Appendix I –

Motorcycle Data Collection Methods

APPENDIX I. FHWA MOTORCYCLE DATA COLLECTION AND ANALYSIS IN MONTANA

Safety on our nation's highways, including motorcycle safety, is a principal feature of the Infrastructure Investment and Jobs Act (IIJA), the current Federal Transportation Bill. These State and Federal agencies will, eventually, develop motorcycle-related safety programs based on Federal guidelines and will implement these programs with Federal aid monies. For these programs to be successful, the first step must be the collection of reliable motorcycle data. Reliable data results in reasonable motorcycle VMT estimates, necessary to help target areas for safety improvement programs. While the Montana Department of Transportation (MDT) has done limited research on what other states do to collect accurate motorcycle data, the research, coupled with a comprehensive look at MDT's ability to collect accurate motorcycle data, leads us to believe there may be other states that may not know or completely understand motorcycle travel within their respective state as it relates to implementing safety programs.

The principal reasons DOTs may not be able to quantify the accuracy of their motorcycle data can be summarized as follows:

1. Traditionally, motorcycles have not been considered "important" in terms of standard vehicle data collection practices as they make up a small percentage of overall traffic volumes and have minimal impact on road design.

2. Current vehicle data collection equipment and technology focuses on Federal Highway Administration (FHWA) vehicle classification types 2-13; overlooking motorcycles (FHWA type 1). Data collection equipment that does detect motorcycles, does not always classify them correctly. In states like Montana, where laws allow motorcycles to travel side-by-side in a single lane of traffic, accurate motorcycle data collection with currently deployed equipment is virtually impossible.

3. Coverage count collection practices outlined in the Traffic Monitoring Guide do not normally take weekend or special event data into account therefore, motorcycle data estimates derived from current traffic data, are statistically inaccurate. In Montana, a significant amount of motorcycle travel is recreational, or event driven. Missing these aspects of travel can lead to false assumptions about the extent of motorcycle travel. States where weather (seasonality) plays a part in motorcycle travel can be even further off in motorcycle travel estimates if they do not develop solid seasonal factors exclusively for motorcycles.

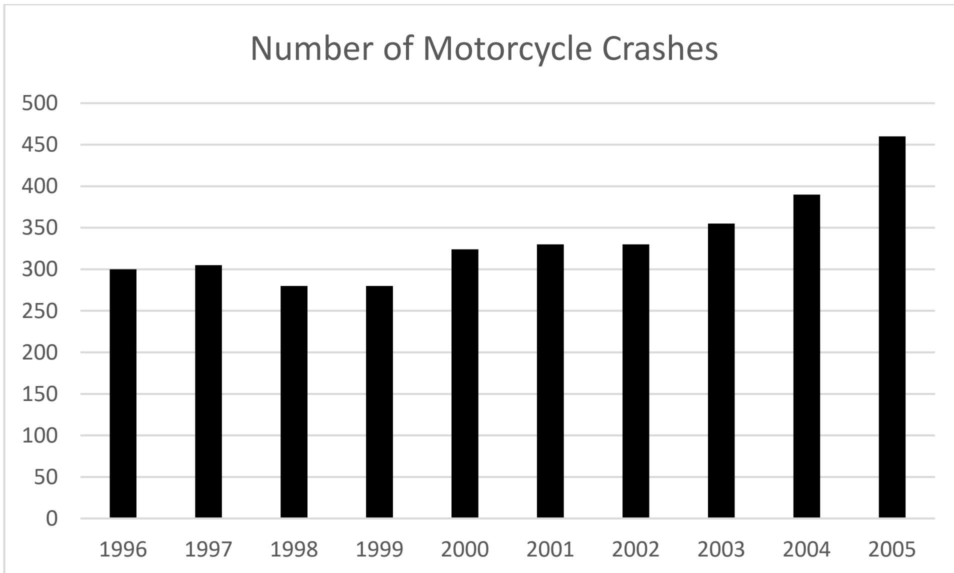
4. Finally, Montana, as is likely the case with other states, is not blessed with surplus resources to properly implement the data collection efforts needed for this type of program.

The FHWA issued an Action memo addressing the collection of motorcycle travel data (January 2007). [1] In the memo, FHWA and the National Highway Traffic Safety Administration (NHTSA) point to an increasing number of motorcycle fatalities nationwide. FHWA concludes better motorcycle data must be obtained to implement a motorcycle-focused safety program. As a result, this memo directed states to report motorcycle travel data, beginning with 2007 HPMS data, in June 2008. FHWA and NHTSA further state that the quality of the data is important and encourages states **"to develop their vehicle classification programs to ensure quality data for this type of vehicle without sacrificing other vehicle classification data."** And, while they are **"confident States will provide quality data that truly reflect motorcycle travel in their State as they fully develop this component of their vehicle classification program considering the guidance in the FHWA Traffic Monitoring Guide"**, FHWA has not put forward guidelines or solutions as to how this data collection is to be accomplished, nor was there a concerted effort put forth to inform or work with the vendors of traffic data collection equipment to try and develop any kind of data collection

[1] ACTION: Motorcycle Travel Data, issued January 30, 2007 by J. Richard Capka, Administrator, FHWA, and Nicole R. Nason, Administrator, NHTSA.

solution.

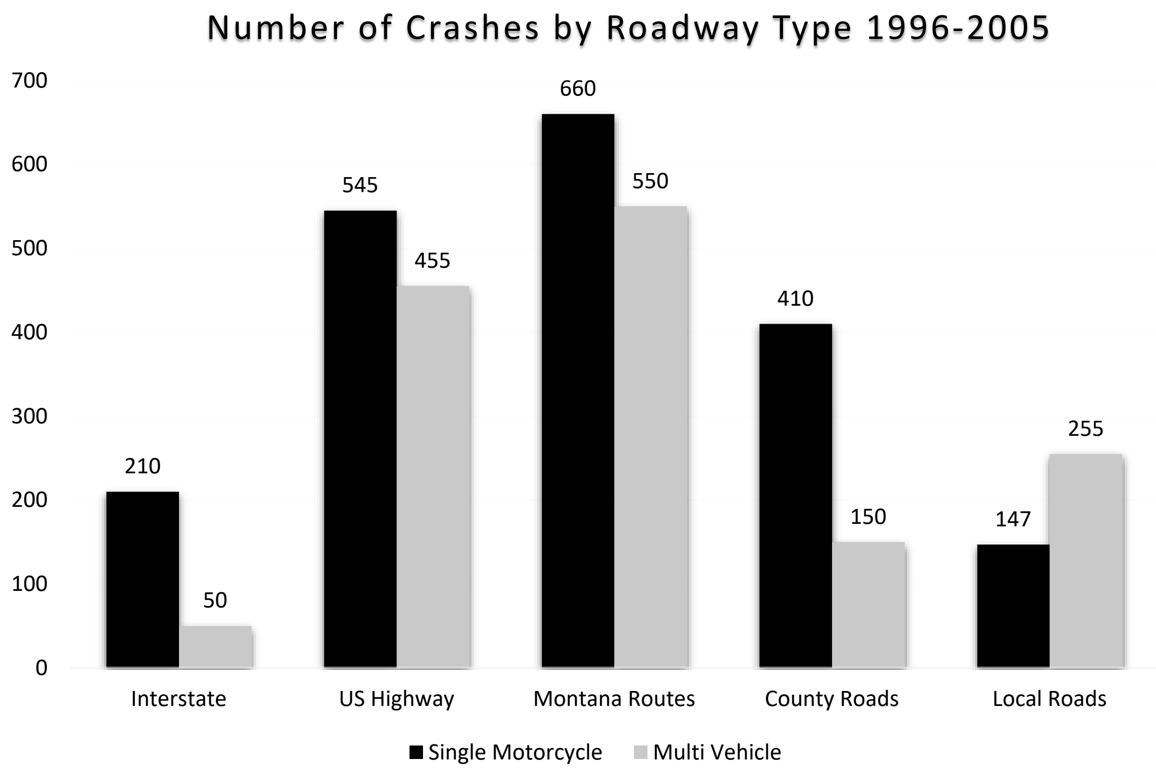
The rise in Montana's motorcycle crashes over the last few years aligns with the national trend. Data compiled by MDT's Safety Management Section shows an increase in motorcycle crashes and indicates that most of the crashes occur on lower functionally classified roads where traffic data collection is limited and cost prohibitive due to the size of the road network.



Source: MDT Safety Management Section

FIGURE I-1: NUMBER OF MOTORCYCLE CRASHES BY YEAR (MONTANA)

Graph from the Montana Department of Transportation's Safety Management Section showing the number of motorcycle crashes occurring in Montana from 1996-2005.



Source: MDT Safety Management Section

FIGURE I-2: MOTORCYCLE CRASHES BY ROADWAY TYPE (MONTANA 1996-2005)

Graph from the MDT's Safety Management Section showing that motorcycle crashes involving 1 or more vehicles occur most frequently on State Highways. Note: Montana Routes includes signed state and secondary routes; County Roads are roads under county jurisdiction, and Local Roads are city streets.

As a result of FHWA's directive, MDT's Traffic Data Collection and Analysis Section (TDCA) was given the task of evaluating its current motorcycle data collection and analysis methods and determining if improvements were needed, and if so, what those improvements might be.

A review of Montana's current motorcycle data collection procedures determined the data will not produce statistically sound motorcycle VMT. As outlined earlier, it is possible to collect motorcycles (FHWA class 1), but MDT's equipment and installation layout principally targets the collection of accurate FHWA classes 2-13.

MDT's continuous count stations use magnetic loop technology (like the loops used to control traffic lights) to detect vehicles. These loops are designed and installed to detect vehicles in a lane of traffic, particularly FHWA classes 2-13. Detecting motorcycles with loops designed for the larger vehicle classes is difficult.[2] Additionally, if a motorcycle is detected by a loop, it must also pass over an axle detection sensor to have its axles counted and the spacing measured to be properly classified in the FHWA scheme. Classification from length-only data is not defined in FHWA schemes for types 1-13.

The problem of capturing accurate motorcycle data with a detecting loop and axle sensor is further compounded by Montana's law which allows motorcycles to travel two abreast in a single lane of traffic. This law (MCA 61-8-359) listed on the official 2007-2008 Montana Highway Map under the "Safety Tips"

[2] See attached document entitled "Motorcycle Classification Issues". Listed in attachments.

section, item 3, states “No more than two motorcycles may be operated in a single traffic lane.”[3] There are no traffic data collection devices currently deployed in Montana that are designed to capture more than one vehicle per lane of travel. Regardless of the technology in use or its capability to detect a motorcycle, detecting and properly classifying two vehicles traveling adjacent to each other in a single lane of traffic with our existing equipment is not possible.

These problems led MDT to look for alternate solutions. The goals are to find ways to collect accurate motorcycle data at permanent and portable sites and produce data files requiring little or no manipulation in the traffic data analysis software. And, since using loops to detect motorcycles pose more problems than it solves, MDT wants to eliminate the loop from the detection system.

One approach to the problem which did not require a change to traffic data collection infrastructure is through statistical analysis of the motorcycle data MDT feels is reliable. This is data obtained during manual counts, conducted at continuous count stations each quarter to verify the accuracy of the data. Cambridge Systematics, Inc. is currently looking into a statistical methodology to estimate motorcycle travel on Montana roads. At the time of this writing, that task has not yet been completed.

FHWA also proposed using odometer readings and motorcycle registration data to estimate motorcycle travel and VMT. At first glance, this appears to be a cost effective and simple method to implement. Unfortunately, upon closer review, utilizing this approach in Montana would produce inaccurate results.

For an odometer readings-based methodology to be statistically sound, the majority of motorcycle owners traveling in Montana have to participate. That would require a legislative act and could only ensure compliance of motorcycle owners living in Montana. Gathering data from local groups, such as motorcycle clubs or associations, to make statistical calculations would skew the statistics as these groups represent only a small part of motorcycle travel in Montana. Tourists and travelers visiting or passing through Montana on the way to an event or destination is a significant component of motorcycle travel within the state. Miles traveled by those groups would not be reported in Montana’s odometer readings, and thus would not be reported in the state’s VMT. Conversely, groups participating in a Montana volunteer program may also travel out of state, making their reported mileage invalid, unless reported by in-state vs. out-of-state travel. It was determined that utilizing odometer readings to estimate Montana’s motorcycle travel is not feasible, especially since the accuracy and completeness of the information would not be easily verifiable.

There are also issues with utilizing motorcycle registration data to estimate travel. In Montana, registration is for the lifetime of the motorcycle, where “lifetime” is defined as the length of time a motorcycle is owned by an individual owner. Some motorcycles used strictly for off-road purposes, may not be registered, while other motorcycles are registered, but rarely, if ever driven, have been sold for parts, etc. Based on this, there is no effective way to use the registration database to estimate motorcycle travel in Montana, whether owned by Montana residents or not. Also, there is no way to estimate out-of-state motorcycle travel in Montana based on registration.

Using motorcycle registration and motorcycle odometer readings would produce questionable motorcycle travel estimates. Montana will not use this methodology even if it is deemed acceptable by FHWA, because the quality of data Montana provides for safety programs will be in doubt.

Next was to look at other technologies. Staff performed internet searches and communicated with several companies looking for a technology that was developed and available for the collection of motorcycle data. This included radar, laser imaging, image (or pattern) recognition, acoustic, and video capture systems. Each system has some limited development in traffic-related applications. For example, radar, acoustic, and video systems are already used to provide traffic volumes and limited classification information (class by length) across multi-lane highways. The problems for these systems are specific identification of a vehicle and identifying vehicles travelling adjacent to each other in a single lane of traffic. As these systems are not mounted in the lanes of travel they can suffer from occlusion if used in a side-fire configuration

[3] 2007-2008 Montana Highway Map is produced by Department of Commerce’s Travel Montana and the Montana Department of Transportation.

(detecting traffic from the side of the road instead of overhead). Video can experience problems of night detection unless the view of the camera is enhanced with a visible or infrared light source or placed in an area with ambient light. Data storage requirements for video can be an issue, as video in any form requires many more bytes of storage than the records produced by radar or acoustic systems. Image recognition systems used to capture and identify license plate numbers or faces in a crowd (airport security) would seem ideal for identifying vehicles, but that type of application is not yet available. This is also true for the laser imaging systems. They have not yet been adapted to vehicle detection. Many of the companies contacted indicated motorcycle detection was "an interesting idea" and they were willing to undertake a research project to develop the technology. Montana does not have the resources to dedicate to this development project. While it is possible that with advancing technology, new systems for accurate classification of vehicles will be developed, that development is not yet widespread.

Since the non-intrusive and emerging technologies did not provide a workable solution, staff took a fresh look at the technologies currently in use in Montana to see if adaptation for accurate motorcycle data collection was possible and practical. More internet research and discussions with neighboring states, Utah, Idaho, and Wyoming, led staff to conclude it is possible to adapt a portable as well as a continuous counter to collect motorcycle data. Additionally, the idea of using video as a means to classify motorcycles by having staff conduct visual counts of the recorded video would allow us to classify all vehicles, thus making the data valuable as an overall classification tool, not just a motorcycle data gathering method. Reviewing recorded video is extremely labor intensive, and with limited resources, MDT cannot implement this as the only method of motorcycle data collection. At this time, video data collection will be limited to urban areas, where the data will be useful for classifying all vehicles, not just motorcycles. We will be able to take advantage of urban street lighting, which will prevent the loss of data at night, eliminating the concern of using non-lighted video recording technology. The implementation of video data collection will develop slowly as Montana does not have the resources to deploy and maintain any substantial number of video collection sites.

Update-February 2014: Montana is implementing video technology to collect data using portable camera systems developed by Miovision Technologies. The accuracy of motorcycle detection with the Miovision system is 90+% using their proprietary video processing software. MDT verified the accuracy by performing visual analysis of several video recordings.

Update-May 2020: Montana uses Miovision's camera technology to conduct between 250 to 300 video counts each year. Montana has not yet expanded collection to capture weekends or special motorcycle events.

Internet research provided MDT with a portable motorcycle count setup known as the "Blocker".[4] This device blocks off road tubes in one half of the lane, effectively dividing a lane of travel into two "half-lanes".[5] Setting the road tubes 6 feet apart gives a reasonably small footprint for the layout, which minimizes misclassification due to vehicles potentially passing while traversing the sensors. [6] The blockers are held in place using nylon webbing that is nailed to the pavement, thus eliminating issues with using asphalt tape (dirty road, rain, removal after use, etc.). The road tubes cover the entire lane allowing classification of FHWA types 2-13 as well. Each "half-lane" simultaneously records the class of type 2-13 vehicles, while individually recording motorcycles. Adjacent motorcycles are recorded as one vehicle in each "half-lane". A single counter with 4 road tube inputs captures classification data for each of the two "half-lanes" (one lane of travel) in one data file. The files are from data collection equipment MDT currently uses so the data format is compatible with the traffic processing software. The type 1 counts from each "half-lane" are totaled together to give the motorcycle volume for that lane of travel. It was decided that totals for types 2-13 from the shoulder-side "half-lane" will represent the class totals for that lane of travel. Two counters will be used per setup to cover both lanes of travel on a two-lane road. This system relies on

[4] Trigg Industries, www.triggindustries.com

[5] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

[6] See attached pictures of the layout.

axle detection via road tube impact only: no loops are involved. Being portable, this system can be deployed to target those areas where motorcycle traffic is frequent in Montana, and where we currently have no other data collection coverage.

Testing of this layout proved successful in detecting single as well as grouped motorcycles. The only potential drawback is in the case of tailgating between motorcycles in single file. If the distance between motorcycles, or any two vehicles, is less than 40 feet apart, the two vehicles will be misclassified. The reason for the 40-foot limit is to allow the system to correctly classify the other FWHA types, especially large trucks. Shortening the 40-foot minimum spacing requirement would result in misclassification of those larger vehicles; a consequence of eliminating the loop. While 40 feet seems like a long distance, it is actually the distance from leading edge to leading edge of the center striping on a highway[7]. At posted daylight speed limits, (75 mph for interstate, 70 mph for two lane roads) this distance is covered between 0.36 and 0.39 seconds. While it will occur, operating vehicles this closely together is well beyond the bounds of safety and common sense. From direct observation at various sites throughout Montana, we feel misclassification due to vehicles operating in this unsafe manner will be minimal and will not significantly impact the accuracy of the data.

MDT will put seven to nine of these systems into use this year (2008). This will allow us to collect and analyze data while also focusing our resources to optimize motorcycle data collection efforts.

Update-February 2014: Montana abandoned the portable motorcycle setup for two primary reasons:

1. The labor required to properly set up and maintain the system in the original design configuration is too great to be practical for field technicians to implement along with their other counting duties.

2. The “Blockers” themselves are not constructed to work well with the size of road tube Montana uses and tend to break apart when hit repeatedly by heavy trucks. While there is a specialized road tube that can be purchased for use with the “Blocker”, it was decided the extra expense and effort required was not worth the limited amount of data we would collect.

Using the results learned from the portable system, MDT determined it is possible to re-configure a current continuous count system to achieve the same results. Referring to the attached drawing, “Motorcycle Classification: Temporary and Permanent Layout”[8], a potential layout for the conversion of a permanent system shows the placement of the sensors to divide the lanes of travel into “half-lanes”, and the elimination of the loop as a means to detect vehicles. The potential tailgating drawback still applies. In this case, one permanent unit can handle four “half-lanes”, thus creating one file for the entire two-lane site. MDT will install two continuous count stations in this manner during 2008 and obtain 24/7 data for motorcycle data analysis.

The solutions MDT will implement are designed to target two-lane roadways. Traffic safety information indicates this is where Montana’s greatest problems lie. MDT knows this is only the start and coverage will need to be expanded beyond two-lane roadways. Additionally, we need to collect weekend as well as event-type motorcycle travel to develop a more complete picture of motorcycle travel in Montana. Resource availability, particularly manpower, will play a large part in the extent of data collection and how fast the motorcycle element of the program can be expanded. Technology will also have to move ahead so we have more proven methods of accurate motorcycle data collection available to apply to differing collection needs. MDT will work toward greater coverage throughout the state.

Once the data has been collected it needs to be processed and analyzed to provide the information necessary to correctly target motorcycle safety needs in Montana. As mentioned earlier, Cambridge Systematics is currently developing a method for Montana to statistically calculate motorcycle numbers using existing data. This method is not yet complete, so we have not yet assessed its validity. Should it

[7] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

[8] See attached drawing: Motorcycle Classification: Temporary and Permanent Layout.

prove to be acceptable, it will be valuable at the start of this program while our data collection capability is still limited.

Update-February 2014: The Cambridge Systematics method relies on insurance and registration records, which, as stated in this report, do not work in Montana due to our registration laws. Also, due to MDT's limited availability of motorcycle data, Cambridge Systematics was not able to provide a viable estimation solution.

To produce accurate VMT estimates, a baseline must be established. This baseline must take weekends and event-based travel into account, along with seasonality and off-system route travel information. Initially, Montana will use the portable setups to target many off-system and local roads, as our database is lacking data on these roadways. Coupled with the first two permanent sites, located on NHS non-Interstate routes, we will get a look at motorcycle travel in Montana and evolve the process to produce better data. Given the current limited capacity, this will take some years to achieve, meaning initial estimates will be very rough. While that may not sound like the best solution, it will be much better than any number produced using motorcycle data collected by previous methods, and it has the built-in potential to improve as more motorcycle capable continuous count sites are converted or installed. Motorcycle VMT procedures and processes needed are being developed and should be in place by the end of 2008.

Update-February 2014: We have successfully implemented a continuous count station with the motorcycle configuration. Initial tests and subsequent verifications have shown the system to be accurate to 97%.

Update-July 2020: Montana currently has 17 of these continuous count stations and plans to install or upgrade other sites. Montana verifies all continuous count stations, for accuracy every quarter (4 times per year) and continue to see greater than 95% accuracy across all classes including motorcycles.[9]

In summary, working to meet the Federal requirements to implement an effective motorcycle data collection and analysis program, the results of which will be used to implement motorcycle safety programs, is not just a Montana problem, but a national problem as well. MDT is concerned that the rapidly implemented Federal requirements will catch some states unprepared to deal with this problem; a problem they may not even know they have. Without cohesive guidelines or support, the results will be poorly targeted and/or result in poorly implemented motorcycle safety efforts, which may not produce the desired benefits. By using and adapting existing technology, MDT believes we can begin moving toward the goals put forth by FHWA in their January 2007 Action Memo. And while collecting accurate motorcycle data is important, understanding the purpose and use of that data, and producing the types of refined data products our data customers need is also important. The better we understand our customer's needs, the better we can design our data collection and analysis program to meet those needs. As we implement MDT's motorcycle data collection and analysis program, the Data and Statistic Bureau will be meeting with the Traffic Safety Bureau and the Safety Management Section to have detailed discussions about their specific motorcycle data needs so we can tailor our motorcycle data collection program accordingly. Montana is taking a pro-active approach to this problem, and while by no means complete or perfect, this approach provides a foundation for an accurate and comprehensive motorcycle data collection and analysis program.

[9] See attached summary and pictures.

List of Attachments

Designed and Implemented by the Montana Department of Transportation Traffic Data Collection and Analysis Section's Electronics Equipment Unit.

Staff: Randy Herbst, Electronic Technologist

John Adams, Electronic Technologist

John McDougall, Electronic Technologist

Ron Wuertley, Electronics Engineer

Author: Ron Wuertley

Updates: Bill Cloud

Tedd Little

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Updated February 2014

Updated July 2020

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ACTION: Motorcycle Travel Data

January 30, 2007

Mr. J. Richard Capka (Original signed by J. Richard Capka)

Administrator, Federal Highway Administration (FHWA)

(Original signed by Nicole R. Nason)

Ms. Nicole R. Nason, Administrator, National Highway

Traffic Safety Administration (NHTSA)

DWinter x64631

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NHTSA Regional Administrators

Motorcycle fatalities and the related fatality rate have been significantly increasing over the last 10 years. This has become a serious safety issue for NHTSA and FHWA. Between 1996 and 2005, motorcyclist fatalities increased more than 110 percent and now account for more than 10 percent of all motor vehicle traffic crash fatalities. Over this period, motorcycle registrations increased 61 percent, while the reported Vehicle Miles of Travel (VMT) for motorcycles increased only 8.6 percent, resulting in a 94 percent increase in the motorcycle fatality rate. Since fatality rates based on VMT are the best measure of exposure risk for motor vehicle crashes, it is critical that FHWA receive accurate, complete, and timely VMT data to determine accurate crash rates and to monitor trends. These VMT data (and particularly motorcycle VMT) have been the discussion of recent Highway Performance Monitoring System (HPMS) Reassessment workshops documented in the HPMS Reassessment Safety Issue Paper.

As many of you know, motorcycles are one of the 13 vehicle types monitored by each State's vehicle classification program. These programs are the source of the annual travel data reported by States in the HPMS ("Travel Activity by Vehicle Type" form). Currently, the reporting of motorcycle VMT data in HPMS is optional and consequently, many States choose not to report it. We appreciate the efforts of those States that already are reporting this data, and encourage all States to report these data as part of their 2006 HPMS submittal in June 2007. **The reporting of motorcycle travel will be required for all States beginning with the 2007 HPMS data reported in June 2008.**

The quality of motorcycle travel data is important and we encourage States to develop their vehicle classification programs to ensure quality data for this vehicle type without sacrificing other vehicle classification data. Given the recent trends, there is an immediate need for an accurate measure of motorcycle travel to more clearly determine nationwide crash rates, which will enable us to confidently illustrate trends, to assess impacts of Federal programs, and to perform safety analysis to identify future emphasis areas. We are confident States will provide quality data that truly reflect motorcycle travel in their State as they fully develop this component of their vehicle classification program considering the guidance in the FHWA Traffic Monitoring Guide.

Federal funding for collecting these data is currently available from the Statewide Planning and Research (SPR) program and from NHTSA's Section 408 State Traffic Safety Information System Improvement Grant funds, provided it is included in the Section 408 Strategic Plan.

Please discuss this immediate and critical data need with your State traffic and HPMS staff to assure that these data, if available, are submitted in 2007, and to provide necessary resources and priority for reporting in 2008. Information on funding and technical assistance is available from the following individuals:

HPMS questions:

David Winter at 202-366-4631

Traffic Data Collection questions:

Ralph Gillmann at 202-366-5042

Highway Safety Improvement Program questions:

Robert Pollack at 202-366-5019

NHTSA Safety Program Funding questions

Jack Oates at 202-366-2730

Crash Data Collection Program questions

Dennis Utter at 202-366-5351

We appreciate your continued support of the highway safety programs in your State and look forward to receiving motorcycle travel data in 2007.

Cc: FHWA Directors of Field Services

Motorcycle Classification Issues

Why are motorcycles difficult to classify automatically?

The physical size of the motorcycle compared to the roadway means that motorcycles:

- Can be anywhere in the lane of travel.
- Can be ridden "side by side" in a single lane if more than one motorcycle is present. (See attached drawing and a more detailed explanation below).

Motorcycles are seasonal vehicles with primary usage occurring in the summer months. During this time, many motorcycle-oriented events are conducted throughout Montana and neighboring states.

- The big rallies such as in Sturgis, SD and Billings draw a large number of participants from all over the country.
- Local events held in Montana sponsored by local clubs or dealerships for charity, promotional, or other causes.
- Many local events take advantage of more scenic less congested "back roads" where automatic classification equipment does not exist.
- A large majority of participants in all these activities travel in groups.

Why does the motorcycle's size make it difficult to classify with MDT's current systems?

Typical motorcycle dimensions have a wheelbase of less than six feet, and a width between 18 to 30 inches (not counting the handlebars). There are, of course exceptions to this general description:

- "Hogs" with extra-large saddle bags or front faring.
- "Choppers", which have extended front forks, can make the wheelbase greater than 6 feet.
- Motorcycles with side cars.
- Motorcycles pulling trailers.
- "Tricycles"—motorcycles with a rear axle having two wheels.

To accurately classify any vehicle within the FHWA Scheme F classification definitions, three things must be known:

- The beginning and end of a vehicle. (Identifying a single vehicle).
- The number of axles.
- The spacing between each axle.

Referring to the attached drawing, a typical classification site is laid out to detect vehicles that are:

- In single file.
- Are a minimum of 30 feet apart.
- Occupy at least 50% of the lane width.

To detect an axle, a wheel, or wheels, must physically strike the sensor. As shown in the drawing, the piezo sensor, which counts the number of axles a vehicle has, extends from the shoulder toward the center of the lane covering half of the lane, and is designed to detect the wheels, thus the axles, on the right-hand side of the vehicles. Typical Weigh-In-Motion (WIM) sites utilize piezos that span the entire lane width so all wheels on a given axle are detected at the same time to collect total axle weight.

The loops in the classifier system, which utilize magnetic fields for detection, indicate the presence of a vehicle, the beginning and end and speed of the vehicle, which is used to calculate the space between axles. Note, for a WIM system, a single loop is used to determine the "presence", beginning, and end of a vehicle, while the two piezos are used to determine the number of axles and the speed of the vehicle.

For a loop to detect a vehicle:

- Its magnetic field must be sufficiently "disturbed" to cause a disruption in the flow of the field.
- Disruption is typically caused by passing a metallic mass through the field.
- A large mass (like engine blocks, axles, frames, etc.) passing through a significant portion of the field will achieve detection.
- A small mass (small wheels, small trailers) will not disrupt the field enough to cause detection to occur.

For a system to correctly classify a vehicle, all the sensors must be activated in the proper order. Any sensor that is not activated when a vehicle passes will cause an error in the system, resulting in a classification error.

Given safety factors, legal and other issues, most vehicles are operated in the center of the lane, typically defined by wheel paths that are visual or physical (ruts), or both. Because of their width, most vehicles occupy at least 50% of the lane width and travel in single file.

Motorcycles may legally occupy any part of the travel lane the operator chooses. Because of their width, motorcycles typically occupy less than 30% of the lane, and typically run near the center line or near the shoulder stripe.

Motorcycles:

- Running near the center of the lane will miss the piezo sensor in a typical classification system, causing an error, and will not be classified.
- Running near the center line or near the shoulder stripe will not put enough metal mass into the loop field to cause the disruption necessary for detection. This causes an error and classification will fail.

Why not change the "layout" of the loops to increase the size of the detection field to pick up motorcycles traveling at the edge of the lane?

As noted in the attached drawing, loops are typically centered in the lane, and for maintenance and operational purposes, have traditionally been are placed directly across from each other in adjacent lanes.

Loops:

- Generate a cylindrical magnetic field from each of their "legs" (sides and ends).

- Are sized and placed in a lane so that the bulk of the magnetic field will cover the central part of the lane, but not overlap the adjacent lane.

A rectangular shape for the loop is used so the resultant magnetic detection field is also rectangular in shape. This rectangular field is formed by cylindrical shaped fields generated in each leg of the loop. The cylindrical fields generated by a loop have, in theory, a diameter equivalent to the distance between parallel legs in the loop. Thus, a 5 by 7-foot rectangular loop would generate a theoretical magnetic field with its outside edges forming a rectangle that measures 10 by 14 feet. The interior edges of the cylinders meet at the center of the loop, while the outside edges form the boundaries of the magnetic field at the dimensions listed above. Again, this is the theoretical size and shape of the field but there are many exterior factors that can affect the field.

Some of the factors that affect the size and shape of a magnetic field are:

- Metallic reinforcement material in the pavement (typically in concrete-rebar, metal netting, metal dowel pens, etc.)
- Minerals that are part of the aggregate used in the making asphalt, concrete, and the road base.
- Depth of the loop within the pavement. Think of a barrel floating in a lake that slowly fills with water and begins to sink. As the barrel sinks, its visible width decreases.

As expected, the strongest, or densest, part of the magnetic field lies closest to the physical boundaries of the loop wires. Vehicles traveling legally in a lane will cross some physical part of the loop and place the bulk of their metallic mass within the stronger part of the field and create the necessary disruption to cause detection. Motorcycles that pass through the physical boundaries of a loop may also disturb it enough to cause detection, but as noted before, motorcycles that pass through the edge of the detection field may not disturb it enough for detection.

However, vehicles passing through the edge of the detection field can put sufficient metal mass into the field to cause detection. This is why loops are sized so their fields do not exceed the boundaries of the lanes. Vehicles that drive legally in the lane, but are hugging the center line, can cause detection to occur in the adjacent lane if that adjacent field is sufficiently disturbed.

Physically increasing the size of the loop to occupy more of the lane width will:

- Cause a proportional increase in the magnetic field that will overlap adjacent lanes.
- Provide enough overlapped field area to cause vehicles driving legally in a lane to be incorrectly detected in the adjacent lanes, even if they are not hugging the center line.
- Potentially cause electronic "crosstalk" between loops that are directly opposite each other in adjacent lanes

Staggering the expanded loops by moving them physically apart so they are not opposite each other in adjacent lanes will:

- Cure the electronic "crosstalk" between loops that are directly opposite each other.
- Still cause a field to be generated that will overlap the adjacent lane, resulting in errors being generated by the detection of vehicles that pass in that adjacent lane.

- Provide enough overlapped field area to cause vehicles driving legally in a lane to be incorrectly detected in the adjacent lanes, even if they are not hugging the center line.

Why do groups or "packs" of motorcycles cause classification problems?

Because of their small size, motorcycles traveling in groups tend to ride abreast of each other, something other vehicles cannot legally do, as well as closer to each other in the direction of travel (tailgating distance).

Given the physical size of the loop-piezo configuration:

- It is possible for multiple motorcycles to be within the detection area of the sensors at the same time.
- WIM or classification systems are not capable of separating multiple vehicles, including motorcycles, that are detected at the same time in a single lane of travel.
- The systems see simultaneous detection of multiple vehicles in a single lane as one vehicle.. With motorcycles this means incorrect axle counts and axle spacing.

The results are no classification of any of the motorcycles.

Are other methods or systems available to correctly classify motorcycles and will they work?

There are other technologies available for classification of vehicles that don't use loop-piezo sensors to detect and classify vehicles. Some of these technologies are:

- Road tube (short term counters).
- Infra-red and laser sensor detectors.
- Acoustic sensor detectors.
- Digital radar detectors.
- Video classification systems.
- Video tape.
- Manual observations.

Given the three requirements needed to classify any vehicle within FHWA scheme F definitions:

- The beginning and end of a vehicle. (Identifying a single vehicle).
- The number of axles.
- The spacing between each axle.

Road tube, infra-red/laser, and acoustic sensors can satisfy the three requirements, just like loop-piezo systems. They are also subject to one of the same flaws: ***they cannot distinguish an individual vehicle when multiple vehicles pass through the sensor field at the same time in the same lane of travel.*** They do a better job of identifying single vehicles passing through their sensor fields because they do not rely on metallic mass to determine the "presence" of a vehicle. Road tube and infra-red/laser sensors detect the wheels, thus axles of a vehicle, and acoustic sensors determine the location of the axles by identifying the noise the tires make as they travel on the pavement. These detectors all cover the entire lane with their sensors, so the area of the lane occupied by an individual motorcycle does not necessarily cause a problem.

Digital radar and video classification systems cannot determine the number of axles a vehicle has. They can only determine the beginning and end of a vehicle and they cannot distinguish an individual vehicle when multiple vehicles pass through the detection zone at the same time in the same lane of travel.

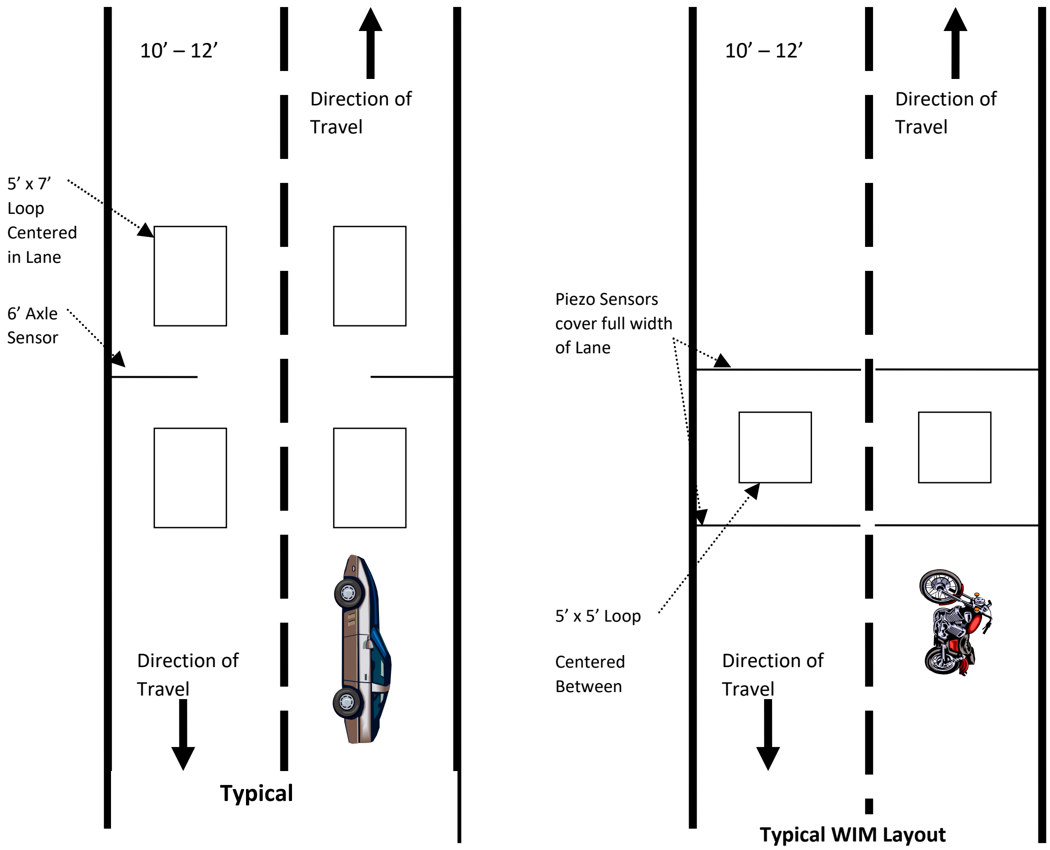
Video tape produces the most accurate recording of the vehicles traveling in a lane but requires someone to manually classify vehicles by watching the video tape. While capable of recording long time periods (using surveillance-type equipment), this method, while potentially 100% accurate, is extremely labor intensive. Reviewing multiple hours of video tape is subject to human error due to fatigue or inattention.

Manual classification has the same pros and cons as video tape with the added problem of being a "one time" observation. Any potential error in observation cannot be reviewed, as could be done with a video tape. An additional problem is the duration of a manual count, which is again subject to human capabilities. The statistical value of manual counts, typically conducted for four hours, to determine actual numbers of motorcycle travel, is highly questionable.

Motorcycle Classification: Temporary and Permanent Layout

Summary

Classification systems are intended to produce accurate class data for all classes of vehicles. Motorcycles, due to their extremely low percentage of the overall volume of vehicles traveling, do not significantly impact the accuracy of a system. Montana is not aware of a vehicle classification system currently available that targets motorcycles only. Trying to adapt current available systems to target motorcycle classification still requires the ability of the system to identify individual motorcycles. As long as motorcycles are not restricted to single-file operation in a lane of travel, accurate individual identification will not be possible with the current technologies used in their present form.



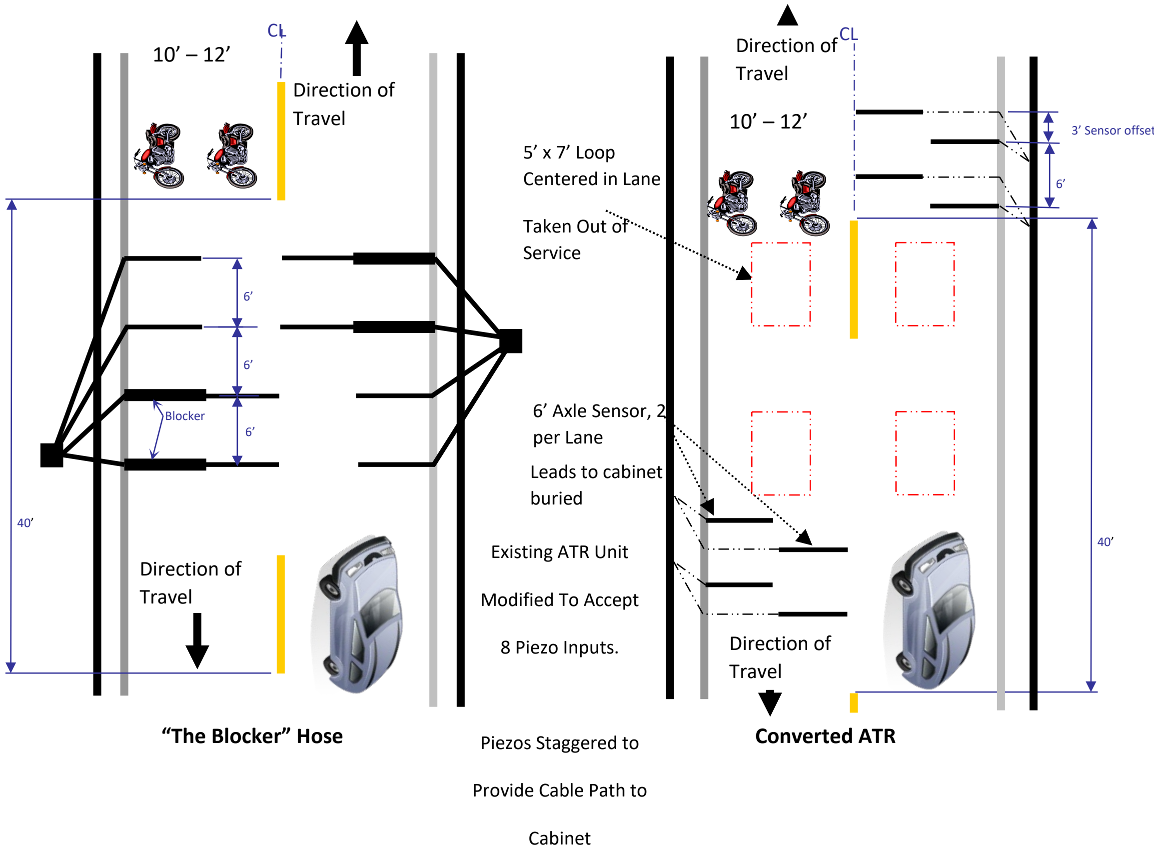
Source: Ron Wuertley, Electronics Engineer, January, 2008

FIGURE I-3: MOTORCYCLE CLASSIFICATION

These diagrams depict typical classification and weigh-in-motion sensor layouts used in Montana.

Note, the layout designs will not accurately classify motorcycles traveling side-by-side.

Motorcycle Classification: Temporary and Permanent Layout

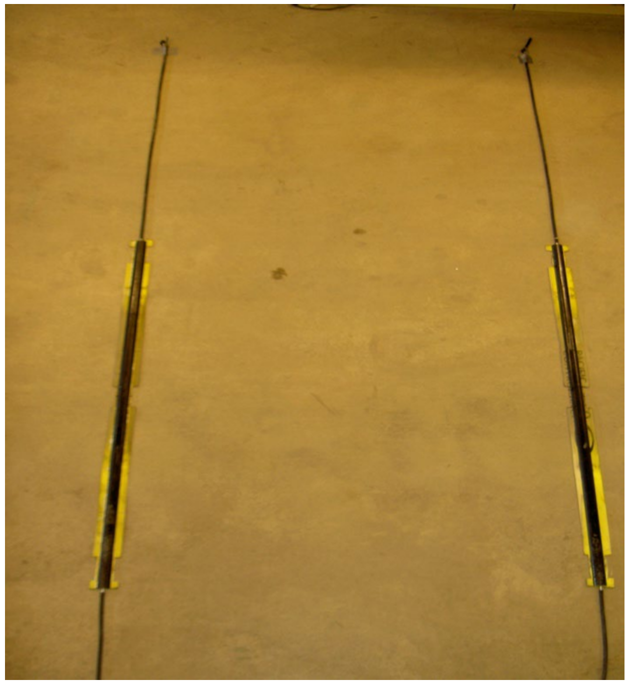


This diagram shows a portable layout using blockers and hoses, and a permanent layout showing potential sensor locations that might be used when converting an existing classification site into a motorcycle-capable class site. The loops have an “X” through them to indicate they will be disabled. Distances between sensors are approximations and will be changed to fit site specific requirements. The portable setup sensor distances work well. The 10-foot spacing between the blockers and the next pair of hoses is not critical, and in practice will probably be reduced to 6 feet.

Source: MDT Traffic Data Collection and Analysis Section

FIGURE I-4: BLOCKER SETUP

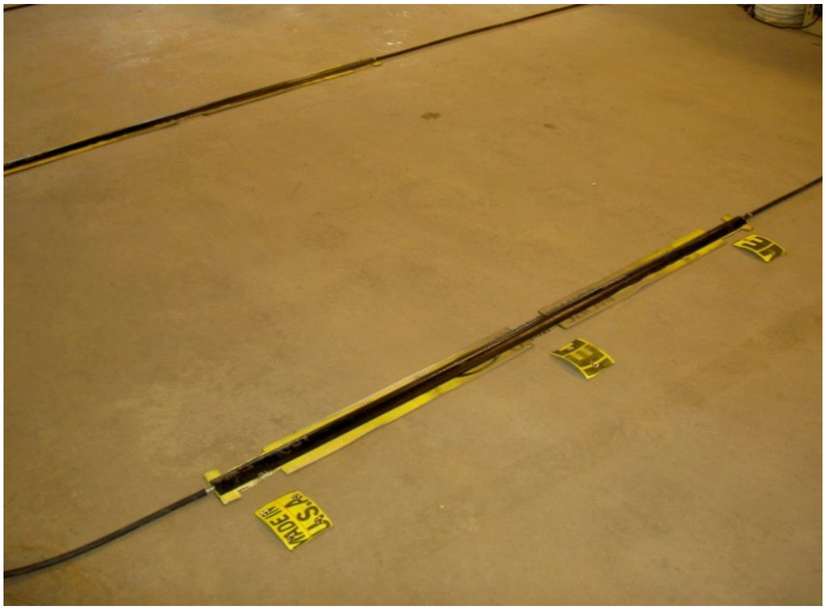
Blocker setup. The blockers are located on the first two hoses at the far left. They "block" the left-hand half lane. The last two hoses, on the other side of the blockers end even with the end of the blockers. They provide the detection for the left-hand half lane. The two short hoses attached to the ends of the blockers and extending out to the right provide the detection for the right-hand half lane.



Source: MDT Traffic Data Collection and Analysis

FIGURE I-5: CLOSE UP OF BLOCKER SETUP

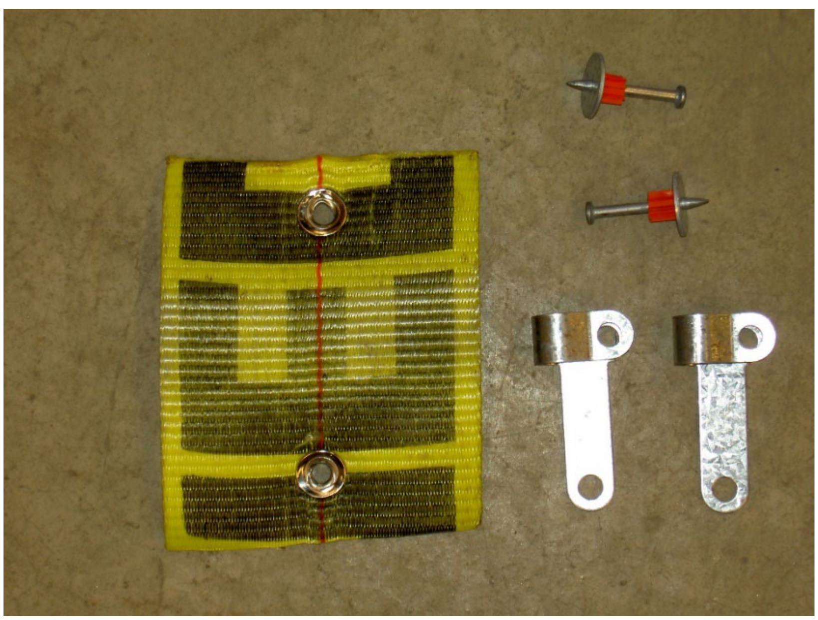
Close up of blockers showing short hoses that detect vehicles in a half lane connected to the ends (hoses at top of picture). The hoses connected to the end of the blocker at the bottom of the picture would go to the counter. The blockers are mounted on a piece of nylon webbing using polyurethane glue. In the grove on the underside of the blocker is a plastic tube with couplers pushed into it, allowing the hoses to be attached to each end of the blocker.



SOURCE: MDT TRAFFIC DATA COLLECTION AND ANALYSIS

FIGURE I- 6: BLOCKER AND STRAPS

Shown next to the blocker are the straps used to hold it in the road. They are placed in the areas where the strap has been notched.



Source: MDT Traffic Data Collection and Analysis

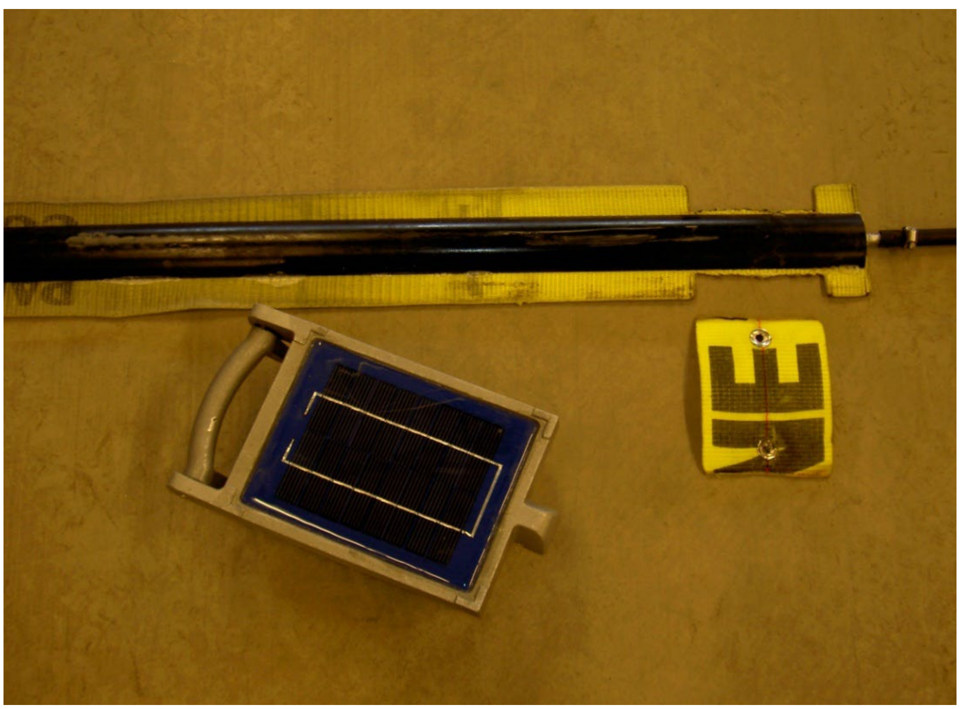
FIGURE I-7: CLOSEUP ON HOLD DOWN STRAP AND HARDWARE

Close up of hold down strap and hardware. The two metal clamps on the right are put over the grommets of the strap, the strap is placed over the blocker, then attached to the road using the construction nails shown at the upper right. The metal clamps provide protection for the grommet and nylon strap material during installation and removal of the nails. The metal clamps are the same ones used with road tube to connect the tube to the pavement.

Source: MDT Traffic Data Collection and Analysis

FIGURE I-8: TUBING WITH COUPLER

The tubing with a coupler placed in the groove of the blocker prior to having the nylon strap glued to the bottom of the blocker. The tube is cut short just for this picture. It normally extends the length of the blocker and has a connector in each end.



Source: MDT Traffic Data Collection and Analysis

FIGURE I-9: TYPICAL COUNTER

Typical counter used to collect data from the blocker setup. Note the hose connected to the end of the blocker is held in place with a small hose clamp.

Motorcycle Site Configuration Details

- **Sensor Type:** MSI-BL Class 1 6 ft. sensor.
- **Electronics: Diamond Traffic Products "Phoenix" model.**
    - Phoenix configured with two piezo boards to handle 8 piezos.
- **Configuration:** Two channels per lane.
- **Layout: 6 ft. spacing between sensors in each wheel path.**
    - Layout is interleaved so the total distance is 9 ft. from first to last sensor in the lane.
- **Maximum axle spacing setting: 40 ft.**
    - Any spacing over 40 feet delineates vehicles.
- **Classification is FHWA 1-13.**
    - Motorcycle totals for each lane are the combined motorcycles from each of the two channels in the lane.
    - FHWA types 2-13 totals may be taken from either channel in a lane MDT uses the outside wheel path channel for these totals.

Sensor Installation Particulars

- **Sensor slot size:**
    - Length—77 in., Width—0.75 in., Depth—1.25 in.
- **Sensor lead cuts:**
    - Width: 0.5 in., Depth:1.5 in. minimum, Length: As needed.
- **Sensor lead protection: Pex tubing.**
    - Pex O.D.: 0.5 inches.
    - Pex I.D.: 0.375 inches (3/8 in.)
    - Pex is purchased as 3/8 inch tubing from retailers that sell Pex-type tubing.
    - The Pex runs from the lead/sensor interface to the pull box, with typically a 1 ft. tail inside the pull box.
- **Installation resin:** MDT uses ECM brand P6G. There are suitable resins available from other vendors.
    - P6G comes in 6 Kg bags w/ One 150 gram bag of catalyst per bag of epoxy
    - Amount of epoxy required per site depends on lane size, shoulder size, cut sizes, and layout configuration. Amounts can vary from 8 to 14 bags depending on the aforementioned parameters.

Pros and Cons of the Design

The Pros

- **Layout Pros:**
  - Tested and verified accuracy is 97% for motorcycle detection. Montana currently operates 17 motorcycle capable sites
    - Note: All of Montana's continuous counter sites (100+) are checked for accuracy once per quarter.
  - Two channels per lane gives accurate motorcycle detection for motorcycles riding side by side in the lane. Montana state law allows this practice on all roadways.
  - No loops. Eliminates the fickle properties of using loops to detect motorcycles.
  - Configuration allows collection of all FHWA classes—not just motorcycles.
  - 6 ft. sensor spacing/9 ft. array spacing allows possible placement of array between transverse cracks in roadway, dependent on transverse crack spacing.
  - Can be installed in roads with ruts due to the flexible nature of the BL sensor.
  - 9 ft. array size minimizes errors due to motorcycles (or any vehicle) passing or changing travel paths while passing over the array.

- **Pex Tubing Pros:**
  - Protects the sensor leads from damage due to cracking.
  - Runs directly to the pull box, eliminating the need for conduit between the edge of the pavement and the pull box.
  - Sealing the end of the Pex tubing inside the pull box minimizes freeze-related damage to the sensor leads.
  - If a sensor fails in the road, the only cut that has to be made to replace the sensor is the actual sensor cut itself.
  - The Pex tubing installed with the original installation can be reused for the sensor lead from the road to the pull box without the need for additional cuts.

Pros and Cons of the Design:

The Cons

- **Layout Cons:**
  - Cannot be used in areas where traffic does not flow freely.
  - Cannot be used in areas where traffic regularly tailgates closer than 40 feet apart.
  - Multiple cuts in the road in proximity of each other can cause pavement deterioration issues if the pavement is of poor quality.
  - Multiple cuts of this depth (1.25 to 1.5 inches) can lead to cracking in thin pavements. Minimum pavement thickness of 3 inches is necessary to minimize these effects.
  - Pex tubing cuts must be at least 1.5 inches in depth to ensure an adequate epoxy cap over the Pex tubing in the cut. Most epoxy resins will not adhere to the Pex tubing itself.
  - Although the Pex tubing normally fits snuggly in the cut, variations in cut width can lead to installation issues including loose Pex tubing in the cut. Loose Pex can float up during the resin application, making the cap too thin, which results in resin coming apart and leaving the cut.
  - All epoxy in travel lanes (and shoulders if possible) must be ground or sanded flat with the contours of the road in order to minimize epoxy damage due to traffic.

Schematic Layout of a Continuous Count Site
Motorcycle Configuration