulting overcounts of Class 1 vehicles are likely to be small, but they may be noticeable during periods when there normally is little or no motorcycle traffic.

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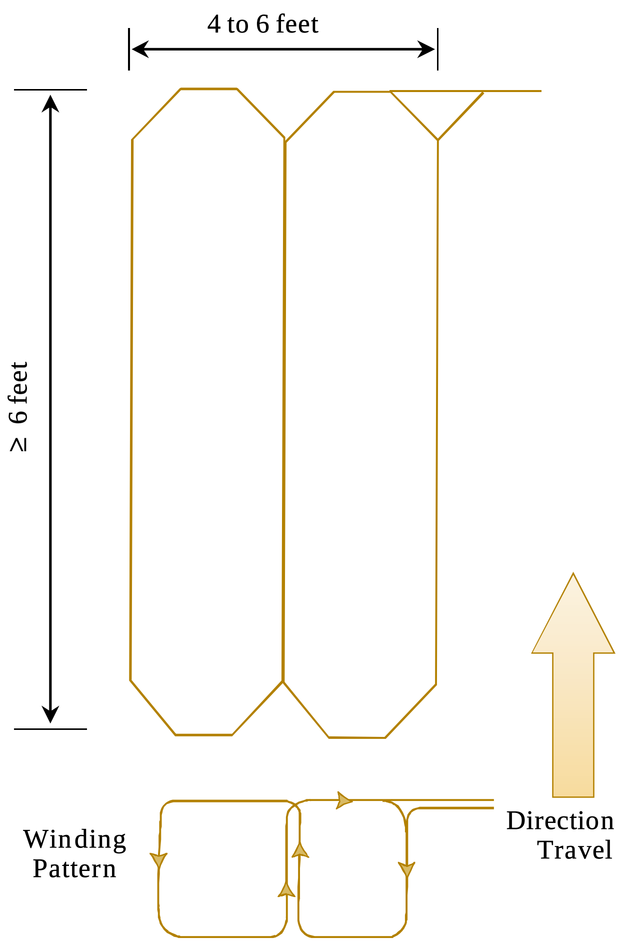
[7] Earl B. Hoekman, EL Enterprises, Roseville, Minnesota, personal communication, January 2010.

[8] Diagonal piezos can also be useful for distinguishing six-tire (Class 5) trucks from four-tire (Class 3) trucks.

Quadrupole Loops and Inductive Loop Signatures

Some interest has been expressed in two alternatives to conventional inductive loops – ***quadrupole loops*** and ***inductive loop signatures.***

Figure 4.1 Quadrupole Loop Configuration



Quadrupole loops are wired in a figure-eight pattern, as shown in Figure 4.1, with one or more wires making two passes through a center sawcut and carrying current in the same direction on both passes.[9] This wiring pattern creates two magnetic fields that reinforce each other, improving the loop's ability to detect small vehicles. These loops are commonly used for vehicle detection at demand-actuated traffic signals, but not for traffic counting or classification. For the specific application of vehicle detection, the overall

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[9] FHWA, ***Traffic Detector Handbook,*** Third Edition, 2006, http://www.tfhrc.gov/its/pubs/06108/06108.pdf, accessed September 17, 2009, pages 4-40 to 4-42.

4-to-6 feet width of the loops as they are commonly installed limits their ability to detect two-axle vehicles traveling near the sides of a lane; however, one observer has suggested that increasing the width of the loops to a total of 10 feet while keeping their length at 6 feet might be an effective means of detecting motorcycles.[10]

Inductive loop signatures are a sophisticated concept that allows the particular "signature" of a vehicle to be obtained from one set of loops and used to ***re-identify*** the vehicle when it passes a second set of loops. This information provides highway agencies with the ability to monitor average roadway speeds between the two sets of loops.[11] Because the signatures of different types of vehicles are distinctly different from each other, this technology has potential for distinguishing motorcycles traveling in groups as well as some potential for providing a more reliable means of distinguishing Class 1 vehicles from Class 2 vehicles than the use of a simple length threshold.

Road Tubes

Pneumatic road tubes are used for short-term vehicle classification on roads with low-to-moderate traffic volumes, with axle spacing used as the basis for classifying vehicles.

Road tubes are normally installed across the full width of a lane, so they do not have a problem detecting motorcycles traveling along the side of a lane as do conventional loops and piezos. On the other hand, the tubes' sensitivity may be insufficient to detect light motorcycles; and, in light traffic, some motorcycle operators may choose to drive around them. For the purpose of counting Class 1 vehicles, however, the most significant limitation of road tubes appears to be that axle spacing cannot be used reliably to distinguish these vehicles from the small subcompacts that have been introduced in the last few years.

When axle spacing is used to distinguish Class 1 vehicles from automobiles, the Vehicle Detector Clearinghouse currently suggests using a threshold of six feet.[12] This suggestion appears to be perfectly appropriate. However, the suggested threshold will result in classifying some subcompact automobiles as Class 1 vehicles, resulting in possible overestimates of the numbers of Class 1 vehicles operating on the road being monitored. Thus, the use of road tubes with a six-foot threshold for counting Class 1 vehicles may tend to produce overestimates of the VMT of these vehicles. Moreover, at least some

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[10]Earl B. Hoekman, EL Enterprises, Roseville, Minnesota, personal communication, January 2010.

[11]Stephen G. Ritchie, ***et. al., Corridor Tracking and Investigation of Anonymous Vehicle Tracking for Real-Time Performance Measurement,*** California PATH Program, Institute of Transportation Studies, University of California, Berkeley, October 2008.

[12]Vehicle Detector Clearinghouse, http://www.nmsu.edu/~traffic/TechAssist.htm, accessed September 14, 2009.

states currently use higher thresholds,[13] which could produce more appreciable overestimates.

Magnetic Detectors

Magnetic detectors measure the change in the earth's magnetic flux created when a vehicle passes through a detection zone. Because of the low iron and steel content of Class 1 vehicles, these vehicles are frequently missed. One test of the use of magnetic detectors (a dual-probe detector in the first lane and a single-probe detector in the second lane) found that they detected only about 35 percent of motorcycles;[14] however, substantially better results can be expected with triple-probe detectors.

n 4.2 Nonintrusive Technologies

Nonintrusive detection technologies are ones that are installed above or on the side of the roadway, without ***intruding*** on the roadway itself. Three such technologies are discussed below: video, radar, and an innovative device known as "The Infra Red Traffic Logger" (or TIRTL).

Video

For purposes of vehicle classification, video cameras may be pole-mounted on the side of the road or in the median; or they may be mounted directly over the roadway, with a separate camera for each lane. For night-time use, video cameras require artificial lighting and they may have difficulty dealing with the glare and shadows caused by headlights. Also, they are inappropriate for use at foggy locations.

Pole-Mounted Video

The principal disadvantage of pole-mounted cameras is that of ***occlusion.*** Vehicles in the lanes closest to the camera tend to block the view of vehicles in lanes that are farther from the camera. The extent of the occlusion problem tends to vary with the angle between the

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[13] One of the surveyed states volunteered that it uses a threshold of eight feet.

[14] Dan Middleton and Ryan Longmire, ***Implementation Efforts Pertaining to a Statewide Traffic Monitoring Equipment Evaluation and Demonstration Facility,*** Texas Transportation Institute, prepared for the Texas Department of Transportation, Project 5-4664-01, December 2008, http://tti.tamu.edu/publications/catalog/record_detail.htm?id=30213, accessed September 10, 2009.

direction of travel and the visual line-of-sight of the video camera; and, more importantly, it increases when the vehicles in the near lanes are large and those in the far lanes are small. For this last reason, occlusion can be a significant problem for counting Class 1 vehicles on roads with significant truck traffic.

The Texas Transportation Institute (TTI) tested a pole-mounted video system on a road with 10 percent trucks (Class 5 and higher) for several hours a day over two three-day periods, finding that motorcycles were undercounted by about 17 percent.[15]

Substantially better results have been obtained with pole-mounted video systems that have been tested at locations with low percentages of trucks.

The Montana Department of Transportation collected video data from pole-mounted systems tested at two major intersections: 36 hours of data from an intersection in Helena; and 37 hours of data from one in Billings.[16] The overall truck percentages were 2.7 percent at the Helena intersection, and 1.5 percent for the Billings intersection. Motorcycle counts were developed from visual inspection of the video tapes and by using an automated turning-movement vehicle classification system provided by Miovision.[17] Over the full counting period, the Miovision system overcounted motorcycles by 4.2 percent in Billings and undercounted them by 0.8 percent in Helena, though the hour-by-hour results indicate that the low overall error rates mask some occasionally larger errors in the hourly counts that tended to cancel each other out.

Somewhat similar results were obtained with a pole-mounted system by researchers from Clemson University using their own algorithm to count motorcycles at two sites in the vicinity of an annual motorcycle rally held in Charleston, South Carolina.[18] At one site, the video camera was mounted in the median of a four-lane divided highway; at the other, the camera was mounted on the side of a road carrying two lanes of traffic in a single direction. Motorcycles accounted for 56 percent of vehicles at the first site and 69 percent at the second. Truck percentages were not stated in the paper but presumably were low.

In the tests, the Clemson system overcounted motorcycles in the departing direction by 4.4 percent at the first site and undercounted them in the approaching direction by 2.6 percent at that site and by 6.2 percent at the second site. Examples are shown in the paper of undercounts occurring because of motorcycles sharing a lane and because of occlusion,

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[15] ***Ibid.***

[16] Becky Duke and Peder Jerstad, Montana Department of Transportation, Helena, personal communications, October and November 2009.

[17] Miovision Technologies, Inc., Kitchener, Ontario, Canada, http://www.miovision.com/home/index.php, accessed October 8, 2009.

[18] Neeraj K. Kanhere, et. al., "Traffic Monitoring of Motorcycles During Special Events Using Video Detection," presented at the Annual Meeting of the Transportation Research Board, January 2010.

and of overcounts occurring because a passenger car or a three-wheel motorcycle is misclassified as two motorcycles. Additional testing is required to determine how well the system will perform on roads carrying a more typical mix of vehicles where occlusion may be a more significant problem, particularly during periods of heavy congestion. Also, the current version of the system focuses on the counting of motorcycles, distinguishing only two other classes of vehicles – four-tire vehicles and trucks – limiting the system's value for general-purpose classification counts.

Although both the Miovision and Clemson systems produce fairly good motorcycle counts when truck volumes are low and motorcycle volumes are moderate to high, there is reason to believe that (like the system tested by TTI) they will undercount when truck volumes are higher. Also, the quality of the Miovision and Clemson counts result partly from the offsetting effects of missed motorcycles and occasional misclassification of passenger cars. At times when the percentage of motorcycles in the traffic stream drop (as in winter), it is likely that the latter effect would overwhelm the former effect, resulting in substantial overestimates of motorcycle volumes. This may not be a significant limitation of these systems for in-season counts, but it may make these systems inappropriate for collecting continuous counts.

Overhead Video

Overhead video cameras do not encounter occlusion. As a result, they are considered to be a highly accurate means of classifying vehicles on the basis of length. One user of this technology has found them to have over 99 percent accuracy in classifying vehicles by length.[19] However, separate statistics on the accuracy of overhead video for classifying Class 1 vehicles are not available. The special characteristics of these vehicles (small size, sharing of lanes, etc.) are likely to make them more difficult to detect than other vehicles, and so it is likely that these vehicles will be missed at a somewhat higher rate than implied by the statistics on overall classification accuracy.

Overhead video cameras do not intrude in the roadway ***per se***, and so they are classified as nonintrusive. However, they do require the use of relatively large overhead structures and artificial lighting for night-time counting. Accordingly, they may be considered to be ***visually*** intrusive, a characteristic that is likely to sharply limit the number of such installations. As a result, these systems are unlikely to become a major source of counts of Class 1 vehicles; and, by themselves, they are unlikely to satisfy the requirements for the continuous classification element of a state's traffic monitoring program.

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[19] Joe Palen, California Department of Transportation, Sacramento, personal communication, October 2009.

Radar

For vehicle classification, pole-mounted radar detectors have performance characteristics that are likely to be fairly similar to pole-mounted video, but without the requirement for artificial lighting and with the ability to operate in foggy areas. No tests of pole-mounted radar on roads with low percentages of trucks were identified in the literature review. However, the TTI study did test such a system at the same site as was used for their tests of a video system. At this site, a frequency-modulated continuous-wave pole-mounted microwave radar system produced an overall undercount of about 19 percent (as opposed to 17 percent for video), with particularly large (and unexplained) undercounts observed on two of the six days of the test.[20]

TIRTLs

The Infra Red Traffic Logger, or "TIRTL", is an active infrared traffic counting and classification system produced by CEOS[21] of Australia and marketed in this country by Control Specialists Company.[22] TIRTLs are designed to detect tires, and so, unlike most other nonintrusive classifiers, they can be used for axle classification and not just length classification.

A TIRTL consists of a pair of tire-height transmitters that is placed on one side of a roadway and a pair of detectors that is placed on the other side. The two transmitters each produce two infra-red beams, one aimed at each of the detectors. Thus, the four beams consist of two parallel beams and two in a crisscross pattern. Tires are detected when the beams are broken.

The time elapsed between the breaking of the two parallel beams provides the information necessary to determine vehicle speed, and the time elapsed between the breaking of any other pair of beams provides the information necessary to determine the lane in which the vehicle is operating as well as the relative position of the detected tire in the lane. The existence of a fourth beam provides some redundancy that reduces the occlusion problem. For the purpose of motorcycle detection, the occlusion problem is also reduced relative to that of length-classification technologies such as video and radar because the differences in wheel size between the wheels of vehicles of different sizes are much smaller than the differences in overall vehicle size.

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[20] Middleton and Longmire, ***op. cit.;*** and Dan Middleton, TTI, personal communication, September 2009.

[21] CEOS Industrial Pty. Ltd., ***TIRTL Technical Overview,*** Heidelberg, Victoria, Australia, http://www.ceos.com.au/pdfs/TIRTLTechnicalOverview.pdf, accessed September 18, 2009.

[22] Control Specialists Company, Winter Park, Florida, http://www.tirtl.com/, accessed December 9, 2009.

In concept, TIRTLs may be installed permanently for use as continuous counters or temporarily for the collection of short counts. However, when used for short counts, it is important that the devices be securely placed so that vibrations caused by truck traffic do not cause the beams to go out of alignment.[23]

TIRTLs require a clear line of sight between the transmitters and the detectors that passes below the automobile chassis and above the crown of the roadway. Thus, they cannot be used on roadways with high crowns. Also, they apparently cannot be used on roads that have Jersey barriers,[24] and it has been found that road spray causes them to undercount traffic during periods of heavy precipitation.[25]

The accuracy of TIRTL classification counts in general, and TIRTL counts of Class 1 vehicles in particular, varies inversely with roadway width. Six limited tests of TIRTLs on two-lane roadways with an overall width, including shoulders, of 39 feet or less indicate that for these roadways, TIRTLs tend to identify more Class 1 vehicles than do manual counts, with an overall net overcounting rate of about five percent,[26] suggesting that TIRTLs may warrant further evaluation for possible use on two and three-lane roadways. On the other hand, five similarly limited tests on roadways with overall distances between transmitters and receivers of 68 feet or more resulted in overcounting rates for Class 1 vehicles of 50 percent or more (as well as significant undercounting of Class 2 and 3 vehicles), with the worst performance occurring when traffic was being classified in lanes that were 60 feet or more from the transmitter.[27]

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[23] Rob E. Robinson, Illinois DOT, personal communication, September 2009.

[24] ***Ibid.***

[25] Jerry Kotzenmacher, Erik Minge, and Bingwen Hao, ***Evaluation of Non-Intrusive Traffic Detection System,*** SRF Consulting Group, prepared for Minnesota Department of Transportation, September 2005, http://www.pooledfund.org/documents/TPF-5_073/final_report.pdf, accessed October 22, 2009, page 32.

[26] French Engineering, LLC, ***Traffic Data Collection Methodologies,*** prepared for Pennsylvania Department of Transportation, Bureau of Planning and Research, Harrisburg, Pennsylvania, April 2006, pages 14-23, and Appendix A; and Kotzenmacher, Minge and Hao, op cit., pages 31-32 and D-2.

[27] French Engineering, ***op. cit.,*** pages 26-34, and Xin Yu, "Evaluation of Non-intrusive Sensors for Vehicle Classification on Freeways", University of Hawaii at Manoa, http://2isfo.eng.hawaii.edu/Presentations/Session%2023_Student%20Competition/23%20-%20Yu.pdf, accessed September 10, 2009, pages 7-9.

4.3 Current Research

Three ongoing research projects are investigating potential improved technologies for counting motorcycles.

One project[28] is investigating the use of diagonally installed full lane-width piezoelectric ceramic/quartz disk sensors for counting and classifying vehicles. Diagonal installation of the sensors results in separate pulses for each wheel that strikes a sensor. The research is addressing both the fabrication of the sensors and the development of algorithms to interpret the pulses produced by the sensors. Having separate pulses for each wheel makes it easy to distinguish four-wheel vehicles from two-wheel vehicles that are not sharing a lane. It is also likely that, under certain circumstances, the availability of separate pulses will permit the proper counting of two-wheel vehicles that are sharing a lane, but this issue is not addressed in the abstract.

The other two projects are being performed under Small Business Innovation Research (SBIR) grants awarded in 2008.[29] The SBIR program provides small businesses with funding to develop new and innovative products. Funding is provided in three phases, with the goal that the recipient will produce a marketable product at the end of the third phase. When contacted, the recipients of both grants were still in Phase 1 of their research and not yet willing to provide any information about the technologies that they have proposed developing.

4.4 Some Observations About Current Classification Technologies

There is now a fairly extensive variety of options available for detecting Class 1 vehicles and for distinguishing them from larger vehicles. However, most counting of these vehicles is still performed using one of three options:

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[28] "Accurate Vehicle Classification Including Motorcycles Using Piezoelectric Sensors," Research Grant for the period July 2009 to June 2011, funded by USDOT, Research and Innovative Technology Administration, Principal Investigator: Hazem Refai, University of Oklahoma, http://rip.trb.org/browse/dproject.asp?n=23061, accessed September 18, 2009.

[29] Richard Kellner, Autonomous Innovations, Inc., Santa Fe, New Mexico, "Collection of Motorcycle Exposure and Crash Factor Data," Project 081-NH2-005 (funded by NHTSA), contacted August 2009; and Bo Ling, Migma Systems, Inc., Walpole, Massachusetts, "A New Multi-Sensor Hybrid System for Motorcycle Detection and Classification", Project 081-FH4-009 (funded by FHWA), contacted August 2009.

1. Road tubes with axle spacing;

2. Conventional loops and piezos with axle spacing; or

3. Conventional loops (with or without piezos) with classification on the basis of magnetic length.

This literature review did not uncover any data on the accuracy of these three technologies for counting Class 1 vehicles. However, as observed in Section 4.1, all three have some limitations. In particular, the difficulty of using axle spacing to distinguish motorcycles from small cars means that the first option is likely to result in some misclassification of motorcycles and small cars; and, when used with an eight-foot threshold (as is the current practice in at least some states), this misclassification may result in appreciable overcounting of the number of motorcycles in operation. On the other hand, the poor lane coverage of conventional 6’x6’ (and smaller) loops means that the third option is likely to result in undercounting these vehicles.

The middle option combines the weaknesses of the other two options. For the middle option, it is not clear how the undercounting and overcounting tendencies balance out. However, an expected increase in the number of short wheelbase automobiles in use over the next several years is likely to result in a continuing increase in the tendency of this option to overcount motorcycles. It is likely that this method of counting motorcycles will eventually produce overcounts, if it is not doing so already.

In recent years, there has been a shift away from using road tubes for collecting classification counts and toward using other technologies, including conventional loops and piezos. Most of the replacement technologies tend either to undercount Class 1 vehicles or to produce smaller overcounts than road tubes. This shift, from technologies that tend to overestimate the VMT of Class 1 vehicles to technologies that either underestimate the VMT of these vehicles or produce smaller overestimates, is likely to be a major reason for the slow growth in these VMT estimates (averaging less than 0.25 percent per year) between 1998 and 2005.[30] It is possible that a reduction in the axle-spacing threshold for distinguishing motorcycles from automobiles in some states may have also contributed to the slow growth in these VMT estimates. On the other hand, the increasing popularity since 2005 of small subcompacts that are sometimes classified as motorcycles on the basis of axle spacing is a likely contributor to the 30 percent increase in estimated motorcycle VMT observed between 2005 and 2007.[31]

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[30] NHTSA, ***Traffic Safety Facts,*** 2008 Data – Motorcycles, DOT HS 811 159, http://www-nrd.nhtsa.dot.gov/Pubs/811159.PDF, accessed December 9, 2009, Table 1.

[31] ***Ibid*** and FHWA, ***2007 Highway Statistics,*** Table VM-1, http://www.fhwa.dot.gov/policy/ohpi/qftravel.cfm, accessed November 25, 2009.

5.0 Using Motorcycle Counts to Estimate VMT

Well established procedures for using classification counts to estimate AADT and VMT by vehicle class are presented in the ***AASHTO Guidelines for Traffic Data Programs***[32] (the ***AASHTO Guidelines***) and FHWA's ***Traffic Monitoring Guide***[33] (FHWA's ***TMG***), and the application of these procedures to motorcycles are made more explicit in the 2008 supplement to FHWA's ***TMG.***[34] However, the use of these procedures for estimating the VMT of Class 1 vehicles poses some particular challenges that are not fully addressed in these documents. This chapter identifies these challenges and presents recommendations for adapting procedures for the specific task of estimating the VMT of Class 1 vehicles.

The recommendations presented in this chapter represent professional judgment based on the relatively limited amount of information that is currently available about the operations of Class 1 vehicles and the technologies that are used to count these vehicles. The report identifies several recommendations that warrant further investigation. Potential areas of future research related to these recommendations are also summarized in Section 7.2.

5.1 Continuous Counts

The AASHTO and FHWA/TMG procedures require the use of continuous classification counts to adjust short-duration classification counts for seasonal and day-of-week (DOW) variation in traffic volumes. In most areas of the country, Class 1 vehicles have seasonal patterns of use that are unlike those of any other vehicle class, and they also have DOW patterns that are unlike those of any other vehicle class. Accordingly, this adjustment process ***requires*** the use of data on the seasonal and DOW variations in traffic volumes of Class 1 vehicles.

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[32] American Association of State Highway and Traffic Officials, ***AASHTO Guidelines for Traffic Data Programs,*** 2009, Chapter 5.

[33] FHWA, ***Traffic Monitoring Guide,*** May 2001, Section 4.

[34] FHWA, ***Traffic Monitoring Guide – Supplement,*** April 2008.

The established way of developing the required data is through the continuous collection of counts of Class 1 vehicles at several sites throughout the year. Continuous counts collected for this purpose must provide a good quantitative understanding of how traffic volumes of Class 1 vehicles vary seasonally and over the course of a week. To minimize the effects of random variations in traffic volume, the daily volume of the vehicles being observed must be at least moderate. Since the volumes of Class 1 vehicles on most roads tend to be small, the sites used for this purpose generally should be sites at which Class 1 traffic volumes are relatively high.

To provide a good understanding of how traffic volumes of Class 1 vehicles vary seasonally and over the course of a week, it also is more important to keep counting errors reasonably consistent (in percentage terms) over the course of the week and over the course of a year than it is to have an accurate weekly or annual total.

It appears that the requirement for temporal consistency is best met by counts collected with inductive loops and piezos, and that it is likely that even conventional loops may be used for this purpose. That is, although conventional loops result in undercounting motorcycles, this undercounting is likely to be reasonably consistent over the course of the week and over the course of the year. Hence, continuous counts collected with conventional loops and piezos may be a reasonable source of the data required for developing seasonal and DOW factors for Class 1 vehicles (even though they are ***not*** a good source of data on the total ***volume*** of such vehicles).

On the other hand, it appears that pole-mounted video and radar systems and TIRTLs probably do not meet the requirement for temporal consistency. Under certain conditions, these systems are capable of producing reasonably good counts of Class 1 vehicles. However, these counts actually are the result of missing some Class 1 vehicles and misclassifying some larger vehicles as Class 1 vehicles. These two effects may tend to cancel when the traffic stream includes a normal in-season percentage of motorcycles. But in colder climates this is not likely to be the case in winter months. As a result, these technologies are likely to produce significantly more overcounting in winter months than in summer months.

Similarly, because of misclassification of vehicles that are changing lanes, inductive loops that are used without piezos on roads with two or more lanes in the same direction are may produce counts of Class 1 vehicles that have a significant upward bias in winter months that is missing or much weaker in summer months. As a result, like the technologies discussed in the preceding paragraph, inductive loops without piezos are may be unsuitable as a source of data to be used in the development of seasonal and DOW factors in areas where there is significant seasonal variation in motorcycle use.

5.2 Factor Groups

The FHWA/TMG and AASHTO processes for adjusting short counts for seasonal and DOW variation require the use of several ***"factor groups",*** with a separate factor group used for any set of roads that has a seasonal or DOW pattern of traffic volume that is distinctly different from the patterns on other roads. In the case of Class 1 vehicles, different factor groups should be used, at least, for roads that are used by these vehicles primarily on weekends and for roads whose use is distributed more evenly throughout the week. In addition, large states generally should develop separate factor groups for each part of the state that has a different seasonal pattern of motorcycle use. It should be noted that the factor groups established for factoring counts of Class 1 vehicles need ***not*** be the same as those used for factoring other vehicle counts.

The number of continuous sites belonging to each factor group will be a function of the number of such sites that are capable of producing reliable information about the seasonal and DOW patterns in the use of Class 1 vehicles. Ideally, as recommended by FHWA's ***TMG*** and the ***AASHTO Guidelines,*** there should be five to eight such sites in each group. However, if the number of such sites in operation is small, it may not be practical to have five continuous sites per group.

When phasing in an improved technology for continuous count sites, it may not be clear whether or not to continue using data from older continuous count sites in the factoring process. To shed light on this decision, consideration should be given to the extent to which the new counters appear to be providing better detection of Class 1 vehicles and, more importantly, the effect that these better counts have on the resulting DOW and seasonal patterns of Class 1 traffic observed at specific sites. If improved technology results in significant changes in the observed patterns, for factoring purposes, use of counts produced by the older technology should be phased out as quickly as practical, even if this means reducing the number of continuous sites belonging to some factor groups to two or three. If the new technology produces relatively minor changes in the observed DOW and seasonal patterns, a more gradual phase-out would be appropriate.

It is more important to create separate factor groups for observably different seasonal and DOW patterns of Class 1 traffic volumes than to increase the number of continuous sites assigned to a group. On the other hand, identifying several such sites with similar patterns of Class 1 volume provides a good understanding of the kinds of roads that are likely to exhibit these patterns, and thus, of the kinds of roads that are appropriately assigned to a given Class 1 factor group. In order to produce good estimates of the VMT of Class 1 vehicles, we recommend that, over time, each state develop a sufficient number of such sites to allow a minimum of five such sites to be assigned to each factor group that has an observably different seasonal or DOW pattern of Class 1 traffic.

n 5.3 Seasonal Factoring for States Where Motorcycle Rallies Are Held

Motorcycle rallies result in very substantial temporary increases in the volume of Class 1 vehicles during a rally and for a few days before and after. In order to obtain information about motorcycle volumes during this period, some states in which these rallies are held collect a significant number of short counts of Class 1 vehicles on potentially affected roads during this period. If properly factored, these counts can be used to estimate AADT on the roads on which the counts are collected and annual VMT on the set of affected roads. However, the standard seasonal factoring procedure, which uses calendar months as the basis for seasonal factoring, generally will produce a significant upward bias in the resulting AADT estimates.[35]

In order to use rally-related counts to estimate AADT on these roads, we recommend that:

1. One or more factor groups be established for exclusive use on roads on which traffic of Class 1 vehicles is significantly affected by motorcycle rallies; and

2. Seasonal factors for these groups be developed for a set of seasonal periods that includes one period that corresponds to the period of increased motorcycle activity.[36]

States adopting this approach probably should start with a single factor group for use on rally-affected roads. However, as a better understanding is developed of how motorcycle traffic on these roads varies before, during and after the rally, these states may wish to create one or more additional rally-related groups and to refine this procedure in other ways.

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[35]To understand the source of this bias, consider a rally that starts in late July. Traffic volumes of Class 1 vehicles on affected roads in late July are larger than they are in early July by an order of magnitude or more, and they are likely to be at least twice as high as the overall average for July. In order to convert a Class 1 count collected on one of these roads in late July to an unbiased estimate of AADT on that road, it is necessary to use a seasonal factor that reflects the very high volume that can be expected in late July rather than a factor that reflects an average of conditions in early and late July. However, conventional calendar-month factors are derived from counts collected in both early and late July. As a result, they will tend to produce significant overestimates of AADT on these roads.

[36]For example, if the rally starts in late July, one possible set of seasonal periods would consist of the rally period, 2 additional periods corresponding to early July and late August, and 10 periods corresponding to the other 10 months of the year, producing 13 seasonal periods (or “months”). Similarly, a rally period that extends from August 5 to August 23 in a given year could be handled using a set of 12 seasonal periods: a “July” period that extends to August 4, the rally period, a “September” period that starts on August 24, and 9 periods corresponding to the other months of the year. States that use these modified seasonal periods for rally-related factor groups may find it desirable to use the same periods for all Class 1 factor groups.

n 5.4 Factors versus Ratios

The ***AASHTO Guidelines***[37] makes a distinction between two ways of converting a short count to an estimate of average volume over an extended period of time. One is to ***multiply*** the count by an appropriately derived ***traffic factor,*** and the other is to ***divide*** the count by an appropriately derived ***traffic ratio.*** The ***Guidelines*** express a mild preference for the use of traffic ratios, which tend to produce slightly more reliable estimates than traffic factors.

Both quantities are derived, using similar procedures, from counts collected at one or more continuous count sites; and, except for the difference between multiplication and division, both quantities are used in the same way. Furthermore, they produce very similar results. However, when traffic factors and traffic ratios are derived using data from two or more continuous count sites, the results almost always differ slightly (frequently by a very small amount), and it appears that the estimates produced by traffic ratios are slightly more reliable than those produced by traffic factors.[38] For this reason, there is a slight preference for using traffic ratios.

n 5.5 AADT Estimates Derived from Short Counts

The use of traffic ratios (or traffic factors) to convert short counts to estimates of AADT is an inherently imperfect process. The seasonal and DOW patterns in traffic volume at any short-count site are likely to differ somewhat from the average of the patterns at the continuous-count sites belonging to the factor group to which the short-count site is assigned, resulting in some error in the resulting estimates of AADT. On a statewide basis, we have estimated that, for total traffic, when using grouped factors, AADT estimates are likely to have a mean absolute error of seven to nine percent.[39]

The accuracy of estimates of the AADT of Class 1 vehicles undoubtedly is substantially poorer than the estimates of total AADT. The volume of Class 1 vehicles is a very small fraction of total traffic volume, there is much higher relative day-to-day variation in the volume of these vehicles, and neither the technology for counting these vehicles nor the

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[37] Op. cit., pages 5-8 to 5-10.

[38] Cambridge Systematics, Inc., Washington State Transportation Center, and Chaparral Systems, ***Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design,*** NCHRP Report 538, 2005, pages 1-12 to 1-15.

[39] Cambridge Systematics, Science Applications International Corp., and Washington State Transportation Center, ***Use of Data from Continuous Monitoring Sites,*** prepared for FHWA, August 1994, Volume II, page 27.

analytic procedures for converting short counts into estimates of AADT of Class 1 vehicles perform as well as the corresponding technology and procedures for total traffic.

Estimates of the AADT of Class 1 vehicles that are derived from short counts are subject to a combination of random errors and systematic errors.

Focusing first on the random errors, we observe that the effects of random errors in AADT estimates derived from counts collected during days when volumes are relatively low get magnified by the factoring process; and, in the case of counts collected at times when Class 1 vehicles normally do not operate, these effects can be quite extreme. On the other hand, errors in counts collected during days when volumes are high tend to get muted by the factoring process. For this reason, estimates of the VMT of Class 1 vehicles should be developed only from counts that are collected “in season”. Also, if roads belonging to one or more factor groups have volumes of Class 1 vehicles that are much higher on weekends than on weekdays, it would be desirable for estimates of the VMT of Class 1 vehicles on these roads to be developed only or primarily from weekend counts, despite the extra cost of collecting weekend counts.

When VMT estimates of Class 1 vehicles are derived from sets of AADT estimates that are collected entirely in season, the random errors in the AADT estimates tend to cancel. If a sufficiently large number of AADT estimates are used, the effect of these errors on the resulting VMT estimates becomes reasonably small. However, the effect of the systematic errors remains. Thus, for the purpose of estimating the VMT of Class 1 vehicles, the systematic errors in the AADT estimates are likely to be of substantially greater concern than the random errors.

There are two principal sources of systematic error in estimates of the AADT of Class 1 vehicles. One is the tendency of most technologies to produce either consistent undercounts or consistent overcounts of Class 1 vehicles. One possible means of addressing this source of error is to develop data that provides an indication of the extent of undercounts or overcounts and to adjust all counts accordingly. If carried out carefully, this adjustment process can produce improved estimates of the AADT and VMT of Class 1 vehicles, and it has the potential of largely eliminating this source of VMT underestimation.

The potential issue of undercounting or overcounting motorcycles by the current equipment limits the effectiveness of the factoring procedure that is used to convert short counts to estimates of AADT in the standard AADT estimation procedure and in the motorcycle procedure published in FHWA’s 2008 supplement to the ***TMG***. Biases will result if continuous counters produce a consistent pattern of variations in undercounts or in overcounts over the course of a week or over the course of a year. For example, consider continuous monitoring equipment that produces undercounts on some roadway systems that are greater on weekends than on weekdays (e.g., because of more side-by-side operation of motorcycles during weekends). When traffic ratios (or traffic factors) that are derived from these continuous counts are applied to short counts collected on weekdays, AADT estimates will be produced that are downwardly biased (even if the short counts themselves are not downwardly biased).

On the other hand, consider continuous monitoring equipment that produces undercounts on some roadway systems (e.g., urban systems) that are greater on weekdays than on weekends (e.g., because of increased use of congestion-avoidance strategies by motorcycles on weekdays). If traffic ratios (or traffic factors) derived from these continuous counts are applied to accurate short counts collected on weekdays, the resulting AADT estimates will be upwardly biased; and if they are applied to downwardly biased short counts they will tend to reduce the downward bias in the resulting AADT estimates.

For the purpose of estimating system-wide VMT (but not for the purpose of estimating AADT on an individual road), one potential way of reducing the undesirable effects of continuous counts that produce undercounts that vary in intensity over the course of a week would be to apply the resulting traffic ratios (or factors) to an appropriate mix of weekday and weekend short counts. However, this is a relatively costly option, and it may have the undesirable effect of significantly reducing the total number of Class 1 counts collected. Hence, although weekend counts may be necessary on roads where weekend use of motorcycles is much higher than weekday use, they do not appear to be a cost-effective means of addressing deficiencies in the DOW adjustments made by the factoring process.

As indicated by the above discussion, when estimating the AADT of Class 1 vehicles, there does not currently appear to be a satisfactory way of eliminating bias from the factoring process. Rather, at the present time, we recommend that the goal should be to try to minimize this bias and to be aware of it when using estimates of the AADT of Class 1 vehicles and count-derived estimates of the VMT of these vehicles.

n 5.6 "Current-Year," "Historic," and "Rolling Average" Traffic Ratios

The ***AASHTO Guidelines***[40] distinguishes three alternatives for computing and applying traffic ratios (or traffic factors):

- ***Current-year traffic ratios*** are computed at the end of any calendar year and are applied to short counts collected during that year to estimate AADT and AADT by vehicle class (VC) for that year;

- ***Historic traffic ratios*** are computed at the beginning of any calendar year using data that had been collected in previous years and are applied to short counts collected during the year in question to estimate AADT for that year as soon as the short counts are collected; and

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[40] Op. cit., pages 5-11 to 5-13.

- ***Rolling-average traffic ratios*** are computed every month using data for the previous 12-month period and are applied to short counts collected during the last month of this 12-month period to produce an estimate of AADT during that 12-month period.

Of these three alternatives, historic ratios are the easiest to develop and use. However, as observed in the ***AASHTO Guidelines,*** they fail to take into account how conditions that exist at the time a short count is collected may differ from conditions that existed in previous years; and, as a result, they produce AADT estimates that are slightly less accurate than the other alternatives.

Because of the weather-dependence of motorcycle volumes, year-to-year variations in monthly traffic volumes tend to be more significant for Class 1 vehicles than they are for other vehicle classes. For example, a cold October in one year may reduce motorcycle travel in that month below normal levels. Historic traffic ratios would not reflect the reduced motorcycle travel in this October. Accordingly, historic ratios would not adequately adjust for this reduced travel, and so they would tend to produce underestimates of the AADT of Class 1 vehicles. On the other hand, current-year and rolling-average traffic ratios ***would*** reflect the reduced motorcycle travel in October, enabling them to produce AADT estimates that better adjust for the low motorcycle volumes in October.

For the above reasons, the advantages of using current-year or rolling-average traffic ratios, rather than historic ratios, are somewhat greater when factoring counts of Class 1 vehicles than when factoring volume counts or counts for other vehicle classes. For this reason, it is preferred that estimates of the VMT of Class 1 vehicles for any calendar year be derived from estimates of the AADT of these vehicles in that year that, in turn, are obtained by applying current-year ratios (or factors) to short counts collected in that year.

6.0 Using Numbers of Motorcycles to Estimate VMT

An alternative approach to estimating the VMT of Class 1 vehicles is to derive estimates of statewide VMT from registration data or insurance company records. This approach is commonly referred to as "registration based", though it might also be based on insurance company records.

The registration-based approach can only be used by states which require that Class 1 vehicles be insured or in which these vehicles are registered on an annual or biennial basis and which maintain registration records that make it easy to distinguish these vehicles from other vehicles. By itself, this approach can produce estimates of statewide VMT but not estimates of VMT on individual functional systems or groups of functional systems. Also, this approach is likely to underestimate Class 1 VMT in states in which a significant share of annual motorcycle VMT occurs as a result of out-of-state vehicles attending a major motorcycle rally; and it is likely to produce smaller overestimates of Class 1 VMT in states in which such rallies do not occur. However, the registration-based approach has several advantages that may make it attractive to many states. In particular:

- For states that do not already have a system for collecting classification counts that is capable of producing reliable motorcycle counts at continuous-count and short-count sites, a registration-based system for estimating VMT of Class 1 vehicles generally can be implemented more quickly than can a reliable count-based system.
- In many states, good registration-based estimates of statewide VMT of Class 1 vehicles can be developed less expensively than count-based estimates of equal quality.
- A registration-based system would be capable of producing separate VMT estimates for different types of motorcycles and other Class 1 vehicles, thus providing insight into variations in crash and fatality rates among different types of motorcycles.
- Statewide estimates produced by registration-based systems can be used as checks on the performance of count-based systems. Consistent differences in the estimates produced by the two types of system that are not readily explainable can be used to provide insights that can contribute to improving count-based systems.[41]

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[41] For example, differences in the estimates of truck VMT produced by registration-based systems such as that incorporated into the Bureau of the Census' ***Truck Inventory and Use System*** and those

(Footnote continued on next page...)

- It may be possible to use registration-based estimates of statewide motorcycle VMT to produce estimates of VMT by functional system that are more accurate than those that can be produced by a purely count-based system.

The number of fatalities per registered vehicle varies significantly by type of motorcycle, with the rate for supersports being two to three times the rate for other major types of motorcycle.[42] Hence, to maximize the value of registration-based estimates of the VMT of Class 1 vehicles, it is recommended that any such estimates that are developed be developed separately for each of several types vehicle, distinguishing at least: sport bikes, cruisers, touring bikes, supersports, and "other".

For each separate vehicle type, VMT estimates are obtained by multiplying data on the population of these vehicles based in the state by estimates of annual VMT per vehicle. The first subsection of this section discusses sources of data on vehicle population; and the second discusses the estimation of annual VMT per vehicle. The final subsection discusses potential approaches for using the resulting estimates of statewide VMT to produce estimates of VMT by functional system that could be better than estimates produced by a purely count-based system.

n 6.1 The Population of Class 1 Vehicles

States that require that Class 1 vehicles be registered annually or biennially and that maintain registration data that makes it easy to distinguish Class 1 vehicles from other types of vehicles (such as off-road vehicles) may use their own registration data to estimate the number of these vehicles that are based in the state. Many of these states also require owners to inform the motor vehicle registry (e.g., by turning in their plates) when they dispose of their vehicle or move to another state (or when they cease operating the vehicle and wish to discontinue insuring it). These states have data that can be used to estimate changes in the number of registered Class 1 vehicles over the course of the year. For these states, it is recommended that the number of such vehicles based in the state in a given year be taken to be the number that are registered on a specific day (such as July 1) during the motorcycle season.

States that do not require that owners of Class 1 vehicles inform the registry when they transfer ownership will lack data on the number of such vehicles that are registered on

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produced by early vehicle-classification-based procedures led to significant improvements in the latter procedures. (See Herbert Weinblatt, "Using Seasonal and Day-of-Week Factoring to Improve Estimates of Truck Vehicle Miles of Travel", ***Transportation Research Record 1522,*** 1996, pages 1-8.)

[42]Eric R. Teoh, Insurance Institute of Highway Safety, "Role of Motorcycle Type in Driver Death Rates and Insurance Losses", presented at Lifesavers Conference, April 2008, http://www.lifesaversconference.org/handouts2008/Teoh.pdf, accessed December 9, 2009.

any specific day. They ***will*** have data on the total number of vehicles registered over the course of a one or two-year period. However, this data may include double counting of vehicles that change hands and are registered more than once during the period, and it may also produce overestimates of in-state VMT of vehicles that are based in the state for only part of the period. For any of these states that require that Class 1 vehicles be insured, the best source of data on the population of Class 1 vehicles is likely to be obtained from insurance company records, as discussed in the next paragraph. For states that do not have access to insurance company data, it is recommended that the total number of Class 1 vehicles that are registered in the state in a given time period be downwardly adjusted statistically to approximate the number of Class 1 vehicles that are based in the state and in operation at the peak of the motorcycle season.

States that require that Class 1 vehicles be insured have an alternate source of data on the number of such vehicles based in the state – insurance company records. These states can require that all companies that insure such vehicles in the state provide annual data on the number of such vehicles insured on a given date, such as July 1, by vehicle type. Since this data will be used for improving statistics on motorcycle crash rates and fatality rates, a subject of significant interest to these companies, this is a requirement with which the companies should be happy to comply.

6.2 Annual VMT per Vehicle

For states that require annual or biennial safety or emissions inspections of Class 1 vehicles, the preferred way of obtaining data on annual VMT per vehicle is to obtain odometer readings as part of the inspection process. For any vehicle that remains registered to the same owner, a pair of consecutive odometer readings provides accurate information about VMT accumulated between inspections; and, along with the inspection dates, this information provides the basis for an excellent estimate of annual VMT for the vehicle.

Other states that obtain data on the population of Class 1 vehicles from the registration process or from insurance companies can use this same source to obtain data on VMT accumulated between registration renewals or renewals of insurance policies, though some legislation may be required (e.g., to add a request for an odometer reading to the registration form). Annual VMT estimates obtained for individual vehicles using these odometer readings will be appreciably less accurate than those developed from inspection data, both because self-reported odometer readings will be less accurate than those collected by safety and emissions inspectors, and because the precise dates of the odometer readings generally will not be collected. However, since these estimates will be obtained from a large number of vehicles and averaged, the resulting estimates of average annual VMT per vehicle should be quite good.

Separate estimates of average annual VMT per vehicle should be developed for each type of Class 1 vehicle for which total annual statewide VMT is to be estimated.

n 6.3 Estimating VMT on Sub-State Systems

There are at least two options for using registration-based estimates of statewide motorcycle VMT to produce estimates of VMT by functional system:

1. Scaling count-based estimates by functional system to match the statewide estimates; and

2. Using global positioning system (GPS) data as the basis for distributing the statewide estimates among the functional systems.

These two options are discussed briefly below.

Scaling Count-Based Estimates

There are at least two ways of using registration-based estimates of statewide VMT of Class 1 vehicles to scale count-based estimates of VMT by functional system. The simplest is to use the estimates as statewide control totals and to scale the count-based estimates obtained for individual functional systems (or groups of functional systems) uniformly so that they sum to the statewide estimates.

An alternative to the above procedure exists for states that believe that the quality of their count-based estimates of the VMT of Class 1 vehicles varies by functional system. For example, if counting is performed primarily with pole-mounted radar or video systems, it may be that there is little or no undercounting of these vehicles on functional systems with low truck volumes. If this is the case, it may be preferable to limit scaling to the functional systems where it is believed that most of the undercounting occurs. Similarly, if a state believes that it has high quality VMT estimates on the higher functional systems but performs little or no classification counting on the lower systems, it may choose to use the estimates for the higher systems as is but to scale the estimates for the lower systems.

In the future, with more information about how undercounts of Class 1 vehicles vary with specific influences on the undercounts (e.g., with truck volumes) it may be possible to develop more sophisticated scaling procedures that take these influences into account.

Using GPS Data

The use of GPS data offers a possible option for estimating VMT by functional system without counts of Class 1 vehicles. Under this option, a statistically valid sample of Class 1 vehicles based in a state would be equipped with GPS devices to directly measure their travel over a specified sample period, e.g., two weeks. A GPS unit with an internal battery could be designed with a motion-detection device to turn the unit off and on automatically to conserve battery power. The GPS data would be collected from the units and matched to a map to measure the ratio of travel by different roadway functional classes. The position data would allow the proportion of out-of-state travel to be measured directly.

One problem would be to assure that the GPS unit operates only when the motorcycle engine is on, so that VMT is not counted when motorcycles are being transported in a van or truck (e.g., to a motorcycle rally). A continuous survey sample to capture seasonal variation would have to be developed and tested, and each state that uses this approach would have to develop its own sample. The sample selection to assure geographic representation across different types of urban and rural areas would be very important for this approach to be used. One concern of this approach is whether non-response bias would be so large as to render the results unusable.

7.0 Conclusions and Recommendations

The Section 4.0 review of detection and classification technologies and the Section 4.4 discussion provides the basis for some conclusions about the technologies that are in current use:

- Two technologies, road tubes and TIRTLs, tend to overcount Class 1 vehicles;
- One widely used combination of technologies, conventional loops and piezos with motorcycles distinguished on the basis of axle spacing, combines tendencies to overcount and to undercount these vehicles;
- Most of the other technologies reviewed, including conventional loops and piezos with motorcycles distinguished on the basis of magnetic length, tend to undercount these vehicles to varying degrees;
- The shift from road tubes to other technologies, such as conventional loops and piezos, appears to have produced a downward bias in the rate of growth of estimated motorcycle VMT in the early part of the last decade; and
- Increasing sales of subcompact cars that are difficult to distinguish from motorcycles by devices that classify on the basis of axle spacing appear to have resulted in overestimating the rate of growth in motorcycle VMT since 2005.

The first subsection below presents several recommendations for improving the quality of the counts of Class 1 vehicles and of estimates of motorcycle VMT. The second subsection presents several recommendations for further research with a principal focus on improving our understanding of the accuracy of the equipment that is most likely to be used for counting Class 1 vehicles.

■ 7.1 Recommendations

This subsection presents recommendations for improving the counts of Class 1 vehicles and for producing improved estimates of the VMT of these vehicles.

Recommendations for Counting Class 1 Vehicles

Although all available technologies for counting these vehicles have some limitations, some technologies produce reasonably accurate counts and are appropriate for specific purposes. In particular:

- When using inductive loops and piezos, Class 1 vehicles should be distinguished from Class 2 vehicles on the basis of magnetic length, not axle spacing. The recommended threshold value for the maximum magnetic length of a motorcycle is six or seven feet.

- Wide inductive loops used with upgraded electronics that minimize crosstalk between installations in adjacent lanes and used with full lane-width piezos are appropriate for all purposes. This technology will produce small undercounts as a result of side-by-side operation of Class 1 vehicles and, in some areas, as a result of vehicles that avoid congestion by operating on shoulders or between lanes. It is assumed that, to minimize capital costs, new loops and piezos would be phased in as part of the normal replacement cycle for sensors.

- Conventional inductive loops with piezos appear to be appropriate for collecting continuous counts to be used in the development of seasonal and DOW ratios and factors and for collecting short counts that will be scaled as discussed later in this subsection. However, conventional loops produce appreciable undercounts of Class 1 vehicles, and so they are ***not*** appropriate for short counts without scaling, and continuous counts collected with these loops are not appropriate for producing estimates of AADT at a continuous-count site without an undercount adjustment.

- Pole-mounted video or radar are appropriate technologies for collecting in-season short counts of motorcycles on roads with a low percentage of trucks. On roads with moderate to high percent trucks, these options produce undercounts that increase with percent trucks and can become undesirably high. Also, it is likely that these options significantly overcount motorcycles when the percentage of these vehicles in the traffic stream is very low or zero. As a result, these options probably are not appropriate for collecting continuous counts of Class 1 vehicles. The capital costs of pole-mounted video systems are low, and these systems can be used for several other applications; however, processing of the data is fairly expensive and may limit the number of counts collected.

- Overhead video does not suffer from occlusion and so may be a better alternative than pole-mounted video for collecting short counts on roads with high percentages of truck traffic.

- If road tubes are used for collecting short counts, it is recommended that the threshold value for the maximum axle spacing of a motorcycle be set to six feet.

If loops and piezos are used for counting Class 1 vehicles on two-lane roads, it is recommended that Virginia DOT's "Bin 21" procedure (described in Section 4.1) be used as an aid in classifying these vehicles at any sites at which a piezo has begun to fail.

Recommendations for Estimating VMT of Class 1 Vehicles

In Sections 5.0 and 6.0 of this report, two alternative approaches were discussed for estimating the VMT of Class 1 vehicles:

- Estimate the VMT of these vehicles entirely from classification counts; or
- Estimate statewide VMT from registration data or insurance-company data, and possibly use classification counts for distributing statewide VMT among highway functional classes or other roadway subsystems.

Recommendations related to each of these approaches are presented below.

Count-Based Estimation of VMT

Count-based estimates of the VMT of Class 1 vehicles may be developed for an entire state or for individual functional systems or for groups of functional systems. Furthermore, count-based estimates for individual systems or groups of systems may be used as is, or they may be scaled to match statewide estimates developed from a different source. The requirements for estimates that will be scaled are less stringent than those for counts that will not be scaled. We discuss first the requirements for all estimates, and then specific requirements that apply only to estimates that will be scaled or will not be scaled.

The general procedure for developing count-based estimates of VMT by vehicle class for any system of roads is presented in the ***AASHTO Guidelines***[43] and in FHWA's ***TMG***[44] and is well known. We limit ourselves here to presenting recommendations that apply specifically to the estimation of the VMT of Class 1 vehicles or are particularly important in the case of Class 1 vehicles. Recommendations that apply to all estimates of the VMT of Class 1 vehicles are:

- All factoring of short counts should be performed using traffic ratios (or traffic factors) that are developed exclusively from continuous counts of Class 1 vehicles.
- Continuous counts used for this purpose should be collected at sites with relatively high volumes of Class 1 vehicles using equipment that produces counts that provide as reasonable a representation of the seasonal and DOW patterns in Class 1 volumes as practical. At the present time, it appears that only classification on the basis of magnetic length using data from permanent sites with inductive loops and piezos produces counts that meet these requirements.

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[43] American Association of State Highway and Traffic Officials, ***AASHTO Guidelines for Traffic Data Programs,*** 2009, Chapter 5.

[44] FHWA, ***Traffic Monitoring Guide,*** May 2001, Section 4.

- Separate factor groups should be established for roads that are used by Class 1 vehicles primarily on weekends and for roads whose use by these vehicles is distributed more evenly throughout the week; and large states generally should develop separate factor groups for each part of the state that has a different seasonal pattern of motorcycle use.

- Over time, each state should develop a sufficient number of continuous Class 1 count sites to allow a minimum of five such sites to be assigned to each factor group that has an observably different seasonal or DOW pattern of Class 1 traffic.

- Short counts used for estimating the AADT and VMT of Class 1 vehicles should not be collected during days of the week or times of the year when there is little or no motorcycle activity.

- Factoring of short counts collected in areas where motorcycle rallies take place should be performed using one seasonal period (or "month") that corresponds to the period of the rally, as described in Section 5.3.

In addition to the above recommendations, there are additional recommendations that vary somewhat with the way the resulting VMT estimates will be used.

If the VMT estimates will be used without scaling to control totals that are developed from a different source (such as a registration-based estimate of statewide VMT), then there should be no significant bias in the magnitudes of the AADT estimates that are used to estimate VMT. In particular, ***the AADT estimates should be developed entirely from short counts collected using wide inductive loops or using a video or radar system that meets the requirements discussed earlier in this subsection.*** As previously discussed, conventional loops undercount Class 1 vehicles appreciably and, if short counts are collected using this equipment and a magnetic-length threshold, downwardly biased estimates of the AADT and VMT of these vehicles will result. And, although the number of AADT estimates developed directly from continuous classification data generally is relatively small and thus likely to have only a modest effect on VMT estimates, any of these estimates that are developed from counts collected with conventional loops and piezos will also be downwardly biased, and so should not be used in the VMT estimates.

If the VMT estimates ***will*** be scaled to control totals, then any bias in the AADT estimates is less significant, and continued use of road tubes or conventional loops and piezos may be appropriate. For example, assume that VMT estimates are to be developed separately by functional class and then scaled to a statewide control total. For this case, a bias is not undesirable ***per se,*** but it ***is*** desirable for any bias to be as consistent as practical across all functional systems. To achieve this goal, if two different technologies are used for the counts (both short counts and continuous counts), the division of counts collected with the two technologies should be reasonably similar for each functional system. In particular, if a new technology is being phased in, it should be phased in for use on all functional systems at a reasonably uniform rate (rather than implemented on the higher functional systems first and on the lower systems later).

Registration-Based Estimation of VMT

Procedures for producing good registration-based estimates of the statewide VMT of Class 1 vehicles may be less expensive and easier to implement than count-based procedures, and they may produce better VMT estimates. Registration-based procedures cannot be used directly to produce VMT estimates by functional system, but the statewide estimates that they produce can be used as control totals for scaling count-based estimates of VMT by functional system.

Registration-based procedures are appropriate for use by states that either require that Class 1 vehicles be insured, or that require annual or biennial registration of these vehicles and distinguish these vehicles as a separate vehicle class. For these states, statewide VMT is estimated as the product of vehicles based or registered in the state and estimated annual VMT per vehicle. Recommended procedures for developing these two quantities are presented in Sections 6.1 and 6.2. It is recommended that states that produce registration-based estimates of the VMT of Class 1 vehicles produce separate estimates for four or five types of these vehicles (e.g., sport bike, cruiser, touring bike, super sport, and other).

n 7.2 Areas for Future Research

Counting Technologies

As observed in Section 4.0, most technologies produce counts of Class 1 vehicles that are biased to some extent, with the direction and extent varying by technology and, in some cases, by traffic characteristics. A better understanding of overall accuracy, the extent of any biases, and influences on these biases is needed for all technologies that are or will be commonly used for counting Class 1 vehicles. In particular:

- ***Wide loops and full lane-width piezos*** (when used with magnetic length to distinguish motorcycles from small automobiles) tend to undercount Class 1 vehicles as a result of vehicles sharing a lane and, in congested conditions, vehicles operating between lanes and on shoulders. Information is required about the extent of these undercounts, how they vary by type of road and rural/urban area, and how they vary over the course of the week for different types of roads. Also, further testing and evaluation of alternative length thresholds for distinguishing motorcycles from small automobiles is warranted.

- ***Conventional loops and piezos*** (when used with magnetic length to distinguish motorcycles from small automobiles) undercount Class 1 vehicles for the above reasons and, to an even greater extent, because of incomplete lane coverage. These probably are the equipment types that, at present, are most widely used for counting Class 1 vehicles, but there appears to be no data on the extent of the resulting undercounts and underestimates of motorcycle VMT. Information on the extent of these undercounts and underestimates is needed. Also, although we believe that counts collected with these loops and piezos are not a good indicator of the ***volume*** of these vehicles operating at a site, we have suggested that they are likely to produce continuous counts that are as good an indicator of the DOW and seasonal variations in motorcycle volume as continuous counts produced by wide loops and piezos. More testing is needed to evaluate the validity of this suggestion.

- More information is needed about: the biases in motorcycle counts collected by ***pole-mounted video and radar systems***; increases in downward biases that occur with increases in the percent of small and large trucks in the traffic stream being monitored; any upward biases that may occur (as hypothesized) when the percentage of Class 1 vehicles in the traffic stream becomes small; biases that might exist in night-time counts collected by video systems; and increases in and variations in the biases that occur with variations in the height and angle of mounting, with different equipment, and with different classification algorithms.

- If any use is to be made of ***overhead video systems*** to count Class 1 vehicles, information on the accuracy of these counts is needed and whether or not these counts have any biases that vary over the course of a week or over the course of a year.

- If continued use is to be made of short counts of Class 1 vehicles obtained with ***road tubes***, information on the upward biases in these counts is needed.

- If continued use is to be made of ***TIRTLs,*** more information is needed on how the upward biases in these counts are affected by the number of lanes of traffic being counted and the distance between the transmitters and receivers. Also, if these devices are to be used for continuous counting, more information is needed on the extent to which the upward biases increase when the percentage of Class 1 vehicles in the traffic stream becomes small.

- Quantitative information is needed about the performance under varying conditions (day/night, rural/urban, high/low percent motorcycles, congestion, high percent trucks, etc.) of other technologies that have been proposed for counting motorcycles.[45]

- Evaluations are needed of the purchase, set-up and analysis costs of implementing recommended technologies and the appropriate timeframes for their implementation.

- Evaluations are needed of the safety costs of implementing recommended technologies.

[45] E.g., the counting technologies demonstrated at the Motorcycle Highway Travel Monitoring and Operations Demonstration conducted May 5, 2008. (http://knowledge.fhwa.dot.gov/cops/hcx.nsf/discussionDisplay?Open&id=508FE5C6ABE9170685257408005BA870&Group=Travel%20Monitoring&tab=DISCUSSION#508FE5C6ABE9170685257408005BA870, accessed January 20, 2010).

- Evaluations are needed of the cost/benefit trade-offs between upgrading permanent classification sites and purchasing more reliable portable systems.

- Evaluations are needed of the cost/benefit trade-offs between spending increased traffic-monitoring resources on improving the estimation of motorcycle VMT and on spending these resources on other new traffic-monitoring needs, such as counting ramp traffic.

Other Areas for Future Research

Other areas for future research include:

- Continued investigation of procedures for producing registration-based estimates of statewide motorcycle VMT. If reliable procedures are developed, consideration should be given to focusing on a requirement for statewide estimates of motorcycle VMT and suspending the requirement for estimates by functional system. Also, consideration should be given to applying any requirement for statewide estimates only to states that have the ability to use a registration-based procedure for developing these estimates.

- An evaluation of the appropriate accuracy requirements for published estimates of motorcycle VMT and for the use of these estimates in deriving motorcycle crash rates and fatality rates.

- Improved guidance on the minimum number of continuous motorcycle-count sites per factor group.

- Investigation of the use of scaling to address consistent biases in motorcycle counts produced by some detection technologies.

- Investigation of the possible use of GPS data for distributing statewide VMT of Class 1 vehicles among functional systems, as discussed in Section 6.3.

- Further refinement of the modified procedure presented in Section 5.3 for the seasonal factoring of counts on roads in the vicinity of a motorcycle rally.

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AADT	Annual Average Daily Traffic
DOT	Department of Transportation
DOW	Day of Week
FHWA	Federal Highway Administration
GPS	Global Positioning System
HPMS	Highway Performance Monitoring System
IMSA	International Municipal Signal Association
MPO	Metropolitan Planning Organization
NATMEC	North American Travel Monitoring Exhibition and Conference
NCHRP	National Cooperative Highway Research Program
SBIR	Small Business Innovation Research
TIRTL	"The Infra Red Traffic Logger"
TMG	Traffic Monitoring Guide
TTI	Texas Transportation Institute
VC	Vehicle Class
VDOT	Virginia Department of Transportation
VMT	Vehicle-Miles of Travel
WIM	Weigh-in-Motion

Bibliography

"Accurate Vehicle Classification Including Motorcycles Using Piezoelectric Sensors", Research Grant for the period July 2009 to June 2011, funded by USDOT, Research and Innovative Technology Administration, Principal Investigator: Hazem Refai, University of Oklahoma, http://rip.trb.org/browse/dproject.asp?n=23061, accessed September 18, 2009.

American Association of State Highway and Traffic Officials, ***AASHTO Guidelines for Traffic Data Programs,*** 2009.

Bahoric, Andrea, and Joni Sharp, "Complying with Motorcycle Reporting Requirements: PennDOT Perspective", presented at North American Travel Monitoring Exhibition and Conference (NATMEC), August 2008.

Cambridge Systematics, Inc., Washington State Transportation Center, and Chaparral Systems, ***Traffic Data Collection, Analysis, and Forecasting for Mechanistic Pavement Design,*** NCHRP Report 538, 2005.

Cambridge Systematics, Science Applications International Corp., and Washington State Transportation Center, ***Use of Data from Continuous Monitoring Sites,*** prepared for FHWA, August 1994, Two Volumes.

CEOS Industrial Pty. Ltd., ***TIRTL Technical Overview,*** Heidelberg, Victoria, Australia, http://www.ceos.com.au/pdfs/TIRTLTechnicalOverview.pdf, accessed September 18, 2009.

Control Specialists Company, Winter Park, Florida, http://www.tirtl.com/, accessed December 9, 2009.

FHWA, ***Highway Statistics,*** annual, http://www.fhwa.dot.gov/policy/ohpi/qftravel.cfm, accessed November 25, 2009.

FHWA, ***Traffic Detector Handbook,*** Third Edition, 2006, Two Volumes, http://www.tfhrc.gov/its/pubs/06108/06108.pdf, accessed September 17, 2009.

FHWA, ***Traffic Monitoring Guide,*** May 2001.

FHWA, ***Traffic Monitoring Guide – Supplement,*** April 2008.

French Engineering, LLC, ***Traffic Data Collection Methodologies,*** prepared for Pennsylvania Department of Transportation, Bureau of Planning and Research, Harrisburg, Pennsylvania, April 2006.

Kanhere, Neeraj K., et al., "Traffic Monitoring of Motorcycles During Special Events Using Video Detection", presented at the Annual Meeting of the Transportation Research Board, January 2010.

Kotzenmacher, Jerry, Erik Minge, and Bingwen Hao, ***Evaluation of Non-Intrusive Traffic Detection System,*** SRF Consulting Group, prepared for Minnesota Department of Transportation, September 2005, http://www.pooledfund.org/documents/TPF-5_073/final_report.pdf, accessed October 22, 2009.

Martin, Peter T., Yuqi Feng, and Xiaodong Wang, ***Detector Technology Evaluation,*** prepared for the U.S. Department of Transportation, Mountain Plains Consortium, http://www.mountain-plains.org/pubs/pdf/MPC03-154.pdf, accessed September 28, 2009.

Middleton, Dan and Ryan Longmire, ***Implementation Efforts Pertaining to a Statewide Traffic Monitoring Equipment Evaluation and Demonstration Facility,*** Texas Transportation Institute, prepared for the Texas Department of Transportation, Project 5-4664-01, December 2008, http://tti.tamu.edu/publications/catalog/record_detail.htm?id=30213, accessed September 10, 2009.

Miovision Technologies, Inc., Kitchener, Ontario, Canada, http://www.miovision.com/home/index.php, accessed October 8, 2009.

Montana Department of Transportation, Traffic Data Collection and Analysis Section, "Motorcycle Traffic Data Collection and Reporting Issues in Montana", presented at North American Travel Monitoring Exhibition and Conference (NATMEC), August 2008.

Morris, C. Craig, ***Motorcycle Trends in the United States,*** Bureau of Transportation Statistics, Special Report, May 2009, http://www.bts.gov/publications/bts_special_report/2009_05_14/index.html, accessed September 21, 2009.

NHTSA, ***Traffic Safety Facts,*** 2008 Data – Motorcycles, DOT HS 811 159, http://www-nrd.nhtsa.dot.gov/Pubs/811159.PDF, accessed December 2009.

Ritchie, Stephen G. et al., ***Corridor Tracking and Investigation of Anonymous Vehicle Tracking for Real-Time Performance Measurement,*** California PATH Program, Institute of Transportation Studies, University of California, Berkeley, October 2008.

Schinkel, Thomas O., "Mid-Atlantic Successes and Challenges", presented at North American Travel Monitoring Exhibition and Conference (NATMEC), August 2008.

Teoh, Eric R., Insurance Institute of Highway Safety, "Role of Motorcycle Type in Driver Death Rates and Insurance Losses", presented at Lifesavers Conference, April 2008, http://www.lifesaversconference.org/handouts2008/Teoh.pdf, accessed December 9, 2009.

Vehicle Detector Clearinghouse, ***A Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems,*** New Mexico State University, sponsored by FHWA, August 2007, http://www.fhwa.dot.gov/ohim/tvtw/vdstits.pdf, accessed September 22, 2009.

Vehicle Detector Clearinghouse, http://www.nmsu.edu/~traffic/TechAssist.htm, accessed September 14, 2009.

Yu, Xin, "Evaluation of Non-intrusive Sensors for Vehicle Classification on Freeways", University of Hawaii at Manoa, paper presented at the Annual Meeting of the Transportation Research Board, January 2010.

Appendix A

Summary of Responses to Survey of Data Users

Responses to Survey of Motorcycle VMT Data Users

1) How do you use Motorcycle VMT estimates for:

	Yes	No	In the Future
Crash rates	11	4	2
Fatality Rates	13	2	2

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2) What is the value to you of the following motorcycle VMT estimates

Statewide:		Rural/Urban:	
Valuable:	6	Valuable/helpful:	8
Limited Value:	8	Somewhat valuable:	1
No Value:	3	No response:	9
No answer:	1		
Interstate/Other Arterials/Other:		Other:	
Valuable/helpful:	12	County/jurisdictions:	3
More than statewide:	1	Weather/roadway:	1
No response:	5	No response:	6

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3) What is the value to you of motorcycle VMT estimates by motorcycle type (i.e., sport bike, cruiser, touring bike, etc.)?

Valuable for behavioral programming:	8
Valuable, but hard to capture:	2
Not as valuable as road segments:	2
Not valuable for roadway/highway planning:	3
None/not at this time:	2
No response:	1

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4) Other motorcycle data (specific to VMT) of interest?

Slice various ways, age, gender, speed, helmet/no helmet, wet/dry, motorcycle size, seasonal data, geographic data

Additional demographics might cause one state to change their media efforts, but would more likely rely on more current crash reports.

Responses to Survey of Motorcycle VMT Data Users (continued)

5) How would you compare the value of moderately good statewide estimates developed from registrations with more questionable estimates by functional class? (asked of 8 respondents; some provided more than one response)

More valuable:	2
Not as good/less reliable:	4
Time/day/season/where lost:	4
Two-year registration cycle:	3
"Nanny" state concern:	1
Impact on system concern:	1

6) How valuable are estimates by functional class if they do not distinguish between urban and rural roads? (asked of 8 respondents)

Less valuable:	3
Value would be lost:	2
not an issue:	3

Appendix B

Summary of Responses to Survey of Traffic Monitoring Offices

Responses to Survey of State Traffic Monitoring Offices

1) Do you currently report estimates of the VMT of motorcycles and other Class 1 vehicles to FHWA?

Yes:	20
No:	4

2) If yes, are these estimates derived from classification counts?

Yes:	20
No:	0

3) If Yes,

a) Do you classify on the basis of axles or length?

Axles and Axle Spacing:	16
Axles and Length:	5
Length:	1

b) How would you characterize the quality of your estimates of the VMT of Class 1 vehicles?

Excellent:	1
Good:	6
Fair:	9
Poor:	5

4) What types of equipment do you use or have you tested for collecting counts of Class 1 vehicles?

	Short Counts		Continuous Counts	
	Tested	Use	Tested	Use
Piezo cable:	3	4	9	17
Piezo film:	1	0	4	3
Quadrupole loops:	1	0	1	0
Inductive loop signatures:	1	0	2	1
Conventional inductive loops:	6	2	4	8
Road tubes:	13	20	–	–
Manual	0	1	–	–
Fiberoptic cable:	0	0	0	0
Radar:	7	3	4	5
Video:	1	2	2	1
Infrared (including TIRTLs):	5	0	4	3
Magnetometer:	1	0	2	0
Ultrasonic:	0	0	0	0
Acoustic:	1	0	2	0

5) Do you factor your short-duration counts of Class 1 vehicles?

Yes:	13
No:	11

6) If yes, how do you factor these counts?

By applying seasonal and day-of-week factors derived from continuous counts of Class 1 vehicles?

Yes:	6
Other Responses:	5